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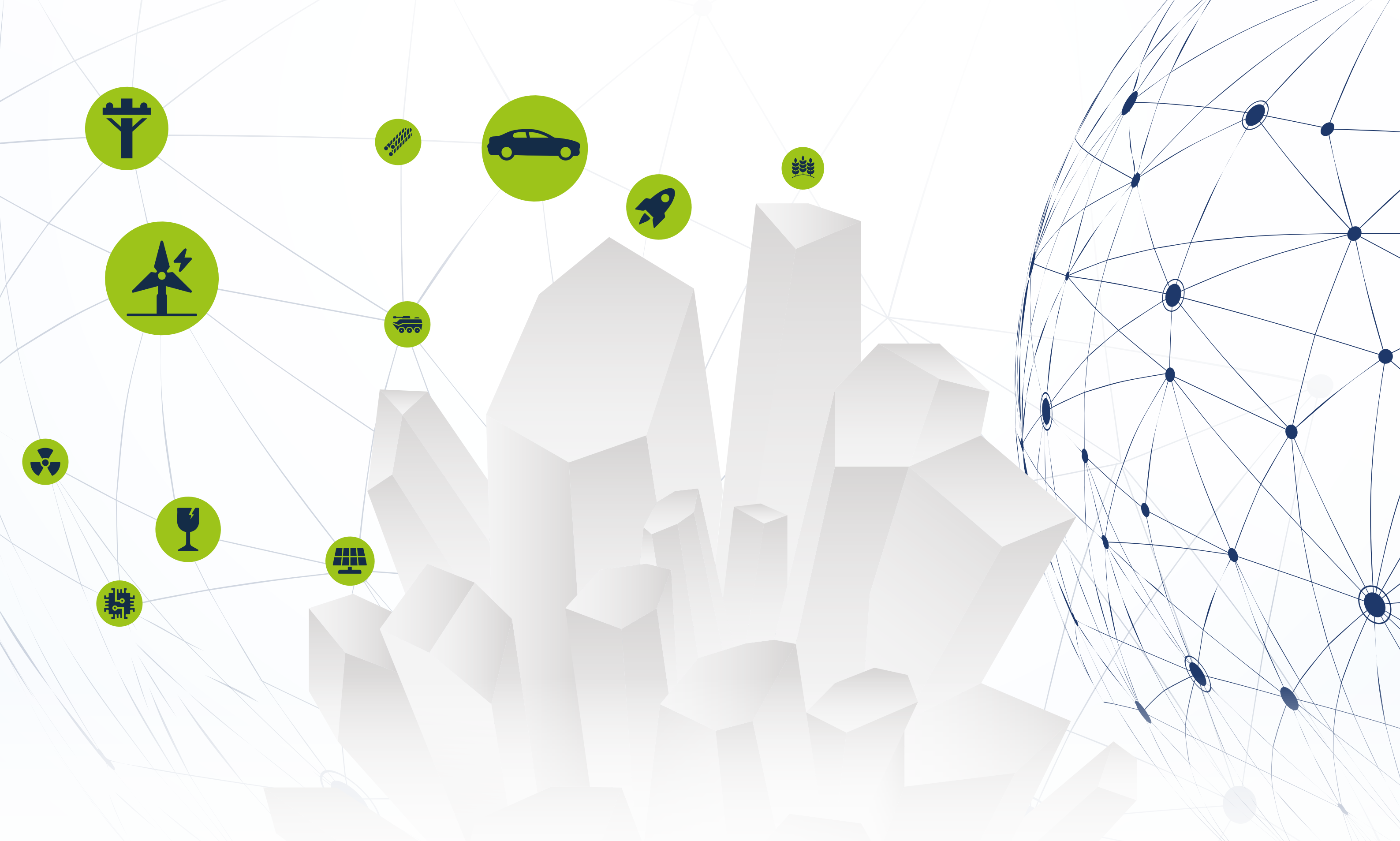

Boron in Energy Transition

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BORON and ENERGY

(BOR ve ENERJİ)

Ferrosilicon-Boron Alloys for Ultra High Temperature, High Density Thermal Energy Storage

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Ferrosilicon–boron (FeSiB) alloys are emerging as highly promising phase-change materials (PCMs) for ultra-high-temperature thermal energy storage. Their exceptionally large latent heat of fusion (> 1 $\mathrm{MWh/m^3}$) and potentially low production cost (< 5 €/kg) enable compact, low-cost storage systems capable of operating at 1200–1500 °C. In such systems, energy is stored by melting the FeSiB alloy and later dispatched as heat or converted to electricity through thermophotovoltaic (TPV) or other conversion pathways. Research on these materials has progressed significantly since 2017 through two EU-funded projects. The AMADEUS project (2017–2019) established the fundamental principles of ultra-high temperature latent-heat thermal storage and demonstrated a first laboratory-scale prototype using Si–B and FeSiB alloys. Building on this foundation, the ongoing THERMOBAT project (2022–2026) is developing a pre-industrial prototype containing more than 100 L of FeSiB alloy, designed to store surplus renewable electricity and deliver combined heat and power on demand. THERMOBAT also targets low-cost, sustainable production routes for FeSiB alloys to enable future scale-up and industrial deployment. This presentation will introduce the latent-heat thermal battery concept1, summarize recent technical advances achieved within THERMOBAT, and discuss techno-economic considerations, key challenges, and commercialization prospects. A comparative overview of competing ultra-high-temperature storage technologies—such as graphite-based sensible-heat systems—will also be provided to contextualize FeSiB alloy–based solutions within the broader energy-storage landscape.

Keywords: Thermal Energy Storage, Thermophotovoltaics, Concentrated Solar Power

Enhancing the Superconducting Properties of MgB_2 Wires Using Carbon-Coated Boron and Low-Temperature Activators

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Magnesium diboride (MgB_2) is widely recognized as one of the most promising superconducting materials for practical applications around 20 K, offering advantages in both cryogenic efficiency and material cost. Among the fabrication techniques for MgB_2 wires, the Powder-in-Tube (PIT) and Internal Magnesium Diffusion (IMD) methods are commonly employed to produce a dense MgB_2 phase with improved grain connectivity, leading to enhanced transport critical current density (Jc). Recently, IMD-processed wires have attracted significant attention, with research efforts focused on optimizing their structural uniformity and filling factor. Türkiye, possessing some of the world's largest and purest boron reserves, has demonstrated strong capability in producing high-quality amorphous boron powders suitable for MgB_2 formation and use in wire fabrication. While extensive research over the past two decades has primarily utilized the PIT method with notable achievements, the IMD process has recently gained prominence for its superior performance with increase in Jc. In this study, recent advancements in developing high-performance, long-length MgB_2 wires using an improved IMD technique for high-magnetic-field applications are to be presented. The objective is to enhance the critical current capacity of IMD-processed wires through the use of carbon-coated boron powders and low-temperature activators such as copper (Cu) and tin (Sn). This approach aims to enable the production of MgB_2 wires suitable for large-scale, high TRL for applications. The temperature-dependent resistivity measurements were performed to evaluate the influence of Sn and Cu coatings, as well as sintering conditions, on the onset of superconductivity. Additionally, transport Jc measurements were conducted under magnetic fields of 10 T. Our results indicate that resistivity measurements are highly sensitive to microstructural variations, impurities, and defects, which can significantly influence experimental outcomes. Both Cu and Sn activators are found to be effective in increasing physical properties relevant for potential applications. However, underlying mechanism is yet to be fully understood for further performance enhancement. To achieve a comprehensive understanding of these effects, more sophisticated experimental work with detailed quantitative analysis into the underlying mechanisms is needful. This work has been supported by TÜBİTAK and Chinese Academy of Sciences (CAS) via Bilateral Cooperation under contract No: 123N624

Keywords: Low Temperature Activators, Critical Current Density, Amorphous Boron Powder

Recent Progress of Hydrogen Boride and Boron Monosulfide

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We have experimentally synthesized hydrogen boride (HB) nanosheets [1] and boron monosulfide (BS) nanosheets [2]. The bandgap of BS nanosheets was found to be tuned to a desired value by controlling the number of stacking BS nanosheets [2]. Moreover, the stacked BS nanosheets, rhombohedral BS (r-BS), is found to be as a p-type semiconductor [3,4] and have a great electrocatalytic property for oxygen evolution reaction in alkaline solution [5,6]. HB nanosheets are composed of boron and hydrogen at a 1:1 stoichiometric ratio, which can be formed by an ion-exchange reaction between protons and magnesium cations in magnesium diboride with exfoliation [1,7]. In the HB nanosheets, boron atoms form a hexagonal 2D network, in which hydrogen atoms are bound to boron by 3-center-2-electron bonds (B–H–B) and 2-center-2-electron bonds (B–H) [8,9]. Experimental studies have clarified that HB nanosheets exhibit solid acid catalytic activity [10,11], metal ion reducibility [12,13], gas-sensor applicability [8], stability against water [14, 15], CO adsorption/conversion property including C-C coupling [16], a light-responsive hydrogen release function [17-21], electric field induced hydrogen release function [22] and material for inactivate viruses, bacteria, and fungi within minutes in the dark conditions [23]. In the presentation, recent progress of BS and HB nanosheets will be introduced by focusing hydrogen creation, storage and usage.

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Keywords: Hydrogen Boride, Boron Monosulfide, Boride, Hydrogen, Two-dimensional Materials

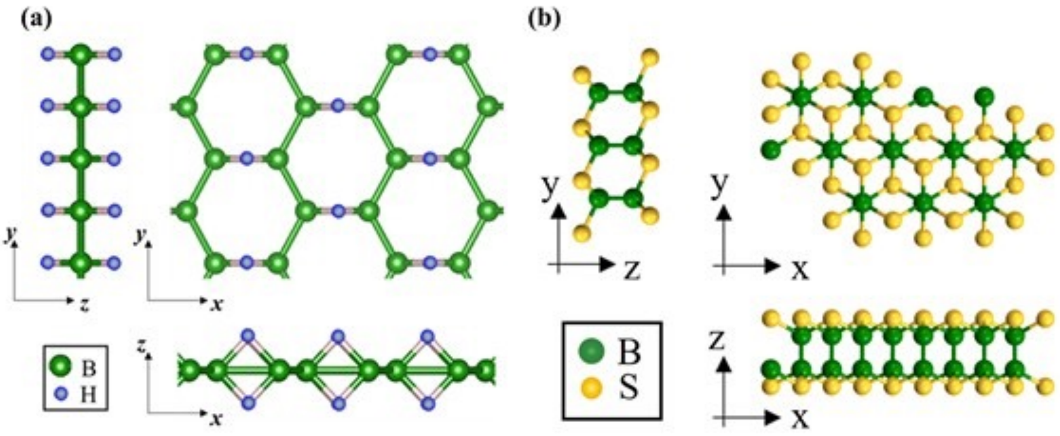

Fig. 1: Schematic image of (a) hydrogen boride sheet, and (b) boron monosulfide sheet.

Magnetic Microwires: Giant Magnetoimpedance and Bistability for Sensor Applications with an Impact on Energy Related Technologies

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Amorphous alloys microwires have attracted considerable attention in recent years due to their unique magnetic properties, which underlie their use as sensing elements in various sensor devices. The atomically disordered nature of these systems is achieved through rapid solidification (e.g., from 1200 ºC down to room temperature in 10-5/10^{-6} s) techniques such as in-water-quenching and quenching and drawing. A typical alloy composition is FeCoSiB, where the magnetogenic Fe and Co atoms provide the magnetic character while non-metallic elements, particularly B, are needed to prevent crystallization (i.e., magnetocrtystalline anisotropy) during the quenching process. Subsequent controlled thermal treatments can cause nanocrystalization, induce engineered magnetic anisotropies and ultimately unwanted growth of larger crystals. The presentation will cover: i) the manufacturing of both types of microwires, including videos, ii) their fundamental soft magnetism, and iii) the description of different sensor applications. The unique properties of amorphous microwires are related to their magnetoelastic anisotropy inherent to the mechanical stresses frozen-in during rapid solidification. Fe-rich alloys have a large and positive magnetostriction (~3×10^{-5} ppm) that generates a strong uniaxial anisotropy and the so-called magnetic bistability, while Co-base alloys exhibit a negative magnetostriction (-2×10^{-6} ppm) with circumferential anisotropy. Outstandingly, for Fe/Co compositional ratio close to 5%, magnetostriction vanishes and its extremely high initial susceptibility (~10^5) gives rise to the observed phenomenon of giant magnetoimpedance, GMI. Various sensor devices employing magnetic microwires, based on giant magnetoimpedance and magnetic bistability, will be described. These applications include particularly sensors for magnetic-field, mechanical stress and temperature detection. Other applications will be also addressed, such as electromagnetic shielding based on the microwave properties, encoding with domain walls or as magnetoelastic microactuators. All these applications are relevant because of their impact on energy technologies mainly due to the tiny size, adaptable shape and low energy consumption to magnetize microwires thanks to their magnetic softness.

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Keywords: Magnetism, Microwires, Sensors, Magnetoimepdance, Bistability

Recent Progress on MgB_2 Superconductors

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MgB_2 superconductors are promising candidates as conductors of various electric devise such as electric magnet, power cable, etc. In this meeting I will talk about recent progress of MgB_2 wires and tapes. Emphasis is put on the (micro)structure of MgB_2 which sensitively influences critical current density, Jc, of MgB_2 wires and tapes. Most popular method of MgB_2 wire fabrication is in situ PIT method, where mixture of Mg and B powder is used. Generally, the relative density of MgB_2 core in an in-situ PIT MgB_2 wire is as small as ~50%, not very far from the predicted percolation threshold density, 25-30%. Hot pressing and hot isostatic pressing (HIP) are effective in increasing the density up to ~70% and improvement of Jc values are obtained. Cold pressing before the heat treatment is also effective in increasing the density of MgB_2 and hence, Jc values. Other promising method to increase the MgB_2 core density is the mechanical alloying and mechanical milling of the starting mixed powder. A high quality MgB_2 crystal shows low upper critical field, H_{c2}, with large H_{c2} anisotropy. In MgB_2 wire having random grain orientation, the number of normal conducting MgB_2 grains increases with increasing applied magnetic field between H_{c2}(H∥c-axis) and H_{c2}(H∥a,b-axis). Thus, superconducting current paths become more limited and Jc decreases rapidly with increasing applied field in this field region. Carbon substitution for B site is effective not only in increasing H_{c2} but also in decreasing the anisotropy of H_{c2}, both of which much improve the field dependence of Jc. The most popular carbon source is SiC, however, impurities such as Mg_2Si precipitate in the MgB_2 matrix. Hydrocarbon or organic acid doping doesn't introduce such impurities and brings about higher Jc values than SiC doping. Ex situ PIT method produces higher MgB_2 density than in situ PIT method. However, higher heat treatment temperatures, ~900 °C, are required, resulting in higher Tc but lower H_{c2} than those of in situ PIT wires. Thus, rapid decrease of Jc with increasing magnetic field is obtained. However, higher Tc results in higher Jc at high temperatures above 20K and low applied fields. Thus, ex situ PIT wires are promising candidates for high temperature and low field applications such as power cable and low field magnet. Internal Mg diffusion (IMD) method realizes higher density of MgB_2 core, around 80%, and much higher Jc values are obtained than those of PIT wires. However, Jc homogeneity of IMD long wire is not as good as that of PIT wires probably due to the inhomogeneity of cross-sectional area of MgB_2 layer along the long wire. Small coils have already been fabricated applying IMD method and tested. At the end of my talk, I will mention several promising applications of MgB_2 wires and tapes such as MRI, power cable, accelerator magnet, etc.

Keywords: MgB_2 Wires and Tapes, In-situ PIT Method, Internal Mg Diffusion (IMD) Method, Superconductors

MgB_2 Wires and Tapes at ASG Superconductors: State of the Art and Future Perspectives

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The production process at ASG Superconductors facilitates the fabrication of MgB_2 based wires and tapes with lengths reaching up to 5-6 km, featuring diverse layouts tailored to meet the specific requirements of various applications. Boron plays a key role in this type of production as it largely determines the superconducting properties of MgB_2. Key parameters are purity, morphology, and doping. These characteristics also significantly determine the cost of boron. These conductors exhibit robust mechanical properties, rendering them suitable for the react-and-wind technique in magnet manufacturing and the react-and-cabling process for power cables. Both tape and round wire configurations are commercially available in a range of sizes. The availability of custom-developed powders with varying doping levels enhances the performance of these conductors in magnetic fields up to 4-5 Tesla, ensuring optimized functionality across different operational conditions and applications. Round wires are particularly adaptable for power cable applications, offering flexibility in terms of wire diameter, filament size, twist pitch, and coating options such as copper, allowing for customization based on specific design-application requirements. This work will provide a comprehensive overview of the characteristics of the wires produced and commercialized, highlighting their primary applications in fields such as magnet technology and DC-or-AC power transmission.Ongoing R&D activities aimed at enhancing the performance of these wires will be discussed, focusing on emerging applications including high-field fast ramping magnets, AC applications, superconducting magnetic energy storage (SMES), fault current limiters (FCL) and AC power transmission cables. These advancements are poised to open new frontiers in superconducting technology, enabling more efficient and versatile use of MgB_2 wires across a broader spectrum of industries.

Keywords: MgB_2, Powder-in-tube (PIT), Boron, Superconducting Wires

Boron Hydrides: A Fuel of Choice for p-B Fusion?

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Aneutronic proton–boron (p–B) fusion — in which a proton fuses with a boron-11 nucleus to produce three alpha particles — promises a revolutionary source of clean, radiation-free energy. Yet despite its appeal, progress towards a practical p–B fusion fuel has been limited. To date, most experimental targets have relied on boron compounds containing additional elements such as nitrogen, silicon, or carbon-rich polymers. These materials not only dilute the boron content but also introduce unwanted contaminants that divert energy away from the desired fusion reaction. In this context, boron hydrides (boranes) represent an intriguing and largely unexplored alternative. Composed solely of boron and hydrogen, boranes form a rich family of polyhedral, spherically aromatic clusters. Though absent in nature, they can be readily synthesised in laboratories like our own from abundant raw materials, with production scalable from milligrams to kilograms. In this contribution, we report the first demonstration of solid boranes as a fuel for laser-driven p–B fusion [1]. Using an “in-target” geometry, the solid boron hydride anti-$B_{18}H_{22}$ (octadecaborane) produced a remarkable yield of approximately 10^9 alpha particles per steradian under sub-nanosecond, low-contrast laser irradiation (PALS, ~10^{16} W cm^{-2}). This result not only highlights the promise of boron hydrides as efficient and clean fusion fuels, but also opens a new avenue for exploring molecularly engineered targets in aneutronic fusion research.

Reference: [1] High Yield of Alpha Particles Generated in Proton-Boron Nuclear Fusion Reactions Induced in Solid Boron Hydride $B_{18}H_{22}$, https://arxiv.org/html/2407.06729v1.

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Keywords: Boranes, Proton-Boron Fusion, Boron Energy

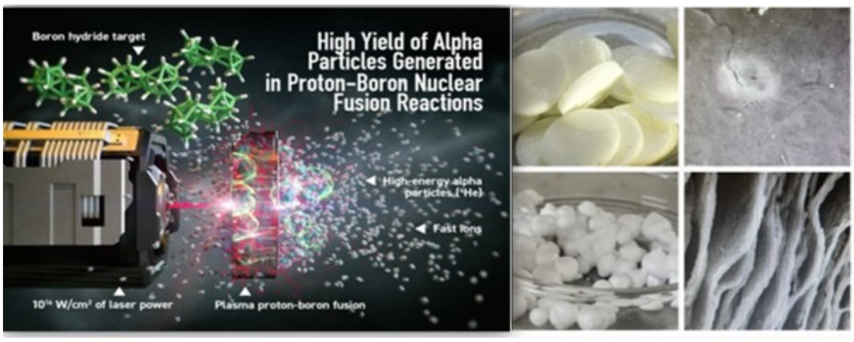

Figure 1. pB fusion from $B_{18}H_{22}$ targets - compressed discs and porous foams.

Expanding the Search-Space for Luminescent Macropolyhedral Boranes

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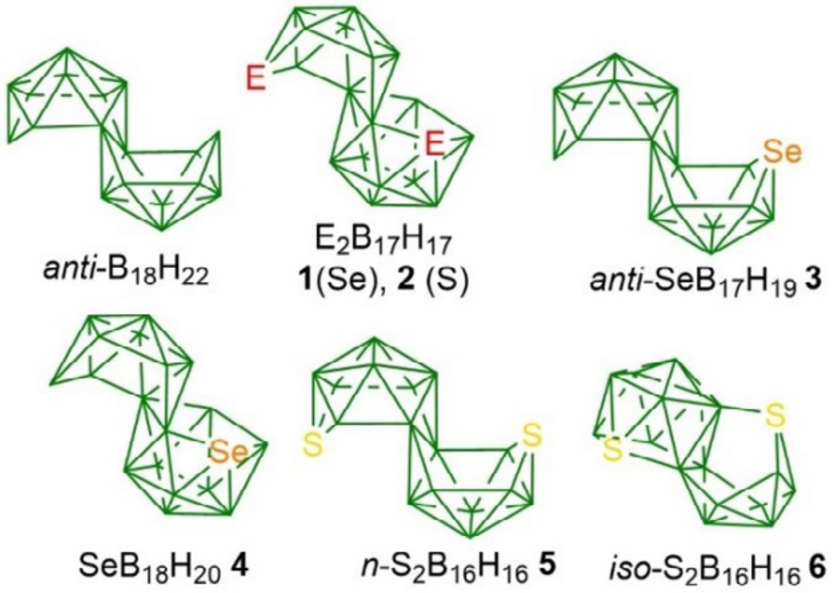
The synthesis of this first macropolyhedral binary borane $B_{18}H_{22}$ was reported in the 1960s. It exists in two isomers syn- and anti-$B_{18}H_{22}$. It was recognised early that the anti-isomer exhibits a strong blue fluorescence. However, it is only recently that this property has begun to be examined and exploited with its use as the gain medium in the first borane laser. Anti-$B_{18}H_{22}$ fluorescent properties may be modified by the introduction of substituents, but it was thought that only this macropolyhedral isomer was capable of fluorescence. We have, however, been able to synthesise new macropolyhedral species, including larger 19-vertex species that are also found to exhibit a range of luminescent properties. These macropolyhedral species are very different from the previously unique fluorescent binary borane $B_{18}H_{22}$ in terms of their structural architectures, by the presence of borane cluster hetero atoms and that, importantly, their synthetic origins are not necessarily derived simply through the modification of $B_{18}H_{22}$ itself. Aspects of the syntheses, structures and photophysical properties will be discussed. This work was supported by the Czech Science Foundation, Project No. 23-07563S.

Keywords: Boranes, Macropolyhedral, Luminescence, Energy



Luminescent Macropolyhedral Heteroboranes

Laser Borane and Plasma Studies with $B_{18}H_{22}$ Derivatives

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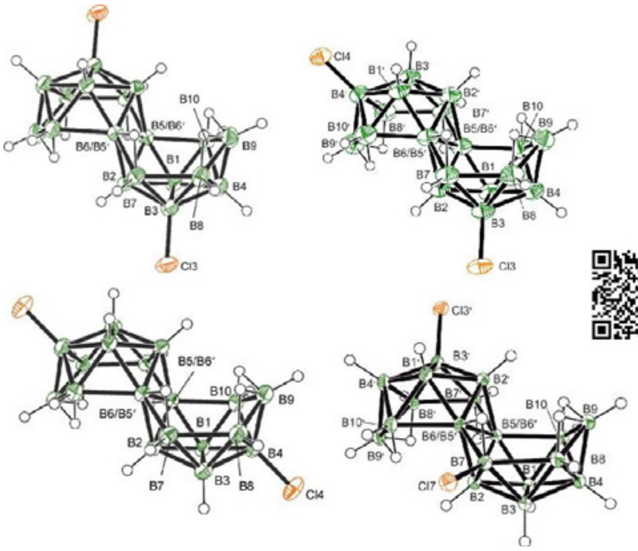
In the quest for new and improved laser systems based on $B_{18}H_{22}$, we studied (besides substitution in the cluster where boron is substituted for different element – see Jonathan Bould`s abstract) substitution on the cluster, where hydrogens are substituted for different elements. In this presentation the focus is on the chlorination of octadecaborane ($B_{18}H_{22}$). We report on the synthesis, separation, and photophysical characterization of several chlorinated derivatives of $B_{18}H_{22}$. The influence of temperatures, resulting in a variety of substitution patterns on the 18-vertex boron cluster is discussed. Photophysical properties of selected compounds were examined. This provides valuable insights into the effects of chlorination on the photophysics of octadecaborane and, more generally, inform on how substituent position on the boron cluster influences wavelength of emission, excited state lifetimes and quantum yield. Together, this information could offer a new avenue for the design of a B18-derivative molecular system with enhanced emission properties. Then application of these compounds for study of plasma properties is discussed as part of broader project Vortex 4 fusion, which aims to deliver more information about boranes as potential fusion fuel (see Michael Londesborough`s abstract).

Acknowledgements: This work was performed jointly at the Institute of Inorganic Chemistry of the Czech Republic and at the PALS Research Infrastructure supported by a program of Ministry of Education, Youth and Sports of the Czech Republic (project No. LM2023068). This research is partially funded by Czech Science Agency, project No. GA23-07563S and from the European Union's Horizon Europe research and innovation programme under grant agreement no 101096317.

Keywords: Boranes, Octadecaborane, Borane Laser, Plasma



(Crystal structures animations QR code)

Evaluation of Cobalt Boride Electrodes for Supercapacitor Applications

Mehtap Arslan Kaba[1], Servet Timur[1], Güldem Kartal Şireli[1]

[1]*Istanbul Technical University*

The rapid growth of the world population and the extensive use of fossil fuels have increased the demand for green and sustainable energy sources. In this context, supercapacitors have attracted significant attention due to their high surface area, specific capacitance, and power density [1]. As electrode materials for supercapacitors, transition metal compounds exhibit pseudocapacitive behavior and offer long cycle life owing to their reversible redox reactions. Among these materials, borides stand out due to the unique characteristics of boron, which provide a wide range of Faradaic reactions as well as high electrical conductivity [2]. In this study, Co/Co_xB composite powders were synthesized via a rapid and green molten salt electrolysis process using an oxide-based electrolyte. The co-deposition of Co and B was carried out at 900 °C under a current density of 600 mA/cm² for 1 h, and their structural and electrochemical properties were systematically investigated. Low-alloy steel substrates were used as the cathode, and their surfaces were cleaned with acetone. The Co/Co_xB powders were produced by molten salt electrolysis, using a mixture of $Na_2B_4O_7$ and $Co(OH)_2$. The electrolysis was performed in a graphite crucible (anode). After production, the Co/Co_xB composite powders were collected and washed with diluted acid. The powders were then ground using a ball mill and cold-pressed into disc-shaped electrodes. Structural characterization was carried out by X-ray diffraction (XRD) and scanning electron microscopy (SEM), while electrochemical performance was evaluated using cyclic voltammetry (CV). The XRD pattern (Figure 1) of the Co/Co_xB composite powder indicates that the sample consists of mixed phases, including CoB, Co_2B, and Co_3B, along with metallic cobalt. The SEM image reveals that the cobalt crystals are reduced in a cubic form and arranged in a chain-like structure (Figure 2a), whereas the boride phases exhibit a network-like morphology formed between the cobalt cubes, as shown in the magnified micrograph (Figure 2b). Figure 3a displays the multi-cycle CV curves of the Co/Co_xB electrode. As the electrode surface became activated, an initial increase in areal capacitance was observed, which subsequently stabilized, exhibiting typical faradaic-dominated pseudocapacitive behaviour. Areal capacitance values were calculated from CV curves recorded at a scan rate of 200 mV/s. The initial capacitance was measured to be 190 mF/cm², which increased to 310 mF/cm² after 750 cycles (Figure 3b). The Co/Co_xB composite powders were synthesized at 900 °C and 600 mA/cm² for 1h via green molten salt electrolysis. Structural analyses revealed the coexistence of Co, CoB, Co_2B, and Co_3B phases. CV tests performed over 750 cycles at a scan rate of 200 mV/s demonstrated a 63.2 % increase in areal capacitance, reaching a final value of 310 mF/cm².

References: [1] Kar, K. K. (2020). Handbook of nanocomposite supercapacitor materials II (Vol. 302). Cham: Springer International Publishing. [2] Arslan-Kaba, M., Timur, S., & Sireli, G. K. (2024). Evaluating the mechanism and the capacitive properties of nickel boride electrodes for supercapacitor applications. Journal of Energy Storage, 99, 113299.

Keywords: Cobalt Boride, Molten Salt Electrolysis, Supercapacitors, Energy Storage

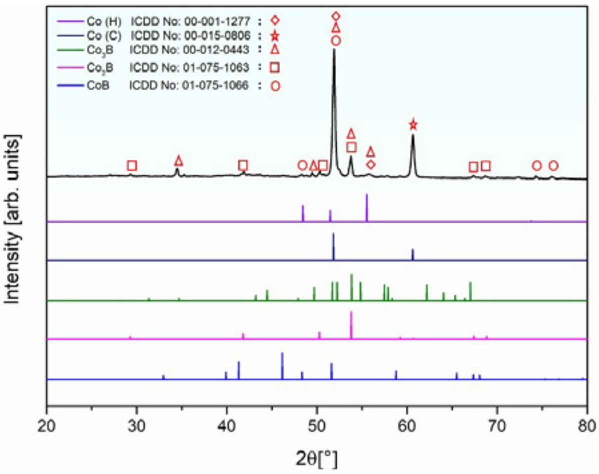


Figure 1. XRD pattern of Co/Co$_x$B composite powders

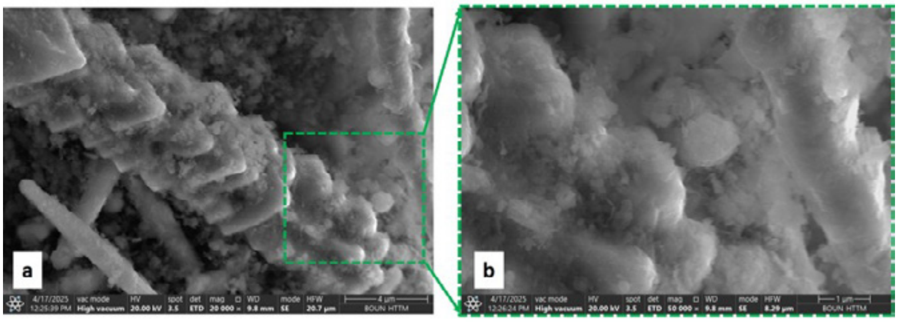


Figure 2. a) SEM image of Co/Co$_x$B composite powders b) corresponding magnified view

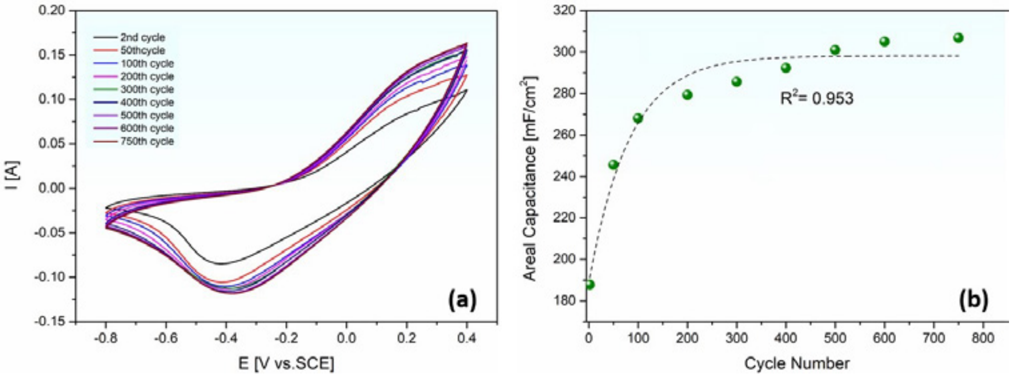


Figure 3. a) Multi-cycle CV curve of the Co/Co$_x$B composite electrode, b) increase in areal capacitance with CV cycle

Boron-Derived 2D Metal Borides (MBenes) for High-Performance Supercapacitor Applications

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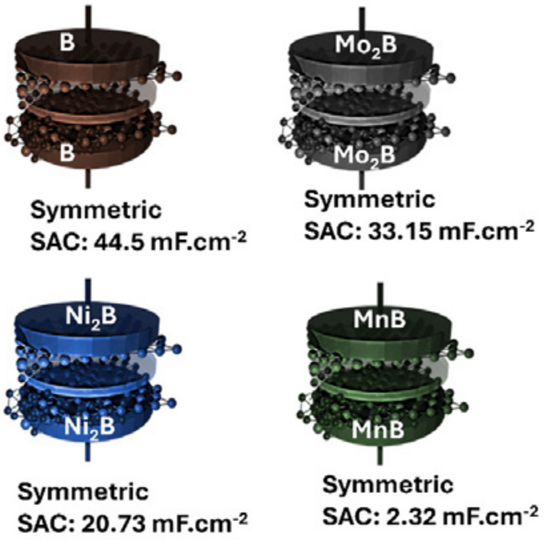
Metal borides (MBenes) have recently emerged as promising materials for next-generation energy storage systems due to their unique combination of metallic conductivity, chemical stability, and two-dimensional layered structure. In this study, various MBene thin films, including B, Mo_2B, Ni_2B, and MnB, were synthesized by chemical vapor deposition (CVD) and systematically investigated as supercapacitor electrode materials. MBene supercapacitor devices were fabricated, and their electrochemical performance was comprehensively evaluated using a Gamry Reference 600 workstation. Cyclic voltammetry (CV) measurements were carried out at different scan rates to determine the potential window and capacitive behavior. Galvanostatic charge–discharge (GCD) tests were performed at various current densities to calculate the specific capacitance and assess rate capability. Furthermore, electrochemical impedance spectroscopy (EIS) was employed to obtain Nyquist and Bode plots, providing insights into internal resistance, ion transport, and frequency response characteristics. The corresponding Randles circuit parameters were calculated using an AI-based computational approach. After long-term cycling tests, the MBene electrodes exhibited remarkable cycling stability and high capacitance retention, demonstrating their potential for durable and high-performance energy storage applications. Overall, this study highlights the effectiveness of the CVD technique for fabricating uniform and conductive MBene thin films, providing valuable insight into the structure–performance relationships of metal boride–based supercapacitors.

Keywords: Metal Borides, MBenes, Energy Storage, Chemical Vapor Deposition



3D models of B, Mo_2B, Ni_2B, MnB supercapacitor devices

Production of Few-Layer Freestanding Borophene and Its Application in Lithium-Ion Batteries

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Two-dimensional (2D) materials have attracted remarkable attention in materials science in recent years due to their broad range of potential applications. Among these materials, the most well-known is undoubtedly graphene—a single layer of carbon atoms arranged in a hexagonal lattice, distinguished by its remarkable mechanical strength, flexibility, and outstanding electrical and thermal conductivity. For a long time, no other 2D material could rival graphene's exceptional properties until the successful synthesis of borophene in 2015 fundamentally shifted the landscape. Structural investigations have revealed that borophene consists of boron atoms arranged in a monolayer hexagonal configuration. However, subsequent studies have demonstrated that borophene can also exist in multilayered forms, exhibiting various atomic arrangements and polymorphs [1]. Each structural phase possesses distinct electronic, mechanical, and optical properties [2]. This structural diversity arises from boron's electron deficiency and its ability to form covalent as well as multi-center bonds. In such multi-center bonding configurations, several atoms share a specific number of electrons, compensating for boron's electron deficiency and enabling the formation of multiple stable borophene structures [3]. The unique bonding characteristics of borophene impart it with exceptional properties, including high thermal conductivity, structural anisotropy, low density, superior electrical conductivity, high stiffness, and an elevated melting point [4,5]. Recently, borophene has emerged as a highly promising anode material for lithium-ion batteries (LIBs). Theoretical studies have reported its outstanding electrical conductivity, ultralow Li-ion diffusion barrier, and strong Li adsorption capability, corresponding to a theoretical specific capacity of approximately 2040 mAh g^{-1}, which is substantially higher than that of graphite (372 mAh g^{-1}) [6]. These characteristics suggest that borophene could enable LIBs with significantly enhanced energy density and accelerated charge–discharge kinetics. All chemicals were used as received without any further purification. The materials employed in this study included boron powder (purity ≥95%) and acetone (purity ≥99.5%). The boron powder precursor was first dispersed in acetone and subjected to probe-type sonication at 400 W under an inert atmosphere for 4 h, followed by centrifugation at various rpm for 20 min. The supernatant was then collected and thermally treated at 150 °C in a Teflon-lined stainless-steel autoclave for 12 h. As a result, freestanding borophene was obtained as a stable dispersion in acetone. Subsequently, the sample was characterized using transmission electron microscopy (TEM) and atomic force microscopy (AFM). For TEM analysis, 0.05 mL of the borophene dispersion was dropped onto a TEM grid, and the solvent was evaporated prior to imaging. TEM analysis was performed using a JEOL JEM-ARM200CFEG UHR-TEM (equipped with STEM, Cs-corrected STEM, EDS, Gatan Quantum GIF, and a digital CCD camera) operated at 200 keV. AFM measurements were carried out using a NanoMagnetics hpAFM system in dynamic (tapping) mode. The ACLA cantilever used had a fundamental resonance frequency of 188,696.451 Hz. Scanning was performed at a constant rate of 2 μm s^{-1}. Optimal feedback control was maintained using the following proportional-integral-derivative (PID) parameters: proportional gain (P) = 30,000, integral gain (I) = 1,000, and derivative gain (D) = 15,000. The total applied force (F_t) was fixed at 2 V. Electrode Fabrication and Half-Cell Assembly is done as follows: The synthetic graphite powder was mixed with carbon-black and sodium alginate, as the binder in water to form a slurry. For the borophene-containing electrodes, a nominal amount of borophene (0.7–1 wt% relative to graphite) was incorporated into the slurry. The slurry was cast onto Cu foil of 10 μm thickness and then dried in a 70 °C oven overnight. Working electrodes were circular discs (10 mm in diameter) that were punched from the dried slurry-on-foil. Swagelok half-cells with a Li chip as the counter-electrode were assembled in a glovebox under the Ar environment. The electrolyte was a 1 M solution of LiPF6 dissolved in a mixed solvent of ethylene carbonate (EC)-diethyl carbonate (DEC). Each cell contained 50 μL of electrolyte and 25 μm thick separator was used in the half-cell. Figure 1 shows the half-cell architecture. The half-cells were charged and discharged in a battery analyzer system (MTI, BTS8-WA) over cut-off potential range of 0.005-1.5 V. The cells were cycled by charging and discharging at 0,083 mA to evaluate performance stability. TEM images (Fig.2a-b) clearly reveal that the material consists of sheet-like borophene structures stacked in patch-like layers with lateral dimensions ranging from approximately 3 to 10 nm. TEM images confirm that the sonication method is effective for producing freestanding borophene. TEM-EDS analyses performed on selected regions showed a strong and dominant boron signal, indicating the successful synthesis of borophene. The presence of the oxygen signal suggests a partial oxidation of the boron layers. Additionally, minor signals corresponding to Mg, Ca, F, Si and S were detected, which are likely attributed either to impurities originating from the boron precursor or to trace contamination from glass and Teflon components used during the freestanding borophene synthesis process (Fig-3). AFM analysis was conducted to better understand the layered structure and determine particle thickness. The relationship between the number of layers of freestanding borophene and the centrifuge speed was investigated by AFM analysis. It was determined that the height of borophene particles varied between 35 nm and 3.5 nm depending on the centrifugation speed. The results indicated that the borophene flakes possess an average height of approximately 3.5 nm at high rpms (Fig-4), which—based on literature-supported DFT modeling—corresponds to an estimated layer number of 10–13 [7-8]. Electrochemical evaluation of electrodes containing 0.7 wt% and 1 wt% borophene demonstrated that the borophene addition significantly enhances both cycling stability and battery lifetime, with improvements ranging from approximately 45% to 75%, depending on the borophene loading (Fig-5).

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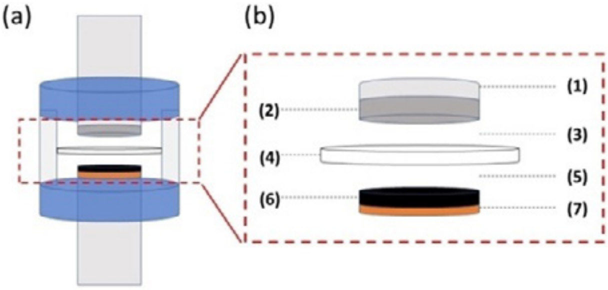
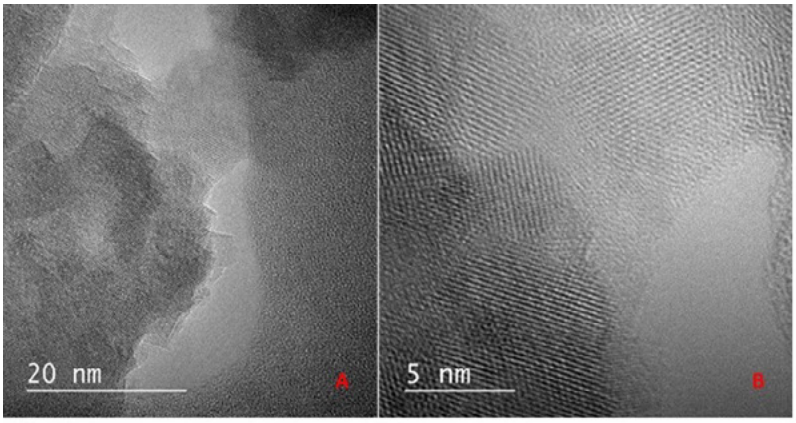
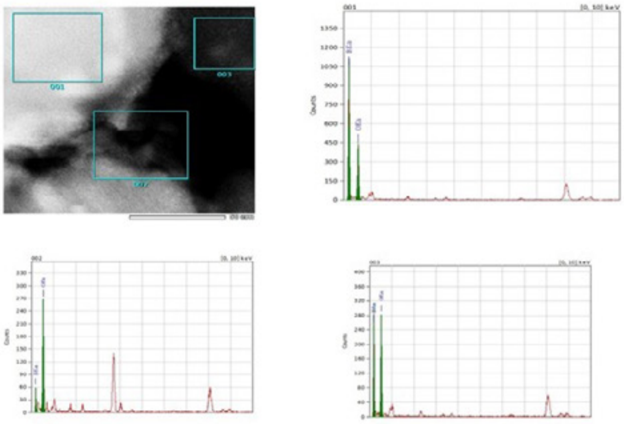
Keywords: Borophene, Sonication, TEM, Li-Ion Battery



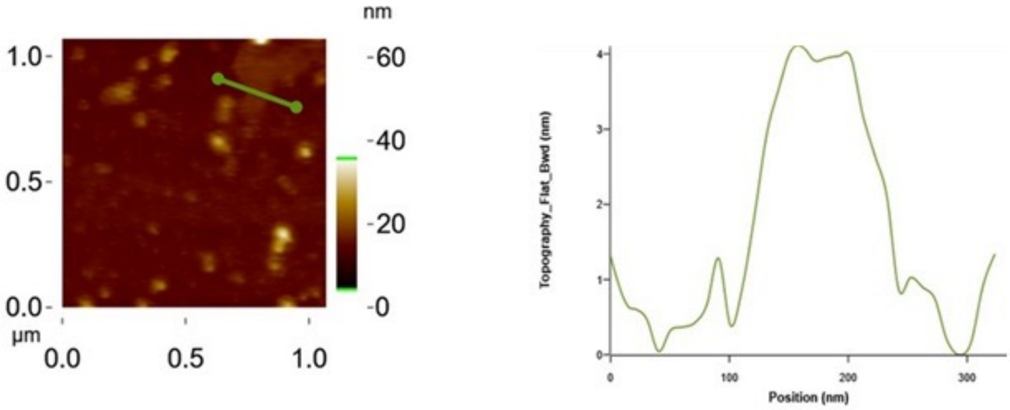
Schematic of the LIB half-cell architecture



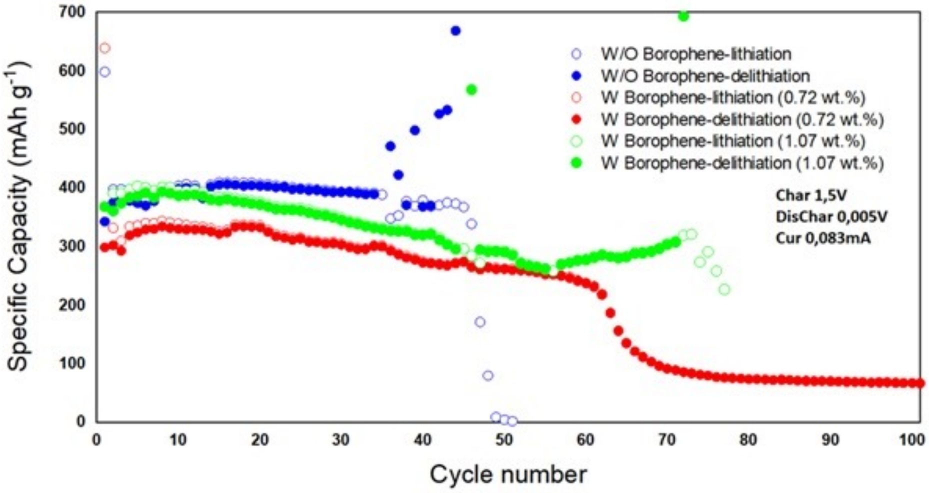
TEM images from selected regions of freestanding borophene



TEM-EDS analysis results on selected regions of freestanding borophene



AFM results of freestanding borophene



Test results of specific capacitance versus cycle number of samples with (W) and without (W/O) borophene doping at different ratios

Borophene/$Ti_2NbC_2T_x$ MXene Hybrids: Emerging Boron-Based Electrodes for High-Performance Supercapacitors

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The integration of two-dimensional (2D) materials with complementary electronic and structural properties has opened new frontiers in advanced energy storage. In this research, a series of 2D/2D hybrid electrodes combining $Ti_2NbC_2T_x$ MXene and borophene nanosheets were designed to exploit their interfacial synergy for enhanced supercapacitor performance. The $Ti_2NbC_2T_x$ MXene, featuring double-transition-metal, provides metallic conductivity and rapid ion diffusion, while borophene contributes high charge-carrier mobility and abundant active sites. The hybrid electrodes were prepared by spray-coating onto carbon cloth using an airbrush, ensuring uniform formation and strong adhesion. Comprehensive characterization (XRD, Raman, FESEM, TEM, and XPS) confirmed the preservation of layered crystallinity and successful interface formation between the MXene and borophene sheets. The optimized composite (MX–B_{10}) exhibited well-balanced electrochemical behavior, showing pronounced redox activity and the lowest charge-transfer resistance (Rct ≈ 8.9 mΩ), which facilitated efficient ion–electron transport. In three-electrode testing, MX–B_{10} delivered a high specific capacitance of 510 F g^{-1} at 0.5 A g^{-1} and retained 92.7% of its initial capacitance after 10,000 cycles. Two-electrode symmetric devices demonstrated wide operational voltage windows (up to 1.2 V) and an impressive energy density of 54 Wh kg^{-1} at 299 W kg^{-1}. To demonstrate their practical capability, three series-connected hybrid supercapacitors successfully powered multiple LED lamps, confirming stable energy storage and discharge behavior (Figure 1). The enhanced performance originates from the 2D/2D heterostructured interface, which promotes efficient charge transport, rapid ion diffusion, and robust structural stability. These findings highlight borophene–$Ti_2NbC_2T_x$ MXene heterostructures as promising next-generation electrodes for flexible and high-rate supercapacitor applications.

Acknowledgements: This research was supported by TÜBİTAK under Project Nos. 223M159 and 120F312.

Keywords: Borophene, $Ti_2NbC_2T_x$ MXene, Hibrid Electrode, Supercapacitor

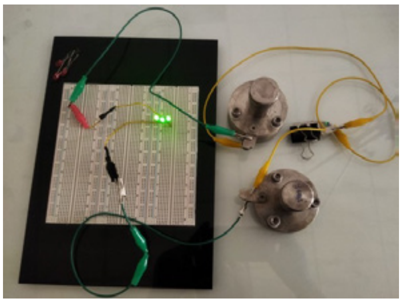

Figure 1. Three series-connected hybrid supercapacitors were able to light up multiple LED lamps

Gel Synthesized Zirconium Diboride (ZrB_2) for Supercapacitor Applications

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[3]*Sabancı University*

In this study, ZrB_2 powders were synthesized using the citrate gel method succesfuly. X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Fourier-Transform Infrared Spectroscopy (FTIR), and X-ray Photoelectron Spectroscopy (XPS) analyses were carried out to investigate for phase contents and microstructure. A three-electrode system used.for electrochemical characterization and the synthesized ZrB_2 powder was mixed with polyvinylidene fluoride (PVDF) and carbon black to form a composite electrode. A solid-state symmetric supercapacitor was assembled using a gel electrolyte, and its performance was evaluated in a two-electrode configuration through Cyclic Voltammetry (CV), Electrochemical Impedance Spectroscopy (EIS), and Galvanostatic Charge–Discharge (GCD) measurements.

Acknowledgment: This study was financially supported by the Kütahya Dumlupınar University Scientific Research Projects Commission (DPU-BAP), project 2021-24, T.R. Presidency of Strategy and Budget, project ‘The establishing the infrastructure for boron-based advanced technology ceramics laboratory’, project number 2022K12-211404 and NATO-SPS program (SPS activity reference G7753)

Keywords: Energy Storage, Zirconium Diboride, Gel Electrolyte, Electrochemical Properties

Enhanced Thermoelectric Performance of $Mg_3(Sb,Bi)_2$-Based Thermoelectrics through Two-Dimensional Interface Modification

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Rising environmental concerns, driven by fossil fuel consumption., underscore the urgent need for sustainable energy recovery. As over 60% of global primary energy is lost as waste heat, developing technologies to reclaim this lost energy is critically important. Among these technologies, thermoelectric (TE) materials have emerged as a sustainable solid-state solution capable of directly converting heat into electricity without moving parts or working fluids, offering a reliable and emission-free route for energy recovery. Despite their potential, achieving high thermoelectric efficiency remains challenging because electrical and thermal transport parameters are strongly coupled. Attaining a high figure of merit (zT) requires fine-tuning to enhance one property without compromising another. Zintl phases, particularly n-type $Mg_3(Sb,Bi)_2$-based TE materials, composed of earth-abundant and non-toxic elements, have emerged as promising candidates for efficient energy conversion in the mid-temperature range. Numerous strategies have been explored to further enhance their performance, including carrier concentration optimization through doping, grain-size refinement, and band structure engineering. Nevertheless, maintaining consistently high zT remains challenging due to microstructural limitations. Recent studies have demonstrated that incorporating two-dimensional (2D) materials such as graphene and MXene into $Mg_3(Sb,Bi)_2$ can modify interfacial transport. While MXene addition enhanced zT by nearly 30%, graphene showed limited improvement, emphasizing that morphology, and distribution critically influence electrical behavior. In this Study, we synthesized $Mg_{3.2}Sb_{1.5}Bi_{0.49}Te_{0.01}$ and enhanced its TE performance through 2D interfacial engineering using Borophene and MgB_2. This approach aims to decouple TE parameters and achieve synergistic optimization of electrical and thermal transport. Detailed structural analyses confirm that introduction of 2D phases creates interfaces that induce additional phonon-scattering mechanisms, resulting in a notable reduction in lattice thermal conductivity while maintaining favorable electrical properties. Hall measurements reveal negligible changes in carrier concentration after 2D incorporation, indicating selective carrier scattering. The optimized sample exhibits a zT approaching 2 at 673 K, compared to 1.6 for the pristine material. Overall, this strategy demonstrates that introducing well-distributed 2D phases with appropriate concentration provides a promising pathway toward high-performance $Mg_3(Sb,Bi)_2$-based TE materials.

Keywords: Thermoelectrics, 2D Materials, Interfacial Engineering

Temperature Effects on Phase Evolution and Particle Morphology in Ce-Rich Commercial NdFeB Magnets During High-Pressure Hydrogen Decrepitation

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NdFeB magnets are essential to clean energy and advanced technological applications due to their superior magnetic properties. However, the availability of rare earth elements is susceptible to geopolitical and environmental challenges. The recycling of NdFeB permanent magnets from secondary sources represents a strategic approach to mitigate these supply risks associated with critical raw materials, particularly Neodymium (Nd) and Dysprosium (Dy). Among the available recycling techniques, Hydrogen Decrepitation (HD) has demonstrated significant potential for the efficient recovery of these elements from commercial magnets. This study investigates the effect of temperature during high-pressure hydrogen decrepitation on the structural, microstructural, and compositional evolution of a commercial NdFeB magnet with relatively high Ce content, which is mainly substituted to reduce the cost and supply risk of highly critical Nd. Experiments were performed at 9 bar hydrogen pressure under constant-time, using three processing temperatures: 25 °C, 50 °C, and 75 °C. Scanning electron microscopy (SEM) of the initial magnet illustrated Ce-rich phases, while X-ray diffraction (XRD) confirmed the presence of $CeFe_2$. According to XRD results, the main $RE_2Fe_{14}B$ phase transformed $RE_2Fe_{14}BH_x$ hydride phase after the hydrogenation process. However, the $CeFe_2$ peaks disappeared, suggesting a possible amorphous phase transformation. In addition to the hydride phase, the presence of the Nd_2O_3 phase was detected. LECO elemental analysis was performed to quantify the amount of oxygen and hydrogen in as-received magnet and hydrogenated powders. The results demonstrated that powders processed at 75 °C retained higher oxygen levels than those processed at 25 °C or 50 °C. Powders processed at 75 °C retained higher oxygen levels than those treated at 25 °C and 50 °C, despite exhibiting more agglomerated morphologies with limited cracking, which would typically reduce oxygen uptake. This counterintuitive result suggests a complex interplay between hydrogen desorption, surface activation, and re-oxidation at elevated temperatures, but a definitive mechanism cannot be identified from the current data. Overall, the study sheds light on the effect of temperature on particle morphology, particle fragmentation, and oxidation behaviour during HD. These insights provide valuable guidance for the optimization of NdFeB magnet recycling and reprocessing strategies.

Keywords: NdFeB Magnets, Hydrogen Decrepitation, Recycling, Critical Minerals

MgB_2-Based Superconducting Joints for Reacted MgB_2 and NbTi Wires

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The global move toward sustainable and helium-free superconducting technologies has renewed focus on magnesium diboride (MgB_2), a boron-based superconductor that combines cost-effectiveness, ease of synthesis, and high critical current density near 20 K. However, the practical implementation of MgB_2 magnets has been constrained by the absence of reproducible, ultra-low-resistance joints. In our recent study (Supercond. Sci. Technol., 36 (11), 115008, 2023), we demonstrated a fully reacted MgB_2–MgB_2 joint exhibiting ultra-low resistances below 10^{-12} Ω under 20 K–1 T and self-field conditions, carrying 160 A and 172 A, respectively. A critical current ratio (Ic_{joint}/Ic_{wire}, CCR) of up to 78% was achieved under 1 T field through the use of a tailored MgB_2 filler and a precisely controlled post-joint heat-treatment process. These results represent the highest performance reported to date for joints fabricated between reacted MgB_2 conductors.

Building upon this foundation, a patent application has been filed (currently within the 18-month confidentiality period) introducing the first NbTi superconducting joint that utilizes MgB_2 as an active filler material. This design achieves ultra-low resistance ($<0.5 \times 10^{-12}$ Ω) and excellent trapped-current performance, 210 A at 4.5 K, 0.25 T and 359 A under self-field enabling stable operation in persistent-mode magnet systems. This innovation establishes a superconducting diffusion bridge between NbTi wires, enabling persistent or driven-mode hybrid magnet architectures. Critically, the method eliminates the need for Pb-based solders, which—though traditionally used for NbTi jointing—are now being phased out under forthcoming EU environmental and occupational health regulations. Together, these two advances demonstrate the versatility of MgB_2 as both a superconductor and an enabling jointing medium across distinct material systems. The MgB_2–MgB_2 joint validates the feasibility of fully reacted, persistent MgB_2 circuits, while the NbTi– MgB_2 hybrid joint establishes a sustainable, lead-free pathway bridging low- and intermediate-temperature superconductor regimes.

Currently, ongoing studies at BOREN focus on developing next-generation MgB_2 wires and cables using novel Ti-based sheath alloys to further enhance performance and mechanical robustness. Collectively, these works expand the functional and environmental boundaries of superconducting wire and joint technology, positioning MgB_2 as a cornerstone material for next-generation, helium-free magnet systems.

Keywords: Boron-Based Materials, MgB_2, NbTi, Superconducting Joints, Superconducting Persistent Magnets

Enhanced Electrochemical Performance of Zirconium and Hafnium Boride–Carbide Composite Electrodes for Energy Storage

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Transition metal boride and carbide-based materials are attracting growing interest as promising candidates for high-performance energy storage applications. This study investigates the synthesis and electrochemical behavior of zirconium- and hafnium-based boride–carbide systems (ZrB_2–ZrC and HfB_2–HfC). Pure boride and carbide compounds, along with their composite powders, were synthesized via a mechanical activation-assisted route followed by controlled heat treatment. Characterization techniques, including X-ray diffraction (XRD), scanning electron microscopy (SEM), dynamic light scattering (DLS), and Brunauer–Emmett–Teller (BET) surface area analysis, confirmed the high purity, submicron-scale particle sizes (below 400 nm), and high surface areas (up to 10,5 m^2/g) of the synthesized materials. Electrochemical measurements, including cyclic voltammetry (CV), potentiostatic electrochemical impedance spectroscopy (PEIS), and galvanostatic charge–discharge (GCPL) tests, were conducted at room temperature using symmetric two-electrode supercapacitor configurations. Both ZrB_2–ZrC and HfB_2–HfC composite electrodes exhibited enhanced electrochemical properties compared to their pure boride counterparts, demonstrating the beneficial effect of carbide incorporation. The composite structures achieved a specific capacitance of 214 mF/g, significantly higher than that of pure borides (79-100 mF/g). The incorporation of an optimal amount of ZrC and HfC also led to improved energy and power densities. Cycling tests revealed excellent stability, maintaining 99.4–99.9% capacitance retention after 5000 cycles for both systems. These findings demonstrate that the incorporation of carbide phases significantly improves the electrochemical performance of boride-based electrodes, making ZrB_2–ZrC and HfB_2–HfC composites promising materials for next-generation high-performance supercapacitor applications.

Keywords: Zirconium Boride, Hafnium Boride, Electrochemical Properties, Energy Storage, Powder Synthesis

Polyoxometalate Containing Boron Nitride Quantum Dots for Electrochemical CO_2 Reduction

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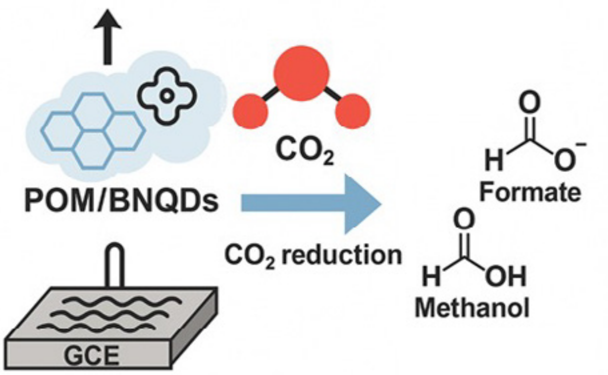
The sustainable and cost-effective electrochemical reduction of CO_2 into value-added fuels is a promising approach to mitigate greenhouse gas emissions and address global energy demands. In this study, a novel electrocatalyst based on polyoxometalate (POM) containing boron nitride quantum dots (BNQDs) was presented for efficient electrochemical CO_2 reduction. After completing the formation of BNQDs, BNQDs was functionalized by POM through electrostatic interaction between the POM and BNQDs to produce a electrocatalyst (POM/ BNQDs) and modified onto a glassy carbon electrode (POM/BNQDs/GCE). The POM/ BNQDs was utilized as a conductive catalytic platform to provide abundant active sites and facilitate electron transfer during the CO_2 reduction process. Subsequently, POM/BNQDs was introduced as a co-catalyst and electron mediator to enhance charge separation efficiency and boost catalytic activity. The prepared POM/ BNQDs was characterized using electrochemical impedance spectroscopy (EIS), cyclic voltammetry (CV), scanning electron microscopy (SEM), X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), transmission electron microscopy (TEM), and fourier transform infrared spectroscopy (FTIR). The optimized electrode exhibited superior electrocatalytic performance, achieving a Faradaic efficiency of with high current density, excellent CO_2 conversion efficiency, and enhanced selectivity toward formate and methanol under mild operating conditions. These results indicate that the synergistic interaction between POM/BNQDs provides an effective strategy for constructing advanced nanostructured catalysts for efficient CO_2 electroreduction.

Keywords: Polyoxometalate, Boron Nitride Quantum Dots, Electroreduction, Electrocatalyst



Electrochemical reduction of CO_2 on POM/BNQDs/GCE

Cables Containing Zinc Borate Nanocomposite Additives Derived from Boron Enrichment Process Waste

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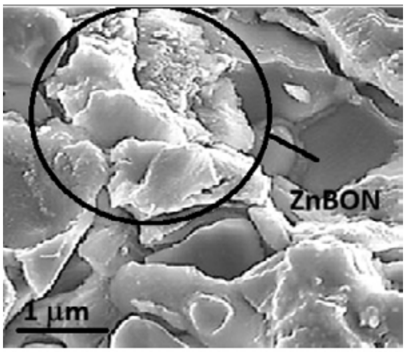
Increasing environmental challenges and economic demands have made waste recovery and the development of related technologies a necessity. During the production process, approximately 5–10% of B_2O_3 is generated as a by-product in boron enrichment plants. The wastes containing high concentrations of B_2O_3, derived from the strategically important boron mineral, pose serious environmental threats, including air, water, and soil pollution. Furthermore, large areas are required for the storage and disposal of such wastes. Instead of depositing recoverable wastes in storage areas, their utilization as secondary raw materials would both reduce the industry's dependence on primary resources and provide economic benefits. In order to enhance the contribution of boron resources to the national economy, it is essential to develop new boron-based products, identify novel application areas for existing boron compounds, strengthen the boron-related industrial sector, increase employment opportunities, and raise domestic consumption levels of boron products. This project aims to enhance the economic value chain of boron in Türkiye by synthesizing Zinc Borate Nanocomposites (ZnBON) from boron enrichment process wastes. The objective is to develop sustainable, renewable, and environmentally friendly cable materials with high added value and functional properties such as fire resistance and thermal stability. The development and large-scale industrial production of such next-generation cables are expected to contribute significantly to the cable manufacturing industry, the energy sector, and the national economy. Moreover, the project is expected to make a significant contribution to reducing carbon emissions. By preventing emissions associated with the disposal processes of boron enrichment wastes and minimizing the energy intensity required for the extraction and processing of virgin raw materials, the project will support a low-carbon production framework. The reuse of boron enrichment residues in manufacturing processes not only decreases energy consumption but also promotes the transition toward a sustainable and circular economy.

Keywords: Boron, Nanocomposite, Waste, Cable



SEM Image

Nanoboron, Metalic and Bimetalic Nanoparticles Doped Porous Carbon Material Derived from Waste Biomass and Its Hydrogen Storage Capacity

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Porous carbon materials derived from biomass wastes have attracted significant attention due to their remarkable properties. These include abundant and easily accessible raw materials, simplified production processes, tunable properties, cost-effectiveness, low mass density, high specific surface area and porosity, structural diversity, and sustainable renewability. These features make them promising candidates for further research in hydrogen storage devices, particularly in achieving high H_2 uptake capacity. The use of plant-based biomass-derived porous carbons has been investigated as key components in the development of porous carbon storage devices, encompassing activated porous carbons, heteroatom-doped porous carbons, and their composites. The synthesis and characterization of each form, as well as their hydrogen storage capacities, are emphasized. Although each material shows great promise, it should be noted that they also possess certain technological limitations. Overcoming these limitations through further research and development is critically important to fully realize the potential of these materials in the emerging hydrogen economy. According to studies conducted so far, several major challenges still exist in hydrogen storage. Although four different methods are available for hydrogen storage, a fully optimized technology without drawbacks in terms of stability, kinetics, capacity, cost, temperature, pressure, and safety has not yet been achieved. However, in recent years, the physisorption method using lightweight porous materials has shown promising results and contributed to solving some of these issues. In this project, a boron nanocomposite will be obtained from boron industry waste through an environmentally friendly method. Porous carbon materials derived from biomass and doped with metallic/bimetallic nanoparticles using the obtained boron-containing nanocomposite will be prepared and characterized. The potential of these prepared materials for large-scale hydrogen storage for practical daily use will be investigated.

Keywords: Nanoboron, Nanoparticle, Waste Biomass, Hydrogen Storage Capacity

Gel Synthesized Metal Borides and Their Electrochemical Analysis

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In this study, the synthesis of Titanium Diboride (TiB_2), and Calcium Hexaboride (CaB_6) powders via citrate gel methode and their structural characterization is proposed, and the electrochemical characteristics for a potential electrode for supercapacitors are investigated. Structural features of powders were characterized using X-ray powder diffraction (XRD), Scanning electron microscopy (SEM) and Fourier-Transform Infrared Spectroscopy (FTIR). Electrochemical characterization (Cyclic voltammetry, potentiostatic electrochemical impedance spectroscopy, and galvanostatic charge-discharge with potential limitation) of electrodes using a two-electrode system with a potentiostat device (BioLogic Science Instruments, France) were determined.

Keywords: Energy Storage, Metal Borides, Gel Sythesis, Electrochemical Properties

Türkiye Füzyılı (Proton-Bor Füzyonu)

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Günümüzde hızla artan enerji ihtiyacı ve fosil yakıtların çevresel etkileri, dünya genelinde temiz ve sürdürülebilir enerji kaynaklarına olan yönelimi zorunlu kılmıştır. Bu doğrultuda, yenilenebilir enerji kaynakları, hidrojen teknolojileri, küçük modüler reaktörler (SMR), klasik nükleer santraller (NGS) ve özellikle füzyon enerjisi gibi ileri teknolojiler, gelecek projeksiyonlarında merkezi bir konuma yerleşmektedir. Füzyon teknolojileri hem karbonsuz enerji üretimi hem de yüksek enerji yoğunluğu sunması nedeniyle dikkat çekmekte; enerji arz güvenliği, emre-amadelik ve temiz enerji gibi temel enerji politikası kriterlerini karşılayan bir çözüm olarak öne çıkmaktadır. Mevcut küresel projeler (ITER vb.) doğrultusunda, döteryum-trityum (DT) füzyonunun ticarileşmesinin önümüzdeki 20 yıl içinde mümkün olabileceği öngörülmektedir. Diğer taraftan DT füzyonunda, trityum kaynağının sınırlı olması ve reaksiyonda nötron üretimi nedeniyle radyoaktivite oluşması üzerinde çalışılması gereken önemli konular arasındadır. Buna paralel olarak, son yıllarda özellikle dikkat çeken proton-bor (pB) füzyonu, sahip olduğu özelliklerle hem çevresel hem de teknolojik açıdan füzyonun en temiz ve güvenli türü olarak değerlendirilmektedir. Proton ile Bor-11 izotopunun özel plazma koşullarında etkileşmesi neticesinde üç adet alfa parçacığı ve yaklaşık 8.7 MeV gibi oldukça yüksek enerji açığa çıkmaktadır. Bu reaksiyon karbon salınımı üretmediği gibi, ana reaksiyon sonucunda nötron kaynaklı radyoaktivite de ortaya çıkmamaktadır. Ayrıca, doğrudan elektrik üretimine olanak tanıyan yapısı sayesinde enerji verimliliğini ciddi ölçüde artırmakta; bu yönüyle uzay teknolojileri gibi enerji-yoğun ve hassas alanlarda kullanılabilirliği güç kazanmaktadır. Sürdürülebilir plazma koşulları başta olmak üzere mevcut teknolojik problemlerin çözülmesi durumunda karbon emisyonu olmayan, radyoaktivite içermeyen temiz ve yoğun enerji üretimi söz konusu olabilecektir. pB füzyonu teknolojisinin kritik bir bileşeni olan bor-11 izotopu, pB füzyonunun ana yakıtı olup, doğal borun %80'ini oluşturmaktadır. Türkiye, dünya bor rezervlerinin yaklaşık %73'üne sahip olması sayesinde yalnızca bu alanda enerji üretimi potansiyeline değil, aynı zamanda küresel ölçekte stratejik bir yakıt tedarikçisi olma avantajına sahiptir. "TÜRKİYE YÜZYILI" vizyonu kapsamında, bu konuda gerekli adımların atılması önem arz etmektedir. Bu bağlamda, önümüzdeki 10 yıllık süreçte, Türkiye'nin hedefi; pB füzyon teknolojilerine yönelik ulusal Ar-Ge altyapısını geliştirmek, deneysel projelere katkı sağlamak, uzman insan kaynağı yetiştirmek ve uluslararası girişimlerde aktif rol alması planlanmalıdır. 20 yıllık perspektifte ise, Türkiye'nin bor tabanlı bu teknolojiye dayalı sistemlerde teknolojik ortak ve stratejik yakıt sağlayıcısı konumuna gelmesi hedeflenmelidir. Bu hedeflere ulaşılabilmesi için; pB füzyon teknolojilerine yönelik küresel gelişmelerin yakından takip edilmesi, çok disiplinli araştırma projelerinin desteklenmesi, kamu-özel sektör iş birliklerinin kurulması, bor ürünlerinin bu bağlamda yeniden stratejik önceliklendirilmesi ve uzun vadeli bir devlet politikasının oluşturulması gerekmektedir. Türkiye'nin sahip olduğu doğal kaynak avantajı, yüksek potansiyele sahip bilimsel altyapısı ve vizyoner enerji politikaları ile pB füzyon alanında öncü ülke olma potansiyeli oldukça yüksektir. Bu teknoloji, yalnızca bir enerji çözümü değil, aynı zamanda 2053 hedefleri doğrultusunda ulusal kalkınma, enerji bağımsızlığı ve stratejik üstünlük sağlayabilecek bir fırsat olarak değerlendirilmelidir. Bu hususta önerimiz, FUsion TURkiyE (FUTURE) Araştırma Merkezinin oluşturulması ve "TÜRKİYE YÜZYILI" vizyonuna 2053 hedefli olmak üzere "TÜRKİYE FÜZYILI" adı altında katkı sunulmasıdır.

Anahtar Kelimeler: Temiz Enerji, Proton-Bor Füzyonu, Bor-11, Füzyon Teknolojileri, Sürdürülebilir Enerji

TÜRKİYE FÜZYILI

(Proton-Bor Füzyonu)

Doç. Dr. Bülent BÜYÜK
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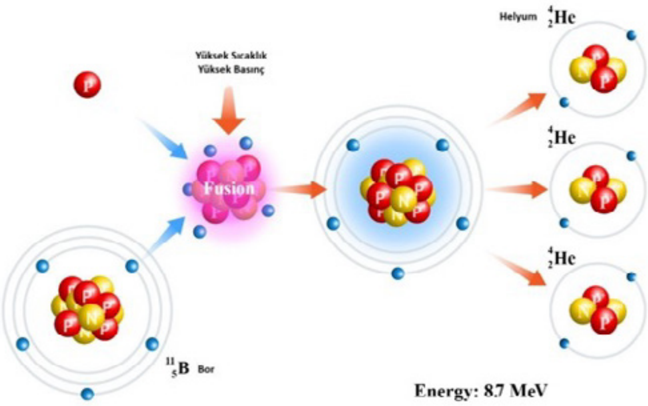
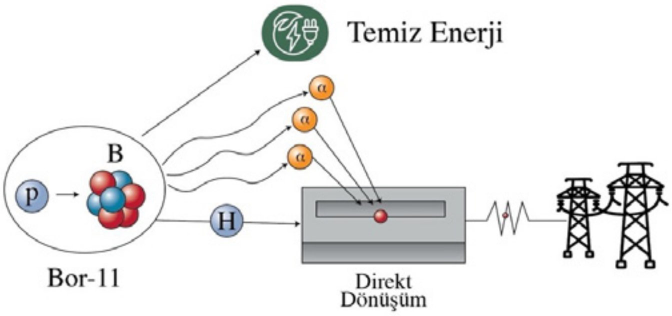
Türkiye Füzyılı



Proton-Bor (pB) Füzyon Reaksiyonu



pB Füzyonu Enerji Üretimi

Boron-Based Quantum Dots in Advanced Supercapacitor Systems

Mehmet Şükrü Dündar[1], Sait Altun[2], Bahadır Keskin[1], Hasan Göçmez[2]

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Supercapacitors, which combine the advantages of batteries and capacitors, have gained attention due to the global demand for sustainable energy storage. They provide long cycle life, quick charging, and high-power density [1]. In this context, boron-doped carbon quantum dots (BCQDs) offer improved conductivity and surface activity, while phthalocyanines offer stability and rich π-electron structures. Incorporating boron increases overall efficiency by enhancing ion mobility and charge transport at the interface. Notably, BCQDs can be made using microwave-assisted synthesis, which is environmentally friendly and consistent with the principles of green chemistry [2]. These characteristics collectively make BCQDs promising materials for developing boron-based sustainable energy technologies and for next-generation supercapacitors.

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Keywords: Supercapacitor, Quantum-Dots, Boron, Electrochemical Analysis

Influence of Different Temperatures on Hydrogen Decrepitation of Scrap Hard Disk Drive NdFeB Magnets

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Demand for rare earth elements (REEs) in NdFeB permanent magnets used in renewable energy and EV necessitates efficient recycling to address supply chain vulnerabilities and environmental concerns. Hydrogen decrepitation (HD), a low-energy technique, offers a promising method for processing end-of-life Hard Disk Drive (HDD) NdFeB magnets by converting them into demagnetised powders while preserving microstructural integrity. This study investigates the impact on hydrogenation temperature (room temperature, 50 °C, 75 °C) on the recycling process at 4 bar hydrogen pressure. Results indicate that reduced temperatures promote hydrogen absorption, diminish oxidation, and produce finer particles characterised by typical intergranular fractures. Phase analysis support the synthesis of $Nd_2Fe_{14}BH_x$ and increase of Nd_2O_3 at elevated temperatures. According to these results, HD at room temperature under 4 bar is optimal for the effective and sustainable recycling of NdFeB magnets, eliminating the need for further heat treatment.

Keywords: NdFeB, Hydrogen Decrepitation (HD), Recycling, Rare Earth Elements (REEs), End of Life (EoL) Magnet

Optimization of Growth Conditions for Hexagonal Boron Nitride Thin Film on Dielectric Substrates

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Hexagonal boron nitride (h-BN), a wide bandgap material known for its exceptional thermal stability, chemical inertness, and optical transparency, has attracted increasing attention for advanced electronic and optoelectronic applications—particularly in missile warning systems, UV ozone treatment, space observation, and UV communication technologies. When synthesized in its two-dimensional (2D) form, h-BN exhibits enhanced optical and electronic characteristics due to reduced defect density, improved interlayer uniformity, and superior surface smoothness. These features make it a promising dielectric layer and protective barrier material for next-generation nanoscale and optoelectronic devices. In this work, h-BN thin films were synthesized on non-catalytic quartz substrates using the low-pressure chemical vapor deposition (LPCVD) technique. Quartz was selected as the substrate because of its dielectric nature, high UV transparency, and thermal robustness, enabling accurate optical and electrical characterization of the grown layers and supporting their integration into UV photodetector architectures. LPCVD was preferred over other deposition techniques owing to its controllable process parameters, scalability, and partially eco-friendly characteristics, which facilitate large-area and uniform thin film growth. The effects of precursor quantity (200, 150, 100, and 50 mg) and growth duration (90, 60, 30, and 15 minutes) on the crystalline quality of the h-BN films were systematically analyzed using X-ray Photoelectron Spectroscopy (XPS). The XPS results revealed significant variations in the B1s and N1s bonding states depending on the synthesis conditions, indicating changes in stoichiometry and crystal ordering. Among the investigated samples, the film synthesized with a 100 mg precursor and a 60-minute growth period exhibited the sharpest and most symmetric B–N peaks with reduced FWHM values, suggesting improved crystallinity and lower defect density.These findings highlight the crucial role of precursor amount and growth duration in tailoring the structural and optical quality of h-BN films grown on dielectric quartz substrates, offering valuable insights for optimizing their synthesis in optoelectronic and UV detection applications. Additionally, these results will be further supported by investigations using Raman and PL spectroscopy.

Keywords: Hexagonal Boron Nitride Thin Films, XPS Investigations, LPCVD, Dielectric Substrates

BORON IN DEFENSE INDUSTRY

(SAVUNMA SANAYİNDE BOR)

Design and Development of High Toughness B_4C–TiB_2 Ceramics for Lightweight Armor Systems

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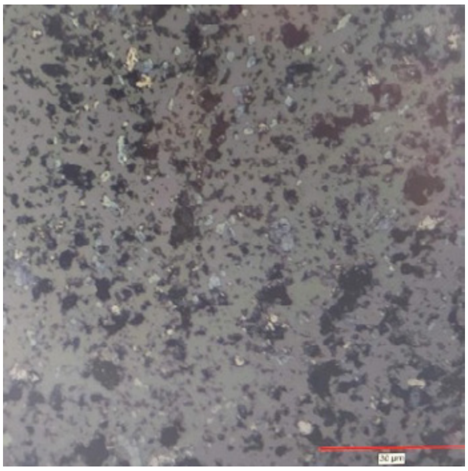
Ceramic materials showcase superior characteristics such as hardness, lightness and wear resistance, which make them ideal choice for body armors, platform add-on armors, thermal shields and many other protective structures. Owing to their exceptional hardness and low density boron carbide (B_4C) ceramics are especially the subject of interest. However, B_4C ceramics showcase high brittleness and glassy microstructure formation under elevated impact forces which decrease its potential to be used against high kinetic energy rod type threats. In order to achieve higher ballistic protection capability, brittleness of the B_4C ceramics should be improved without decreasing the hardness by the manipulation of microstructural crack behaviour. Such toughening mechanisms in the B_4C microstructure can be achieved by the addition of other ceramic reinforcements to be located in the grain boundaries but the processing of dense, defect-free and high mass blocks is still a challenge. Therefore, in this study ballistic B_4C-TiB_2 (85:15, 90:10 wt%) ceramic composites were densified via a novel mixing and hot pressing method. Sintered ballistic ceramic composites investigated in the means toughening and crack propagation mechanisms and physical/chemical properties. Both samples exceeded 27 GPa hardness and showcased almost doubled toughness. Ballistic protection capability of the sintered ballistic ceramic composites were determined by ballistic test shots conducted with a solid propellant gun using tungsten high alloy (WHA) projectiles. This study aims to explain the relation between processing, microstructural/material properties and ballistic properties using both advanced characterization and real-time ballistic testing.

Keywords: Ceramic Matrix Composites, Ballistic Ceramics, Ballistic Testing, Crack Propagation, Hot Press Sintering



SEM Image of the B_4C-TiB_2 (90:10 wt%) Ceramic Composite

Hassas Dönüölçerlerde Kullanılan Polarizasyon-Korumalı Optik Fiberlerde Borun Önemi ve Kullanımı

Ali Karatutlu[1], Bülend Ortaç[2]

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Yüksek çift kırınıma sahip özel optik fiberlerde polarizasyon koruma (PM) bor katkılı stres uygulama bölgeleri (SUB'lar) ile sağlanır. Bu duruma çekirdek bölgesinin her iki yanına dairesel veya papyon şekilli ve göreli olarak yüksek bor katkılı silika yapılarının entegre edilmesi ile mümkündür. Sırasıyla, bu özel fiberler Panda-tipi veya Papyon tipi PM fiberler olarak ticari olarak erişilmektedir. Bu sunumda, özellikle ülkemizde savunma sanayi uygulamalarında karşımıza çıkan atalatsel ölçüm birimlerinde yer alan dönü ölçerlerde kullanılan PM fiberin üretimi ve bor katkılı SUB'ların pozisyonu ve yeni yaklaşımlar gösterimi gerçekleşecektir. Ayrıca, yüksek polarizasyon sönümlenme oranına sahip yeni nesil eliptik çekirdek geometrisinde Panda tipi PM fiberler sunulacaktır.

Anahtar Kelimeler: PM Fiberler, Özel Optik Fiberler, Yüksek Çift Kırınım, Polarizasyon Sönümlenme Oranı, Dönüölçer

Mechanical Performance of Oxidation-Resistant h-BN Coated Carbon Fiber Bundles and Fabric-Reinforced Composites

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Carbon-fiber fabrics are essential in lightweight aerospace structures but oxidize rapidly above ~600 °C. We previously developed and demonstrated multiple CVD routes, namely boron-oxide-assisted CVD, AB/THF-fed CVD, and TMB-fed CVD, that deposit conformal h-BN on the fiber surface, increasing the oxidation-onset temperature by ~140–250 °C (TGA in air, 10 K min^{-1}) relative to uncoated fabrics. Beyond acting as a promising oxidation barrier, the hBN layer establishes a fiber–epoxy matrix interphase that can govern interfacial adhesion, load transfer, and failure modes. Among the routes we developed and demonstrated, the trimethyl borate (TMB)–based process emerges as the most promising, affording scalable h-BN deposition under mild conditions while preserving fiber integrity. Here we examine how this TMB-enabled coating affects the inplane tensile response of fiber bundles and carbonfiberreinforced polymer (CFRP) laminates. Epoxymatrix composites were fabricated from (i) de-sized fabrics, (ii) untreated fabrics, and (iii) h-BN coated at 900 °C for 1h, the condition that yielded the most crystalline, continuous hBN in our prior study. To isolate coating effects, layup, cure schedule, and areal weight were held constant, and fiber volume fraction was measured to capture any coatinginduced changes. Rectangular coupons were tested in tension per ASTM D3039 with bonded tabs. Reported metrics include modulus, ultimate tensile strength, strain to failure, and tensile energy to break (area under the stress–strain curve).The study maps processing–structure–property relationships between BN coverage/crystallinity and laminate tensile behavior, clarifying the dual role of hBN as (i) an oxidationresistant barrier and (ii) an interphase that can be tuned to balance stiffness retention with strength and ductility.We discuss potential tradeoffs arising from coating thermal exposure (e.g., sizing removal or fiber damage) and outline post-coating strategies to tailor adhesion without sacrificing oxidative robustness. The results inform the design of BNcoated CFRP laminates for service in oxygenrich, hightemperature environments where ambienttemperature load bearing must coexist with oxidation resistance.

Keywords: Hexagonal Boron Nitride (h-BN), Chemical Vapor Deposition, Carbon Fiber, Oxidation Resistance, In-Plane Tensile Properties

Development of Novel Advanced Ceramics: High Entropy Boride-Carbide Materials as Wear-Resistant Components

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This project involves hybridization of metal boride (HfB_2, TiB_2, ZrB_2, Mo-boride, W-boride) or metal carbide (HfC, ZrC, TiC, MoC, WC) powders by mechanical alloying in the form of three, four and/or five-component high-entropy boride (HEB) and high-entropy carbide (HEC) in equimolar ratios; assembly of hybrid powders into high-entropy boride-carbide powders containing 6-10 components. Then, they were mechanically alloyed and densified to produce single-phase high-entropy ceramics. HEB and HEC ceramics were hybridized separately by mechanical alloying for 6 h and 3 h, respectively. Tungsten carbide vials and balls were used during mechanical alloying, and the ball-to-powder weight ratio was determined as 10:1. The hybridized powders were converted into densified bodies by spark plasma sintering at 1800°C and 30 MPa. To determine the properties of the HEB and HEC ceramics, microstructural (scanning electron microscopy, energy dispersive spectroscopy), physical (powder and Archimedes densities), mechanical characterizations (Vickers hardness, wear tests), thermal characterization, and phase analysis (X-ray diffractometry) were performed for both the powder and sinter compositions. The highest hardness value of approximately 27 GPa was achieved for the $(HfTiZrMoW)B_2$ - (HfTiZrMoW)C composition. Similarly, the lowest friction coefficient, 0.35, was observed for the same composition. Average density values ranged from 8.89 g/cm^3 to 6.41 g/cm^3. High-intensity HEB/HEC peaks were observed in the structure, along with low amounts of oxidized phases.

Acknowledgement: This study was supported by the Istanbul Technical University Scientific Research Projects with the project number of MUA-2025-46987. Also, this study was supported by The Scientific and Technological Research Council of Türkiye 2209-A-Undergraduate Students Research Projects Support Program.

Keywords: High Entropy, Mechanical Alloying, Hardness, Microstructure, Spark Plasma Sintering

Boriding of a Refractory High Entropy Alloy for Wear-Related Engineering Applications

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[1]*Istanbul Technical University*

Refractory high entropy alloys (RHEAs) have emerged as a new class of materials exhibiting competitive properties compared to both commercial high temperature alloys (i.e. nickel-based superalloys) and biomedical materials (i.e. titanium alloys). In this respect, enhancing their surface properties, particularly hardness and wear resistance, to extend their service lives has become one of the most important topics in the literature. Besides there are vast number of studies focusing on the boriding of Fe, Cr, Al, Co, Ni-containing HEAs, mostly in face-centred cubic crystal structure, studies addressing the boriding of Ti, Hf, Zr, Nb-containing RHEAs having body-centred cubic crystal structure remain scarce in the open literature. This study investigates the effect of boriding on the surface features of the RHEA, containing Hf, Nb, Ta, Ti, and Zr, with the aim of fabricating hard and wear-resistant boride coating. Boriding process was employed at 1000 ºC for 8 h. Structural characterizations made by X-ray diffractometer and energy dispersive spectrometer equipped scanning electron microscope revealed the formation of ~10 µm thick total boride layer consisting of boride phases of constituent elements. This boride layer increased the surface hardness from ~400 to ~2700 HV0.025, resulting in two orders of magnitude increment in the dry sliding wear resistance. Decrease in the wear loss can be attributed to the suppression of plastic deformation induced adhesive wear during sliding contact owing to the presence of hard boride coating at the external surface. This pioneering study demonstrated the effectiveness of boriding process as a technological solution for surface engineering of RHEAs.

Keywords: Refractory High Entropy Alloy, Boriding, Wear

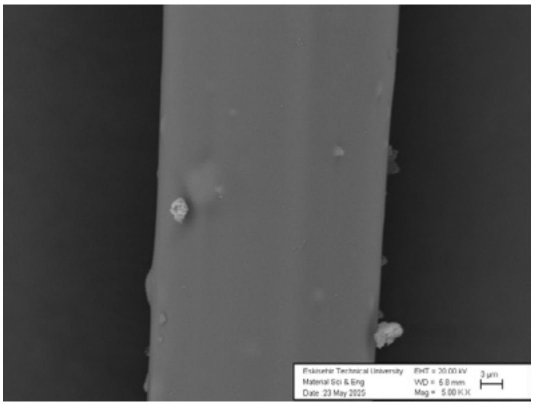
Fiber Drawing from CMAS (CaO-MgO-Al_2O3-SiO_2) Glass Systems and Characterization of Drawn Fibers

Gülseda Şenel[1], Emrah Dölekçekiç[1], Mert Gül[1], Hüseyin Boğaç Poyraz[1], Aydın Doğan[1]

[1]*Eskisehir Technical University*

Glass fibers are widely employed to enhance the mechanical performance of composite materials owing to their high tensile strength, elastic modulus, and low density. Among commercial variants, E-glass (with improved electrical properties) and S-glass (high-strength) are commonly selected for application-specific requirements. While CMAS (CaO–MgO–Al_2O_3–SiO_2) compositions are reported across numerous domains, no studies explicitly addressing fiber drawing from CMAS glasses have been reported. The present work therefore aims to establish a viable temperature–viscosity window for fiber drawing from CMAS systems without triggering crystallization. In this study, CMAS-based glass frits were produced by melt quenching to obtain an amorphous structure, which was verified by X-ray diffraction (XRD). The compositions were subsequently characterized by X-ray fluorescence (XRF), boron content was quantified by a wet-chemical method, thermogravimetric/differential thermal analysis (TG/DTA), and hot-stage microscopy to determine critical temperatures and processing limits. Relative to boron-free CMAS reported in the literature, our ulexite-derived ~10 wt% B_2O_3 lowers the glass transition temperature (Tg) while raising the crystallization temperature (Tx), thereby expanding the stability window (ΔT = Tx – Tg) and highlighting improved processability and a wider, crystallization-free viscosity range suitable for fiber drawing. Drawing of fibers with an average diameter of approximately 30 µm was achieved; however, process discontinuities were observed during fiber drawing and are being investigated to determine their origin. To ascertain this, samples of the CMAS composition were prepared and held at critical temperatures, and the crystals formed within the structure were identified. The crystalline phases were identified by XRD and SEM analyses of the samples. By lowering Tg, elevating Tx, and thereby widening ΔT (Tx–Tg) to enable a crystallization-free viscosity window for fiber drawing, the research contributes to the development of high-performance fibers for applications in aerospace, energy, and advanced composite industries.

Keywords: Glass, Glass Fibers, Crystallization



SEM image of Drawn CMAS Fibers

Design and Development of a Domestic Autonomous Ground Vehicle Equipped with Boron-Based Radiation Shielding

Ahmet Emir Şahin[1], Doğukan Elmas[1], Hilal Akbaş Yaman[1], Fatih Yarar[1]

[1]*Alpagu Savunma Sanayi*

In this study, a domestic unmanned ground vehicle capable of operating in environments with radiological risks was developed, featuring a boron-based composite coating designed for radiation attenuation. The system was conceived to minimize human intervention in nuclear facilities, research laboratories, and CBRN hazard zones. The vehicle platform is built on a lightweight aluminum chassis with an IP54 protection rating. Its software infrastructure integrates data from multiple sensors, such as a camera, LiDAR, and IMU, within a modular control architecture that enables both manual and semi-autonomous operation. All critical parameters, including speed, position, battery status, and system health, can be monitored in real time through a user interface. A gamma radiation sensor calibrated by the Nuclear Regulatory Authority was integrated into the system. Measurement data are combined with positional information to generate real-time dose maps, allowing simultaneous visualization of the radiation levels and the vehicle's trajectory. The shielding structure employs a boron carbide (B_4C)-reinforced composite coating, taking advantage of boron's neutron absorption capability. Based on theoretical analyses and attenuation coefficients reported in the literature, a 0,5 cm thick boron-based layer is estimated to provide approximately 40–60 % gamma radiation attenuation within specific energy ranges. The developed platform represents one of the first domestically designed autonomous systems in Türkiye, specifically intended for radiological environments. This work demonstrates the potential of boron-based materials in nuclear safety and defense applications, while also contributing to the integration of indigenous software and sensor fusion technologies into national R&D capabilities.

Keywords: Boron, Radiation Shielding, Unmanned Ground Vehicle, Composite Material, Nuclear Safety

Synthesis and Development of Elemental Amorphous Boron Powders with Different Particle Sizes and Calorific Values for Pyrotechnic Applications

Selçuk Acar[1]

[1] *Pavezyum Kimya*

This study focuses on the synthesis and development of elemental amorphous boron powders with different particle sizes and calorific values, optimized for pyrotechnic and energetic applications. Given that Turkey possesses 73% of the world's boron reserves, converting this resource into high-value, advanced boron-based materials holds major strategic and economic significance. Elemental amorphous boron, known for its high energy density and reactivity, is widely used in defense, aerospace, and automotive sectors—particularly in airbag initiator systems and solid fuel formulations. However, its combustion efficiency and performance are highly dependent on particle size and morphology. In this study, novel production methods—spray drying, NaCl flux-assisted metallothermic reduction, thermal treatment, and physical sieving—are employed to control the particle size distribution of amorphous boron powders without compromising their amorphous structure. The relationship between particle size and calorific value, reactivity, and combustion kinetics were systematically investigated. Characterization include XRD, SEM, BET surface area, calorimetry, and combustion tests using high-speed imaging. The resulting materials will be tailored for specific industrial needs, providing optimized energetic properties for defense and automotive pyrotechnic applications. The work represents Turkey's first large-scale attempt to produce modified amorphous boron powders with tunable particle sizes using innovative local technologies. The outcomes include the establishment of new synthesis protocols for particle size adjustment, entry into the airbag materials export market, and strengthening of domestic supply chains for energetic materials. Ultimately, this project will enhance the technological independence and global competitiveness of Turkey in advanced boron-based materials.

Keywords: Elemental Boron, Energetics

BORON-BASED CHEMICALS

(BOR TABANLI KİMYASAL SİSTEMLERİ)

Activation of Small Molecules: Can Boron Act as a Transition Metal?

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The activation of small molecules is generally associated with transition metals (TMs) and constitutesthe basis of catalysis. It was earlier believed that TM catalysts are required to facilitate processes suchas the activation of H_2 and other unreactive substrates. However, exciting recent developments in maingroup element chemistry have shown that carbenes, FLPs and heavy main group species are capable of TM-like activation reactions [1]. Our ongoing studies on low-oxidation-state boron compounds such asborylenes, diborenes, and diborynes have shown that these low-valent species exhibit a very richchemistry, which is distinctly different from that of common compounds derived from boron in the oxidation state +3. Particularly interesting is the metal-like behavior of some borylenes and diborynes, which form CO complexes analogous to TMs, bind and convert H_2 and unsaturated organic substratesunder mild conditions, and even activate and reduce N_2 [2].

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Keywords: Small-Molecule Activation, Low-Valent Boron Species, Borylenes, Diborenes, Diborynes

Development of Pd-B/Al_2O_3 Catalyst for Methane Pyrolysis Reaction

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[2]*Gazi University, Graduate School of Natural and Applied Sciences*

Methane pyrolysis is considered an environmentally friendly hydrogen production method, as it generates only hydrogen and solid carbon without releasing CO_2. However, the carbon formed during the reaction accumulates on the catalyst surface, blocks active sites, and leads to rapid catalyst deactivation. In this study, new catalyst structures were developed to reduce carbon deposition by modifying the base Pd/Al_2O_3 catalyst with boron and by introducing nickel and cobalt to form bimetallic systems. Three different catalysts—Pd-B/Al_2O_3, Pd-Ni-B/Al_2O_3, and Pd-Co-B/Al_2O_3—were prepared, and the effect of boron within these structures was examined. All catalysts were synthesized using the wet impregnation method, and their surface properties before and after the reaction were analyzed by X-ray Photoelectron Spectroscopy (XPS). Reaction tests showed that the highest methane conversion, 80%, was achieved with the Pd-Co-B/Al_2O_3 catalyst. This result suggests that cobalt and palladium create more stable active sites together, improving catalytic performance. The lowest conversion, 56%, was observed for the unmodified Pd/Al_2O_3 catalyst. In terms of carbon deposition, the highest amount (25%) occurred on the Pd-Ni-B/Al_2O_3 catalyst, which is consistent with nickel's tendency to form carbon filaments. The lowest carbon deposition, 4.2%, was measured on Pd/Al_2O_3. Overall, the results indicate that boron does not significantly improve the performance of Pd when used alone. However, in bimetallic systems—especially Pd-Co-B/Al_2O_3—boron helps increase methane conversion and reduces carbon deposition by 28% compared to the Pd-Ni-B/Al_2O_3 system. These findings provide valuable insight for designing more durable catalysts for methane pyrolysis.

Keywords: Methane Pyrolysis, Carbon Deposition, Boron, Bimetallic Catalyst

Structural, Optical, and Neutron Sensitivity Properties of Yb^{3+}/Tb^{3+} Codoped Alkaline Earth Tetraborates

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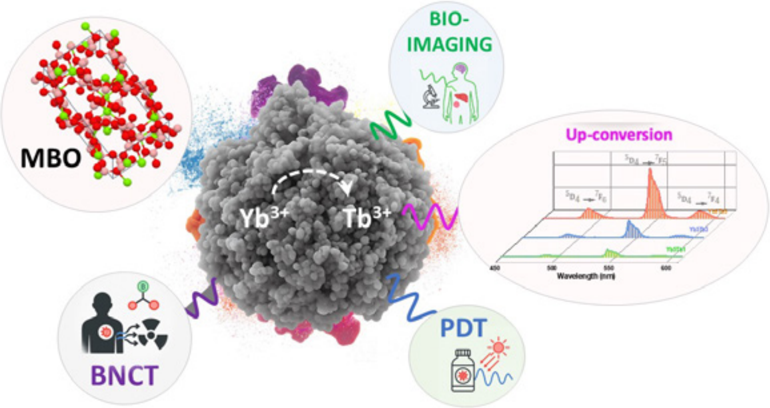
[2]*Department of Bioengineering, Hacettepe University*

Multifunctional boron-rich crystalline inorganic compounds that concurrently provide optical transduction, neutron capture, and acceptable cytocompatibility are critically needed to advance minimally invasive cancer treatments. Herein, Yb^{3+}/Tb^{3+} codoped alkaline earth tetraborates—CaB_4O_7, MgB_4O_7, and SrB_4O_7—were synthesized via solid-state, combustion, and solution combustion routes. X-ray diffraction patterns confirmed phase-pure monoclinic CaB_4O_7 and orthorhombic MgB_4O_7/SrB_4O_7 structures; SEM revealed around 200 nm particle sizes. Under 980 nm excitation, pronounced upconversion emissions were observed in all, where CaB_4O_7 and MgB_4O_7 showed best response at 5 mol% Yb^{3+} / 5 mol% Tb^{3+}, with quantum yields approaching ~0.35, evidencing highly efficient cooperative Yb→Tb energy transfer. This NIR responsivity is directly relevant for photodynamic activation in optically restricted tissue volumes. ^{10}B enrichment (98%) markedly increased macroscopic neutron absorption cross sections (up to +62–76%), thus enabling BNCT functionality without auxiliary boron carriers. HUVEC assays indicated maintained viability > 80% for CaB_4O_7 at 500 µg mL^{-1}, underscoring favorable biocompatibility at biologically meaningful doses. Taken together, these results identify Yb^{3+}/Tb^{3+} codoped tetraborates as a robust single-phase inorganic class that intrinsically integrates high boron density with NIR-gated upconversion and benign cytocompatibility. Such materials are compelling candidates for multifunctional theranostics coupling BNCT, NIR-activated photodynamic therapy, and imaging.

Keywords: Tetraborates; Lanthanide Codoping; NIR-to-Visible Upconversion; Boron Neutron Capture Therapy (BNCT); Theranostic Nanomaterials



Multifunctional properties of alkaline earth tetraborates (CaB_4O_7/ MgB_4O_7/SrB_4O_7)

Cage-carbon Substituted Amine and Nitrile Derivatives of Cobalt bis(dicarbollide) Anion

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[2]Institute of Inorganic Chemistry of CAS, Hlavní 1001, 250 68 Řež, Czechia

Direct functionalization of carbon vertices of the metallacarborane cages remained underexplored. In this study, modification of the cage-carbon atoms of cobalt bis(dicarbollide) anion with the formula; $[(1,2\text{-}C_2B_9H_{11})_2\text{-}3,3'\text{-Co(III)}]^-$ (short name COSAN) bearing -NH_2 and -CN groups obtained by the direct functionalization of the parent metallacarborane cage are explained. Two methods were employed for azide and amine functionalization. Curtius rearrangement and direct functionalization by tosyl azide after lithiation of the parent cobalt bis(dicarbollide) cage under strictly anhydrous conditions under Ar atmosphere using Schlenk techniques afforded mono $[(1\text{-}N_3\text{-}1,2\text{-}C_2B_9H_{10})(1',2'\text{-}C_2B_9H_{11})\text{-}3,3'\text{-Co(III)}]^-$ and diazido-COSAN *rac*-$[1,1'\text{-}(N_3\text{-}1,2\text{-} C_2B_9H_{10})_2\text{-}3,3'\text{-Co(III)}]^-$ derivatives. The azide products have shown dissimilar reactivity compared to their organic analogues and they could be reduced into amines using an excess of $NaBH_4$ under $CoCl_2$ catalysis in 50% aqueous MeOH. Position of the -NH_2 group on the cage-boron versus a cage-carbon have proven significantly different acidity [1]. Cyano functionalized COSANs were obtained by deprotonation of the cage C-H hydrogens by n-BuLi, followed by the reaction with tosyl cyanide. Monosubstituted, and two isomers of disubstituted nitrile derivatives, *racemic* and $C(1,8)\text{-}(CN)_2$ of cobalt bis(dicarbollide) ion $[(1,2\text{-}C_2B_9H_{11})_2\text{-}3,3'\text{-Co(III)}]^-$ were isolated as the main products from low-temperature reaction of the lithiated ion with tosyl cyanide. As follows from chemical DFT computations, the C(1,2) substituted intermediate species corresponding to *vicinal* isomer forms at the initial stages of the reaction and then undergoes to a unique cage skeletal rearrangement, involving migration of one of the cyano-substituted cage-carbon atoms to the upper pentagon belt, even below the room temperature [2]. DFT computations indicate that the rearrangement process is triggered by unprecedented electron-donation from the cyano-groups. The lower energy barrier causes the rearrangement occur below 25 °C, which is in sharp contrast to 340 °C, the lowest previously known temperature of the rearrangement of 1,2-COSAN to the corresponding 1,8-isomer [3].

Acknowledgement: Support from Czech Science Foundation, project No. 25-16216S

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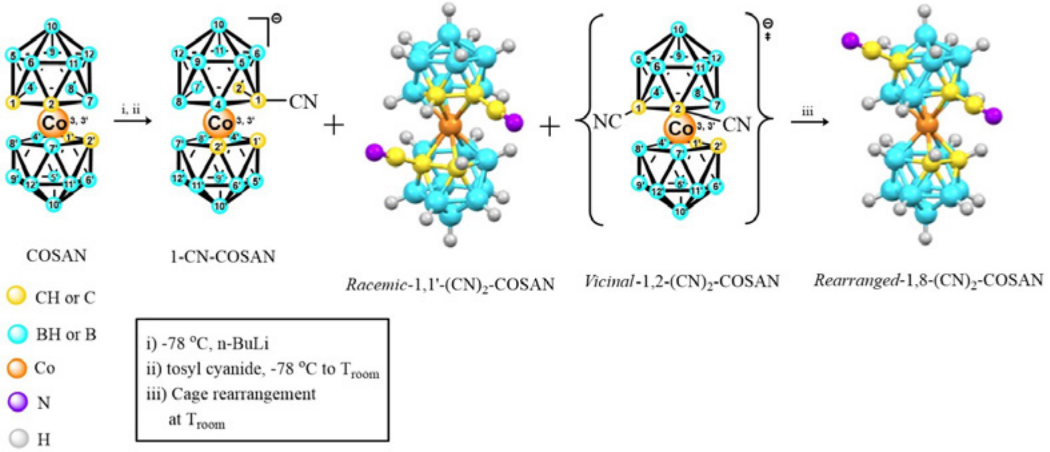
Keywords: Carboranes, Metallacarboranes, Cobalt bis(dicarbollide), Cluster Chemistry



Synthesis of the cyano-derivatives of cobalt bis(dicarbollide)

New Boron-Containing Conjugated Systems for TADF OLED Application

Semih Can Çakmaktepe[1], Oğuzhan Karakurt[1], Elif Fatma Demirgezer[1], Murat Daştemir[1], Hector Miranda-Salinas[2], Erkan Aksoy[3], Andrew Danos[2], Andrew Monkman[2], Erol Yıldırım[1], Ali Çırpan[1]

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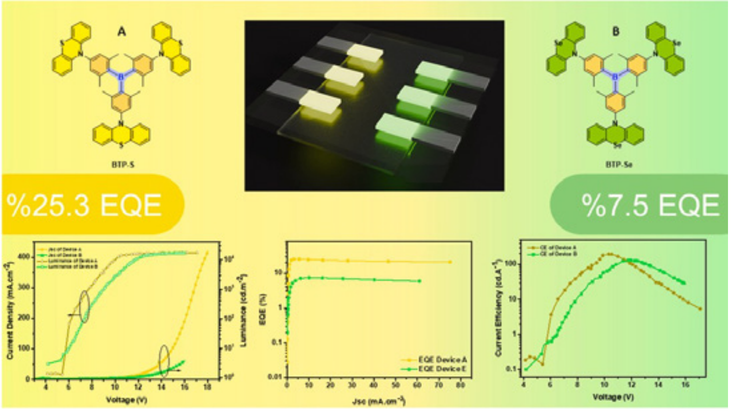
In this study, particular emphasis is placed on the design and synthesis of boron-containing small-molecule acceptors for application in thermally activated delayed fluorescence (TADF)-based OLED devices, with the aim of enhancing device efficiency and color purity through molecular engineering. TADF is a mechanism that enables the conversion of triplet excitons into singlet excitons through reverse intersystem crossing facilitated by a small energy gap between the singlet and triplet states. By harvesting both singlet and triplet excitons, TADF materials can theoretically achieve up to 100% internal quantum efficiency (IQE). For performance evaluation, two boron-based emitters incorporating phenothiazine and phenoselenazine donor units were synthesized. Their optical, electronic, and electroluminescent properties were thoroughly characterized. Among them, BTP-S exhibited superior device performance, achieving an external quantum efficiency (EQE) of 25.3% and a maximum luminance of 17356 cd/m², whereas BTP-Se displayed an EQE of 7.5% and a luminance of 16826 cd/m². These results demonstrate that boron-based acceptor units represent promising candidates for next-generation high-efficiency OLED displays.

Keywords: Organoboron, Phenoselenazine, Phenothiazine, TADF, OLED

New Boron-Containing Conjugated Systems for TADF OLED Application



Graphical Abstract Representing J-V-L Curves and EQE Curves of Boron Containing OLED Devices

All Facets of Carboranes: From Fascinating Chemistry to Promising Applications

Igor Sivaev[1]

[1]*A. N. Nesmeyanov Institute of Organoelement Compounds, Russian Academy of Sciences*

Icosahedral carboranes and metallacarboranes, complexes based on them, have reached their 60th anniversary. However, it is premature to talk about their retirement - chemistry leads to new discoveries and promises a wide variety of applications from molecular switches to new luminescent materials. Recent fascinating results in the field of carborane and metallacarborane chemistry obtained at the A. N. Nesmeyanov Institute of Organoelement Compounds will be considered. [1-5]. This research was supported by the Russian Science Foundation (25-43-00072).

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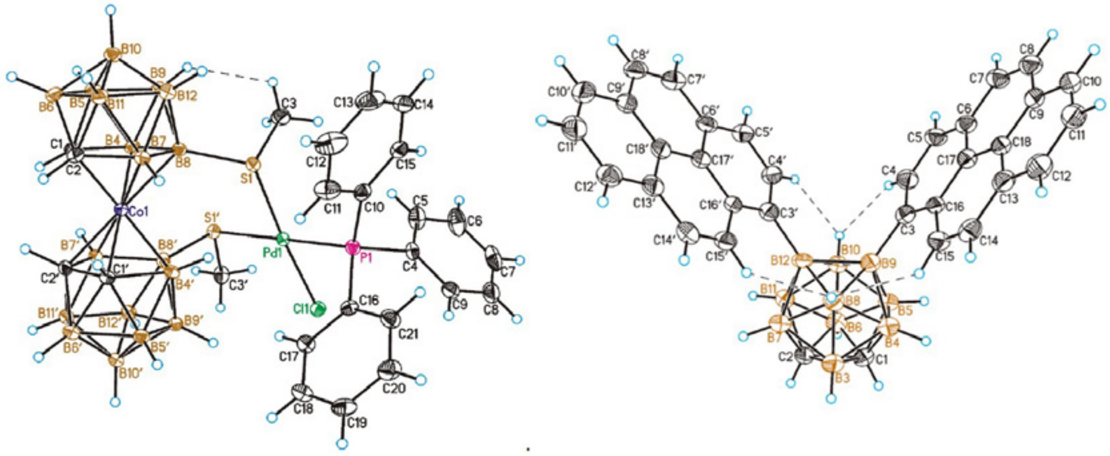
Keywords: Carboranes, Metallacarboranes, Molecular Switches, Luminescent Materials



Molecular structures of some synthesized compounds

Syntheses, Spectral and Stereogenic Properties of Multi-Heterocyclic Di- and Trinuclear Boron Complexes

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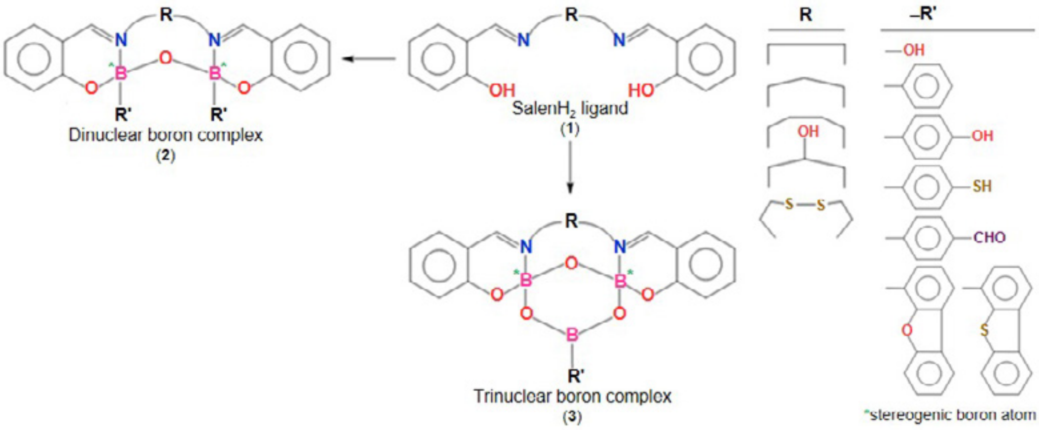
A significant amount of research has been devoted to investigate stereogenism in compounds with tetra-coordinated main group elements other than carbon like nitrogen, phosphorus, silicon, and sulfur for decades. The study of compounds with tetra-coordinated boron as a stereogenic center has not been carried out at a much more intensive level, and stereomerism that relies solely on this element has been considered elusive for a long time. For the past few years, we have had a motive to better understand the reasons leading to the formation of different stereoisomers in boron compounds. Therefore, we have been interested in preparing multi-heterocyclic structures that have a skeleton consisting of two or three boron atoms. In this study, many series of dinuclear (2) and trinuclear (3) boron complexes based on boroxane and boroxine archhitectures, respectively, were synthesized from salenH2 type symmetrical bulky ligands [HOArCH=N-R-N=CHArOH (1)], arylboronic acids (phenylboronic acid, 4-formyl/hydroxy/mercaptophenylboronic acid, dibenzofuran-/dibenzothiophene-4-boronic acid), and boric acid for the investigation of their spectral and stereogenic properties (Scheme). The salen-boron complexes are the only examples of compounds in which the stereogenism is imparted exclusively by two equivalent boron centers, giving rise to diastereoisomers. These complexes were examined for their stereogenic properties, and the effects of the R bridge linking the two salicylidene groups on the stereogenic properties originating from the boron center were investigated using the combination of nuclear magnetic resonance (NMR) and circular dichroism (CD) spectroscopies for the first time by our research group. It is possible to determine the number of stereoisomers present in boron complexes using NMR data. However, NMR data is not sufficient for identifying the stereoisomer type. The type of a stereoisomer was determined based on CD. In other words, CD spectroscopy was used to decide which diastereisomer was formed in boron complexes having two equivalent stereogenic boron centers or to determine whether the boron complex contained only a single diastereomer or a mixture of diastereomers. It is important to note that the most significant outcome is derived from the combination of CD and NMR spectra of the boron complexes. On the other hand, stereoisomers were compared with each other for two different architectural types, dinuclear complexes based on boroxane architecture (RB-O-BR) (2) and trinuclear complexes based on boroxine architecture [(B-O-B)-(O_2BPh)] (3), with seven-, eight-, nine- and eleven-membered heterocycles [(B-O-B)-(N-CH_2-R-CH_2-N)]. It is concluded that the number of members in the heterocycles, and planar and bulky groups included in the structure of the bor-salen complex have been suggested to be a significant factor in the formation of stereoisomers. The knowledge obtained from this study is very important not only for boron complexes stereogenic only at the boron atom but also for the other systems containing stereogenic centers and/or groups.

Reference: Bilge Koçak, S., Kaya, Ö., Kiliç, Z., Coban, B., Yildiz, U., Çoşut, B. 2020. "Syntheses, spectral and chiral properties and DNA interactions of multi-heterocyclic di- and trinuclear boron complexes", New Journal of Chemistry, 44(48), 20966-20981.

Acknowledgements: Selen Bilge Koçak is grateful to the The Scientific and Technological Research Council of Turkey (TÜBİTAK) (Project No. 124Z461) and Ankara University Scientific Research Projects (BAP) (Project No. 13B4240011, 15L0430008 and 21B0430003).

Keywords: SalenH_2 Ligands, Heterocyclic Boron Rings, Srereogenism, Diastereoisomers, Spectroscopy



Formula of dinuclear (2) and trinuclear (3) boron complexes

Sulfur and Selenium Functionalized Boron-Based Multiresonance TADF Emitters

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Sulfur and Selenium Functionalized Boron-Based Multiresonance TADF EmittersBoron's high electron affinity, Lewis acidity, and ability to adopt three-coordinate architectures make it strategic in modern chemistry and materials science. These features turn boron-containing aromatic structures into promising emitters for energy, electronics, and optoelectronics—especially OLED (Organic Light-Emitting Diode) technologies. In OLEDs, multiresonance thermally activated delayed fluorescence (MR-TADF) emitters are highlighted by atomically patterned frontier orbitals that deliver a small singlet–triplet energy gap (ΔEST), narrow emission, and high color purity. To accelerate reverse intersystem crossing (RISC), heavier donor atoms such as sulfur and selenium (via stronger spin–orbit coupling, SOC) are attractive. However, accessing S/Se-containing boron-based MR-TADF derivatives remains challenging due to low yields, multistep and side-reaction-prone sequences, and stability/purification issues; the limited number of systematic studies further compounds these difficulties [1]. To address this key synthetic limitation, the Hatakeyama route was adapted and a strategy was devised that leverages the inherent weakness of the C–I bond in iodoarenes at the lithiation step to improve yield and reproducibility [2].Here, a Modified Hatakeyama Method (MHM) is presented that replaces bromides with iodo precursors to facilitate Li/halogen exchange, suppress undesired C–Se bond cleavage, enable late-stage S/Se functionalization, and promote boron-centered ring closure under side-reaction-minimizing conditions [3]. This streamlines purification and significantly raises reaction yields: applying the method increases reported values for SeBSe from ≈9% to 67% [4] and for SBS from 40% to 81% [5]; moreover, SBSe is obtained for the first time at ≈75% yield [3]. In conclusion, the Modified Hatakeyama Method provides a reliable, modular, and scalable route for the synthesis of S/Se-functionalized MR-TADF candidates based on the 5,9-X_2-13b-boranaphtho[3,2,1-de]anthracene (X–B–X; X = S, Se) core; the results indicate a solid foundation for producing OLED-grade materials with high purity and yield.

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Keywords: Boron, Three-Coordinate Boron, MR-TADF, OLED, Modified Hatakeyama Method

Theoretical Study on The Closo-Borate and Carba-Closo-Borate: Their Potential Application as Anionic Counterions In Polyelectrolyte Complex Materials

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Closo-borate anions with the formula $[B_nH_n]^{2-}$ and carba-closo-borate with the formula $[CB_{n-1}H_n]^-$ have been explored both by theoretically and experimentally. These 1D stable molecular clusters have a highly symmetrical structures. These anions and their derivatives have very low toxicity which let them to be used in many applications in photochemistry and medicine. Compared to their other applications, these anions such as $[B_{12}H_{12}]^{2-}$ and $[CB_{11}H_{12}]^-$ clusters have relatively been less investigated and discussed as a counterions in polyelectrolyte complexes. They can be potentially utilized as anionic counterions for cationic polyelectrolytes that are a class of polymers that carry a positive charge along their backbone such as poly(diallyldimethylammonium chloride) (PolyDADMAC) and Poly(4-vinylpyridine) (P4VP). In this study, electronic properties of closo-borates and carba-closo-borates will be determined and their potential as anionic counterions in polyelectrolyte complexes (PECs) formed by the spontaneous organisation of oppositely charged polyelectrolytes will be elucidated. Their applications both in polyelectrolyte multilayers by the sequential-alternating adsorption as well as in PECs by direct bulk mixing will be explored by Density Functional Theory calculations and molecular dynamics simulations. Use of anionic borate cages in polyelectrolyte complexes and determination of stable complexes can open a new window both for boron chemistry and polymer science.

Keywords: Closo-Borate, Carba-Closo-Borate, Polyelectrolyte Complex, Density Functional Theory

Closed Reactor Approach in Ammonia-Boron-Based Catalytic Hydrogen Production

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Ammonia-borane (AB, NH_3BH_3) is a leading candidate among chemical hydrogen storage materials due to its high hydrogen content (19.6 wt% H_2), low toxicity, chemical stability, and stable structure at room temperature. The primary objective of this study is to establish a scientific foundation for the design of a compact hydrogen production reactor with catalytic AB dehydrogenation that can be used in emergency situations or for portable energy needs, and to experimentally investigate the behavior of a closed reactor for this purpose. AB and catalysts (Ru@GO/Rh@GO) were synthesized in house by solution and chemical reduction method respectively. The experiments were carried out in a closed autoclave reactor (Parr Instruments 300 mL). The AB solution (3g/150 mL), and catalysts were fed sequentially into the reactor. With the AB:catalyst ratio of 30:1 in the experiments started at room temperature under 1 bar Ar. The reaction time, pressure change due to hydrogen generation, and temperature profile were monitored throughout the reaction. The temperature profile remained essentially isothermal (no measurable run-away), indicating stable operation. Using Ru@GO and Rh@GO the system reached 45 bar and 42 bar corresponding to ~93.4% and ~86.9%. of the theoretical H_2 yield indicating Ru@GO outperforming Rh@GO. Gas chromatography (GC) showed ~99.5% H_2 (balance Ar) with no detectable volatile B–N–H impurities under these conditions. This approach enables pressure-based tracking of reaction progress, sparsely represented in the literature, and addresses a methodological gap while directly informing the design of a briefcase-style portable hydrogen system. Guided by these data, engineering has been initiated for a field-deployable unit integrating a compact pressure reactor, safety relief and leak-tight fittings, gas scrubbing, and a regulated low-pressure AB solution delivery stage for fuel-cell applications.

Keywords: Ammonia-Borane, NH_3BH_3, Catalyst, Dehydrogenation, Chemical Hydrogen Storage

Influence of Synthesis Route on the Catalytic Performance of Spinel Ferrites in $NaBH_4$ Methanolysis

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Spinel ferrite nanoparticles have attracted significant attention as versatile catalysts for hydrogen generation due to their magnetic recoverability, chemical stability, and tunable surface chemistry [1,2]. However, the influence of the synthesis technique on their catalytic efficiency remains insufficiently understood. In this study, iron (II, III) oxide (Fe_3O_4) and various metal ferrites were synthesized by both hydrothermal and microwave-assisted routes and evaluated as catalysts for hydrogen generation via sodium borohydride ($NaBH_4$) methanolysis. Structural and surface analyses were conducted using X-ray diffraction (XRD), scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR) and X-ray photoelectron spectroscopy (XPS) to elucidate the relationship between synthesis conditions and catalytic behavior. It was observed that microwave-assisted synthesis consistently produced ferrite particles with smaller crystallite sizes and more defect-rich surfaces, resulting in markedly enhanced hydrogen generation rates and turnover frequencies (TOF) compared to hydrothermally prepared analogues, with improvements on the order of 35–40%. The enhanced activity is attributed to increased surface area, higher oxygen vacancy concentration, and favorable Fe^{2+}/Fe^{3+} redox balance, all of which promote BH_4^- activation and methanolysis kinetics. This study highlights the decisive role of synthesis method in tailoring the catalytic performance of ferrite-based systems and provides a promising approach for developing efficient, magnetically separable hydrogen generation catalysts.

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Keywords: Microwave-Assisted Synthesis, Spinel Ferrites, $NaBH_4$ Methanolysis, Hydrogen Generation

The Essential Role of High Resolution Mass Spectrometry in the Fast and Detailed Characterization of Variously Substituted Cobalt Bis(Dicarbollide) Ions

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High-resolution mass spectrometry (HRMS) has undergone significant technological advancement, establishing itself as a crucial tool in modern analytical chemistry. HRMS enables precise and accurate determination of the mass-to-charge ratio (m/z) of ions, providing substantially higher resolving power compared to conventional mass spectrometry. Owing to its ability to measure the subtle differences between exact and nominal masses, referred to as mass defects; HRMS allows for the discrimination of compounds possessing identical nominal masses. This analytical capability renders HRMS particularly valuable for the structural elucidation and characterization of compounds within complex mixtures, including those encountered in boron cluster chemistry, as demonstrated in this study. Here, we present selected examples of HRMS analyses performed via direct sample infusion, highlighting its application as a qualitative technique for investigating variously substituted cobalt bis(dicarbollide) ions (COSAN–) [1]. Particular attention is given to analytical scenarios in which the obtained spectra exhibit overlapping or coinciding nominal masses among the analyte, minor side products, unreacted precursors, or unexpected by-products. We present here concrete examples, where the role of HRMS brough indispensable information about type of substitution and bonding to cobalt bis(dicarbollide) ion and contributed to resolving ambiguous substitution pathways. Our results demonstrate that direct sample introduction into the ionization source considerably streamlines the analytical workflow and enables reliable identification of anionic boron-containing species. This approach proves particularly effective when sample complexity is moderate and does not necessitate chromatographic separation or fractionation prior to mass spectrometric analysis.

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Keywords: High Resolution Mass Spectrometry, COSAN

Large scale production of elemental nano boron powder

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The present work is focusing on the large scale (> 100 kg/year) production of high purity (> 99% B) elemental boron in amorphous form. The production route for the commercially available elemental boron in the first step is based on the reduction of B_2O_3 with magnesium, which is also known as metallothermal or Moissan method. The further purification of the products occurs via acid leaching. However, during the reaction of B_2O_3 and Mg, poorly crystallized Mg_2B_{25} is formed as the major byproduct - besides some B_6O and B_7O - which cannot be removed by conventional acid treatment. According to the literature, the most suitable production methods for high purity elemental boron are the reduction of $BCl_3$with hydrogen gas at elevated temperatures - yielding diborane gas (B_2H_6) as the intermediate - or pyrolysis of pure diborane gas. As diborane consists of only boron and hydrogen, its thermal decomposition yields only boron in solid form and hydrogen gas. The problems with diborane gas are the availability, price and toxicity. High purity (> 99.99%) diborane is commercially available for 1500 €/tank (28 g gas per tank) and requires 6 months for shipping. In addition, diborane is extremely toxic and explosive when exposed to atmospheric air. It burns rapidly when combined with oxygen and water forming boric acid. The novelty in our approach in obtaining high purity amorphous boron is the development of a synthesis technique for "on-demand-diborane" which can be in-situ pyrolyzed to the elements at $T > 573$ K. Beside the above mentioned reaction of BCl_3/H_2 gas, there are several methods for the preparation of B_2H_6 reported in the literature. A great majority of them are solvent based reactions requiring further purifications and removal of solvents. Solid state reactions are easier to handle and do mostly not need additional refining. In the last ten years new B_2H_6 production methods were introduced one of which is the metathesis reaction of metal chlorides with alkaline metal boron hydrides via ball-milling. In the present study, the time-consuming ball milling process was replaced by "gentle heating" of the mixture of the solid reactants which were pressed to pellets beforehand. In our studies, the gas phase pyrolysis of B_2H_6 yielded> 98.5% pure amorphous boron. The rest isoxygen impurity resulting from the surface oxidation of the very reactive sub-micron (<300 nm) boron particles, nitrogen as in the form of surface nitride. The methods described in this work have been utilized in the production site of Pavezyum Kimya for more than 10 years and over 100 kg/year elemental nano boron production has been achieved safely and successfully. Almost all MgB_2 bulk and wire producers have been using this powder as the raw material of MgB_2 production.

Keywords: Elemental Boron, Diborane

Boron Carbon Nitride Materials for Heavy Metal Removal from Simulated Wastewater

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Water pollution is a critical environmental issue worldwide, under the pressure of rapid industrialization. Different facets of the problem require the implementation of different measures. Yet, the need for more effective yet affordable adsorbents is increasing for removing various contaminants, including heavy metals. Among the currently developed adsorbent systems, boron carbon nitrides (in short, BCNs) stand out with their tunable chemical and physical properties similar to graphene and boron nitride materials [1-3]. Nevertheless, the BCNs are still poorly investigated, although they can be synthesized using rather facile methods, such as thermolysis. In this study, we explore the synthesis of BCNs using thermolysis by focusing on the effect of precursor ratio and thermolysis temperature on the adsorptive removal of lead (Pb^{2+}). We have employed scanning electron microscope (SEM), X-ray diffractometry (XRD), and Fourier-transform infrared spectroscopy (FTIR) to characterize as-produced BCNs. To better understand the removal performance, the adsorption behavior was analyzed via isotherm models. Melamine and boric acid were mixed in a ratio of 3:1 and 3:5 using ethanol as the solvent. Afterwards, thermolysis was conducted at 500 °C and 600 °C for 4 h (Table 1). While SEM and XRD analyses were conducted to determine the morphological and structural properties of BCN, FTIR was used to examine the composition of functional groups. Pb^{2+} removal performance of as-produced BCNs was obtained by measuring using a thermostatic shaker bath with 50 ppm Pb^{+2} solution at 185 rpm and 30 °C for 24 h. The remaining Pb^{2+} concentration was identified by inductively coupled plasma mass spectrometry (ICP-MS). Using the material with the highest adsorption capacity under 50 ppm conditions, adsorption isotherms were formed in the range of 25-250 ppm Pb^{2+} solutions following the same experimental route. The results were further evaluated in terms of their fit to the Langmuir and Freundlich isotherm models to show how the adsorption process is taking place. SEM images (Figure 1) indicated that the samples have irregular structures composed of agglomerated particles without any large visible pores. XRD measurements showed that those irregular and B-containing agglomerates are amorphous-like in nature with broad peaks belonging to BCNs observed at around 26.3° and 41.3° (Figure 2) [4, 5]. Moreover, FTIR analyses demonstrated the rich functional group profile of resulting materials, including $-NH_2$, $-NH-$, O−H, C−N, B−O, C−N−(C) −C or C−NH−C, and B−N−B bonds (Figure 3) [6]. Thus, the synthesis of BCN was carried out successfully. As for the adsorption performance, the sample coded as BCN-3 removed 96% of Pb^{2+} from the solution (Figure 4) with an adsorption capacity of 99 mg/g. To further investigate the BCN-3's adsorption behavior, adsorption isotherms were composed, and the maximum adsorption capacity for BCN-3 was found to be 263.34 mg/g. Based on the non-linear regression (least squares) analysis, the adsorption behavior of the sample under the investigated conditions was in accordance with the Freundlich isotherm, which is described as multilayered and heterogeneous (Figure 5) [7].In conclusion, thermolysis was a successful method in synthesizing BCNs, and their potential as an adsorbent in wastewater treatment were shown. Among the investigated thermolysis properties, the temperature did not significantly affect the structure or the adsorption performance. However, the effect of the precursor ratio was immense on the adsorption capacity. BCN-3 and BCN-4 were found to be an agreeable adsorbent in wastewater treatment. Further studies are needed to show that BCNs as adsorbents can be effective against other pollutants.

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Keywords: Thermolysis, Surface Adsorption, Lead Removal, Wastewater, Adsorbent

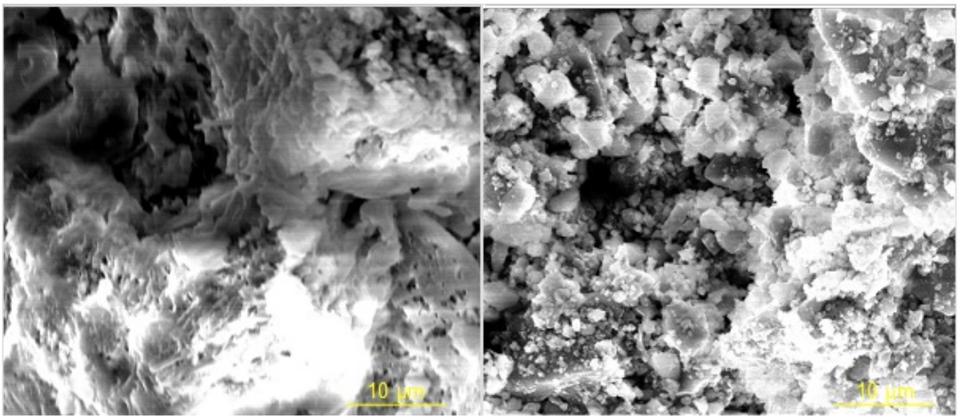

Figure 1. SEM images of BCN-1, and BCN-3.

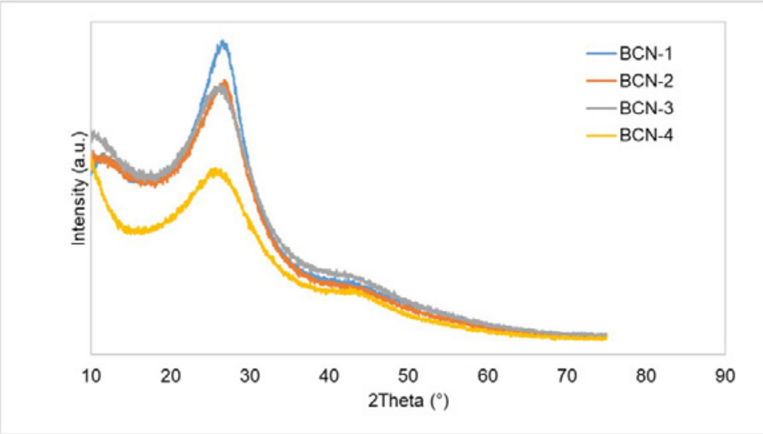

Figure 2. XRD pattern

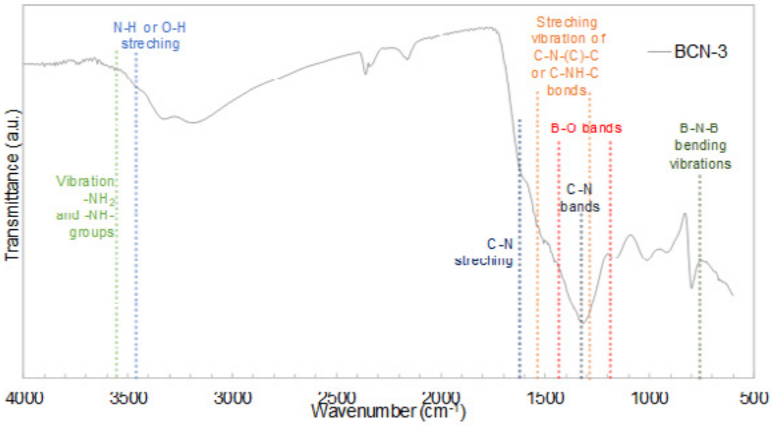

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Figure 3. FTIR spectrum of BCN-3

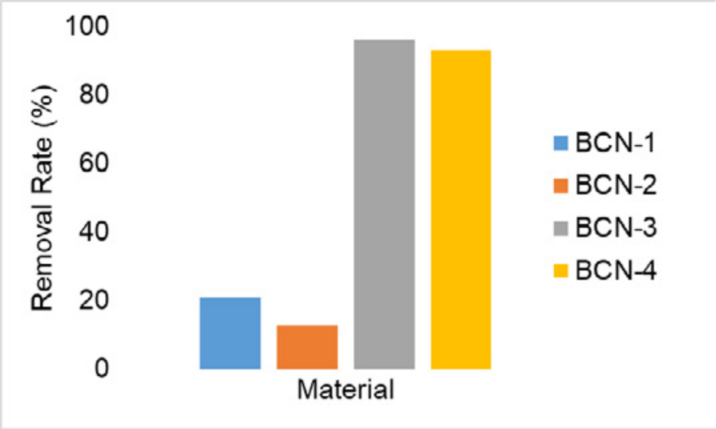

Figure 4. Adsorptive Pb^{2+} removal rate of materials

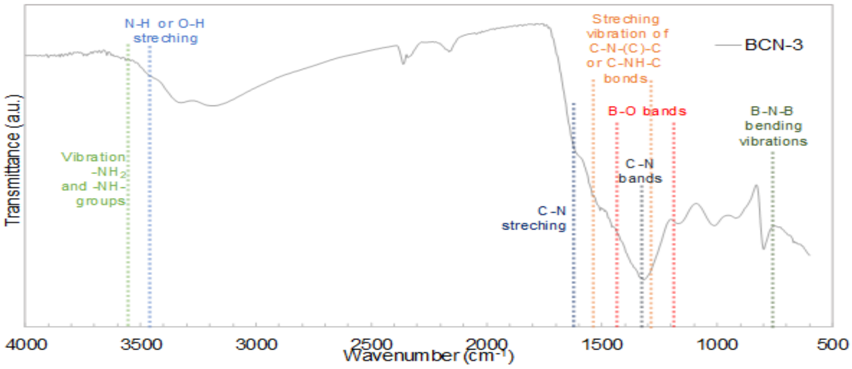

Figure 5. Adsorption isotherm of BCN-3

Table 1. Experimental conditions for the synthesis of BCNs.

Sample Label	Precursor Ratio	Thermolysis Temperature (°C)	Thermolysis Duration (h)
BCN-1	3:1	500	4
BCN-2	3:1	600	4
BCN-3	3:5	500	4
BCN-4	3:5	600	4

Kobalt Borat Bileşiğinin Sentezlenmesi ve Kırmızı Fosfor ile Sinerjik Etki Sağlanarak Epoksi Esaslı Kompozitlere Yanmazlık Özelliğinin Kazandırılması

Ahmet Bulut[1], Murat Rakap[1], Mehmet Yurderi[2], Çağrıalp Arslan[3], Ümit Tayfun[3]

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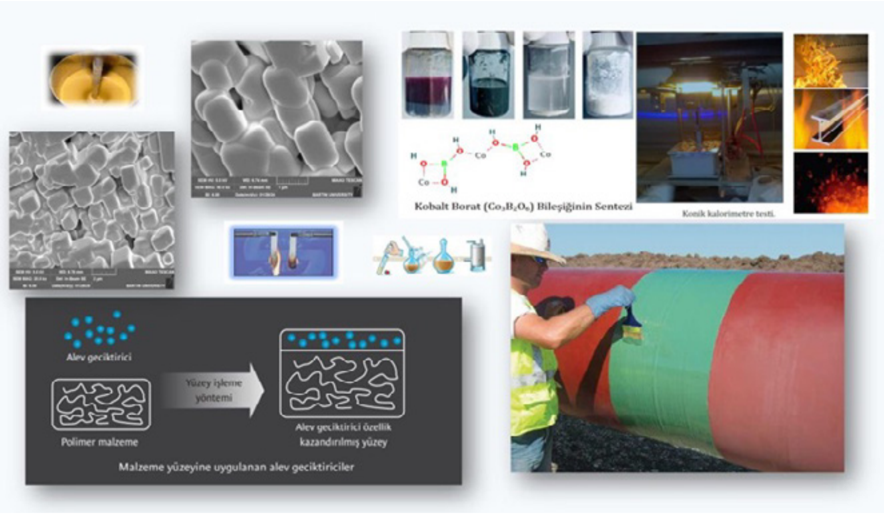
Uzay, otomotiv, inşaat ve elektronik sektörler termoset reçineler kullanılmaktadır. Bu kullanım alanlarının çoğunda termoset reçinelerin belirli bir yanmazlık düzeyine sahip olması beklenir. Güç tutuşur özellik kazandırmak için epoksi gibi sentetik reçineye dolgu malzemesi eklemek, halen tercih edilen önemli ve yaygın bir uygulamadır. Bu amaçla, halojen içeren bileşikler (örneğin, klor ve brom), metal hidroksit (örneğin, aluminyum trihidrit-ATH ve magnezyum hidroksit-$Mg(OH)_2$) ve fosfor içeren güç tutuşurluk maddeleri sıklıkla kullanılmıştır. Bununla birlikte, halojen esaslı bileşiklerin kullanılmasına getirilen kısıtlamalar ve metal hidroksitlerin oldukça yüksek (%50) oranlarda kullanılması nedeniyle güncel çalışmalar fosfor esaslı güç tutuşurluk maddelerinin kullanımına ve etkinliğini artırmak üzerine yoğunlaşmıştır. Termoset reçinelerde tek başına borlu bileşiklerin güç tutuşurluk etkisini araştıran çalışma sayısı mevcut değildir. Güç tutuşurluk eklentisi ile yapılan çalışmalar, bor içeren bileşikler ile sinerjik etkileşim sağlanması üzerine kurgulanmaktadır. Bu çalışmalarda, güç tutuşurluk maddelerinin etkinliğini artırmak ve kullanım miktarlarını düşürmek yoluyla mekanik özelliklere olası zararlı etkilerini azaltmak amaçlarına odaklanılmaktadır. Çalışma kapsamında erimiş tuz destekli borotermal indirgeme yöntemiyle sentezlenen kobalt borat bileşiğinin, epoksi reçinelerinde tek başına kullanıldığında güç tutuşurluk etkinliğine ek olarak, kırmızı fosfor yanmazlık eklentisi ile sinerjik etkinliği araştırılmıştır. Araştırmanın ilk aşamasında, kobalt borat bileşiğinin sentez işlemi, kobalt metalin tuzu ve borik asit türevleri kullanılarak sulu ortamda otoklav içinde 240 °C sıcaklıkta sıcaklık-katı reaksiyonla üretilme yöntemi ile gerçekleştirilmiştir. Sentezlenen bileşiğin karakterize edilmesinde X-ışını analizi (XRD), SEM-EDX analizi, termogravimetrik analiz (TGA) ve Fourier dönüşümlü kızılötesi ışın (FTIR) spektroskopisi kullanılmıştır. Sentezi gerçekleştirilen $Co_3B_2O_6$ bileşiği, öncelikle tek başına ağırlıkça değişik oranlarda kullanılarak güç tutuşurluk etkileri incelenmiş olup, daha sonraki aşamada ise kırmızı fosfor içeren güç tutuşurluk eklentisi ile birlikte kullanılarak sinerjik etkileşimleri UL-94, sınırlayıcı oksijen indisi (LOI) ve konik kalorimetre testleri ile değerlendirilmiştir. Yanmazlık testleri sonucunda, %1 oranında kobalt borat ile %9 oranında kırmızı fosfor içeren kombinasyon, yanmaya karşı direnç açısından ön plana çıkmıştır. Bu numunede, UL-94 dikey testinde V0 değerine ulaşılmış, sınırlayıcı oksijen indisi (LOI) değerinde eklentisiz epoksiye kıyasla 1,5-2,0 birim artış olup kalorimetre testinde eklentisiz epoksiye göre %30 civarında daha düşük ısı salınım miktarı (HRR) gözlenmiştir.

Anahtar Kelimeler: Metal Borat Sentezi, Yanmazlık, Kobalt Borat, Kırmızı Fosfor, Epoksi Reçine



Çalışmanın sentez, üretim ve karakterizasyon aşamalarını özetleyen görsel

Syntheses, Spectral and Chiral Properties, and DNA Interactions of Macrocyclic Boronates Based on Boroxane and Boroxine Architectures

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When a central atom is tetra-coordinated, the compound becomes optically active by having four different atoms or groups surrounding it. The complexation of boronic acids with a Schiff base ligand is a common way to acquire tetra-coordinated boron atoms. The use of chiral Schiff base ligands has resulted in the synthesis of diastereomerically and enantiomerically pure macrocyclic boronates (boron complexes), but the chirality of these compounds is not solely due to the boron atom. On the other hand, in the studies of macrocyclic boronates with Schiff base ligands, chirality only at the boron atom is much less common. Our approach has been to develop macrocyclic boronates, with the two boron atoms being tetra-coordinated to improve stability, and chirality is only seen in the boron atoms. Therefore, we have utilized achiral tetradentate salenH2 type symmetrical bulky ligands (1) which have two imine groups in their structures to react with dibenzofuran-4-boronic acid. In this study, we have synthesized a series of new macrocyclic boronates containing a planar and bulky dibenzofuranyl group with two different architectural types for the investigation of their spectral and chiral properties, and DNA cleavage activities. Firstly, salenH$_2$ ligands [HOArCH=N-R-N=CH-ArOH (1); R=(CH_2)n, n=2-4, and R=$(CH_2CH(OH)CH_2)$] were obtained from the reactions of salicylaldehyde with 1,2-diaminoethane, 1,3-diaminopropane, 1,4-diaminobutane and 2-hydroxy-1,3-diaminopropane, respectively, in dry MeOH. Dibenzofuran-4-boronic acid and salenH$_2$ type ligands (1) were brought to condensation reactions in a 2:1 stoichiometry in toluene to obtain dinuclear macrocyclic boronates with a boroxane group (RB-O-BR) (2). Trinuclear macrocyclic boronates (3) with a boroxine group (B-O-B)-(O_2BPh) were synthesized through the combination of boric acid/dibenzofuran-4-boronic acid and salenH2 type ligands (1) in asetonitrile. Macrocyclic boronates contain a central seven-, eight- and nine-membered heterocycles [(B-O-B)-(N-CH_2-R-CH_2-N)] with an oxygen atom bridging two boron atoms, and possess two equivalent chiral boron centers. The structures of the macrocyclic boronates were characterized by elemental analysis, FTIR, MS, 1D 1H, 13C and 11B NMR, and 2D HSQC techniques. It was determined from the NMR spectra that dinuclear (2) and trinuclear (3) macrocyclic boronates had only one stereoisomer, and from the circular dichroism (CD) spectra it was determined that they had only one of the enantiomers. The literature is lacking sufficient research on the interaction of dibenzofuran derivatives with DNA, but it has been demonstrated that dibenzofuran derivatives interact with DNA and bind to it through intercalation. Therefore, the gel electrophoresis and UV titration methods were employed to examine interactions between DNA and macrocyclic boronates. It was found that dinuclear macrocyclic boronates (2) did not have any effect on DNA but did cause it to precipitate in the gel. DNA was damaged at a high concentration of trinuclear macrocyclic boronate [R=$(CH_2CH(OH)CH_2)$].

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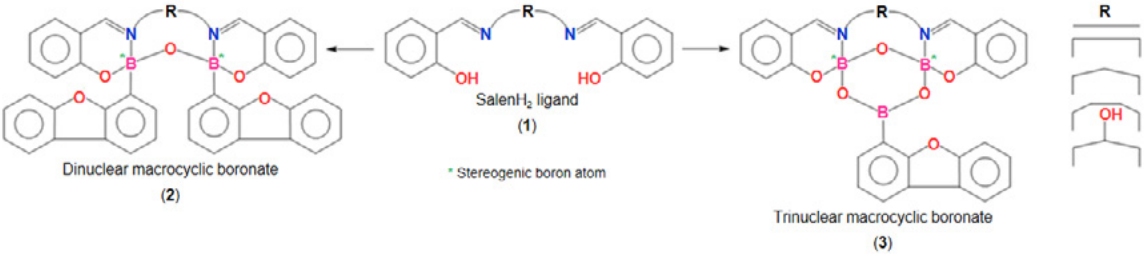
Acknowledgements: Selen Bilge Koçak is grateful to the The Scientific and Technological Research Council of Turkey (TÜBİTAK) (Project No. 124Z461).

Keywords: SalenH$_2$ Ligand, Macrocyclic Boronate, Dibenzofuran, Chirality and Spectroscopy, Plasmid DNA



Structure of dinuclear (2) and trinuclear (3) macrocyclic boronates with boroxane and boroxine architectures, respectively

ADVANCED BORON MATERIALS, PROCESSING and APPLICATIONS

(İLERİ BOR MALZEMELERİ, İŞLEME ve UYGULAMALARI)

From Alchemical Curiosity to Strategic Advanced Material: Evolution of Elemental Boron Production and Technology

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Elemental boron occupies a unique position in the modern materials landscape: simultaneously ancient in curiosity, modern in application, and technically challenging in synthesis. Since its discovery in 1808 by Gay-Lussac, Thénard, and independently by Davy—during a period marked by intense chemical exploration and early electrochemical reduction—boron has transitioned from a laboratory novelty to a cornerstone of advanced technology platforms. For over two centuries, its path has been shaped by the quest to isolate the element in pure, crystalline form and to unlock its extraordinary combinations of hardness, low density, neutron absorption capacity, high melting point, and complex allotropy. This presentation traces the scientific, technological, and industrial evolution of elemental boron, highlighting the milestones that enabled its entry into high-value sectors including defense, energy, aerospace, electronics, and nuclear systems. The early synthetic efforts were dominated by impure materials, often referred to as "amorphous boron," produced via reduction of boric acid or boron oxide using potassium, sodium, or magnesium. Although these classical methods—particularly the magnesium reduction process (Moissan reaction)—remained dominant well into the 20th century, they frequently yielded boron contaminated with residual metal oxides, borides, and carbon. The persistent challenge of obtaining ultra-high-purity boron ($>$ 99.99%) stimulated the development of advanced routes such as chemical vapor deposition (CVD) using boron halides, high-temperature reduction with hydrogen, halide electrolysis, plasma-assisted synthesis, and more recently laser-driven and carbothermal hybrid reduction processes under controlled atmospheres. These innovations enabled the production of crystalline β-rhombohedral boron and opened pathways toward isotopically enriched ^{10}B and ^{11}B boron, essential for neutron shielding, quantum materials research, and emerging semiconductor applications. Contemporary production methodologies continue to evolve, with a strong emphasis on thermodynamic optimization, impurity control, and reactor design. Purification strategies such as acid leaching, controlled oxidation-reduction cycles, sublimation refining, and zone purification are increasingly integrated with scalable reaction engineering. Meanwhile, the growing demand for nano-scale boron and boron-rich phases—driven by applications in energetic materials, superconductivity (e.g., MgB_2), solid-state batteries, and next-generation coatings—has inspired research into solvothermal, plasma-nano, and mechanochemical synthesis strategies capable of precise morphology and particle-size control. This presentation provides a systematic comparison of traditional and modern production routes, their thermodynamic basis, scalability, purity limits, and relevance to industrial deployment. In parallel, the historic journey of boron will be contextualized within the evolution of scientific discovery, illustrating how an element once mistaken for a mere curiosity became a strategic material for future-oriented technologies. By bridging historical insight with modern process innovation, this work aims to highlight the remarkable scientific persistence that defined boron's story and to outline the technological frontiers that will shape its next chapter.

Keywords: Elemental Boron, High-Purity Synthesis, Advanced Reduction Routes, Strategic Applications

A New 2D Frontier: Hydrogenated Borophene for Rapid Water Purification

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Water scarcity continues to be one of the most urgent global issues, compounded by the growing contamination of freshwater sources with hazardous pollutants such as heavy metals, dyes, pesticides, hormones, pharmaceuticals, and industrial effluents [1]. These persistent contaminants threaten both human health and ecological stability due to their toxicity, bioaccumulation, and carcinogenic nature [2]. Accordingly, extensive research efforts have focused on developing efficient purification technologies, including membrane filtration, catalytic degradation, and adsorption processes [1]. Among these, adsorption stands out as an exceptionally versatile and scalable method owing to its operational simplicity, cost-effectiveness, and high removal efficiency [3]. Nanostructured materials have recently attracted considerable interest as next-generation adsorbents because of their high surface area, tunable chemistry, and strong affinity toward diverse pollutants. Graphene-based systems and other carbon adsorbents have achieved notable success but still suffer from limitations such as slow adsorption kinetics, surface agglomeration, and the restricted accessibility of active sites [4,5]. To overcome these constraints, it is essential to explore alternative two-dimensional (2D) materials that combine high chemical activity with structural stability. Herein, we report the first experimental demonstration of hydrogenated borophene (HB) as an ultrafast and high-capacity adsorbent for water purification. Using methylene blue (MB) as a representative contaminant, HB exhibited a record adsorption capacity of 1428,57 mg g^{-1} and achieved over 99.8% removal efficiency within five minutes, outperforming state-of-the-art graphene-based materials. Mechanistic studies confirmed that adsorption follows the Langmuir isotherm and pseudo-second-order kinetics, governed primarily by synergistic electrostatic interactions and π-π stacking between the negatively charged HB surface and cationic dye molecules.These findings establish HB as a transformative 2D platform that bridges the gap between theoretical predictions and practical water purification technologies, offering new opportunities for rapid, efficient, and sustainable wastewater treatment.

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Keywords: Borophene, 2D Boron, Water Treatment

Structural and Thermal Evaluation of TiB_2 Coatings on Ti-6Al-4V Alloy

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Titanium alloys are widely employed in aerospace, biomedical, and high-performance engineering applications due to their outstanding properties, such as high specific strength and excellent corrosion resistance. In addition, these alloys exhibit remarkable compatibility with advanced functional materials. However, their relatively low surface hardness remains a critical limitation in severe service environments. Among several surface modification techniques, boriding has been recognized as an effective approach to enhance the surface hardness and wear resistance of titanium alloys, particularly Ti-6Al-4V. In this study, a TiB_2 coating layer was fabricated on Ti-6Al-4V alloy using the CRTD-Bor (Cathodic Reduction Thermal Diffusion-based Boriding) technique. A dense TiB_2 layer approximately 3 µm thick was obtained after a 45 min process at 1000 °C under a current density of 200 mA/cm^2. The structural and thermal properties of the resulting coating were subsequently investigated. The boriding process was carried out in a molten salt bath composed of 90 wt.% $Na_2B_4O_7$ and 10 wt.% Na_2CO_3. Grade 5 Ti-6Al-4V alloy specimens were used as the cathode, while a graphite crucible served as the anode. The system was heated using a medium-frequency induction furnace. After the CRTD-Bor process, the specimens were quenched in water and subsequently normalized to eliminate the residual thermal effects induced by high-temperature exposure. The resulting boride layer was characterized by X-ray diffraction (XRD) and scanning electron microscopy (SEM) analyses, while thermal reflectivity was measured in accordance with ASTM E408. SEM observations (Figure 1a) revealed that a dense TiB_2 coating layer approximately 3 µm thick was formed on the Ti-6Al-4V substrate. Additional XRD analysis (Figure 1b) confirmed the stoichiometric TiB_2 growth. Thermal reflectometer tests revealed that the boriding process increased the emissivity values of the specimens. An average emissivity value of 0.89 was observed for 8-12 µm wavelength at an average of 20° and 60° incidence angle for TiB_2-coated specimens. Emissivity values are remarkable for two different aspects, which both can be understood by contemplating thermal radiation (Table 1) The study demonstrated that a TiB_2 coating layer was successfully formed on the Ti-6Al-4V substrate at 1000 °C and a current density of 200 mA/cm^2 during a 45 min CRTD-Bor process. The presence of this coating resulted in a notable increase in the emissivity of the specimens. The enhancement in emissivity within the 8–12 µm wavelength range can be interpreted as a reduction in infrared observability, which is a desirable attribute for stealth and thermal camouflage applications.

Acknowledgement: We would like to thank to Turkish Aerospace Materials Test and Characterization Laboratories.

Keywords: TiB_2 Coating, CRTD-Bor Technique, Mechanical Properties, Tensile Strength, Thermal Emissivity

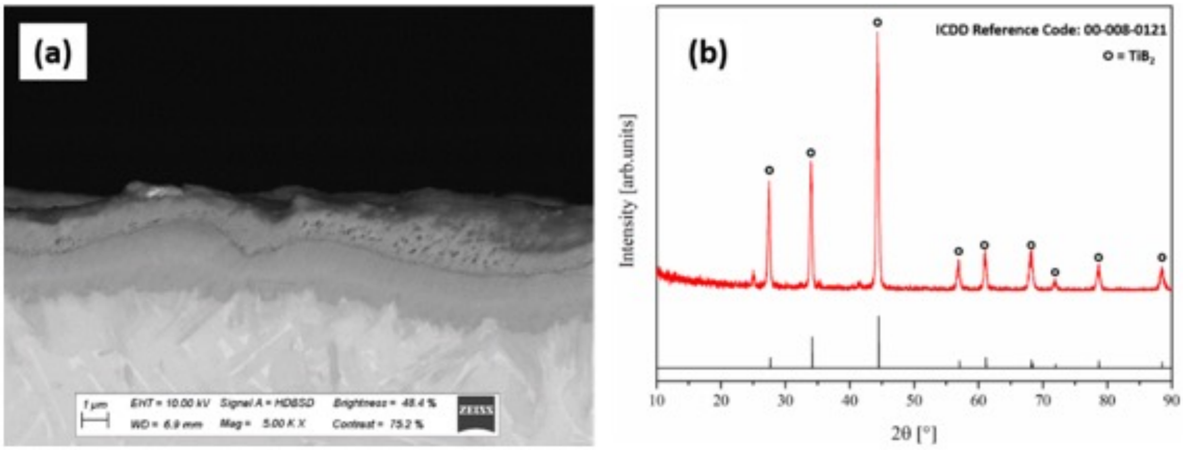

Figure 1. a) Cross-sectional SEM image b) XRD pattern of TiB_2 coating

Synthesis of Cerium Hexaboride Powders via Molten Salt Electrolysis

Kemal Kağan Heper[1], Selim Ertürk[1], Mehtap Arslan-Kaba[1], Güldem Kartal Şireli[1]

[1]*Istanbul Technical University*

Rare-earth hexaborides (RB_6) are advanced ceramic materials that exhibit a combination of high hardness, chemical inertness, and low work function, making them ideal for use as thermionic cathodes, electron emitters, and high-temperature protective coatings. Among these compounds, cerium hexaboride (CeB_6) is particularly attractive due to its low work function (~2.5 eV), excellent oxidation resistance, and high stability under vacuum conditions. These properties arise from its simple cubic CaB_6-type lattice, in which the cerium atoms are encased by rigid B_6 octahedra providing strong covalent bonding [1]. Conventional synthesis methods such as borothermal reduction, flux growth, and spark plasma sintering often require complex equipment, elevated temperatures, and prolonged processing times. Therefore, the development of an alternative, green, and scalable approach is essential to obtain high-purity CeB_6 with lower cost and reduced environmental impact [2]. The primary objective of this research is to synthesize CeB_6 powders via oxide-based molten-salt electrolysis using a $Na_2B_4O_7$–CeO_2–CaF_2 electrolyte. The study aims to elucidate how electrolysis parameters affect phase formation, particle morphology, and structural integrity of the resulting CeB_6 powders. Electrolysis was conducted in a medium-frequency induction furnace, employing a graphite crucible as the anode and a titanium substrate as the cathode. The effects of temperature (800–1100 °C) and current density (70–500 mA/cm^2) were investigated to determine the optimum conditions. After electrolysis, the obtained powders were washed with diluted acid to remove residual salts and subsequently characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), and particle size analysis to evaluate their phase composition, crystal morphology, and grain growth behavior. XRD analysis confirmed the formation of single-phase CeB_6 powders (Figure 1a), while SEM revealed uniform cubic grains consistent with the CaB_6-type structure (Figure 1b). Temperature optimization demonstrated that 900 °C was the ideal. Below this temperature, the high viscosity of the electrolyte restricted ionic transport, whereas temperatures above 1000 °C led to instability of the molten bath and partial degradation of CeB_6 crystallinity. Experiments conducted at different current densities showed that CeB_6 remained the dominant phase under all tested conditions. The optimum current density was identified as 200 mA/cm^2, which yielded high phase purity, uniform morphology, and efficient energy utilization.) XRD pattern b) SEM images of synthesized powders [900 °C, 200 mA/cm^2] Figure 1. a) XRD pattern b) SEM images of synthesized powders [900 °C, 200 mA/cm^2] High-purity CeB_6 powders were successfully synthesized via molten-salt electrolysis employing an oxide-based, green electrolyte system. The optimum parameters were identified as 900 °C, 200 mA/cm^2, and 60 min. After acid purification, the obtained powders exhibited well-defined cubic morphology and high phase purity, confirming the effectiveness of the electrochemical route for producing cost-efficient and sustainable CeB_6 materials.

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Keywords: Cerium Hexaboride, Molten Salt Electrolysis, Rare-Earth Borides, Co-Deposition

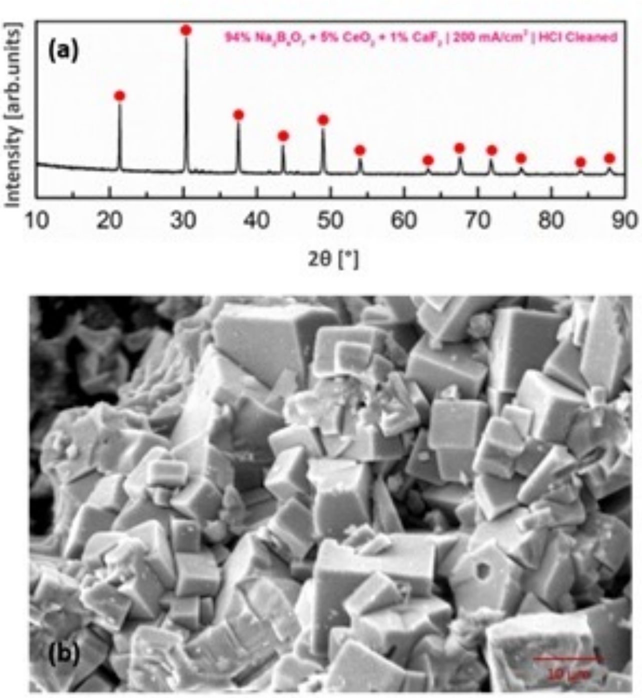

Figure 1. a) XRD pattern b) SEM images of synthesized powders [900°C, 200 mA/cm^2]

Investigation of Shape Memory Properties of Polycaprolactone/ B^{+3} and Fe^{+3} Dual Doped Hydroxyapatite Composites

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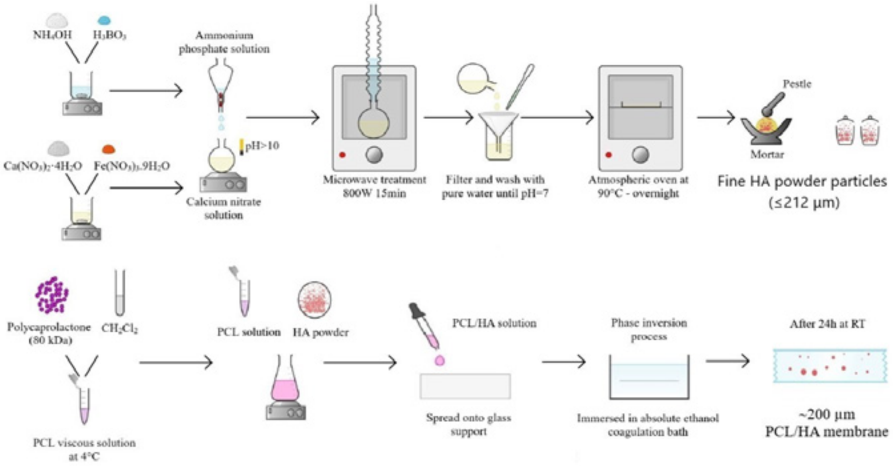
Many biomaterials have been investigated for scaffold fabrication in hard tissue engineering; however, an optimal structure that fully demonstrates the requisite physicochemical and biological properties to fulfill all clinical standards has yet to be developed. In this context, it was aimed to develop PCL/HA membrans containing different amounts of B and Fe dual-doped hydroxyapatite (HA) that can provide bone regeneration in the bone defect area and to investigate the effect of both microstructural properties, shape memory effect and biological properties. B-Fe dual-doped HAs were synthesized by microwave irradiation method and samples were sintered at 900 °C characterized by FTIR, ICP-MS, XRD and SEM analyses. Then, PCL/HA membrans containing different amounts of HA (10%, %15 and 30 wt%) were successfully prepared by non-solvent induced phase separation (NIPS) method. Thermal, biological and morphological characteristics of the membrans are investigated. Saos-2 cell line was used in biological examinations. For biological characterizations, Alamar Blue™ assay to detect viability and alkaline phosphatase activity (ALP) assay to detect differentiation were done. In the relative cell viability (%) test, the highest viability was observed on the membrans with %15 HA group. It was observed that 0.05B and 0.10Fe addition increased the cell viability and alkaline phosphatase activity. In addition, the shape memory recovery ratio investigated the presence of different B and Fe doped HA concentration in the PCL membrans. It was concluded that PCL/HA composite scaffolds with 0.05B 0.10Fe have the potential to be used in BTE.

Keywords: Hydroxyapatite, Polycaprolactone, Shape Memory, Composite, Bone Tissue Engineering



Schematic illustration of the synthesis process of B/Fe-HA using microwave-assisted heating, followed by the fabrication of a PCL/HA composite membrane via the NIPS method

Table 1. Molar ratios of the elements used in the preparation of pure and doped HA

Sample	Reactants molar ratios			
	Ca	Fe	P	B
HA	10	-	6	-
B-HA	10	-	5.95	0.05
0.01Fe/B-HA	9.99	0.01	5.95	0.05
0.05Fe/B-HA	9.95	0.05	5.95	0.05
0.10Fe/B-HA	9.90	0.10	5.95	0.05
0.25Fe/B-HA	9.75	0.25	5.95	0.05

Table 2. PCL/DCM and PCL/HA membrane samples with solution concentrations (%w/v) and additive ratios (%)

Membrane Sample	PCL/DCM (%w/v)	HA/(PCL/HA) (%)
PCL	%7,5	0
PCL/HA		10, 20, 30
PCL/B-HA		
PCL/0.01Fe/B-HA		
PCL/0.05Fe/B-HA		
PCL/0.10Fe/B-HA		
PCL/0.25Fe/B-HA		

Table 3. The chemical composition of HA, B-HA, and Fe/B-HA according to wt.% of constitutional elements

Sample	Theoretical Molar Ratio		Measured Molar Ratio			
	Ca/P	(Ca+Fe)/(P+B)	Ca/P	(Ca+Fe)/(P+B)	Fe/Ca	B/P
HA	1.67	1.67	1.64	1.64	0	0
BHA	1.68	1.67	1.72	1.70	0	0.0089
0.01FeBHA	1.68	1.67	1.66	1.66	0.0011	0.0057
0.05FeBHA	1.67	1.67	1.65	1.65	0.0047	0.0067
0.10FeBHA	1.66	1.67	1.66	1.67	0.0095	0.0069
0.25FeBHA	1.64	1.67	1.69	1.71	0.0233	0.0078

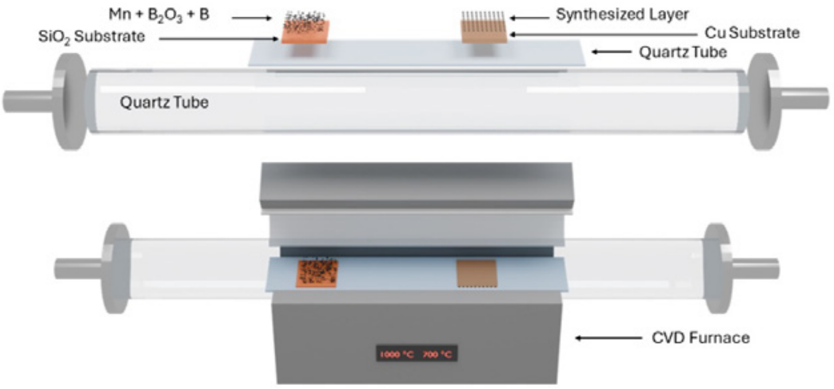
Synthesis of Manganese Boride (MBene) Thin Films by CVD Process: Microstructural Analyses

Mehmet Bay[1], Gökhan Kuzaliç[1], Nihan Kosku Perkgöz[1]

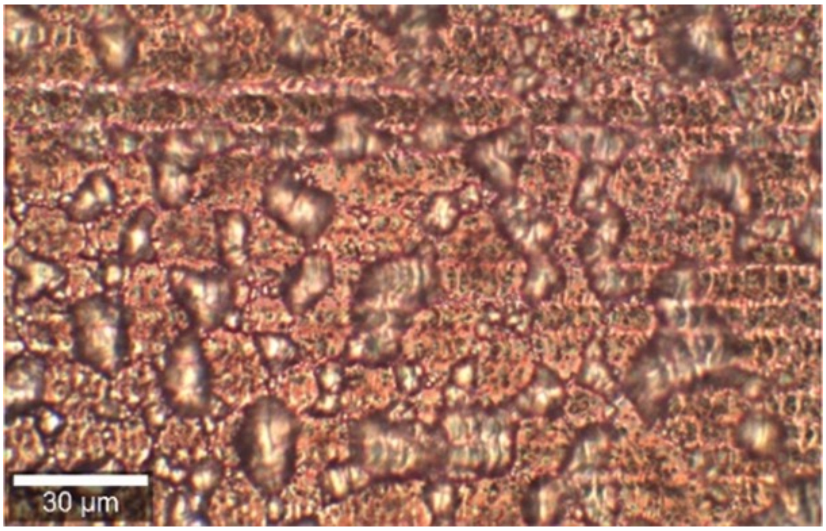
[1] *Eskişehir Technical University*

In this study, manganese boride (MBene)-based thin films were synthesized by chemical vapor deposition (CVD) to be investigated as potential functional materials for energy storage and electronic device applications. Manganese borides are particularly attractive due to their excellent thermal stability and metallic conductivity, making them strong candidates for multifunctional thin-film applications. In this process, Mn, B_2O_3, and B precursors were utilized for depostion on a Cu substrate in a quartz tube and reacted under controlled N_2 and H_2 gas flow at two different temperature ranges (700 °C and 1000 °C) as shown in Figure 1. This configuration resulted in the formation of a homogeneous and continuous MnB thin film on the substrate. The structural and morphological properties of the synthesized films were investigated by optical microscopy, scanning electron microscopy (SEM), Raman spectroscopy, and X-ray diffraction (XRD). Optical and SEM analyses confirmed that the film formed a uniform and continuous layer, while Raman and XRD results demonstrated the successful formation of MnB phases with high crystallinity. The findings reveal that the CVD method is an effective technique for the synthesis of large-area MBene-based thin films in a controlled manner, yielding optimized structural and morphological properties.

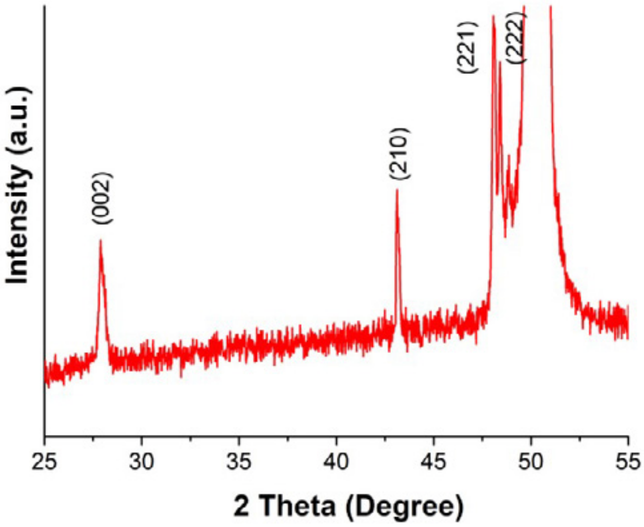
Keywords: Manganese Boride, Energy Storage, CVD, Supercapacitor, MBene



The CVD setup



Optical microscope analysis



XRD analysis

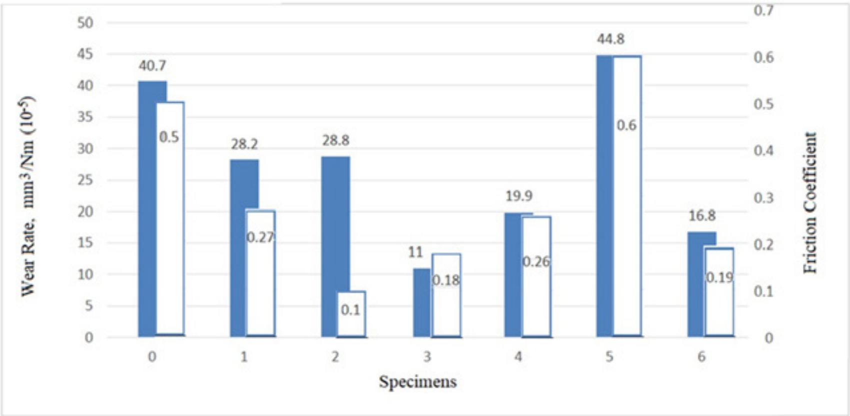
Wear Property of Ti_6Al_4V Alloy Coated with $TiC+TiB_2$ by Electro-Spark Deposition

Şükrü Talaş[1], Mesut Gökçe[1]

[1]*Afyon Kocatepe University*

The ESD coating process for metallic surfaces is simple and quick, requiring minimal surface preparation prior to coating and minimal damage to the base metal during the coating process. Metallic elements and alloys, as well as ceramic-based compounds, can be used to deposit a coating layer on the desired surface. TiC and TiB_2 coatings are preferred for improved wear resistance and heat transfer efficiency. In this study, composite electrodes consisting of 60% TiC, 30% TiB_2 and 10% Co were produced and used to coat Ti_6Al_4V alloy sheets. The aim of this study was to coat the surface of the Ti_6Al_4V alloy, which is widely used in many industries, in order to improve its surface properties with regard to wear resistance and increase its surface hardness, thus allowing it to operate at severe conditions.

Keywords: $TiC+TiB_2$ composite, ESD Coating, Ti_6Al_4V



Coefficient of friction vs wear rate of specimens coated with $TiC+TiB_2$ with varying levels of voltage and frequencies of coating process

Investigation of Neutron Absorption of Different Boron and Boron Containing Filters

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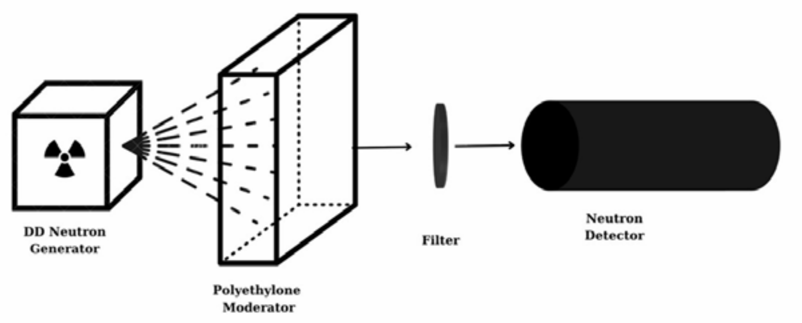
The increasing use of neutron sources in laboratory, industrial and security applications has created a growing need for thin, lightweight and functional neutron filters to provide controlled neutron fluxes in specific energy ranges, to protect detectors and to ensure operator safety. Boron and boron containing compounds are prominent candidates for this purpose due to their high thermal neutron capture cross sections and flexible formulation capability. In this study, the neutron absorption performance of various boron-based filters prepared in an epoxy matrix for use in fields generated by a DD neutron generator is investigated experimentally. The prepared samples consist of elemental boron with different purities, various borides, borates, borides with different counter metals, and B_4C based composites designed with different loadings and particle sizes. All samples were produced as epoxy-based plates with identical geometry and a fixed thickness of 5 mm, and their attenuation behaviour was measured in a DD neutron field thermalized with 6 cm polyethylene by performing count rate based (cps) transmission measurements relative to a reference plate. In this way, the neutron absorption behaviour is systematically evaluated as a function of boron atomic fraction, compound structure, counter metal type, concentration and particle size. The study aims to provide a comprehensive data set that enables an unbiased comparison of different boron-based filter candidates within the same experimental platform and matrix. The results are intended to define practical design criteria for the selection of optimum materials and compositions for neutron reference fields, portable neutron systems and application specific filter designs.In this experimental study, the effect of the following parameters on neutron absorption behaviour is investigated under the same measurement geometry:Elemental boron with different puritiesBorides with different stoichiometries (BN, TiB_2, B_4C, AlB_{12}, etc.)Different counter metals in similar boride structures (TiB_2, ZrB_2, MgB_2)Various borates (H_3BO_3, B_2O_3)Concentration variation in B_4C based compositesB_4C particle size, from very coarse to very fineCompound and mixture effects (e.g. B_4C vs (4B + C) vs 5C; ZrB_2 vs (ZrO_2 + 2B).In this framework, neutron absorption performance is evaluated in relation to neutron absorption cross section, boron atomic fraction, material density, matrix effect, concentration and particle size, and optimal material combinations are identified for potential filter and shielding designs.The experiments were carried out using a DD neutron generator producing neutrons with an energy of 2.45 MeV. A 6 cm thick polyethylene moderator placed at the generator outlet shifts the neutron spectrum towards the thermal region, allowing the absorption efficiency of boron-based materials to be observed more distinctly. After moderation, a reference epoxy plate without powder and, in a separate configuration, an epoxy composite plate containing boron or a boron compound were placed between the source and the detector. For each configuration, the count rate (cps) was measured using a thermal neutron detector with appropriate efficiency. Background and reference corrections were applied for each sample, and statistical uncertainties were controlled by repeated measurements. The filter samples were prepared using an epoxy resin system cured at room temperature with a defined amount of boron-based powder. The general procedure was as follows: epoxy (E) and hardener (H) were weighed in stoichiometric ratio, the selected boron or boron compound powder (P) was mixed homogeneously with the epoxy to obtain the mixture (M), gentle mixing and, if necessary, vacuum treatment were applied to minimize bubble formation, the hardener was then added and the final mixture (S) was poured into molds. All samples were cured to obtain plates with a diameter larger than 7,62 cm and a fixed thickness of 5 mm. The first sample without powder was prepared as a BLANK REF plate to be used as the reference. The same procedure was repeated for all boron and boron derivative powders, and each sample was labelled and stored in a dark environment until measurement. With this approach, the matrix structure, sample thickness and geometry were kept constant, so that the effects of filler type, concentration and particle characteristics on neutron attenuation could be isolated. For each sample, the transmission value normalized to the reference, T=C_"sample" /C_"reference" , is determined and used to derive the effective macroscopic absorption coefficient and the attenuation behaviour per unit thickness. The resulting data are then correlated with key material parameters, including boron atomic fraction and 10B content, the chemical structure and stoichiometry of the compounds, the contribution of the counter metal to neutron interactions, the weight fraction of B_4C and other boron-containing phases, the particle size distribution of B_4C, and, for a fixed total boron content, the relative performance of elemental boron, compounds and oxide or mixed systems. This study enables the systematic comparison of different boron and boron-containing compounds as thin epoxy-based filters under identical experimental conditions and establishes a comprehensive reference data set in which neutron absorption performance is quantitatively correlated with key parameters such as boron atomic fraction, compound type, counter metal, concentration and particle size. The resulting findings provide practical design criteria for material selection in the development of thin, lightweight and tunable filter and shielding configurations for DD neutron generator applications.

Keywords: Boron Filters, Neutron Absorption, DD Generator, B_4C, Nuclear Filter



Parameters of Interest	Neutron absorption cross sections
	Atomic fraction
	Active material density
	Matrix effect
	Concentration effect

The Effects of Different Composite Approaches on the Thermoelectric Properties of B_4C/SiC Composites

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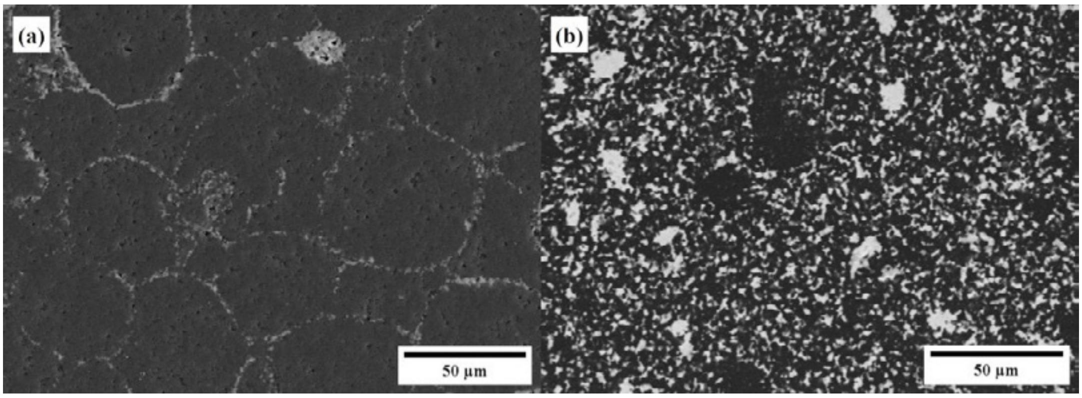
Boron carbide offers interest as a low-cost alternative to the common high-temperature thermoelectric materials, thanks to having hopping-type electrical conductivity, a relatively high Seebeck coefficient, low thermal conductivity, and excellent high-temperature thermomechanical properties. In this study, B_4C was reinforced with SiC by implementing different composite approaches, namely particulate and network-structured composites, to improve the thermoelectric properties of B_4C. The effects of different composite approaches and resulting microstructures on the thermoelectric performance of spark plasma sintered B_4C/SiC composites were investigated comparatively. SiC additions of 25 to 75 vol.% % and 2 to 8 vol.% were used for particulate and network structured composites, respectively. It was observed that the SiC addition increased the Seebeck coefficient but decreased the electrical conductivity of B_4C for both approaches. In addition to this, the thermal conductivity of the particulate composite deteriorated with SiC addition due to the intrinsically high thermal conductivity of SiC, ultimately reducing the thermoelectric performance of B_4C. On the other hand, implementing a network structure of SiC reduced the thermal conductivity of B_4C thanks to increased phonon scattering, combined with the enhanced Seebeck coefficient values an improved ZT value was obtained.

Keywords: Thermoelectric, Boron Carbide, Silicon Carbide, Spark Plasma Sintering, Composite.



Comparative microstructures of B_4C/SiC composites with (a) network structure and (b) particulate composite approaches

Sythesis and Characterization of High Entropy Boride Powders via Floating Zone Method and Their Electrochemical Analysis

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[1]National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
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In this study, the zone melting technique was employed to synthesize fiber-shaped high-entropy borides $(Ti_{0.2}Zr_{0.2}Hf_{0.2}Nb_{0.2}Ta_{0.2})B_2$. As the starting materials, binary diborides TiB_2, ZrB_2 HfB_2, NbB_2 and TaB_2 were selected. The synthesized high entropy borides were characterized using X-ray Diffraction (XRD), Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), Electron Paramagnetic Resonance (EPR) and Scanning Electron Microscopy with Energy-Dispersive X-Ray Spectroscopy (SEM-EDX) techniques. The final products were used as electrode materials in a two-electrode system, and their electrochemical analysis was carried out with Cyclic Voltammetry (CV), Potentiostatic Electrochemical Impedance Spectroscopy and Galvanostatic Charge-Discharge with Potential Limitation measurements.

Keywords: Energy Storage, Zone Melting, High Entropy Borides, Electrochemical Properties

Development of Boron-Functionalized Nonwoven PP/PE Fabrics for Rare Earth Element Recovery and Antimicrobial Applications

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The increasing global demand for rare earth elements (REEs) and the growing need for multifunctional materials have prompted the development of advanced novel polymeric adsorbents. In this study, a nonwoven polyethylene/polypropylene (PE/PP) fabric was surface-modified via plasma-assisted graft polymerization using a boron-containing vinyl monomer. The plasma treatment introduced reactive functional groups onto the inert polymer surface, enabling covalent grafting of the boron compound without compromising the mechanical integrity of the fabric. The modified fabrics were evaluated for their ability to selectively recover rare earth elements (light rare elements such as La^{3+}, Nd^{3+}, and heavy rare earth elements such as Dy^{3+}) from aqueous media. The boron-containing functional groups are expected to enhance the affinity and selectivity toward REE ions through complex formation, which will be verified using ICP-OES analyses under varying pH and concentration conditions to optimize the sorption mechanism. In addition to their potential for REE recovery, the boron-functionalized surfaces were examined for their antimicrobial properties. Antimicrobial potential of the fabrics was assessed against Escherichia coli, Staphylococcus aureus and Candida albicans according to the AATCC 100 standard. This dual-functional approach aims to develop a novel boron-based material that not only enables efficient recovery of valuable rare earth elements but also exhibits antimicrobial performance suitable for use in medical textiles, filtration systems, and environmental applications. The study highlights the versatility of boron in polymer science and surface engineering for sustainable and multifunctional material design.

Keywords: Boron, REE Recovery, Plasma Grafting, Antimicrobial, Surface Modification

Effect of Structural and Morphological Transformations on the Magnetic Properties of FeSiBNbCu Alloys with Rare-Earth Element Addition

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Soft magnetic alloys based on the Fe–Si–B–Nb–Cu system, commonly known as Finemet-type materials, have attracted considerable attention owing to their superior combination of low coercivity, high saturation magnetization, and excellent thermal stability. Their exceptional soft magnetic behavior is primarily attributed to the formation of α-Fe(Si) nanocrystals (10–20 nm) uniformly dispersed in an amorphous matrix, which can be achieved through appropriate thermal annealing of rapidly solidified ribbons. In recent years, several studies have demonstrated that minor additions of rare-earth (RE) elements such as Sc, Tb, Y, Nd, or Dy can further enhance the magnetic and thermal properties. In this study, a Finemet-type soft magnetic alloy was designed via microalloying and modified by adding a rare-earth element (at. % 1 Tm) to improve its structural stability and magnetic performance. The alloy was prepared in three different forms, rod, ribbon, and powder, and their morphological differences were correlated with the microstructural evolution, crystallization behavior, magnetic and thermal properties of the material. Initially, the alloy was prepared by vacuum arc melting under an inert atmosphere and re-melted several times to ensure chemical homogeneity. The bulk alloy was then cast into rod form via the suction casting technique, after rapidly solidified into ribbon form using the melt-spinning method. To extend the study toward morphology-dependent properties, a portion of the ribbon was milled into powder form by the ball-milling technique. The physical, structural, thermal, and magnetic characteristics of the three morphologies were systematically investigated using XRD, LECO, SEM-EDS, DSC, and VSM analyses. Furthermore, the ribbon samples were subjected to controlled annealing treatments to induce nanocrystallization, allowing a direct investigation of the relationship between heat-treatment, grain size evolution, and magnetic properties. Overall, this approach provides valuable insights into how structure and properties are connected in rare-earth-doped Finemet-type alloys, paving the way for designing the next generation of soft magnetic materials used in transformer cores, sensors, and power-electronics devices.

Keywords: Soft Magnetic Alloys, Microalloying, Magnetic Properties, Rare-Earth Element, Amorphous Alloy

Development of Boron Nitride Coatings for Industrial and Medical Applications

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[1]*Atılım University*

Boron Nitride (BN) has seven allotropes such as hexagonal (h-BN), cubic (c-BN), turbostratic, amorphous, explosive, rhombodoidal and wurtsic. They all have different properties. h-BN is soft and lubricious whereas c-BN is hard and abrasive. A method of coating of these allotropes are developed on metals using a Physical Vapor Deposition (PVD) process. Depending on the coating parameters, different allotropes can be obtained. As applications of this developed coating technology, cutting tools and dies are coated for increased hardness and extended life. Implants are coated to provide osteoblastic and antibacterial property. Wires are coated for promoting healing of bone fractures. Optical lenses are coated to provide a transparent and a hard coating for protection. Bearings are coated to provide a non-electrical conducting surface. Other products can also be coated for high temperature protection. Theoretical modeling of the coating process is developed. Artificial Intelligence is applied to improve the coating process.

Keywords: Coatings, Antibacterial, Osteoblastic, Hard, Transparent

Borofen’in Bilimsel Evrimi: Teorik Çalışmalardan Endüstriyel Uygulamalara Literatür Temelli Bir Yol Haritası

Nida Nisanur Gözetlik[1], Hakan Ateş[1]

[1]*Gazi Üniversitesi*

Bu çalışma, borofen’in bilimsel evrimini 2015–2025 dönemi literatürü temelinde inceleyerek, teorik keşiflerden endüstriyel uygulamalara uzanan kapsamlı bir yol haritası sunmaktadır. İki boyutlu bor elementi olarak borofen, yüksek mekanik dayanımı, elektronik iletkenliği ve kimyasal reaktivitesiyle son on yılda yoğun ilgi görmüştür. Çalışma kapsamında, borofen’in farklı yapısal fazları, hesaplamalı modelleme teknikleri (DFT, MD vb.), patent verileri ve endüstriyel yönelimler sistematik olarak analiz edilmiştir. Literatür taraması, borofen’in potansiyel uygulama alanlarının (enerji depolama, sensör teknolojileri, nanoelektronik) giderek çeşitlendiğini ve akademik araştırmaların teknoloji transferiyle bütünleşmeye başladığını göstermektedir. Ayrıca, bilimsel gelişmelerin politika ve yatırım stratejilerine etkisi değerlendirilerek, gelecekteki araştırma ve ticarileşme eğilimlerine dair öngörüler sunulmuştur. Bu yönüyle çalışma, yalnızca akademik bir derinlik sunmakla kalmayıp, borofen’in stratejik konumlanmasına dair çok boyutlu bir perspektif geliştirmektedir.

Anahtar Kelimeler: Borofen, Yapısal Fazlar, Hesaplamalı Malzeme Bilimi, Endüstriyel Uygulamalar

Synthesis and Structural Characterization of Neodymium Hexaboride (NdB_6) Powder

Nadide Münevver Doğduaslan[1], Osman Can Özer[1], Mehtap Arslan Kaba[1], Güldem Kartal Şireli[1]

[1]*Istanbul Technical University*

Rare-earth (RE) borides exhibit distinctive properties arising from f-electron interactions, providing strong potential for high-temperature applications. Among RE hexaborides, NdB_6 represents the most thermally stable phase. Its technological relevance is attributed to its high melting point, low work function (~1.6 eV), low vapor pressure, excellent chemical stability, and narrow-band semiconducting nature [1,2]. NdB_6 powders have been synthesized through several approaches [3]; however, these processes often suffer from issues related to contamination, phase control, or limited crystallinity. In contrast, the molten-salt electrolysis technique developed in this study is a greener, scalable, and cost-effective route that yields high-purity NdB_6 using oxide-based salts. In particular, the use of borax enables high throughput and significantly shorter processing times. The electrolyte (94 wt% $Na_2B_4O_7$, 5 wt% Nd_2O_3, 1 wt% CaF_2) and 60 min electrolysis time followed our group's prior work. Titanium (Grade 2) and low-carbon steel (AISI 1018) served as cathodes, with a graphite crucible as the anode. Experiments systematically varied current density (0.1, 0.2 and 0.4 A/cm^2) and temperature (900–1000 °C). Powders, containing minor impurities, were purified by HCl leaching, then subsequently filtered and dried. Structural characterization employed XRD, SEM, and particle-size distribution analysis. The XRD results of powder collected on the cathode surface in the experiment are presented in Figure 1. NdB_6 was obtained under these parameters; besides the main NdB_6 phase, $NdBO_3$ appeared before HCl cleaning and was completely removed afterward. SEM micrographs (Figure 1b–c) show the characteristic cubic morphology with a uniform distribution. Consistent with XRD, no phases other than NdB_6 were detected after HCl cleaning. With increasing temperature, particle size increased, whereas no significant correlation with current density was observed. At high current densities, agglomeration caused bulk spalling from the cathode. The average particle size was 52.13 µm (Figure 1d). Using a low-carbon-steel cathode produced similar XRD and SEM outcomes; the mean particle size from particle-size analysis was 82.01 µm (Figure 1g). In this study, high-purity NdB_6 powder was successfully produced via molten-salt electrolysis using a borax-based electrolyte. XRD and SEM analyses confirmed the phase purity and characteristic cubic morphology of the powders. Particle-size analysis revealed that larger particles were obtained using a steel cathode compared to titanium. Since finer powders are desirable for forthcoming functional applications, titanium will be preferred as the cathode material in future work.

References: [1] Zhao, X., Liu, X., Lin, F., Liu, W., & Su, W. (1997). A new route for the synthesis of boron-rich rare-earth boride NdB6 under high pressure and high temperature. Journal of alloys and compounds, 249(1-2), 247-250. [2] Cahill, J. T., & Graeve, O. A. (2019). Hexaborides: a review of structure, synthesis and processing. Journal of Materials Research and Technology, 8(6), 6321-6335. [3] Sonber, J. K., Murthy, T. S. R. C., Paul, B., Majumdar, S., Sairam, K., Sahoo, D., ... & Kain, V. (2024). Studies on synthesis, densification, and characterization of neodymium hexaboride. International Journal of Applied Ceramic Technology, 21(3), 1425-1437.

Keywords: Co-Deposition, Molten Salt Electrolysis, Rare Earth Borides

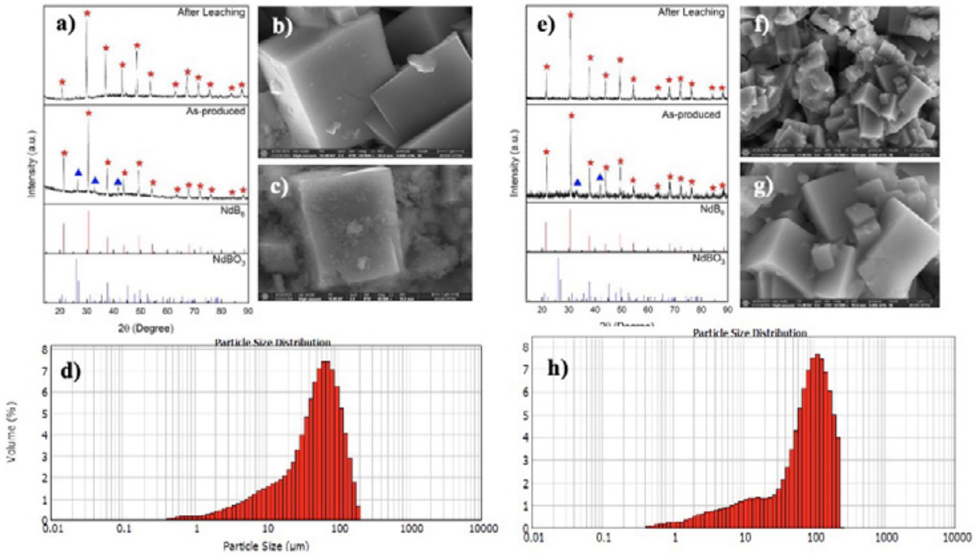

Figure 1. (a) XRD pattern, (b) as-produced (c) HCl-cleaned SEM images, (d) particle size distribution of NdB_6 powder synthesized from an electrolyte composed of 94 wt% $Na_2B_4O_7$, 5 wt% Nd_2O_3, and 1 wt% CaF_2 at 0.2 A/cm² and 900 °C using a titanium cathode. (e–h) Corresponding results obtained under identical conditions using a low-carbon steel cathode

Synthesis of Vanadium Borides by Molten Salt Electrolysis

Elif Ecem Özgüvenç[1], Simay Yanık[1], Mehtap Arslan Kaba[1], Güldem Kartal Şireli[1]

[1] *Istanbul Technical University*

Metal borides with distinct stoichiometries and structures are widely utilized in cutting tools, wear- and corrosion-resistant coatings, and high-temperature components [1]. Within this class, vanadium borides exhibit high hardness, excellent oxidation and wear resistance, and, due to their multiple oxidation states, hold great potential as electrode materials for batteries and capacitors [2]. Compared to other synthesis routes of borides, molten-salt electrolysis offers several advantages, including simple equipment requirements, short processing times, and economic as well as environmentally friendly features [3]. This study aims to produce vanadium boride phases via molten-salt electrolysis using an oxide-based electrolyte and to elucidate the effects of process parameters on phase formation and powder morphology. Molten-salt electrolysis was carried out in a medium-frequency induction furnace using a graphite crucible as the anode and a low-carbon steel plate as the cathode. The electrolysis was performed at 900 °C for 1 h. The temperature and duration were adopted from previous studies, while the optimum current density was explored in the range of 70–500 mA cm^{-2}. To evaluate the effect of current density at constant temperature and time on the composition and morphology of V_xBy powders, X-ray diffraction (XRD), scanning electron microscopy coupled with energy-dispersive spectroscopy (SEM/EDS), and particle size analysis were performed. According to the XRD results, VB was deposited at the lowest current density (70 mA cm^{-2}), whereas VB_2 powders formed at higher ones (100, 150, 200, and 500 mA cm^{-2}) (Figure 1(a)). SEM indicates that particle morphology varies with current density: irregular, dispersed particles appear at lower current densities (70–150 mA cm^{-2}), while hexagonal VB_2 grains emerge at higher ones (200 and 500 mA cm^{-2}) with a particle agglomeration. From an energy standpoint, the cell potential increased with current density, demonstrating that production at lower current densities did not require high energy input. Consequently, under the fixed electrolysis time and temperature conditions, a current density of 200 mA cm^{-2} was identified as optimal. This study demonstrates a scalable, environmentally benign, rapid, and cost-effective route for producing VB/VB_2 powders in an oxide-based, stable, and low-viscosity molten-salt medium. In particular, it shows that high-phase-purity VB_2 can be obtained by optimizing temperature, current density, and electrolysis duration.

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Keywords: Vanadium Boride, Molten Salt Electrolysis, Co-deposition

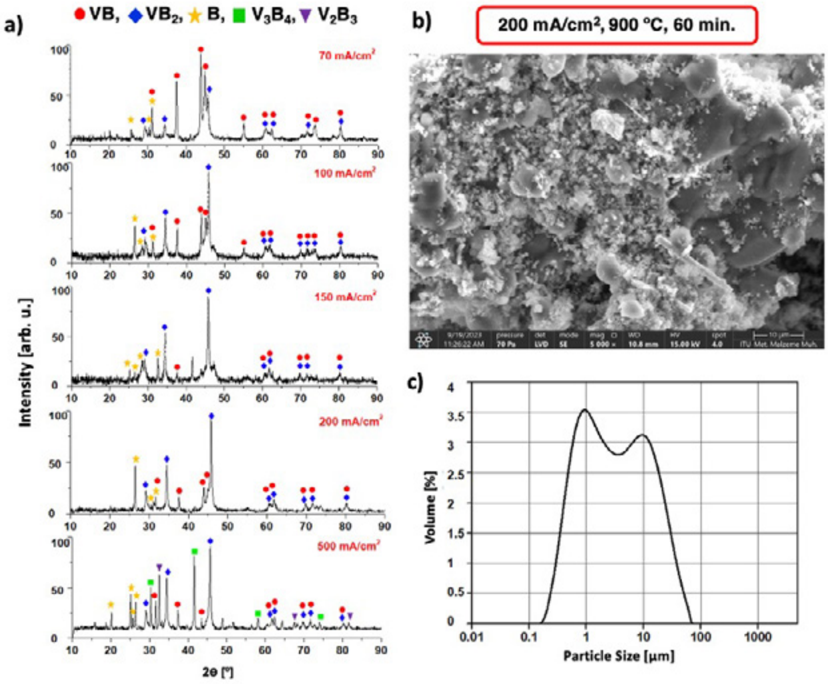

Figure 1. (a) XRD pattern of VxBy powders at different current densities (70-500 mA cm^{-2}) at 900 °C and 60 min., (b) SEM image and, (c) Particle size analysis of VxBy powders produced at optimum temperature, time and current density values [200 mA cm^{-2}, 900 °C and 1h.]

Boron as a Dopant in Lead-Free Electroceramics

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Currently, $Pb(Zr,Ti)O_3$ (PZT) and its derivatives are widely used in various electronic applications such as sensors, transducers, and actuators due to their superior piezoelectric properties and performance. However, there has been intense research over the past twenty years for the development of more environmentally friendly alternatives to PZT, due to the toxicity of lead (Pb) in the composition. $Bi_{0.5}Na_{0.5}TiO_3$ (BNT) based lead-free piezoelectric ceramics are emerging as one of the prominent material candidates to replace PZT. In this research, it is aimed to investigate property and performance of BNT based binary (BNT-BT and BNT-BKT) and ternary (BNT-BKT-BT) solid-solutions doped with different elements. The effects of these dopants on piezoelectric (d33), dielectric (εr, tanδ, Td ve TC), and ferroelectric (Ec, Ps ve Pr) properties were investigated as well as crystal structure and microstructure. Throughout the study, $0.94(Bi_{0.5}Na_{0.5}TiO_3)$-$0.06(BaTiO_3)$ (BNBT6), $0.80(Bi_{0.5}Na_{0.5}TiO_3)$-$0.20(Bi_{0.5}K_{0.5}TiO_3)$ (BNKT20), and $0.854(Bi_{0.5}Na_{0.5}TiO_3)$-$0.12(Bi_{0.5}K_{0.5}TiO_3)$-$0.026(BaTiO_3)$ (BNKBT12) ceramics were doped with Al^{3+}, La^{3+}, Mn^{3+}, and Nb^{5+} ions, which were predicted to show donor and/or acceptor behavior in light of existing literature and scientific theories. In order to systematically investigate the effects of different doping ions on the electrical properties, essential dielectric, piezoelectric and ferroelectric measurements were performed as a function of temperature, voltage, and time. The obtained results from the doping of boron (B^{3+}) alone, as well as in combination with Al^{3+}, La^{3+}, Mn^{3+}, and Nb^{5+} ions were systematically discussed and evaluated. It was shown that boron (B_2O_3) doping, in addition to its well-known effect of lowering the melting point to facilitate sintering in ceramic and glass materials, also significantly improved the electrical properties by modifying the perovskite crystal structure and defects chemistry in lead-free piezoelectric ceramics which hold the potential for the development of next-generation, environmentally friendly smart energy harvesting and storage devices.

Keywords: BNT-BKT-BT, Boron, Dopants, Lead-Free Piezoelectric Materials, Energy Harvesting and Storage

Development of Eco-Friendly Polypropylene Composites Reinforced with Borate and Hemp Fibers for Electrical Applications

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This study aims to develop an environmentally friendly, safe, and locally sourced composite material for use in the production of power strips in the electrical industry. In the project, borate compounds obtained from Turkey's rich natural resources and high-strength lignocellulosic hemp fibers were added to a polypropylene (PP) matrix, a thermoplastic polymer. As a result, an innovative material formulation with improved mechanical and thermal strength, as well as enhanced flame-retardant and smoke-suppressing properties, was achieved. Borate compounds improve safety performance through their low toxicity, high thermal stability, smoke suppression, and corrosion-inhibiting effects. During combustion, they reduce the number of free radicals, slow down flame propagation, and form a molten layer on the surface that limits heat transfer, thereby minimizing fire risk. Hemp fibers, due to their natural structure, high tensile strength, and low density, improve the strength-to-weight ratio of composites and contribute to thermal and acoustic insulation. The innovative aspect of the project lies in combining borate and hemp fibers to create a composite material that is both environmentally and technically superior. Turkey holds 73.2% of the world's boron reserves, and utilizing this potential enables the diversification of boron-based materials in industrial applications. Locally produced hemp fibers offer advantages such as low cost, easy availability, and high sustainability. The synergistic effect of these two components supports the development of next-generation electrical equipment in line with "green transformation" and "clean production" goals. The technical objectives of the research include determining the effects of borate and hemp fiber content on mechanical, thermal, and electrical properties, and identifying the optimum formulation. In this context, PP/borate/hemp composites with different compositions were produced, aiming to improve parameters such as tensile, flexural, impact, hardness, thermal conductivity, corrosion resistance, and flame retardancy. The expected performance outcomes include a 20% reduction in thermal conductivity and a 30% increase in thermal stability with borate addition, as well as a 20% increase in tensile strength and a 10% improvement in impact resistance with hemp fiber reinforcement. Economically, the project aims to reduce imported chemical additives by 10–30% and lower costs through local production. Consequently, it is expected to increase the market share of eco-friendly power strips by at least 20% and provide a competitive advantage. Furthermore, replacing imported flame retardants with domestic boron compounds will promote the use of national resources and reduce chemical dependency. From an environmental perspective, the project aligns with the European Green Deal principles by reducing dependence on fossil resources and lowering the carbon footprint. The biodegradable structure of hemp is expected to reduce plastic waste, while the halogen-free and non-toxic gas-forming properties of boron compounds will minimize environmental damage after fires. Additionally, a production approach based on local resources supports circular economy and sustainable manufacturing policies. In the laboratory-scale production process, a twin-screw extrusion method was used, optimized to ensure uniform fiber distribution and minimize fiber breakage. The prototype power strip components were subjected to thermal analysis (TGA, DSC), tensile and flexural tests, UL94 flammability tests, and SEM microstructure examinations. The results show that the synergistic effect of borate and hemp additives in the PP matrix provides significant improvements in both mechanical strength and flame retardancy. This project is carried out under the leadership of Borsan Elektrik A.Ş. in partnership with BC Teknoloji Ltd. Şti., and it is supported by TÜBİTAK's SME R&D Initial Support Program (Project No: 7240224). The technology readiness level (TRL) was initially set at 1, with a target of reaching TRL 5 after environmental validation of the laboratory prototype. In conclusion, the developed PP composite power strip reinforced with borate and hemp fibers represents a safe and eco-friendly product, combining flame-retardant and corrosion-resistant properties with a biodegradable, locally sourced structure. This study expands the application areas of boron-based additives in advanced material technologies, demonstrates the industrial feasibility of natural fibers like hemp, and contributes scientifically to Turkey's goals of sustainable production, circular economy, and green innovation.

Keywords: Biodegradable, Fibrous Composites, Borate Compounds

Electroactive Vibration Damping Properties of Boron-Containing Substances

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Electrorheology refers to the study of materials—typically suspensions or colloidal systems—whose rheological (flow) properties change reversibly and rapidly when subjected to an external electric field. In an electrorheological (ER) fluid, the application of an electric field induces polarization of the dispersed particles, leading to the formation of chain-like or columnar structures along the field direction. This microstructural transformation causes a dramatic increase in apparent viscosity and yield stress, effectively converting the fluid from a liquid-like to a solid-like state within milliseconds. The key parameters used to characterize ER behavior include yield stress, field strength, shear rate, dielectric permittivity, relaxation time, and response time. ER fluids are commonly evaluated through steady shear and oscillatory rheology under varying electric fields. Due to their fast, reversible, and controllable response, ER materials find application in adaptive damping systems, clutches, brakes, vibration control devices, actuators, and tactile or haptic interfaces, as well as emerging uses in smart materials and soft robotics.

In substances, boron usually bonds to electronegative atoms such as oxygen and nitrogen. Besides, many boron-containing substances have ions in their nature. Hence, they potentially have dielectric permittivity and electrorheological activity. Here, we report dielectric and electrorheological properties of some boron-containing minerals and polymer dispersion in silicone oil. Borax, colemanite, zinc borate, boronic acid polymers, and organoboron-based polyelectrolytes are the materials investigated. When compared with colemanite and zinc borate, borax exhibits better polarizability under an applied electrical field, resulting in higher electrorheological performance. Moreover, colemanite exhibited a negative electrorheological effect, meaning its dispersion viscosity decreased once the electrical field was applied, due to particle migration to the electrode. However, the addition of a surfactant to the dispersion enhanced the ER activity. For the dispersions of boronic acid polymer, namely poly(3-aminophenylboronic acid) and poly(thiophene-3-boronic acid), dielectric analyses revealed that the dispersions did not have enough polarizability for the desired ER performance. Their polarizabilities were improved by adding Triton-X, a surfactant. When the organoboron-based polyelectrolytes are compared, it is found that polymeric lithium tartaric acid borate has better electrorheological activity than polymeric sodium tartaric acid borate. In conclusion, boron derivatives are good candidates for potential vibration damping applications.

Acknowledgements: We are grateful for the support of this studies to Tübitak (Project no: 107T711, 112T811), Cost Actions (D43, CM1101) and Eti Holding

Keywords: Dielectric, Electrorheology, Vibration Damping

Investigation of the Tribological Properties of A7075 Matrix Composites Using Taguchi Analysis

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In this study, the tribological performance of A7075 aluminum matrix composites reinforced with 5% B_4C was investigated using the dry pin-on-disk method in accordance with the ASTM G99 standard. The effect of three different loads (10, 20, 30 N) and three different sliding speeds (1, 1.5, 2 m/s) on wear behavior was evaluated at a constant friction distance of 2500 m. Taguchi S/N ratio analysis was used to determine the relative effects of the parameters and the optimal conditions. The analysis results revealed that the most effective factor on both mass loss and friction coefficient was the applied load, while the effect of sliding speed remained secondary. The test results showed that the increasing load increased mass loss in accordance with Archard's Law but significantly reduced the average coefficient of friction (COF). This decrease in COF has been attributed to the protective tribo-film formed by the effects of increased load and surface temperature. This film reduced metallic contact and lowered friction by creating a solid lubricant effect. However, the fluctuations observed in the COF curves indicate that this film is not fully stable and continuously forms and breaks down during wear. The effect of sliding speed was not linear; specifically, under high load (30 N) and medium speed (1.5 m/s) conditions, the mass loss decreased compared to low speed (1 m/s) (39 mg vs. 33 mg), indicating that the protective layer became more effective under certain conditions. According to the optimization results, the most suitable values were determined to be 10 N for minimum wear and 30 N for minimum friction coefficient. The prediction accuracy of the developed statistical models was found to be high for COF (82.97%) and relatively low for mass loss (35.19%). This indicates that mass loss is strongly influenced by complex, nonlinear mechanisms such as tribo-film formation and thermal softening.

Effects of wear test parameters (sliding speed and load) on the coefficient of friction (COF) and mass loss according to the S/N ratio using Taguchi analysis (the smaller is better criterion was used)

Faktörler	Seviye 1	Seviye 2	Seviye 3	Delta	Sıra
Kayma Hızı (m/s) - COF	19,63	18,91	18,36	1,27	2
Yük (N) - COF	17,2	19,06	20,64	3,44	1
Kayma Hızı (m/s) – Kütle Kaybı	-28,46	-29,86	-28,43	1,43	2
Yük (N) – Kütle Kaybı	-25,25	-30,39	-31,11	5,86	1

The Taguchi S/N (Signal-to-Noise) ratio analysis results presented in the table statistically reveal the order of importance of factors affecting wear behavior. According to the analysis, the load applied to both the coefficient of friction (COF) and mass loss has a much more dominant effect than the sliding speed. Specifically, the Delta value of the load factor for mass loss (5.86) is approximately four times greater than the Delta value of the speed (1.43). This indicates that the most critical parameter in controlling the tribological performance of the material is the normal force to which it is subjected, while speed has a secondary effect. According to the optimization data, the ideal load value to reduce mass loss is 10 N, but to minimize the coefficient of friction, the opposite is true, with the load being optimal at 30 N. This situation can be explained by Archard's Wear Law and the stability of the tribo layer, as high loads create a tribo layer on the surface, resulting in a lower coefficient of friction (COF), but also increased mass loss.

Keywords: A7075, B_4C (Boron Carbide), Hybrid Composite, Wear, Taguchi Method

Development of Cr-V Layered Boride Coatings on AISI 4140 Steel by Using a Two-Stage Thermoreactive Diffusion (TRD) Process

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Due to its high strength, toughness, and wear resistance, AISI 4140 steel is widely used in critical parts such as shafts, gears, fasteners, mold steel, weapon bodies, slide mechanisms, and missile system components in the automotive, machinery, defense, energy, and oil and gas sectors. However, the surface hardness of this steel can be limiting in high temperatures, abrasion, and corrosive environments. The aim of this study was to develop Cr-V layered boride coatings on AISI 4140 steel using a two-stage Thermoactive Diffusion (TRD) process. In this context, the samples were first subjected to boriding at 1000 °C for 2 hours using the TRD method after the surfaces were sanded and cleaned with alcohol. In the second stage, the boronized samples were coated with a mixture of coating powders containing Ferro Cr-V at 900 °C for 2 hours. The obtained samples were metallographically prepared, and initial examinations with an optical microscope revealed the formation of a multiphase coating structure with a saw-tooth morphology. The resulting coating layer was found to be homogeneous and continuous, with an average total coating thickness of approximately 100 μm. Microhardness measurements revealed that the coating, at approximately 1900–2320 HV, was approximately seven times the hardness of the substrate (300–350 HV). The experimental processes of the study are ongoing and XRD, EDS, SEM, wear and corrosion tests are planned to be carried out further.

Keywords: Two-Stage TRD, AISI 4140, Layered Coatings, Boriding

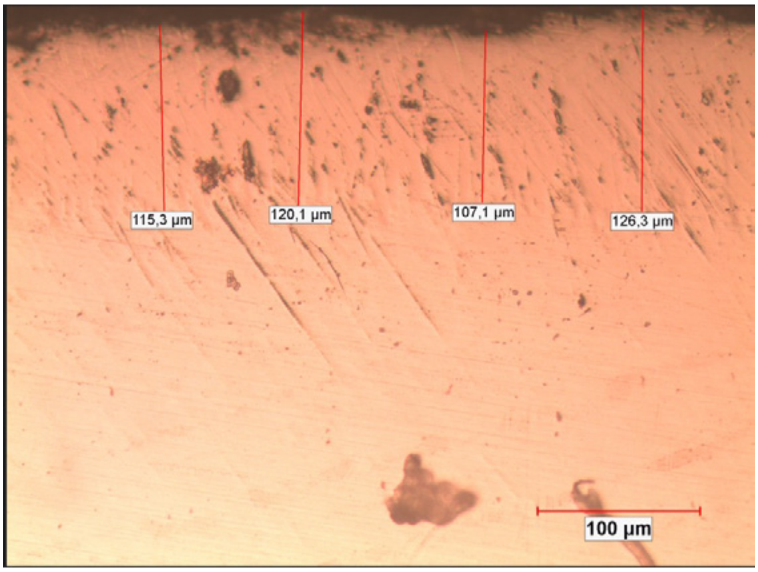

Image of Microstructure

Pilot-Scale Production of Metal Borides With a Special Furnace Design That Prevents Boron Oxide Loss at High Temperatures

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Pavezyum Kimya aims to design a system for the 100% domestic production of micro-structured TiB_2 and ZrB_2 powders. This study seeks to provide a competitive advantage in the aluminum casting and metallurgy sectors, increase exports, reduce foreign dependency, and meet the demands of the defense industry. Key objectives include designing a specialized reactor to prevent boron oxide loss for high-purity production, implementing an efficient induction furnace for rapid heating and cooling, achieving over 20% improvement in product yield, optimizing parameters to quadruple capacity, and expanding the use of domestically produced alternatives to high-priced imported products. Innovative aspects include the first pilot-scale production systems for TiB_2 and ZrB_2 in Türkiye, a furnace design capable of reaching 2200 °C rapidly, shock heating and rapid cooling methods, and a projected 30-40% increase in yield. According to the study results, TiB_2 and ZrB_2 powders have been successfully produced with a purity of over 96% and particle size distribution below 10 microns.

Keywords: Titanium Diboride, Zirconium Diboride, High Temperature Synthesis, Defense Industry

From Laboratory Synthesis to Industrial Scale-Up: Low-Temperature Production of Metal Boride Nanoparticles from Metal Chloride and Elemental Boron Precursors

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In this study, the laboratory-scale synthesis and subsequent industrial adaptation of transition metal diborides, namely ZrB_2 and HfB_2, known for their outstanding chemical and mechanical properties, were successfully achieved. A novel synthesis route was developed using metal chlorides and elemental boron (PavTec boron) as precursors, enabling the formation of high-purity ZrB_2 and HfB_2 powders at a remarkably low temperature of 850°C—significantly lower than most conventional methods reported in the literature. Unlike multi-step syntheses based on metal oxides and boron oxides, this process requires only a single reaction step. Considering both the starting materials and the temperature parameters, the method offers an efficient and economically viable route for boride powder production. The reactions were carried out under argon flow in a horizontal tube furnace using the "inorganic molten salt technique," where $ZrCl_4$/$HfCl_4$–B–Mg mixtures were combined with a LiCl–KCl eutectic flux. Post-reaction, hot-water leaching was employed to remove residual chlorides, resulting in high-purity powders. After optimizing the synthesis under laboratory conditions, the process was scaled up to pilot-level production. Industrial-scale experiments were conducted using a horizontal furnace with a daily feed capacity of 1 kg. Powder mixtures were pelletized using an industrial powder compaction system, and the pellets were reacted in graphite crucibles under identical conditions. As a result, the production capacity increased from 2–3 g per batch in the laboratory to 25–35 g per batch and up to 200–280 g per day during continuous operation under industrial-scale production conditions. The developed process yielded powders with a purity exceeding 98%, average particle sizes of 300–400 nm, and specific surface areas of 10–11.5 m^2/g. The improved purity, reduced particle size, and enlarged surface area indicate a significant increase in product value, suggesting strong potential for commercialization and competitive market performance. This work was supported by The Scientific and Technological Research Council of Turkey (TÜBİTAK) under Project No. 5210099 within the 1505 University–Industry Collaboration Support Program.

Keywords: Metal Borides, Nanoparticles, Low Temperature Synthesis, Elemental Boron, Industrial Production

Improving Interfacial Compatibility of h-BN through Dopamine and Silane Sequential Functionalization

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Hexagonal boron nitride (h-BN) is widely recognized for its high thermal conductivity, chemical stability, and thermal resilience, making it a promising filler for polymer composites. However, poor interfacial compatibility often leads to particle agglomeration, limiting the performance of h-BN-reinforced composites. To overcome this intrinsic incompatibility between h-BN and polymer matrices, surface functionalization has become a crucial strategy to tailor the filler–matrix interface and enhance dispersion stability. In this study, three surface modification strategies were developed to improve the dispersion and polymer-filler interaction: dopamine coating (DC), dopamine on silane coating (DSC), and silane on dopamine coating (SDC). The coating processes involved sequential dopamine polymerization and silane coupling reactions conducted under controlled pH and temperature conditions. Dopamine treatment was performed in Tris buffer at pH 8.5 to form a uniform polydopamine layer on the h-BN surface, whereas silanization using 3-glycidoxypropyltrimethoxysilane was carried out in an ethanol–water medium at 70–75 °C to establish covalent bonding between the functional groups and the substrate. The resulting h-BN powders were dried under vacuum and subsequently characterized to verify the effectiveness of the surface modification process. FT-IR confirmed the successful surface functionalization through the appearance of dopamine- and silane-related bands, while SEM/EDS revealed distinct morphological features and uniform elemental distribution. TGA analysis demonstrated improved thermal stability of the coated particles, particularly in the DSC sample, indicating the formation of a robust and thermally stable surface structure.

Keywords: Boron Nitride, Surface Modification, Dopamine, Silane

Improvement of Superconducting Properties in Multifilament MgB_2 Wires Produced by Cu-Coated IMD Process

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Magnesium diboride (MgB_2), with a superconducting transition temperature near 39 K, offers an exceptional balance of performance, material availability, and cost efficiency, positioning it as a competitive candidate for practical superconducting applications operating in the intermediate cryogenic temperature range. In recent years, the Internal Magnesium Diffusion (IMD) method has emerged as a superior fabrication method compared to conventional Powder-in-Tube (PIT) processing, primarily due to its capability to form a dense superconducting matrix with enhanced grain connectivity and high transport critical current density (Jc). Moreover, recent studies on multifilament MgB_2 wires have shown that splitting the superconducting core into several fine filaments helps improve stability and current performance in real systems. In this study seven-filament MgB_2 wires were fabricated through the IMD method using C-coated boron powder with two precursors: (i) pure magnesium rods and (ii) copper-coated magnesium rods. The aim is to improve the superconducting performance of IMD-processed multifilament wires by promoting efficient magnesium diffusion and refined microstructural evolution through Cu activation. Microstructural and characteristics were examined via Scanning Electron Microscopy (SEM) and optical microscopy, while superconducting performance was assessed through transport Jc measurements under magnetic fields and Temperature-dependent Resistivity (R-T) analyses to determine the onset of superconductivity. The use of Cu-coated Mg precursors resulted in a more uniform filament structure and improved grain connectivity, yielding higher Jc values at 10 T. Resistivity analysis further indicated that Cu promotes more efficient diffusion and a sharper superconducting transition. These findings demonstrate the promise of Cu-assisted IMD processing for advancing multifilament MgB_2 conductors, while emphasizing the need for further quantitative studies on underlying diffusion and reaction mechanisms. This work has been supported by TÜBİTAK and Chinese Academy of Sciences (CAS) via Bilateral Cooperation under contract No: 123N624

Keywords: MgB_2 Multifilament Wires, Critical Current Density, Amorphous Boron Powder

Investigation of the Mechanical and Tribological Properties Of AISI 1018 Steel Thermochemically Borided Using A Novel Paste Composition

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The boriding process is a surface hardening treatment carried out to improve the tribological and corrosion properties of ferrous or non-ferrous materials by forming a hard boride layer on the surface. For ferrous materials, the resulting boride layer typically exhibits a saw-tooth microstructure with a thickness of 75–200 µm from the surface toward the core, a hardness of 1700–2300 HV, and a single-phase (Fe_2B) or dual-phase (Fe_2B + FeB) constitution, depending on the substrate and coating conditions. The boriding process has a wide range of industrial applications, from automotive transmissions to excavation equipment used in the petrochemical industry. In this study, AISI 1018 low-carbon steel was borided at 1000 °C for 4 hours using a novel in-house-formulated low-porosity boriding paste that adheres well to substrate and more importantly can be removed easily after the treatment. The formation of single-phase (Fe_2B) and dual-phase (Fe_2B + FeB) structures was achieved through compositional adjustment. The obtained dual-phase structures were converted into a single-phase structure by an additional annealing treatment at 1000 °C for 4 hours under a protective atmosphere. After the boriding treatment, comprehensive characterization was carried out. Phase analysis was performed using X-ray diffraction (XRD), mechanical properties were evaluated via micro- and nano-hardness measurements, and the resulting microstructure was examined using field emission scanning electron microscopy (FE-SEM) and optical microscopy. Microscopic examinations revealed that the total layer thicknesses were approximately 200 µm, 264 µm and 325 µm for the single-phase, dual-phase and diffusion-annealed samples respectively. The untreated steel exhibited a hardness of approximately 261 Vickers, whereas the borided samples showed average hardness values of 1908 HV, 1926 HV and 2123 HV for the single-phase, dual-phase and diffusion-annealed samples respectively. Furthermore, tribological properties such as wear and friction were evaluated. Tribological tests were performed in reciprocating mode using 6 mm diameter Al_2O_3 balls under a load of 20 N and a sliding distance of 500 m. The coefficients of friction for the untreated, dual-phase, single-phase, and diffusion-annealed samples were measured to be approximately 0.55, 0.58, 0.60, and 0.65 respectively.

Keywords: Termochemical Boriding, Boriding, Paste Boriding

High Temperature Tribological Behavior of $NaBH_4$-Reduced Electroless Ni–B Coatings on 14NiCr14 Steel

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Electroless nickel–boron (Ni–B) coatings, which are deposited via an autocatalytic chemical reduction process, exhibit high hardness, self-lubricating properties, low friction, wear resistance, corrosion protection, and thermal stability. Owing to these advantages, components coated with the electroless Ni–B method are widely utilized in the defense, automotive, energy, and aerospace industries [1,2]. In this study, the electroless Ni–B coating reduced by sodium borohydride was applied to specimens fabricated from DIN 14NiCr14 (1.5732) case-hardening steel—commonly used in high-load mechanical components such as bolt mechanisms in defense applications—to enhance their high-temperature tribological performance. After being ground and polished to achieve a mirror-like finish, the specimens underwent alkaline degreasing in a hot NaOH solution to remove residual organic contaminants and oils, followed by acid pickling in dilute HCl and H_2SO_4 for micro-etching and oxide removal to promote surface activation. The electroless Ni–B bath was prepared in deionized water under continuous stirring by sequentially adding nickel chloride hexahydrate ($NiCl_2 \cdot 6H_2O$, nickel source), ethylenediamine ($C_2H_8N_2$, complexing agent), sodium hydroxide (NaOH, pH regulator), lead (II) nitrate ($Pb(NO_3)_2$, stabilizer), and sodium borohydride ($NaBH_4$, reducing agent). The coating was performed at 90 ± 1 °C with magnetic stirring at 135 rpm for 1 hour in the plating bath to ensure uniform mixing and coating homogeneity. The as-deposited Ni–B samples were heated to 350 °C at 5 °C/min under an inert argon atmosphere, held isothermally for 1 hour at this temperature, followed by furnace cooling to room temperature. The coating microstructure and phases were characterized by FE-SEM and XRD. Hardness and elastic modulus were measured by nanoindentation equipped with a Berkovich diamond indenter. To evaluate delamination and crack-propagation characteristics of the deposited layer, the Rockwell-C test was implemented. Ball-on-disc dry sliding tribometer tests were conducted at RT, 300, and 500 °C to assess the wear performance of the coated samples, using an alumina ball as the counterbody. As a result of this study, heat treatment at 350 °C for 1 hour transformed the as-deposited amorphous/nanocrystalline Ni–B structure into crystalline hard nickel–boride phases, improving wear resistance, hardness, and friction coefficient compared to the substrate. The width of the wear track was measured and analyzed. The decrease in the friction coefficient at elevated temperatures can be attributed to borate-rich tribofilm layers formed by the reaction of boron in the coating with ambient oxygen and moisture [3].

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Keywords: Nickel-Boron Coating, Electroless, Tribology, 14NiCr14 Steel, High Temperature

The Effect of Deposition Parameters on Hardness and Wear Resistance in CrBCN Thin Films Produced via Hybrid Cathodic Arc and Magnetron Sputtering Coating Methods

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Nanostructured quaternary transition metal carbonitride coatings have attracted considerable attention owing to their superior mechanical and tribological performance compared with conventional binary and ternary counterparts. Among them, boron-incorporated chromium carbonitride (CrBCN) coatings show great promise for high-demand applications due to their enhanced hardness, wear, and oxidation resistance [1,2]. In this study, CrBCN coatings were deposited using a hybrid physical vapor deposition (PVD) process that combined cathodic arc evaporation (Cr target) and magnetron sputtering (B_4C target). A Cr/CrN interlayer was introduced to improve adhesion and mitigate residual stresses, while the hybrid configuration was designed to enhance hardness and wear resistance through simultaneous incorporation of Cr, B, C, and N species. The effects of substrate bias voltage (−100 V and −150 V) and Ar/N_2 gas ratio (50/50% and 80/20%) on the microstructural and mechanical properties were systematically investigated, while keeping other deposition parameters constant, including magnetron power, cathodic arc current, process temperature, process pressure, and substrate rotating speed. Cross-sectional FE-SEM revealed a dense coating with total coating thicknesses ranging from 900 nm to 1.2 μm. Nanoindentation results showed a pronounced increase in hardness with higher bias voltage at a 50/50% gas ratio, reaching a maximum hardness of 29.2 ± 3.5 GPa at −150 V. At an 80/20% ratio, however, the hardness values remained nearly constant, suggesting a compositional stabilization effect at lower nitrogen contents, as also supported by XPS results showing reduced nitrogen incorporation at this gas ratio. A reciprocating wear test was performed to investigate the tribological behavior of the coatings deposited under different conditions. These findings demonstrate that controlling the bias voltage and gas composition in hybrid PVD processes is an effective strategy to tailor the structure and improve the mechanical and tribological performance of CrBCN coatings for advanced engineering applications.

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Keywords: Cathodic Arc, Magnetron Sputtering, Boron Carbide, Chromium

3D-Printed h-BN/PLA Nanocomposites for Thermal Management in Electronic Devices

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The integration of electronic devices into a wide range of applications—from everyday appliances to industrial systems—has grown rapidly, increasing the demand for effective thermal management to enhance device performance, efficiency, and longevity. Exfoliated hexagonal boron nitride nanosheets (h-BNNS), with their excellent thermal conductivity and electrical insulation, offer a promising solution. In this study, h-BNNS were incorporated as fillers into a polylactic acid (PLA) matrix to form nanocomposites suitable for 3D printing. A composite filament was first prepared and then used to fabricate heat sinks and LED bulb holders via 3D printing. The addition of 40 vol. % h-BNNS led to a 400% increase in the thermal conductivity of PLA. These composites demonstrated heat dissipation performance comparable to commercial aluminum heat sinks and exhibited a 220% improvement over neat PLA. Furthermore, the 3D-printed h-BNNS/PLA LED holders dissipated excess heat more effectively than commercially available counterparts. Overall, the results demonstrate that h-BNNS/PLA nanocomposites hold strong potential for thermal management in electronic applications.

Keywords: 3D Printing, Nanocomposite Filament, Thermal Management, Hexagonal Boron Nitride Nanosheets, Polylactic Acid

BORON IN STRUCTURAL and FUNCTIONAL APPLICATIONS

(YAPISAL ve FONKSİYONEL UYGULAMALARDA BOR)

Borates in Wood Protection and Pest Control

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Borates are one of the safest and most cost-effective preservatives and are extensively used in wood protection, termite and pest control around the world. In the USA they are used by traditional vacuum pressure, diffusion processes and topical treatments to protect sill plates and framing lumber in construction. They are used for the protection of railway ties during seasoning (protecting half their strength) and in use, after over treatment with copper naphthenate or creosote and are the leading preservative used for composites, especially for exterior siding. They are also used in many insect baits where they have both non-target and non-resistance benefits. Recent successes, potential issues and the importance of formulation will be reviewed, as well as new opportunities to grow borate applications that have yet to be tapped.

Keywords: Wood, Impregnation, Termite and Pest Control

Encapsulation of Railway Sleepers Treated with Copper Boron

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Treating unseasoned wood railway sleepers (crossties) with osmotic copper borate salts. After dip-treating in the viscous sodium borate solution the ties are encapsulated in layers of polymer film shrink tubes. The encapsulation is permanently installed into track with the sleeper. The wood sleeper remains at high moisture content it's entire service life, greatly reducing seasoning defects and greatly extending defusion of the osmotic salts. Leaching of the copper boron is controlled by the encapsulating polymer films.

Keywords: Boron, Crossties, Sleeper, Leaching, Encapsulation

Melamin-formaldehit Tutkalına Bor Katkısının Kontrplak Levhalarda Performans Üzerine Etkisi

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Ahşap esaslı levhalar, mobilya ve yapı sektörlerinde yaygın olarak kullanılan kompozit malzemelerdir. Bu levhalarda bağlayıcı olarak genellikle üre-formaldehit (UF) ve melamin-formaldehit (MF) tutkalları tercih edilmektedir. Ancak formaldehitin uçucu organik bileşikler arasında yer alması, hem insan sağlığı hem de çevre açısından önemli riskler oluşturmakta ve bu durum düşük formaldehit emisyonlu tutkallara yönelik çalışmaları teşvik etmektedir. Formaldehit emisyonunun azaltılması sürecinde levhaların fiziksel ve mekanik özelliklerinin korunması büyük önem taşımaktadır. Bu çalışmada, bor bileşiklerinin melamin-formaldehit tutkalının sentez aşamasında kullanımının tutkal özellikleri ve kontrplak levha performansı üzerindeki etkileri araştırılmıştır. Sentezde borik asit (BA), boraks pentahidrat (BPH) ve boraks dekahidrat (BDH) bileşikleri kullanılmış; elde edilen tutkallar kontrplak üretiminde değerlendirilmiştir. Üretilen levhalarda fiziksel (rutubet miktarı, yoğunluk, kalınlığa şişme, su alma), mekanik (eğilme direnci, elastikiyet modülü, yapışma direnci) ve formaldehit emisyonu testleri gerçekleştirilmiştir. Sonuçlar, bor bileşiklerinin formaldehit emisyonunu önemli ölçüde azalttığını ve özellikle boraks pentahidrat (BPH) ilavesinin emisyonu en etkin biçimde düşürürken levhaların fiziksel ve mekanik özelliklerinde kayda değer bir azalmaya yol açmadığını göstermiştir. Elde edilen bulgular, bor bileşiklerinin melamin-formaldehit tutkallarının sentezinde çevre dostu modifikasyon ajanı olarak değerlendirilebileceğini ortaya koymaktadır.

Anahtar Kelimeler: Bor, Ahşap, Melamin-Formaldehit, Yapı Malzemeleri

Yangına Dayanıklı Bor Katkılı MDF Üretimi

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Ahşap esaslı kompozit paneller, özellikle orta yoğunlukta lif levhalar (MDF), yüksek yüzey kalitesi, işlenebilirlik, homojen yapı ve çevre dostu özellikleri sayesinde mobilya, iç mekân tasarımı ve inşaat sektörlerinde yaygın olarak tercih edilmektedir. Ancak bu malzemelerin en önemli sınırlayıcı özelliği, yanma eğilimlerinin yüksek olması ve yangın sırasında hızla tutuşarak yapısal bütünlüğünü kaybetmeleridir. Yangın güvenliği, özellikle yapı malzemelerinde sürdürülebilirlik ve insan güvenliği açısından giderek daha kritik bir hale gelmiştir. Bu bağlamda yapılan araştırmalar, MDF gibi lignoselülozik temelli malzemelerin yanıcılığını azaltmak için çeşitli alev geciktirici katkı maddelerinin üretim sürecine dâhil edilmesinin etkili bir yöntem olduğunu göstermektedir. Bu çalışmada, MDF üretiminde bor bileşiklerinin yangına dayanım üzerindeki etkileri kapsamlı biçimde incelenmiştir. Özellikle boraks pentahidrat ($Na_2B_4O_7 \cdot 5H_2O$), borik asit (H_3BO_3), çinko borat ($2ZnO \cdot 3B_2O_3 \cdot 3.5H_2O$) ve üleksit ($NaCaB_5O_9 \cdot 8H_2O$) katkılarının farklı oranlarda kullanımıyla üretilen MDF numunelerinin fiziksel, mekanik ve termal özellikleri değerlendirilmiştir. Bor bileşiklerinin lif yapısı, reçine polimerizasyonu ve panel içi ısı transferi üzerindeki etkileri, üretim sürecinde oluşan kimyasal ve fiziksel etkileşimler açısından analiz edilmiştir. Çalışmanın sonucunda, bor katkılı MDF üretiminin yangına dayanıklı, çevre dostu ve ekonomik olarak uygulanabilir bir alternatif oluşturduğu ortaya konulmuştur. Özellikle borik asit gibi yerli bor minerallerinin kullanımının, Türkiye'nin doğal kaynaklarını katma değerli ürünlere dönüştürmesi açısından stratejik önem taşıdığı değerlendirilmektedir. Bu kapsamda, bor bileşiklerinin uygun kombinasyonlarla ve kontrollü oranlarda MDF üretimine entegre edilmesi, hem malzeme güvenliğini artırmakta hem de sürdürülebilir üretim anlayışını desteklemektedir. Deneysel bulgular, bor katkılı MDF levhaların alev ilerleme hızını düşürdüğünü, karbonizasyon tabakası oluşturarak ısı transferini sınırlandırdığını ve tek alev kaynağı (testlerinde belirgin biçimde daha iyi performans sergilediğini göstermiştir. Bor bileşiklerinin lif-reçine etkileşimi sonucu, çekme ve eğilme dayanımlarında sınırlı düşüşler gözlemlenmiştir. Ancak bu düşüşler, üretim sürecinde üre-formaldehit tutkal oranının optimize edilmesiyle başarıyla dengelenmiştir. %8–10 aralığında yapılan tutkal artışı, lifler arası kohezyonu güçlendirerek levhanın mekanik dayanımını yeniden standarda taşımıştır. Bu sayede hem yangına dayanıklılığı yüksek hem de kalite parametreleri TS EN 622-5 standardı ile uyumlu MDF levhalar elde edilmiştir. Çalışmanın en önemli çıktılarından biri, laboratuvar ölçeğinde geliştirilen reçetenin endüstriyel üretim hattında başarıyla uygulanmış olmasıdır. Üretilen levhalar, akredite laboratuvarda yangına tepsi sınıfı için teste tabi tutulmuş ve MDF için en üst sınıf olan B1, s1, d0 sınıfı yangın dayanım sınıfı ile belgelenmiştir. Bu sonuç, geliştirilen kompozisyonun yalnızca araştırma aşamasında değil, endüstriyel ölçekte doğrulanmış, sertifikalı bir ürün haline geldiğini kanıtlamaktadır. Sonuç olarak, optimize edilmiş bor katkı oranları ve tutkal modifikasyonu sayesinde yangına karşı yüksek dirençli, mekanik olarak kararlı ve çevre dostu MDF levhalar elde edilmiştir. Bu başarı, hem malzeme güvenliği hem de yerli hammadde kaynaklarının katma değerli kullanımını destekleyen sürdürülebilir bir üretim yaklaşımını temsil etmektedir.

Anahtar Kelimeler: MDF, Bor Bileşikleri, Sürdürülebilir Malzeme, Alev Geciktirici, Yangına Dayanım

Tinkal ve Boraks Pentahidrat ile Modifiye Edilmiş Poliüretan Köpüklerin Performansının İncelenmesi

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Poliüretan köpükler; ısı, ses ve nem yalıtımı gibi üstün özellikleri sayesinde inşaat, otomotiv, beyaz eşya ve mobilya sektörlerinde yaygın olarak kullanılmaktadır. Hafif yapısı, yüksek enerji emme kapasitesi ve düşük ısı iletkenliği nedeniyle sandviç panel sistemlerinde tercih edilmektedir. Ancak, bu malzemelerin mekanik dayanım ve çevresel sürdürülebilirlik açısından geliştirilmesi gerekmektedir. Bor mineralleri, yüksek ısıl kararlılık, alev geciktiricilik ve kimyasal direnç kazandırma özellikleriyle polimer matrislerin performansını artıran çevre dostu katkı maddeleri olarak öne çıkmaktadır. Bu çalışmada, sandviç panellerin çekirdek malzemesi olarak kullanılan poliüretan köpüklerin mekanik ve fiziksel özelliklerinin geliştirilmesi amacıyla, farklı oranlarda bor minerali katkılarının etkisi incelenmiştir. Bu kapsamda, poliüretan matrisine ağırlıkça %1, %2 ve %3 oranlarında tinkal ve boraks pentahidrat ilave edilmiştir. Elde edilen numuneler üzerinde yapılan deneysel çalışmalar sonucunda, %2 tinkal katkısının poliüretan köpüğün çekme dayanımını yaklaşık %20 oranında artırdığı, buna karşılık yoğunluğunu %24 oranında azalttığı belirlenmiştir. Diğer yandan, poliüretan içerisine %1 boraks pentahidrat ilavesinin çekme dayanımında %14 artışa, yoğunlukta ise %5 azalmaya neden olduğu tespit edilmiştir. Sonuçlar, bor türevlerinin poliüretan yapısına entegrasyonunun köpük malzemenin hafifliğini korurken mekanik dayanımını iyileştirebileceğini göstermektedir. Bu bulgular, bor mineralleriyle modifiye edilmiş poliüretan köpüklerin, yüksek performanslı ve sürdürülebilir kompozit panel uygulamaları için potansiyel taşıdığını ortaya koymaktadır.

Anahtar Kelimeler: Poliüretan, Tinkal, Boraks Pentahidrat, Sandviç Panel, Mekanik Dayanım

Effect of scale on ZnB synthesis for wood coating

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Zinc, boron and zinc borate are waterborne wood preservatives based on inorganic compounds which have shown effectiveness against both abiotic and biotic degradation agents. Zinc borate (ZnB) is widely used in compounds, and can be used as part of coatings. In a previous study, zinc borate was synthesized on a laboratory scale and mixed with an acrylate based waterborne resin, and with an alkalyd resin, which were compared in their effectiveness as coatings on eucalyptus grandis and pinus taeda wood. In this study, the ZnB synthesis was carried out under the same conditions (temperature, stirring rate, time...) but on a larger, pilot scale, on a multiphase reactor. Since the formation of tetrahedral (BO_4) and trigonal (BO_3) units, and the different arrangements that originate polyborates highly depend on the conditions of the reaction, the change in scale could result in different chemical species with differing biocidal activity. The laboratory scale ZnB was compared with the pilot scale ZnB using X-ray powder diffraction and through their antifungal activity against stain fungi (Fusarium sp and Aspergillus niger) and rot fungi (Gloeophyllum trabeum and Trametes versicolor). The results show the difference to be minimal, although the antifungal capacity was indeed slightly lower for the pilot scale. This finding underscores the importance of carefully optimizing synthesis conditions to maintain the protective properties of zinc borate in practical applications

Keywords: Wood Protection, Scale-up, Zinc Borate

Akrilonitril-Bütadien-Strien Terpolimerine Çinko Borat ve Kırmızı Fosfor Sinerjik Etkisi Sayesinde Yanmaya Karşı Dayanım Kazandırılması

Kübra Hilal Çalış[1], Volkan Murat Yılmaz[1], Ümit Tayfun[2]

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Akrilonitril-bütadien-stiren kopolimeri (ABS) günlük hayatımızda çeşitli uygulamalar sağlamaktadır. Başlıca uygulamalar spor malzemeleri, kasklar, ev aletleri, telefon santral panelleri, elektronik ekipmanlardır. Ayrıca ABS, pürüzsüz yüzeyi sayesinde otomotiv sektöründe de geniş bir kullanım alanı bulmuştur [1-5]. Son yıllarda ABS, 3D baskı teknolojisi alanında polimerik monofilament kullanımıyla popülerlik kazanmıştır. Eriyik karıştırma, endüstriyel ölçekte en çok tercih edilen üretim yöntemidir ve temel olarak 3D baskı uygulamalarıyla benzer işleme parametreleri sağlar. ABS ve kompozitlerinin reolojik parametreleri, katkı maddesi üretim uygulamaları için önemli bir rol oynar. ABS'nin eriyik akış davranışı, 3D baskılı ürünün istenilen seviyelerde üretilmesini etkiler [6-8]. ABS'nin kayma incelmesi ve viskozite özellikleri, enjeksiyon kalıplama, sıkıştırma kalıplama ve 3D baskı dahil olmak üzere çeşitli işleme teknikleri için viskozite kontrolünü daha kolay ve daha esnek hale getirir [9]. ABS ve kompozitlerinin özelliklerinin incelenmesine dayanan araştırma konularının sayısı son on yılda önemli ölçüde artmıştır. Tüm avantajlarının yanında ABS, polimerler arasında en kötü alev geciktirici özelliğe sahip olan malzemedir. Bu nedenle, literatür araştırmasına göre birkaç çalışmada çinko borat, ABS bazlı kompozitler için alev geciktirici katkı maddesi olarak kullanılmıştır [10,11,12]. Önceki çalışmalarda, çeşitli polimerlerde kırmızı fosfor (KF) ile mineral bazlı alev geciktiriciler arasındaki etkileşim araştırılmıştır. Bu çalışmalarda, Kırmızı fosfor, ABS üzerinde yeni bir şişen-büzülen alev geciktirici sistem oluşturmak için ikinci asit kaynağı olarak işlev sergilemiştir [13]. Çinko borat (ÇB) ve kırmızı fosfor kombinasyonu ABS kopolimeri için daha önce denememiştir. Bu açıdan çalışma özgün bir değere sahiptir. Bu çalışmada, ABS kopolimerine değişik oranlarda ÇB ve KF yüklemeleri laboratuvar ölçekli çift vidalı ekstruder kullanılarak yapılarak kompozitler hazırlanmıştır. Kompozit numunelerin ısısal dayanım karakterizasyonu için ısısal gravimetrik analiz (TGA), çekme dayanım, darbe direnci ve shore sertlik testlerini içeren mekanik karakterizasyonlar, taramalı elektron mikroskopu (SEM) ile morfolojik yapı incelenmesi, eriyik akış hızları ölçümleri, UL yatay-dikey yakma ve Sınırlayıcı oksijen indisi (LOI) testleri kullanılarak alev alma özellikleri ve konik kalorimetre ile yanmazlık analizleri gerçekleştirilmiştir.

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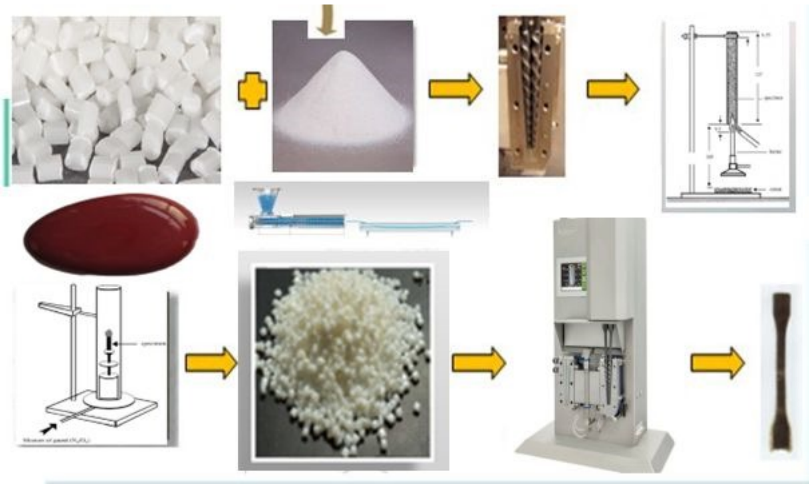
Anahtar Kelimeler: Çinko Borat, Polimer Kompozitler, Borlu Bileşik, Yanmazlık, ABS Kopolimer



Çinko Borat-Kırmızı Fosfor Kombinasyonu ile Yanmazlık Özelliğine Sahip ABS Esaslı Kompozitlerin Üretimi

Contributing to Zero Waste and Energy Efficiency: The Potential of Boron Waste as a Sustainable Sound Insulation Material

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Increasing noise pollution and demand for sustainable materials are making the reevaluation of industrial waste increasingly critical. Due to Türkiye’s significant boron reserves and the associated mining waste, it is crucial to evaluate the environmental and economic impact of these waste materials. This study aimed to assess the potential of boron waste for use in building acoustics. The acoustic performance of boron waste samples obtained from the Eti Maden-Emet facilities was examined using the impedance tube method, in accordance with the TS EN ISO 10534-2 standard. Sound transmission loss (TL) values were measured to determine the material’s sound insulation performance. The results of the experiments showed that boron waste could be an effective insulating material, particularly at medium and high frequencies. TL values were measured between 15 dB and 37 dB for frequencies above 1000 Hz. This performance is comparable to that of some alternative materials, such as cellulose-based panels and polyurethane foam. Boron waste exhibits sound-blocking capabilities due to its low density and porous structure. Using boron waste offers important advantages in terms of low-cost local sourcing and environmental sustainability. However, the material alone cannot meet the acoustic performance limits specified in building acoustics regulations (C class ≥ 52 dB). Therefore, to improve its performance and offset its weakness at low frequencies, it is recommended that it be combined with composite systems containing fibrous support materials or hydrophobic binders. Taking into account the other advantages of boron waste, such as fire resistance and chemical stability, it is predicted to be strategically valuable in the development of energy-efficient, multifunctional building materials.

Keywords: Boron Waste, Sound Insulation, Sustainability, Building Acoustics, Energy Conversion

Development of Sustainable Boron-Enriched Cement-Free Composite Panels for Neutron Shielding Applications

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The increasing demand for sustainable and radiation-resistant construction materials has led to growing interest in boron-based systems due to boron's high neutron absorption capability. This study focuses on the development of cement-free composite binders activated through alkali-carbonate systems and enriched with boron mine wastewater (BMWW) obtained from Türkiye's major boron processing facilities. Conducted within the framework of the TÜBİTAK–NRF bilateral project, the research aims to establish an innovative pathway for utilizing boron-rich industrial by-products as key functional components in next-generation shielding materials. The main objective is to transform these waste-derived resources into low-cost, environmentally friendly composites suitable for neutron shielding in nuclear, defense, and energy infrastructures. A comprehensive experimental plan has been designed to investigate the influence of boron incorporation and alkali activation chemistry on the reaction mechanisms, structural integrity, and stability of the composites. The ongoing work emphasizes formulation optimization and durability evaluation to ensure long-term performance. This study highlights the feasibility of reusing boron-containing waste streams in advanced construction materials, contributing to waste valorization, sustainable material innovation, and national material security objectives.

Keywords: Boron Mine Wastewater, Cement-Free Composites, Neutron Shielding, Alkali Activation, Sustainability

BORON FOR HEALTH and BIOTECHNOLOGY

(SAĞLIK ve BİYOTEKNOLOJİDE BOR)

Boron Clusters as Newly Emerging 3D Platform for Design of Specific Inhibitors of Pharmaceutically Relevant Enzymes

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This contribution gives an overview over the boron cluster compounds and their emerging potential as unconventional 3D pharmacophores in drug design. In particular, our original results are presented that cover successful synthesis of specific inhibitors designed for two different types of medicinal targets. We have previously identified metallacarboranes as a promising class of inhibitors of viral HIV protease (HIV-PR) enzyme [1]. More recently our focus has been re directed to Carbonic Anhydrase IX CA-IX, which is an enzyme associated with solid hypoxic tumors and belongs currently to validated targets for cancer therapy and diagnostics. The scope of currently available site-directed modifications on various boron cages is critically discussed, with an emphasis on the progress in the synthesis of carboranes and metallacarboranes substituted by sulfamide, sulfonamide and other similar groups, i.e. functions known to bind tightly to the zinc atom in the active site of CA-IX. The new series of boron-cluster inhibitors of CA-IX, based on optimized substitutions, exhibit significantly enhanced in vitro activities with corresponding Ki values in low nanomolar or even picomolar range [2-4]. The structure-activity relationship (SAR) observed within a small library of ca. 80 substituted carboranes and metallacarboranes is discussed. A rationale for observed activity and selectivity trends is supported by high resolution synchrotron structures of the enzyme-inhibitor complexes from both families of compounds. The results are complemented with preclinical evaluation of selected compounds that revealed favourable pharmacokinetic properties and ability to reduce tumour growth. Due to promising inhibitory properties, these boron species may also offer a reasonably high potential for future use in cancer diagnostics and combination treatment with BNCT.

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Keywords: Carborane, Metallacarborane, HIV-Protease, Carbonic Anhydrase IX, BNCT

Investigation of the Effects of Boron Derivatives on Gut Microbiota Composition in an ALS Mouse Model

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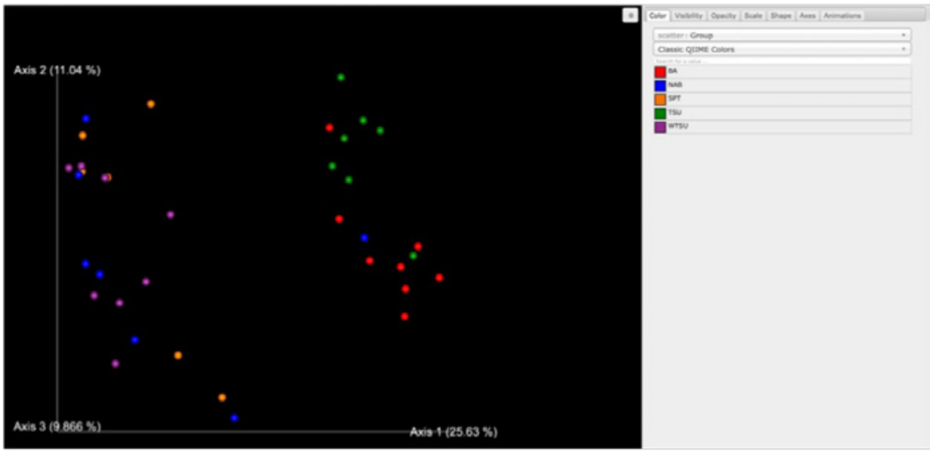
Amyotrophic lateral sclerosis (ALS) is a progressive neurodegenerative disease characterized by motor neuron loss, inflammation, and systemic metabolic disturbances. Emerging evidence suggests that gut microbiota may play a crucial role in modulating neuroinflammatory responses and disease progression in ALS. This study aimed to investigate the effects of different boron derivatives on gut microbiota composition in the SOD1-G93A transgenic ALS model to evaluate their potential modulatory impact on microbial diversity and taxonomic distribution. The experimental design included a transgenic control (TC) and a wild-type control (WTC) group, both of which received only drinking water, while boron derivative-treated groups received sodium pentaborate (NAB), sodium perborate tetrahydrate (SPT), or boric acid (BA), each dissolved in drinking water and administered ad libitum. DNA was isolated from fecal samples collected from all groups. The bacterial community composition was characterized using 16S rRNA gene amplicon sequencing targeting the V3–V4 hypervariable regions, and sequencing data were processed and taxonomically annotated through the QIIME2 bioinformatics pipeline. Alpha diversity analysis, represented by the "observed_features" metric, revealed a near-significant difference between TC and WTC groups ($p = 0.06$), indicating a mild reduction in microbial richness in ALS mice. No statistically significant differences were observed among other groups for additional alpha diversity indices. Beta diversity comparisons, assessing compositional dissimilarities between groups, showed distinct clustering of TC and BA groups, separating them from NAB, SPT, and WTC groups. Pairwise comparisons indicated that 14 taxa exhibited statistically significant differences in relative abundance at the family taxonomic level ($p < 0.05$, $q < 0.25$), particularly between TC and WTC groups. Furthermore, microbiome profiles of NAB, BA, and SPT groups were evaluated relative to the TC group to assess the potential modulatory effects of boron derivatives on ALS-associated dysbiosis. Comparative analysis demonstrated that BA treatment led to significant alterations in two taxa, whereas NAB and SPT treatments resulted in differential abundance across four and three taxa, respectively, at the family level. These findings suggest that specific boron compounds may partially restore microbial balance disrupted in ALS, potentially shifting the gut microbiota composition toward that of wild-type controls. In conclusion, this study provides preliminary evidence that boron derivatives influence gut microbial community composition in an ALS model. Ongoing investigations focusing on genus- and species-level characterization are expected to provide deeper insights into the mechanisms underlying boron–microbiota interactions and their potential therapeutic implications in neurodegenerative disorders.

Keywords: ALS, Gut Microbiota, Boron Derivatives



Beta Diversity Analysis (Bray–Curtis PCoA) Demonstrating Distinct Clustering Among Groups

Comprehensive Radiochemical, Analytical and Pharmacokinetic Evaluation of [^{11}C]BPA and [^{11}C]FBPA as Model Agents for Boron Neutron Capture Therapy

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BNCT relies on boron-containing agents that can be quantified and compared under conditions relevant to therapy [1-5]. Within this paradigm, BPA has become a clinical mainstay, aided by PET imaging strategies that estimate tissue boron concentration before neutron irradiation [4-6]. FBPA differs from BPA by a single fluorine atom and is widely used as a PET surrogate in its fluorine-18 form; however, fluorine substitution can alter kinetics and tissue distribution relative to BPA, which complicates like-for-like interpretation [7,8]. In current BNCT workflows, PET/CT quantification is often performed with [^{18}F]FBPA to guide dosing decisions, whereas therapy frequently employs BPA [6]. Although FBPA is a close analogue, the additional fluorine means it is not chemically identical to BPA and may exhibit distinct in vivo behaviour [7,8]. To avoid cross-molecule and cross-radionuclide confounds, both BPA and FBPA were radiolabelled with carbon-11 at C-1, thereby preserving each compound's native structure while using the same radionuclide. This design enables a direct, like-for-like comparison of pharmacokinetics under harmonised radiosynthetic, analytical and biological conditions [9,10]. Both tracers were prepared on E&Z Modular-Lab hardware using an aldehyde-catalysed imine–carboxylate exchange with [^{11}C]CO_2, privileging C-1 labelling on the native amino acid with a timeline compatible with 11C. Purification employed the E&Z Modular-Lab HPLC module. Analytical characterisation was done with UV detection at 220 nm and in-line radio detection under an isocratic method (water+0.1%TFA:acetonitrile+0.1%TFA). The HPLC method was validated for linearity, repeatability, precision at LOQ, accuracy, LOD/LOQ, carryover, robustness, and SST, confirming suitability for RCP assessment and quantification. Dynamic in vivo PET/CT was performed in healthy mice (n=4 for each radiotracer) to compare biodistribution and pharmacokinetics; serum stability was evaluated at 37 °C by HPLC (UV and radio where activity permitted). Decay-corrected RCY was 12% for [^{11}C]BPA and 10% for [^{11}C]FBPA; crude RCP was ~80% and 85%, respectively, rising to 100% after purification. Final analytical profiles showed [^{11}C]BPA at 7:07 min (cold 6:46) and [^{11}C]FBPA at 8:55 min (cold 8:49) with high UV purities and 100% parent by radio-HPLC. Biodistribution in healthy mice showed renal elimination with high kidney and bladder signal, consistent with amino-acid-like transport; comparative organ kinetics were obtained without disclosing numerical uptake here. Using carbon-11 for both BPA and FBPA enables PET/CT comparison under harmonised radiosynthetic and analytical conditions. The study demonstrates feasible production on E&Z platforms, validated analytics suitable for release-style decisions, high radiochemical integrity post-purification, and stable serum profiles over 60 min, thereby establishing a practical framework for BNCT-oriented evaluation.

Acknowledgements: The Republic of Türkiye Ministry of National Education and EPSRC are gratefully acknowledged for funding my education, our laboratories and research (EP/S032789/1, EP/W021307/1).

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Keywords: BNCT, [^{11}C]BPA, [^{11}C]FBPA, PET/CT, radiochemistry

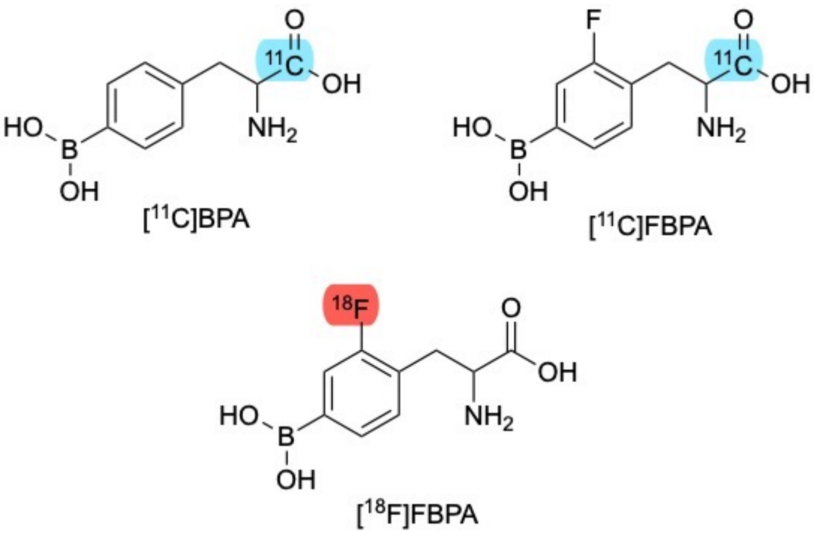

Figure 1. Different BPA tracers; [^{11}C]BPA (borono-[^{11}C]phenylalanine), [^{11}C]FBPA (4-borono-2-fluoro-L-[^{11}C]phenylalanine) and [^{18}F]FBPA (4-borono-2-^{18}F-fluoro-L-phenylalanine)

Bor Tabanlı Translasyonel Yaklaşımlar: Mikrobiyota–Beyin Ekseni ve Osteoartrit Tedavisinde Yeni Nesil BOROBİYOTA ve STEMBOR Platformları

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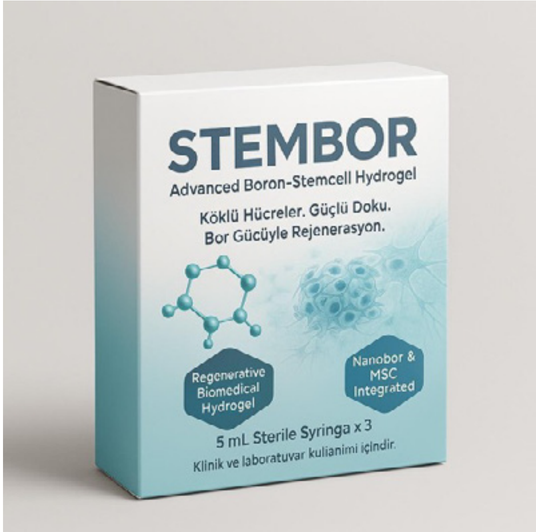
Boron (B) elementi, son yıllarda hem nörodejeneratif hastalıklar hem de dejeneratif eklem patolojileri için yenilikçi tedavi stratejilerinde ön plana çıkmaktadır. Bu bildiride, Türkiye’nin yerli bor kaynaklarından yararlanılarak geliştirilen iki özgün translasyonel platform – BOROBİYOTA ve STEMBOR – üzerinden borun sağlık bilimlerindeki çok yönlü etkileri ele alınmıştır. BOROBİYOTA, bor destekli mikrobiyota temelli bir biyoterapötik ürün olup, bağırsak–beyin ekseninde nöroinflamasyonu azaltma, sitokin dengesini düzenleme ve sinaptik plastisiteyi güçlendirme potansiyeli göstermektedir. Hücre kültürü ve hayvan deneylerinde elde edilen veriler, bor bileşiklerinin oksidatif stres ve HPA ekseni düzenleyici etkileriyle birlikte mikrobiyotanın nöroaktif kapasitesini artırdığını göstermiştir. STEMBOR ise osteoartrit tedavisinde bor nanoparçacıkları, mezenkimal kök hücre (MSC) ve hiyalüronik asit (HA) içeren rejeneratif bir hidrojel olarak geliştirilmiştir. Bu sistem, kıkırdak rejenerasyonunu desteklerken semaforin-3A (SEMA3A) biyosensör temelli biyobelirteç izleme yaklaşımıyla da yenilikçi bir mekanizma sunmaktadır. Her iki platform da TÜSEB destekli projeler kapsamında geliştirilmiş olup, patent başvuruları tamamlanmıştır. Sonuç olarak, borun mikrobiyota-beyin ve sinoviyal rejenerasyon eksenlerinde moleküler arayüz görevi görebileceği; BOROBİYOTA ve STEMBOR ürünlerinin ise ülkemizde bor tabanlı translasyonel tıp uygulamalarına öncülük edebileceği gösterilmiştir.

Anahtar Kelimeler: Bor, Osteoartrit, Translasyonel Tıp, Mikrobiyota–Beyin Ekseni, Kök Hücre



Use of Pyridoxine Borate Ester as a Dietary Supplement

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In recent years, the discovery of preventive, protective, supportive, and therapeutic compounds have gained great importance for enabling people to live healthier, longer, and higher-quality lives. In this context, the element boron (B), which is naturally occurring and has a wide range of biological effects, has attracted increasing attention for its potential in the field of health [1]. Boron is known to be an essential element for maintaining the life cycles of living organisms. Owing to its potential effects on bone health, hormonal balance, and energy metabolism, "boron-containing dietary supplements" have become a subject of growing public and scientific interest. These supplements typically contain boron minerals (such as borax, borate, or boric acid derivatives) and are often formulated together with bone-supportive nutrients like calcium, magnesium, and vitamin D [2]. Research has demonstrated that boron has regulatory effects on energy, mineral, and hormone metabolism, and that it plays a key role in the development and functionality of bone structure. Moreover, recent studies have revealed that boron contributes to DNA protection and the reduction of oxidative stress. Due to all these properties, boron is considered a promising element for the development of new therapeutic agents [3,4]. The use of boron and its derivatives in dietary supplement formulations has increased significantly in recent years. In this study, boron monoester and diester structures were synthesized using pyridoxine as a biological ligand. To stabilize the boron ester structures, Na, K, Mg, and Ca cations were utilized. The structural characteristics of the synthesized compounds, as well as those of the molecules recovered from aqueous solutions in solid form using a pilot-scale spray dryer, were analyzed using infrared spectroscopy (FT-IR), thermal analysis (TGA/DTA), and inductively coupled plasma mass spectrometry (ICP-MS) techniques.

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Keywords: Boron, Pyridoxine, Boron Esters, Dietary Supplement

In vitro Evaluation of Wound Healing and Antifungal Activities of Hypericum Perforatum L. Extract Combined with Boron and Boric Acid

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Hypericum perforatum L., also known as St. John's Wort, is a perennial plant with significant biological and chemical activities and a wide range of medicinal applications, including skin wounds, eczema, burns, and psychological disorders. Boron has the ability to form various borate minerals with different structural properties. Furthermore, the chemical properties of this mineral can be combined with different plants to enhance the effectiveness of these plants. Therefore, in our study, ethanol-extracted Hypericum perforatum L. extract combined with boron and boric acid was used in human endothelial healthy cell line HUVEC (ATCC) cells. Cell viability was assessed spectrophotometrically using the MTT (3-[4,5-dimethylthiazol-2-yl]-2,5 diphenyl tetrazolium bromide) assay at 24 and 48 hours, and the results were recorded statistically. Following cell viability, the following groups were created: control, plant solvent group, dimethylsulfoxide (DMSO), Hypericum perforatum L. extract, boron, boric acid, Hypericum perforatum L. extract + boron, and Hypericum perforatum L. extract + boric acid combination. Cell wound healing was photographed using an inverted microscope at 0, 12, 24, and 48 hours. In this study, the antifungal activities of the extract obtained from Hypericum perforatum L. flowers and leaves, the boron + plant extract, and the boric acid + plant extract groups were evaluated against Candida albicans (ATCC 14053) and Candida glabrata (ATCC 15126) strains. Additionally, their activities against fluconazole and amphotericin B were determined using the Kirby-Bauer disk diffusion method.

Keywords: Hypericum Perforatum L., Boron, Boric Acid, Wound Healing

Apoptosis Induction by Boric Acid and Venetoclax Combination in HG-3 and MEC-1 Chronic Lymphocytic Leukaemia Cell Lines: In Vitro and Computational Modelling Approach

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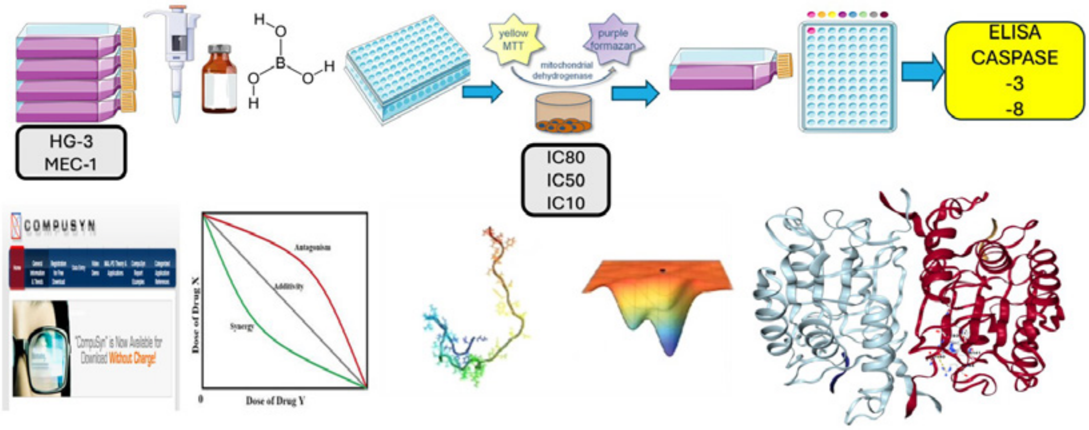
Boron, which does not occur in nature in its elemental form, is found as borax, boric acid, and borate due to its high affinity for oxygen. Its biologically available form is boric acid. Although epidemiological studies have shown that boric acid has potential cancer-preventive properties, its mechanism of action remains unclear. Venetoclax, used in the treatment of chronic lymphocytic leukemia, negatively affects treatment due to developing chemoresistance and undesirable side effects. Our study evaluated the apoptotic, antiproliferative, and synergistic effects of boric acid and Venetoclax used in combination on HG-3 and MEC-1 cells using in vitro and in silico approaches. Boric acid and venetoclax were applied at varying concentrations, and their cytotoxicity was determined using the MTT assay to establish the IC50 value after 24- and 48-hour treatments. Synergistic and antagonistic effects were evaluated using the Chou-Talalay method. Caspase-3 and caspase-8 activity was assessed using the ELISA method after obtaining lysates following a 24-hour treatment. In the in silico phase, AutoDock Vina was used for molecular docking, and GROMACS programs were used for molecular dynamics. Boric acid and venetoclax administered at varying doses demonstrated antiproliferative effects in HG-3 and MEC-1 cells in both 24-hour and 48-hour treatments. The activities of caspase-3 and caspase-8 was determined to increased compared to the control group. In silico analysis, boric acid showed significant binding affinity, similar to venetoclax. According to the Chou-Talalay method, combined use showed a synergistic effect at all doses. Boric acid has shown anticancer activity in chronic lymphocytic leukemia cell lines, showing promise in the treatment of chronic leukemia.

Keywords: Apoptosis, Computational Analysis, Chronic Lymphocytic Leukemia



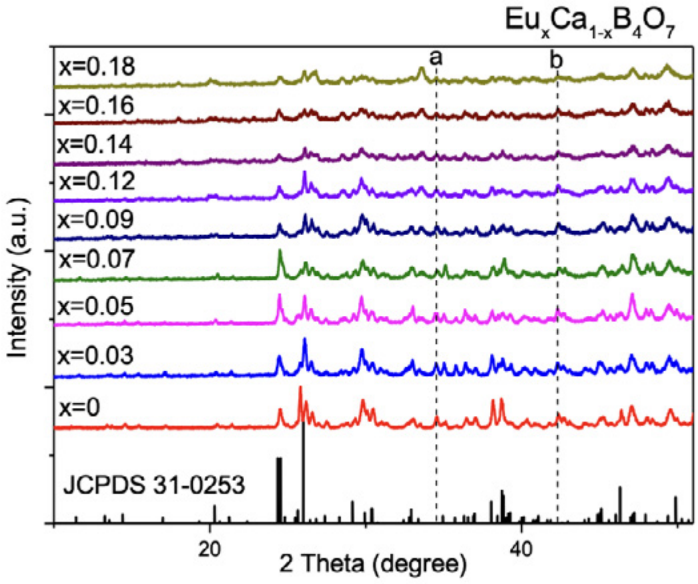
Synthesis, Characterization, and Biomedical Application of Europium Doped Calcium Tetraborate Nanoparticles

Huseynagha Abasov[1], İpek Yıldırım[1], Ayşen Yılmaz[1]

[1]Middle East Technical University

Attention to inorganic nanoparticles has spanned various but not limited to disciplines, including photodynamic therapy, antibacterial coatings, drug delivery systems in pharmacology and toxicology, and optics and electromagnetism. This study aims to explore the application of synthesized polyethylene glycol (PEG) and folic acid (FA)-coated calcium tetraborate nanoparticles doped with lanthanides, Eu^{3+}. Calcium tetraborate particles (CTB), which have not been proven to be potent drug-delivering nanoparticles with Eu^{3+} dopant, have been synthesized and doped with Eu^{3+} with varying proportions. Optimum molar conditions have been set for the dopant-to-host ratio with optimization studies utilizing photoluminescence spectroscopy to obtain the highest intensity. In this work, Eu^{3+} doped CTB has been investigated as a drug delivery system for the first time. The single-doped nanoparticles have been coated with some functional groups, such as polymers, in order to aid them in carrying the drug particles. The functional group in this study are polyethylene glycol (PEG) and folic acid (FA), which is a biocompatible material with surface functionality. This feature of the PEG-FA coating makes it a potential host to attract drug particles for constant, slow, and controlled delivery to the cancer cell lines. Moreover, the further modifiability characteristic of PEG-FA coating provides alternative routes from the coating perspective. It should be noted that CBO coating with PEG-FA as a drug delivery platform has never been studied before. Additionally, the effect of single doping has been investigated as to how photoluminescence phenomena will be affected with PDA surface coating. Drug loading experiments have been performed with Doxorubicin dissolved in PBS (phosphate buffer saline) solution. Drug loading performance of the CBO@PDA will be executed with the help of UV-VIS spectrophotometry. Drug release profiles of the CBO@PDA with Amoxicillin will be analyzed in a pH of 7.4 phosphate buffer and a pH of 5.5 acetate buffer.

Keywords: Drug Delivery System, Calcium Tetraborate Nanoparticles, Europium Doping



XRD Spectra of Synthesized Calcium Tetraborate Nanoparticles and Their Eu^{3+} Doped Derivatives

Calcination Temperature (°C)	Calcination Time (Hour)
800	2
800	3
800	4
800	6
850	2
850	3
850	4
850	6

BORON IN AGRICULTURE and ENVIRONMENTAL SUSTAINABILITY

(TARIM ve ÇEVRESEL SÜRDÜRÜLEBİLİRLİKTE BOR)

Potential Fertilizer Boron Requirement in Pakistan is 24-Times Greater than Its Current Use: A Case Study

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[2]*Fauji Fertilizer Company Limited, Rawalpindi, Pakistan*

Soil boron (B) deficiency is a major constraint to crop productivity across 22 million ha of Pakistan's agricultural land, characterized by alkaline–calcareous soils low in organic matter. Although the first field evidence of B deficiency in cotton was reported in 1970, systematic research gained momentum only in the mid-1980s on learning better soil-plant B analysis techniques. Subsequent field and laboratory studies revealed B deficiency in 35–56 % of cropped areas, leading to significant yield, produce quality, and income losses. Boron fertilizer application has proven highly cost-effective, with recorded yield increases of 14 % in cotton and wheat, 15–25 % in rice, and 23 % in peanut, along with produce quality improvements — such as rice milling yield and cooking quality traits. Soil application of 0.75–1.0 kg B ha^{-1} or 2–3 foliar sprays of 0.1 % B solution effectively corrects deficiency and leaves a beneficial residual effect without inducing toxicity. Encouraged by extensive field evidence and published research, demonstrating attractive agronomic and economic benefits of B fertilization, two major fertilizer industry players, i.e., FFC and Engro Fertilizers, have recently initiated B addition to DAP and urea, respectively. This marks a significant industry response for addressing widespread B deficiency through B-enriched fertilizer products. Despite this R&D progress, the overall use of B fertilizers in Pakistan remains sporadic and minimal. National import data show that imported boric acid and some other B compounds are utilized across several industries, including glass, ceramics, and chemicals; therefore, it is difficult to determine their exact quantity used in agriculture. Based on available trade statistics and literature, it is estimated that only 10–20 % of total imported B products are directed toward agriculture, corresponding to roughly 100 t B yr^{-1} used in fertilizers. Using the recommended-rate approach — accounting for residual beneficial effect and cropped areas requiring B fertilization — the potential annual requirement of fertilizer B for all field crops, vegetables, and fruits in the country is estimated to be 2,396 t B yr^{-1}, nearly 24-fold greater than the current agricultural use.Bridging this gap offers major opportunities to enhance crop yields, farmer profitability, and soil resource productivity, while supporting national food security and sustainable agriculture intensification initiatives. Constraints to B fertilizer adoption and strategies for improving its availability, awareness, and integration into national nutrient management programs are discussed.

Keywords: Soil B Deficiency, B Fertilizer, Actual Use, Potential Requirement, Pakistan

Farklı Bor (B) ve Potasyum (K) Dozlarının Fındık Turpu (Raphanus Sativus L. var. Sativus) Morfolojisi, Besin Elementi Alımına ve Yumru Kalitesi Üzerine Etkileri

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Bu araştırma, sera koşullarında yetiştirilen fındık turpu (Raphanus sativus L. var. sativus) bitkisine uygulanan altı farklı bor (0, 0.2, 1, 2, 4 ve 8 mg B kg -1) ve üç farklı potasyum (0, 75 ve 150 mg K kg-1) dozunun morfolojik, fizyolojik ve kalite parametreleri üzerindeki etkileşimlerini incelemeyi amaçlamıştır. Yaprak sayısı, artan K dozlarıyla azalma eğilimi göstermiş; özellikle yüksek K ile yüksek B kombinasyonlarında istatiksel olarak en düşük düzeylerde anlamlı kaydedilmiştir. Bu bulgu, yüksek konsantrasyonlarda uygulanan B ve K’nın bitkide besin elementleri arasındaki dengeyi bozarak vejetatif gelişimi baskıladığını göstermektedir. Yeşil aksam besin elementi konsantrasyonları, istatistiksel olarak anlamlı düzeyde ($p < 0.05$) K ve B uygulamalarından etkilenmiştir. Artan K dozları, azot (N), kalsiyum (Ca) ve magnezyum (Mg) konsantrasyonlarında düşüşe neden olurken, bu durum K’un Ca ve Mg ile olan antagonistik ilişkisini desteklemektedir. Öte yandan, yüksek K dozları demir (Fe), mangan (Mn) ve bor (B) konsantrasyonlarını artırıcı bir etki göstermiştir. Artan B dozlarının ise özellikle Mn ve B birikimini anlamlı biçimde artırması, B’nin mikro besin elementlerinin metabolik etkinliğini ve taşınımını teşvik ettiğini göstermektedir. Yumru renk ölçümlerine bakıldığında; B uygulamaları L* (parlaklık) değerleri üzerinde belirleyici olmuş, düşük ve orta düzey B uygulamaları daha yüksek parlaklık sağlamıştır. a* (kırmızılık) ve b* (sarılık) değerleri üzerinde ise potasyumun ana etkisi anlamlı bulunmuştur. Elde edilen bulgular, K fazlalığının renk kalitesini olumsuz etkileme potansiyeli taşıdığını, B’nin ise belirli dozlarda bu etkiyi dengeleyebileceğini ortaya koymuştur. Sonuç olarak, optimal verim ve kalite için B ve K dozlarının, besin dengesini koruyacak şekilde dikkatle belirlenmesi gereken kritik bir etkileşim içerisinde olduğu tespit edilmiştir.

Anahtar Kelimeler: Besin Antagonizmi, Bor (B), Fındık Turpu, Potasyum (K)

Utilization of Duckweed for the Phytoextraction of Boron and Other Nutrients From Agricultural Drainage Water to Produce an Organic Slow-Release Fertilizer

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Agricultural wastewater often contains excessive nutrient loads, posing both environmental and agronomic challenges. Duckweed (Lemna minor), a fast-growing aquatic macrophyte, offers a sustainable approach for nutrient recovery from agricultural drainage water while generating biomass suitable for use as an organic, slow-release fertilizer, which is rich in not only boron but also primary macronutrients including nitrogen and phosphorus. In this study, duckweed was cultivated in various agricultural wastewater sources, including greenhouse and vertical farming effluents, to recover nutrients through biomass production. The harvested biomass was subsequently incorporated into soil during a 90-day incubation experiment. Duckweed amendment enhanced overall nutrient availability and moderated soluble B concentrations, demonstrating characteristics of slow-release fertilizers. Spectrometric analyses indicated that duckweed biomass reduced the availability of excess B under alkaline pH conditions, suggesting its potential to stabilize B in soil. Chemical characterization revealed a balanced macro- and micronutrient composition suitable for a complete fertilizer. Under B stress, duckweed application improved plant performance, increasing shoot biomass by 44% and 28% in 0.25% and 0.50% treatments, respectively, compared with the control. Collectively, these findings highlight the potential of duckweed-derived biomass from agricultural wastewater as a sustainable, nutrient-enriched organic fertilizer that enhances soil fertility while regulating boron availability.

Keywords: Duckweed (Lemna Sp.), Organic Fertilizer, Boron Availability, Soil Amendment, Slow-Release Fertilizer

Effects of Different Mitigant Applications on Monocotyledonous Plants Grown in Boron-Deficient Conditions

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Boron (B) is an essential micronutrient that plays a role in fundamental physiological and biochemical processes in plants, such as cell wall structure, carbohydrate transport, lignin synthesis, and membrane stability. Monocotyledonous plants are among the species more susceptible to boron deficiency due to limited phloem transport. In strategically important cereals such as wheat (Triticum aestivum L.), barley (Hordeum vulgare L.), maize (Zea mays L.), and rice (Oryza sativa L.), boron deficiency can cause retarded root and shoot development, necrosis, and chlorosis in leaf tips. These physiological deteriorations in plants limit the water and nutrient uptake capacity, reducing photosynthetic activity and biomass production, thus impacting agricultural productivity. As plant defense mechanisms become restricted in the presence of boron deficiency, various mitigating (stress-reducing) treatments have been developed to mitigate the effects of stress through external interventions. These treatments include biostimulants such as salicylic acid, selenium, trehalose, proline, glycine betaine, humic acid, amino acid complexes, and micronutrient supplements. Mitigants can reduce the accumulation of reactive oxygen species (ROS) by activating plants' antioxidant defense systems. In plants, mitigating agents support cellular homeostasis by maintaining osmotic balance and can protect the integrity of cell membranes and protein structure. To explore these mechanisms, our study investigated the effectiveness of various mitigants such as selenium and trehalose to alleviate stress responses in monocot barley and wheat plants under B deficiency conditions. As a result of these treatments, changes in free radical (OH and H_2O_2) values, and antioxidant enzyme activities (SOD, POX, CAT, APOX, and GR) were evaluated using physiological and biochemical indicators. Under boron-deficient conditions, plant growth parameters and antioxidant enzyme activities decreased, while free radical values increased. It was determined that mitigant applications in boron-deficient conditions resulted in decreases in free radical formation and increases in antioxidant activity. It has been determined that mitigants such as selenium and trehalose alleviated the stress symptoms caused by boron deficiency and have an ameliorative effect on stress tolerance by reducing cellular damage, especially by activating the antioxidant defense system.

Keywords: Boron Deficiency, Monocotyledonous Plants, Selenium, Trehalose, Antioxidant Enzymes

Importance and Utilization of Wheat Genetic Resources in Developing Boron Toxicity Tolerance

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The world population is projected to reach 9.7 billion by 2050, demanding a significant increase in production of crops. However, enhancing crop productivity is becoming more challenging due to persistent climate change. Changes in climate worsen the biotic and abiotic stresses occurring in the agricultural fields. Boron is an important microelement for plant growth whose deficiency and toxicity in soil both have a negative effect on agricultural yields, especially in arid and semiarid regions of the world. In Turkiye, around 22% of agricultural land generally having saline soil and high pH suffers from boron toxicity. Developing boron toxicity tolerant cultivars that can be grown in these affected regions is an ultimate solution to the problem. To develop boron tolerant cultivars, it is necessary to identify boron tolerant genetic resources, understand their underlying tolerance mechanism and employ them in breeding programs. Contrary to the efficient utilization of wheat genetic resources for different stresses such as drought, heat, and salinity, limited studies have been conducted on boron toxicity. To fill the research gap in the literature, we have screened different wheat genetic resources including landraces, wild wheat and neglected wheat species under boron toxic growth conditions in the scope of TÜBİTAK-funded 1001 project (No. 119O455). A number of tolerant genotypes from different species including Aegilops columnaris, Triticum dicoccum, T. urartu, T. dicoccoides, T. zhukovskyi have been identified through several experiments. Transcriptome analysis revealed the involvement of different pathways and mechanisms behind the tolerance of these genotypes. Functional characterization of boron toxicity tolerant genes from T. dicoccoides and T. zhukovskyi in Arabidopsis thaliana demonstrated their role in boron toxicity tolerance. While the boron tolerant genotypes identified in the project will be used as pre-breeding and breeding material in wheat improvement programs, the identified potential genes can be used for the development of functional markers for the assessment of boron toxicity tolerance.

Keywords: Gene Expression, High Boron, Physiological Growth, Stress Tolerance, Wild Wheat

Farklı Kaynaklardan Uygulanan B Gübrelerinin Şeker Pancarı Bitkisinin Gelişimi ve Verimi Üzerine Etkileri

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Bor (B) bitkiler tarafından düşük miktarda ihtiyaç duyulan, eksikliği ile fazlalık sınır değeri birbirine çok yakın olan bir mikro besin elementidir. Şeker eldesi amacıyla yetiştirilen yumrulu bir bitki olan şeker pancarı, bor ihtiyacı en yüksek ve bor eksikliğine en duyarlı kültür bitkilerinden biridir. Bu çalışmada, Türkiye Şeker Fabrikaları A.Ş. Şeker Enstitüsü'nün Etimesgut İstasyon Şefliğinde bulunan deneme arazisinde tarla koşullarında yetiştirilen şeker pancarı bitkisine (Beta vulgaris L.), farklı B kaynakları (Etidot-67 toprak, Etidot-67 toprak+yaprak, ETiGranB10 toprak, ETiGranB15 toprak, %75 Kolemanit+%25 Boraks Pentahidrat toprak) uygulanarak, söz konusu gübrelerin şeker pancarı bitkisinin gelişimi ve B alımına etkileri araştırılmıştır. Bu amaçla şeker pancarı bitkisine ekim öncesinde toprak uygulamaları 0,3 kg da^{-1} B, yaprak uygulaması 300 ppm B dozunda yapılmıştır. Deneme tesadüf parselleri deneme desenine göre, 4 tekerrürlü olarak yürütülmüştür. Yaklaşık 6 aylık gelişme periyodu sonucunda bitkiler hasat edilmiş ve hasat döneminde alınan yumru örneklerinde kök verimi (kg da^{-1}), şeker varlığı (%), sodyum (meq 100 g^{-1} pancar), potasyum (meq 100 g^{-1} pancar), zararlı N veya *-amino N (meq 100 g^{-1} pancar), arıtılmış şeker varlığı (%), arıtılmış şeker verimi (kg da^{-1}) ve kuru madde (Brix) (%) miktarları gibi pancarda verim ve kaliteyi direkt olarak etkileyen parametreler belirlenmiştir. Söz konusu araştırmaya ait çalışmalar hali hazırda devam etmekte olup, Türkiye topraklarında şeker pancarı bitkisinde bor uygulamasına yönelik yapılmış olan bilimsel çalışmalarda %6-15 arasında ürün verim artışı göz önünde bulundurulduğunda, bu çalışmada da önemli sonuçların alınacağı değerlendirilmektedir.

Anahtar Kelimeler: Granül Gübre, Şeker Pancarı, Bor

Removal of Naphthalene from Paraffin by Using Nanoclay Derived from Boron Enrichment Process Waste

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Liquid paraffin oil poses a significant threat to living organisms due to the presence of toxic components such as naphthalene. Owing to its resistance to biodegradation, liquid paraffin oil can accumulate in ecosystems and eventually enter the human body through the food chain. Furthermore, the presence of aromatic hydrocarbons deteriorates the quality and stability of downstream products. Consequently, the removal of aromatic hydrocarbons from liquid paraffin oil is of considerable environmental and industrial importance. With the growing emphasis on environmental sustainability and resource efficiency, the recovery and valorization of industrial wastes have become critical research areas. During the boron enrichment process, approximately 5–10% of B_2O_3 is generated as a by-product. These B_2O_3-rich wastes, originating from strategically important boron minerals, pose serious environmental challenges, including air, water, and soil contamination. Moreover, their storage and disposal require large land areas, creating additional environmental burdens. Instead of storing recoverable wastes, their utilization as secondary raw materials can reduce dependency on primary resources and provide substantial economic and environmental benefits. To enhance the contribution of boron resources to the national economy, it is crucial to develop novel boron-based materials, expand the application areas of existing boron compounds, strengthen boron-related industrial sectors, increase employment opportunities, and promote domestic utilization of boron products.In this study, nanoclay derived from boron enrichment process waste was synthesized and employed as an adsorbent for the removal of naphthalene, a representative aromatic hydrocarbon present in liquid paraffin oil. The prepared nanoclay adsorbents were characterized by Scanning Electron Microscopy (SEM), N_2 adsorption–desorption isotherms, X-ray Diffraction (XRD), and Fourier Transform Infrared Spectroscopy (FTIR). Adsorption kinetics were analyzed using pseudo-first-order, pseudo-second-order, and intra-particle diffusion models, while equilibrium data were fitted using Langmuir and Freundlich isotherm models. The results demonstrate that nanoclay derived from boron enrichment process waste is a promising low-cost and sustainable adsorbent for the effective removal of naphthalene from liquid paraffin oil.

Keywords: Boron Waste, Naphthalene, Paraffin, Adsorption

Facile BN Coating Strategy on Melamine Sponges for Improved Adsorption and Regeneration Efficiency

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The continuous release of wastewater containing a wide spectrum of inorganic and organic pollutants has become a critical global issue, imposing notable pressure on ecological systems and indirectly affecting societal and economic stability [1]. The presence of toxic constituents—ranging from metal ions and petroleum-derived materials to industrial solvents and aromatic dye pollutants—in these effluents has aggravated water contamination concerns and heightened public health threats, largely driven by rapid industrial growth and increasing population density [2]. Conventional practices used to manage oily and organic pollutants in contaminated water, including physical oil removal, chemical purification strategies, and direct on-site burning [3], are accompanied by considerable limitations. These treatment approaches often exhibit poor efficiency, require substantial energy consumption, and may further introduce environmental burdens through the generation of additional contaminants [4]. In this study, boron nitride (BN)-coated melamine sponges were developed as efficient adsorbent materials for removing textile dyes from wastewater. BN was coated onto melamine sponges via a layer-by-layer deposition method based on the principle of electrostatic attraction. Polydimethyl diallyl ammonium chloride (PDDA) was employed as the cationic polymer solution, whereas boron nitride nanosheets were utilized as the anionic component to facilitate electrostatic binding. Sequential coatings of the cationic and anionic solutions on the melamine sponge were performed for 15 cycles. Batch adsorption experiments of methyl orange were conducted to evaluate the adsorption performance of the boron nitride-coated sponges. The repeated deposition cycles enabled uniform distribution of BN nanosheets throughout the sponge's porous network, enhancing surface area and dye adsorption capacity. Structural and morphological characterizations using FTIR, SEM, and BET analyses confirmed that BN layers were successfully coated without compromising the integrity of the melamine framework. Adsorption tests conducted with a model dye, methyl orange, demonstrated rapid uptake kinetics and achieved approximately 70% dye removal. The adsorption process was mainly driven by electrostatic interactions, π–π stacking, and the surface affinity of BN nanosheets. Moreover, the BN-coated sponges retained their adsorption performance over multiple regeneration cycles, highlighting their high reusability. Overall, these BN-modified melamine sponges offer a cost-effective, durable, and reusable solution for treating dye-contaminated wastewater.

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Keywords: Boron Nitride, Melamine Sponges, LBL Deposition, Wastewater Treatment, Textile Dyes

Biochemical Changes in Wheat Plants under Boron Toxicity Conditions

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Boron (B), an essential micronutrient in plants, plays a critical role in vital physiological and biochemical processes such as cell wall stabilization, membrane permeability regulation, carbohydrate transport, lignin synthesis, and signal transduction. Adequate boron availability in plants is particularly important for the development of meristematic tissues and the functional integrity of reproductive organs. However, both boron deficiency and excess cause disruptions in plant metabolism. Boron toxicity stands out as a significant abiotic stress factor that threatens agricultural production, particularly in regions with boron-rich soils. Toxicity occurs when high concentrations of boron accumulate in plants, disrupting intracellular ion balance and triggering excessive production of reactive oxygen species (ROS). This leads to oxidative stress in plant cells and irreversible damage to membrane structures, proteins, and nucleic acids. Plants activate their antioxidant defense systems to limit the effects of oxidative stress and maintain cellular integrity. Key components of this system include enzymes such as superoxide dismutase (SOD), peroxidase (POX), catalase (CAT), and glutathione reductase (GR). These enzymes contribute to the maintenance of intracellular redox balance by converting ROS into less harmful compounds. Wheat (Triticum aestivum L.) is a strategic cereal grain species that is a major food source worldwide. Due to its extensive cultivation area and ability to adapt to diverse environmental conditions, understanding its physiological and biochemical responses to boron toxicity is crucial for stress tolerance. In this direction, our study investigated the effects of boron toxicity on antioxidant enzyme activities and free radicals of wheat variety, Karahan 99. In addition to measurements of growth parameters such as shoot and root length, fresh/dry weight, changes in free radical (OH and H_2O_2) values and antioxidant enzyme activities (SOD, POX, CAT, APOX, and GR) were evaluated. Under boron toxicity conditions, free radical OH and H_2O_2 values increased in the Karahan 99 wheat variety. Furthermore, SOD, POX, APOX, and GR antioxidant enzymes increased, while CAT enzyme decreased. Different wheat genotypes exhibit varying susceptibility to boron toxicity, and these differences can be assessed through antioxidant enzyme activities. It has been observed that the antioxidant system functions more effectively in tolerant genotypes, while it is insufficient in susceptible genotypes. For this purpose, examining the effects of boron toxicity on antioxidant enzyme activities in wheat plants provides a scientific contribution to stress physiology and is crucial for identifying and developing wheat varieties resistant to boron toxicity.

Keywords: Boron Toxicity, Oxidative Stress, Antioxidant Enzymes, Reactive Oxygen Species, Triticum Aestivum L.

RNA Sequencing Reveals Pathways Involved in Boron Toxicity Response in {Triticum urartu}

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Global climate change is currently one of the biggest issues confronting the human population. To meet the expectations of the growing population, it is necessary to introduce novel genotypes that can adapt to the shifting climate without decreasing the quality. Wild progenitors of wheat are effective candidates for enhancing the gene pool of modern wheat. The wild species, Triticum urartu has been discovered as the donor of the A-genome of tetraploid and hexaploid wheat types, and it may be employed as a gene source for wheat breeding programs targeting stress tolerance. Though T. urartu species has been explored for different stress conditions, it has not been well studied for boron toxicity stress. Boron toxicity is one of the significant agricultural problems negatively affecting wheat yield around the world. Here, we report different KEGG (Kyoto Encyclopedia of Genes and Genomes) pathways that were enriched in a boron toxicity-tolerant T. urartu genotype in boron toxic growth environment. KEGG pathway-dependent analysis provides an idea of the biological functions that are influenced by the interaction of the differentially expressed genes (DEGs) under a specific condition. Interestingly, different pathways, including global and overview maps, energy metabolism, translation, and carbohydrate metabolism, showed the highest number of DEGs. The maximum rich ratio in the KEGG pathway enrichment was observed in photosynthesis, oxidative phosphorylation, linoleic acid metabolism, and RNA polymerase. The obtained information can be employed to understand the gene network and its functioning in a boron-tolerant T. urartu genotype that can be further used to develop boron toxicity tolerance in modern wheat cultivars.

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Keywords: Boron Toxicity, Tolerance, Gene Networks, Pathway Analysis, Wheat Wild Relatives

SPECIAL TOPICS IN BORON SCIENCE and TECHNOLOGY

(BOR BİLİMİ ve TEKNOLOJİSİNDE ÖZEL KONULAR)

Araştırmadan Gerçeğe: Bor Aktivasyonlu Çevreci Çimento Üretimi

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[1]*Limak Çimento*
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Türkiye, dünya bor rezervlerinin yaklaşık %73'üne sahip olmasıyla stratejik bir avantaja sahiptir. Bu potansiyelin endüstriyel katma değere dönüştürülmesi amacıyla Limak Çimento ve Eti Maden Genel Müdürlüğü arasında 2021 yılında başlatılan "Yeşil Çimento Dönüşümünde Bor Minerali ile Çimento Üretimi" projesi kapsamında, yeni faz yapısına sahip Boron Activated Cement – Bor Aktivasyonlu Çimento (BAC) geliştirilmiştir. Proje; bor mineralinin özel mineral katkılarla aktive edilmesi, proses parametrelerinin optimize edilmesi ve enerji verimliliğinin artırılması üzerine kurgulanmıştır. Elde edilen sonuçlar, BAC üretiminde fosil yakıt tüketiminde %5, klinker kaynaklı emisyonlarda %3 azalma sağlandığını göstermektedir. Laboratuvar deneylerinden pilot üretime kadar toplam 5 fazda yürütülen çalışma, Limak Çimento Balıkesir Fabrikası'nda sanayi ölçeğinde doğrulanmıştır. Bu bulgu, çimento sektöründe karbon ayak izini azaltmak ve sürdürülebilir üretime geçişte borun stratejik bir rol üstlenebileceğini ortaya koymaktadır. Ayrıca yerli kaynakların kullanımıyla ekonomik sürdürülebilirlik sağlanırken, Türkiye'nin yeşil dönüşüm hedeflerine somut bir katkı sunulmuştur. Bu bildiride, proje sürecinde elde edilen bilimsel bulgular, endüstriyel ölçekleme aşamaları ve kamu-özel sektör iş birliği modelinin sektörel dönüşüme etkileri tartışılmaktadır. Eti Maden Genel Müdürlüğü ve Limak Çimento iş birliğiyle geliştirilen bu yenilikçi yaklaşım, Türkiye'nin bor rezervlerinin katma değerli ürüne dönüşmesinde örnek bir model olarak çimento sektörünün karbonsuzlaşma yolculuğunda yeni bir kilometre taşı olarak değerlendirilmektedir.

Anahtar Kelimeler: Çimento, Kolemanit

Development and Industrial Deployment of an On-line LIBS System for Quantitative Analysis of Boron Ores

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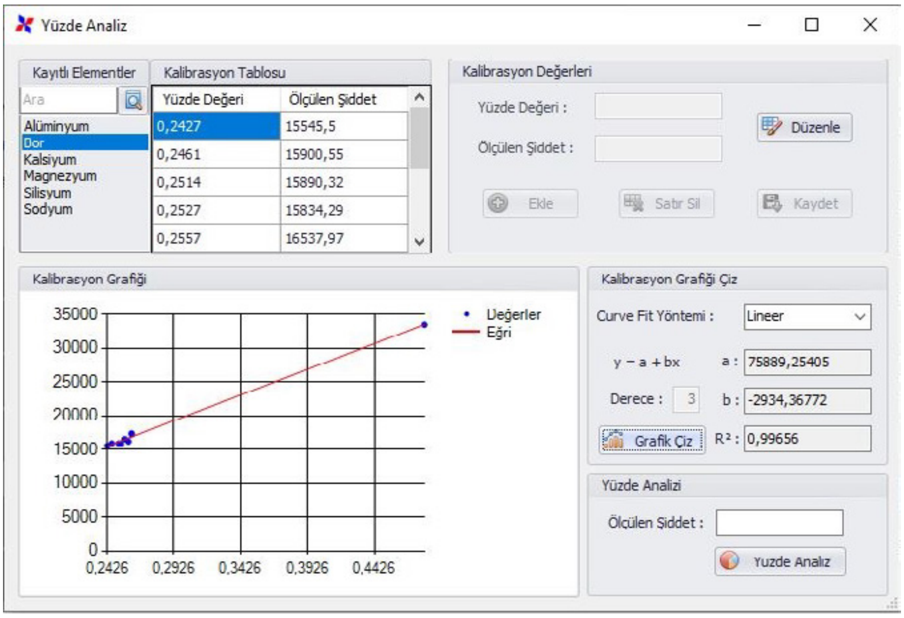
We report the design, development, calibration, and industrial validation of an on-line Laser-Induced Breakdown Spectroscopy (LIBS) system engineered for real-time, quantitative analysis of boron ores on a production line. The goal was to create a robust and high-performance analytical instrument capable of continuous, preparation-free, and multi-elemental monitoring under realistic industrial conditions. The system combines laser–plasma diagnostics, optical design, and chemometric modeling to achieve high sensitivity and accuracy despite the complex matrix of borate ores. The LIBS system integrates a high-repetition-rate Q-switched Nd:YAG laser (1064 nm, 10 Hz, 120 mJ pulses) with a dual-channel high-resolution Czerny–Turner spectrometer covering 200–360 nm. This configuration enables simultaneous detection of boron lines along with Mg, Ca, Si, and Fe emissions that characterize ore composition. A custom-designed optical head, optimized in Zemax OpticStudio, employs a parabolic mirror with a central hole for coaxial focusing and plasma light collection, maximizing photon throughput to a bifurcated fiber bundle connected to the spectrometer. The optical head, protected by stainless-steel housing with sapphire windows and air-purging channels, ensures stability under dust, vibration, and temperature variations typical of ore-handling systems. Quantitative calibration was achieved using pressed boron-ore pellets with B_2O_3 contents between 22 wt% and 30 wt%, analyzed both by LIBS and Optical Emission Spectroscopy (OES). The integrated intensity of the boron line at 249.7 nm, normalized to a reference Mg line, showed excellent linearity ($R^2 > 0.98$). The limit of detection was approximately 0.5 wt% B_2O_3, sufficient for on-line process control. Repeated calibration and cross-validation confirmed the stability and reproducibility of the analytical model, validating its suitability for continuous operation. The system was field-tested at the Eti Maden Kırka Boron Plant, one of the world's largest boron producers. Installed directly above a conveyor belt, the LIBS unit operated continuously, capturing spectra at 10 Hz and processing them in real time using a custom data-acquisition platform that performed background correction, peak fitting, and intensity normalization. Comparison with OES reference data showed average deviations within ±5%, confirming quantitative accuracy. The system maintained optical alignment and signal integrity despite fluctuating ore size, surface roughness, and humidity, proving its mechanical and optical robustness for long-term industrial use. Compared with conventional laboratory-based methods such as ICP-OES or XRF, the LIBS system offers several advantages: it eliminates sample preparation, reduces analysis time from hours to seconds, and provides instant compositional feedback for process optimization. The approach allows operators to adjust feed ratios or furnace parameters immediately, improving efficiency and reducing costs. Furthermore, its reagent-free nature minimizes environmental impact and operational expenditure. The modular design also allows integration into ore sorting, blending, and quality-control stations within modern mining plants. This study constitutes the first comprehensive demonstration of an on-line LIBS system for boron ores operating under genuine production conditions. Previous reports have been limited to laboratory setups or simulated conveyors. By contrast, the present work validates LIBS as a practical, industry-ready tool for continuous compositional monitoring. Its successful deployment marks a significant milestone toward Industry 4.0-oriented smart mining, where automated sensing and closed-loop control systems enhance productivity and sustainability. Future developments will focus on improving environmental mitigation and analytical robustness. Implementation of advanced air-knife systems and adaptive focusing mechanisms can minimize dust and surface effects. Moreover, chemometric and machine-learning approaches such as Principal Component Analysis (PCA) and Partial Least Squares Regression (PLSR) will be incorporated to correct matrix influences and enable simultaneous multi-element quantification with higher accuracy. Extending the method to include light elements such as lithium, sodium, and magnesium is also envisioned, expanding the technology's utility for strategic minerals used in energy storage and high-tech industries. In conclusion, the developed on-

line LIBS system provides a fast, quantitative, and preparation-free solution for monitoring boron content in ore streams. The demonstrated agreement with laboratory OES, combined with stable operation under harsh conditions, proves its readiness for industrial deployment and commercialization. The system's capability for real-time decision support opens the way to intelligent process control and adaptive mining strategies. This achievement bridges the gap between laboratory spectroscopy and field application, establishing LIBS as a cornerstone technology for next-generation mineral analysis and smart mining environments.

Keywords: LIBS, PCA Principle Component Analysis, Elemental Spektroskopi, Bor Cevheri

LIBS Systems



Yüzde Değeri	Ölçülen Şiddet
0,2427	15545,5
0,2461	15900,55
0,2514	15890,32
0,2527	15834,29
0,2557	16537,97

Curve Fit Yöntemi : Lineer
y − a + bx
a : 75889,25405
Derece : 3
b : -2934,36772
R² : 0,99656

Boron Calibration Table and Graph

Seri No: 1509008U2 1509009U2

Geçen Süre: dk 9 9

Ölçüm Sayısı: 155 161

Dedektör Sıcaklığı: °C 8 8

Çalış Kontrolü
○ Off
● Adj
○ Max

Tincal Spectrum of Tuve

Tarih : 30.10.2019
Saat : 14:04:40

Spektrometre
Bağlantı Durumu : Bağlandı
Dedektör Sıcaklığı [C] : 8

Lazer
Bağlantı Durumu : Bağlandı
Lazer Su Sıcaklığı [C] : 29.3

25,38 %	7,84 %
Bor	Kalsiyum
0,45 %	5,65 %
Alüminyum	Silisyum

7,89 %	Sodyum
8,3 %	Magnezyum

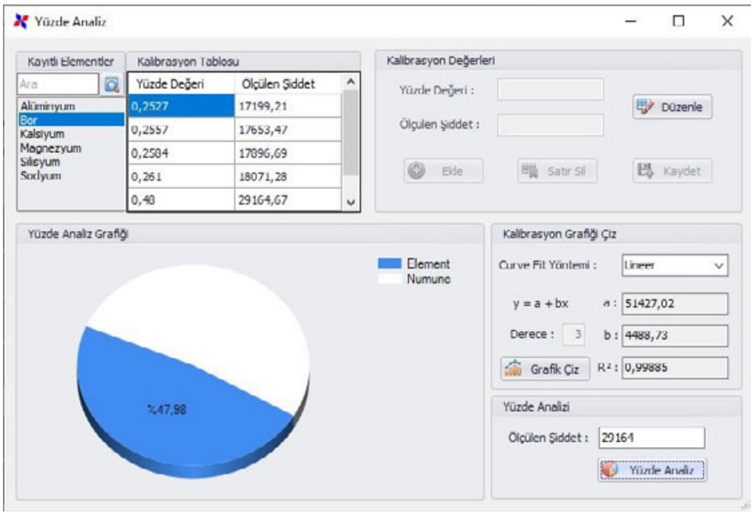
Ortalama Yüzde Değerleri

Bor :	25,88	%
Alüminyum :	0,39	%
Kalsiyum :	6,14	%
Silisyum :	6,64	%
Sodyum :	9,85	%
Magnezyum :	8,38	%

Ortalama Sayısı : 100 Sayaç: 84

Elementler
Bor
Magnezyum
Silisyum
Kalsiyum
Alüminyum
Sodyum
Lityum
Oksijen

Tincal Measurement Interface of the Tube



Kayıtlı Elementler
Alüminyum
Bor
Kalsiyum
Magnezyum
Silisyum
Sodyum

Kalibrasyon Tablosu

Yüzde Değeri	Ölçülen Şiddet
0,2527	17199,21
0,2557	17653,47
0,2584	17896,69
0,261	18071,28
0,48	29164,67

Kalibrasyon Değerleri
Yüzde Değeri :
Ölçülen Şiddet :

Kalibrasyon Grafiği Çiz
Curve Fit Yöntemi : Lineer
y = a + bx a : 51427,02
Derece : 3 b : 4488,73
R² : 0,99885

Yüzde Analizi
Ölçülen Şiddet : 29164

E48 Percentage Analysis Result

Fracture Toughness of Epoxy Composites Reinforced with Waste Tea Plant Powder and Boron Nitride Nanoparticles

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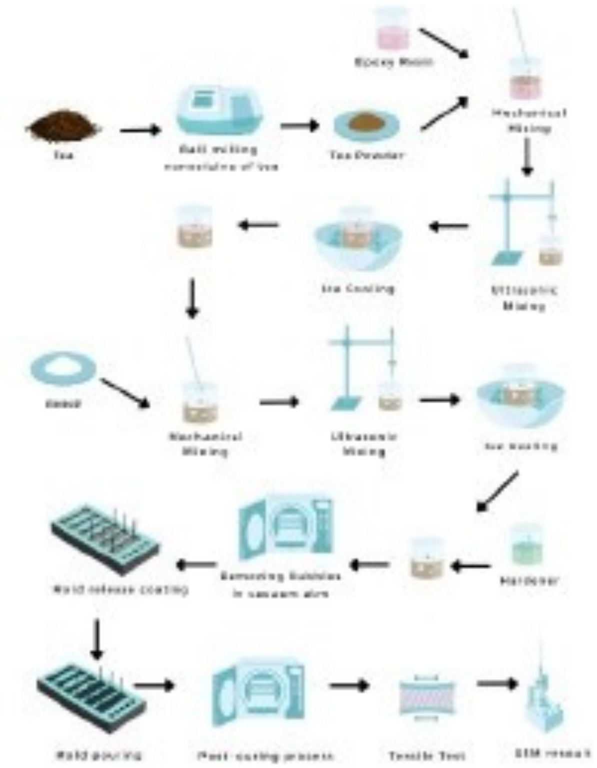
Epoxy resins are a type of thermosetting polymer produced from monomers containing at least two epoxy groups. Advances in material science necessitate the continuous improvement of the performance of polymeric materials used in engineering applications. Epoxy resins exhibit resistance to scratching, impact, and abrasion by providing high mechanical strength after curing. These superior mechanical properties are the main reasons they are preferred in the production of high-performance composite products. Their high corrosion resistance and durability when exposed to chemical agents for long periods provide a critical advantage in industrial applications. Thanks to their excellent adhesion properties, strong bonding to various surfaces is possible. Although they have a wide range of applications due to their superior mechanical, chemical, and electrical properties, they also have some limitations. One of the most significant limitations is their brittleness and low fracture toughness. This lack of toughness is a fundamental issue that prevents epoxies from reaching their full potential in a wide range of applications. This situation necessitates a detailed understanding of the deformation and fracture mechanisms in the materials and the mitigation of these weaknesses. Hybrid studies are conducted to improve the mechanical properties of epoxy resins. Hybrid composites aim to overcome the limitations of a single reinforcement material and improve overall performance through synergistic effects by combining different reinforcement materials (e.g., natural fibers and nanoparticles). This study investigated a hybrid approach that combines waste tea plant powder and boron nitride nanoparticles, which offer the potential for sustainability and performance enhancement. For this purpose, the effects of different ratios of tea waste powder and boron nitride nanoparticles (BNNP) on the mechanical properties of epoxy resin were investigated. First, pure epoxy resin was tested using standard dogbone and fracture test specimens to establish a reference for mechanical strength. Dried tea branches were first broken into fine pieces using a mixer, and then processed in a ball mill to reach micro-sizes, resulting in a powder. The tea powder was added to the epoxy matrix at different weight percentages (1% and 2.5%). Subsequently, each tea-reinforced specimen was modified with the addition of 0.5% BNNP to create hybrid nanocomposites. Tensile and fracture tests were performed on all specimens according to ASTM standards. The morphology and distribution of the nanoparticles within the polymer matrix were examined using a Scanning Electron Microscope (SEM).

Keywords: Boron Nitride, Composite Materials, Epoxy Resin, Fracture Toughness, Tea Waste


Epoxy Resin
Tea
Ball milling
Tea Powder
Mechanical Mixing
Ice Cooling
Ultrasonic Mixing
Mechanical Mixing
Ultrasonic Mixing
Hardener
Removing Bubbles in vacuum oven
Mold release coating
Mold pouring
Post-curing process
Tensile Test
SEM result

Workflow

Bor Konsantratör Tesisi Katı Artıklarından Sıvı Ekstraksiyon Yöntemi ile Lityum Kazanımının Araştırılması

Ceren Uygun[1], Mehmet Tanrıverdi[1]

[1]*Dokuz Eylül Üniversitesi*

Lityum (Li), yeni enerji endüstrisinde stratejik bir metal olarak görülmektedir. Lityumun en yaygın kullanım alanı, küresel talebin yaklaşık %60'ını oluşturan lityum iyon pillerdir ve bu talebin her yıl %21 oranında artmaya devam edeceği öngörülmektedir. Lityum içeren düşük tenörlü killer, dünya genelinde umut verici alternatif lityum kaynakları olarak nitelendirilmektedir. Bu kil kaynaklarının heterojen bileşimi ve karmaşık yapısı, işlenmesini teknik olarak zorlaştırmaktadır. Ancak elektrikli araç pazarının hızla büyümesi ve enerji depolama ihtiyacının artması, sürdürülebilir ve verimli lityum çıkarma teknolojilerini geliştirmeye, killerden lityum üretimindeki tekniksel problemleri çözümlemeye sevk etmektedir. Türkiye bor yataklarındaki killer genel olarak %0,1-0,25 lityum içermektedir. Bu yataklarda yaygın olarak hektorit tipi smektitler bulunmaktadır. Yapılan çalışmada, Bigadiç bor konsantratör tesisi atık barajından alınan kil numunelerinde 1823 ppm Li varlığı tespit edilmiştir. Bu numunelerden sıvı ekstraksiyon yöntemi ile lityum kazanım olanakları araştırılmıştır. Deneyler atmosferik liç koşullarında yürütülmüş ve liç öncesi kavurmanın, çözelti cinsinin ve konsantrasyonunun, lityum verimi üzerindeki etkisi incelenmiştir. Doğrudan liç yönteminde çözelti cinsi incelenmiş olup, aynı molarite kullanılarak yapılan deneylerde çözelti cinsinin liç verimine etkisi $H_2SO_4 > HCl > H_2O$ şeklinde olmuştur. Su liçinde verim %1' in altında iken, HCl liçinde %78 Li verimi, H_2SO_4 liçinde %93 lik bir verim elde edilmiştir. Kavurma cinsinin su liçine etkisi incelenmiş olup, 900 °C'de yapılan kavurma şartlarında en yüksek verimin %28 jips katkılı olan numunede %51 Li verimine ulaştığı gözlemlenmiştir.

Anahtar Kelimeler: Bor Artığı, Kil Tipi Lityum Kaynakları, Lityum Ekstraksiyonu, Asit Liçi, Kavurma Sonrası Su Liçi

Nükleer Enerji Santrallarında Borun Stratejik Kullanımı ve Elektriksel Uygulamaları: Kontrol Çubukları ve Atık Yönetimi Perspektifi

Mehmet Bulut[1,2]

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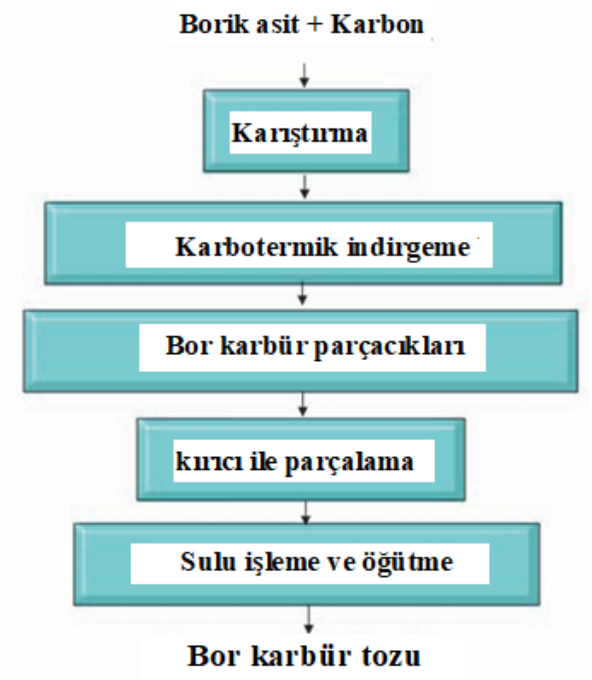
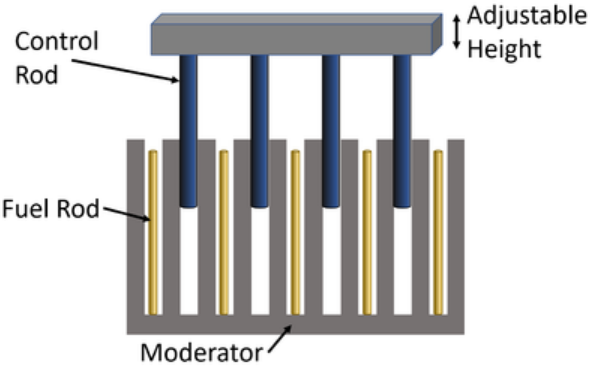
[2]*Elektrik Üretim A.Ş Genel Müdürlüğü*

Nükleer enerji santrallerinde bor elementinin stratejik kullanımı ve bu kullanımların elektrik üretimindeki yeri önemini gün geçtikçe artırmaktadır. Borun nükleer enerjide yüksek nötron soğurma gibi eşsiz özellikleri, onu reaktör güvenliği ve verimliliği için vazgeçilmez bir malzeme haline getirmektedir. Bu makalede, borun nükleer santrallerdeki stratejik rolünü, kontrol çubukları ve nükleer atık yönetimindeki kritik uygulamalarını ele alınmıştır. Özellikle borun nötron emici özelliği ile kontrol çubukları teknolojisindeki rolü ve nükleer atık yönetiminde borun katkıları perspektifinden ele alınmakta ve borun kullanımı ile reaktör güvenliği, verimliliği ve çevresel etkiler değerlendirilmektedir. Çalışmada, borun nükleer santral performansını ve sürdürülebilirliğini optimize etmedeki öneminin vurgulanması, nükleer yakıt döngüsünde gelişmiş bor içeren malzemeler ve geri dönüşüm konusunda gelecekteki araştırma konularına işaret edilmesi amaçlanmıştır. Nükleer enerji sanayii, reaktör tesislerinin güvenliğini, güvenilirliğini ve uzun vadeli performansını sağlamak için büyük ölçüde malzeme testlerine başvurmaktadır. Nükleer reaktörlerdeki malzemeler, yüksek sıcaklıklar, yoğun radyasyon, aşındırıcı ortamlar ve önemli stres yükleri dahil olmak üzere aşırı koşullarla karşı karşıyadır ve bu da zamanla bozulmaya yol açabilmektedir. Bu nedenlerden dolayı, nükleer enerji santrallarının malzeme tedarikçileri, zorlu malzeme spesifikasyonlarını ve niteliklerini karşılamanın yanı sıra bozulmanın izlenmesine, tesis ömrünün uzatılmasına ve gelişmiş reaktör teknolojilerinin geliştirilmesine yardımcı olmak için kapsamlı testler yapmaktadır. Nükleer enerji üretiminde yer alan tüm malzemeler önem arz ederken, bazı malzemeler, özellikle bor karbür (B_4C) gibi bor içeren malzemeler, borun nötronları absorbe etme ve doğru konsantrasyonlarda nükleer fisyon zincir reaksiyonlarını kontrol etme ve hatta durdurma konusundaki benzersiz yeteneği nedeniyle özellikle kritik öneme sahiptirler. Bor, olağanüstü nötron soğurma özellikleri ve aşırı koşullar altında kimyasal kararlılığı nedeniyle uzun zamandır nükleer teknolojide kritik bir element olarak kabul edilmektedir. Radyasyon emici etkisi nedeniyle bor, nükleer reaktörlerin kalkanlama, kontrol ve güvenlik sistemlerinde yaygın olarak kullanılmaktadır. Bor izotopları, özellikle bor-10, bilinen en yüksek termal nötron kesitlerinden birine sahiptir ve bu da onu reaktör kontrolü, güvenliği ve atık yönetimi uygulamaları için vazgeçilmez kılmaktadır. Bor, nükleer reaktör çekirdeğindeki kontrol çubuklarının yapımında kullanılan birincil nötron emicidir. Borun nükleer reaktörlerde kullanımı çeşitli kritik uygulamalarla öne çıkmaktadır. En önemli kullanım şekli, bor karbür (B_4C) bileşiğinin kontrol çubukları içinde nötron emici olarak işlev görmesidir. Bor karbür, yüksek nötron yakalama kesiti, termal stabilite ve mekanik dayanıklılığı ile reaktörde fisyon reaksiyonlarının kontrollü ve güvenli yürütülmesini sağlamaktadır. Borat iyonlarını sıcaklığa bağlı bir işlemle geri dönüşümlü olarak depolayan iyon değiştiriciler, nükleer santrallerin reaktivitesini kontrol etmek için bir bor kontrol sistemi sağlamak üzere buharlaştırıcı borik asit geri kazanım cihazıyla birleştirilir. Yük takip işlemleri için bir nükleer reaktöre değişen miktarlarda borik asit sağlamak üzere birden fazla iyon değiştirici sırayla çalıştırılır. Buharlaştırıcı borik asit geri kazanım cihazı, nükleer reaktör içindeki bor konsantrasyonunda büyük değişiklikler yapmak için kullanılır. Nükleer endüstride, reaktör soğutma sıvısında çözünmüş borik asit, çözünür bir reaktivite kontrol maddesi olarak kullanılır. Nükleer santrallerde reaktivite kontrolü de nötron emici kontrol çubukları tarafından sağlanır. Bu nötron emme görevi, kontrol çubukları ve çözünür borik asit arasında en ekonomik ayrımı sağlayacak şekilde dağıtılır. Tipik olarak, kontrol çubukları hızlı reaktivite değişimleriyle ilgilenirken, borik asit, reaktör soğutma sıvısındaki borik asit konsantrasyonlarını değiştirerek daha yavaş ve uzun vadeli reaktivite kontrolünü sağlar. PWR reaktör tesislerinde, çözünmüş borik asit, borik asit molekülünde bulunan bor-10 izotopunun yüksek termal nötron yakalama kapasitesi nedeniyle çözünür zehir veya kimyasal şim olarak adlandırılır. Borun nükleer reaktörlerde kullanımı 1950'lerden itibaren reaktör kontrol ve güvenliğinde önem kazanmıştır. Borun nötron emme kapasitesi nedeniyle reaktör kontrol çubuklarında yaygın kullanımı, reaktörlerin stabil ve güvenli çalışmasına katkı sağlamıştır. Kontrol amaçlı kullanılan bor bileşikleri teknoloji gelişimiyle çeşitlenmiştir. İlk olarak 1950'lerden itibaren reaktör kontrol çubukları, moderatör kimyasalları ve atık yönetiminde kullanımı yaygınlaşmıştır. Bor karbürün (B_4C) dayanıklılığı ve mekanik özellikleri ile birlikte borik asidin basınçlı su reaktörlerindeki (PWR) rolü, borun nükleer teknolojide stratejik bir unsur olduğunu göstermektedir. Borun nükleer yakıt döngüsünde dikkat çekici rolü, kontrol, çevresel koruma, atık yönetimi ve elektriksel uygulamaları kapsar. Türkiye'nin dünya bor rezervlerinin yaklaşık %73'üne sahip olması, bu teknolojide ulusal üretim ve gelişim için büyük fırsatlar yaratmaktadır. Bor, nükleer enerjide nötron soğurucu malzeme olarak yaygın olarak kullanılır ve bu sayede nötron çoğaltma faktörünü değiştirerek bir nükleer reaktörün kontrol edilmesi mümkün hale gelmektedir. Saeed, çalışmasında, kontrol ve koruma sisteminin (CPS) soğurucu çubuklarının (AR) bor karbüründeki ve VVER reaktörünün soğutucu akışkanındaki borik asit çözeltisindeki ^{10}B izotop içeriği değiştirildiğinde VVER tipi reaktör çekirdeğinin nötron-fiziksel parametrelerindeki değişiklikler ele alınmış ve ayrıca kontrol çubuklarındaki (CR) ^{10}B izotopunun zenginleştirilmesinin artırılmasının pratikliği analiz edilmiştir. Hesaplamalar için VVER-1200 yakıt tertibatı (FA) modeli kullanılmıştır. Hesaplamalar sonucunda, yüksek oranda zenginleştirilmiş borun CPS ve CR sayısını azalttığı görülmüştür. Buradan, AR'de zenginleştirilmiş bor karbür kullanımının, çekirdeğin 1/3'ünden fazlasının MOX yakıtlı yakıt düzenekleriyle doldurulmasını mümkün kıldığı ve ayrıca 235U izotopunda yakıt zenginleştirmesini %6 ve üzerine çıkarabildiği, ancak bunun normal CR'de mümkün olmadığı sonucuna varılabileceği belirtilmiştir. Borun nükleer santrallerdeki stratejik önemi çok yönlüdür ve giderek artmaktadır. Borun, reaktör kontrolündeki kritik güvenlik fonksiyonlarından sürdürülebilir atık yönetimi ve elektrik sistemi güvenilirliğine önemli katkılarına kadar uzanan bir yelpazede yer almaktadır. Bu çalışmada, borun nükleer tesislerideki tüm uygulamarının yanısıra kontrol çubukları ve atık yönetimine odaklanarak nükleer santrallerde borun stratejik önemini ele almakta ve bor kullanımıyla ilgili elektrik sistemi etkilerini incelemektedir.

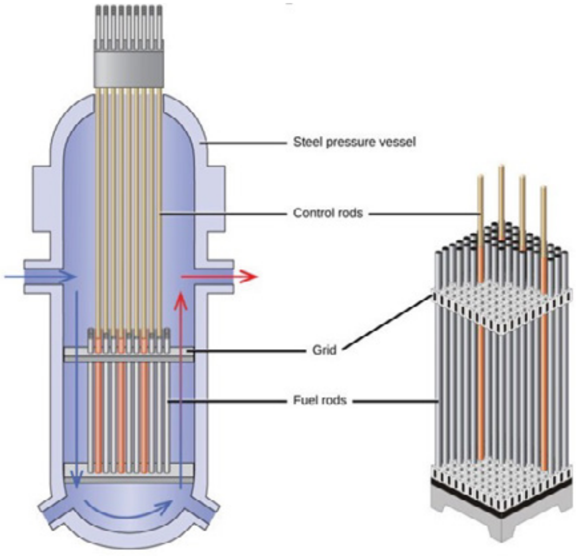
Anahtar Kelimeler: Nükleer Enerji, Bor Alaşımları, Yakıt Çubukları, Bor Temelli Malzemeler, Atık Yönetimi



Bor Karbür Tozu Üretim Süreci



Kontrol Çubukları ile Nükleer Yakıt Çubuklarının Konumu



Reaktör Yapısı İçinde Kontrol Çubukları

Bor Bileşiklerinin Özellikleri

Bor Bileşiği	Nötron Yakalama Kesiti (barn)	Kullanım Alanı
Bor karbür (B_4C)	~3840	En yaygın; kontrol çubuklarında kullanılır
Bor nitrür (BN)	800–1000	Alternatif; özel durumlarda tercih edilir
Bor oksit (B_2O_3)	600–700	Nadiren; özel uygulamalarda kullanılır

Rafine ve Atık Bor Minerali İçeren Alkali Aktive Bağlayıcı Sistemlerin Geliştirilmesi: Yaşam Döngüsü Değerlendirmesi Temelli Bir Yaklaşım

Ezgi Örklemez[1], Serhan İlkentapar[1], Uğur Durak[1], Burak Uzal[2], Okan Karahan[1], Cengiz Duran Atiş[1]

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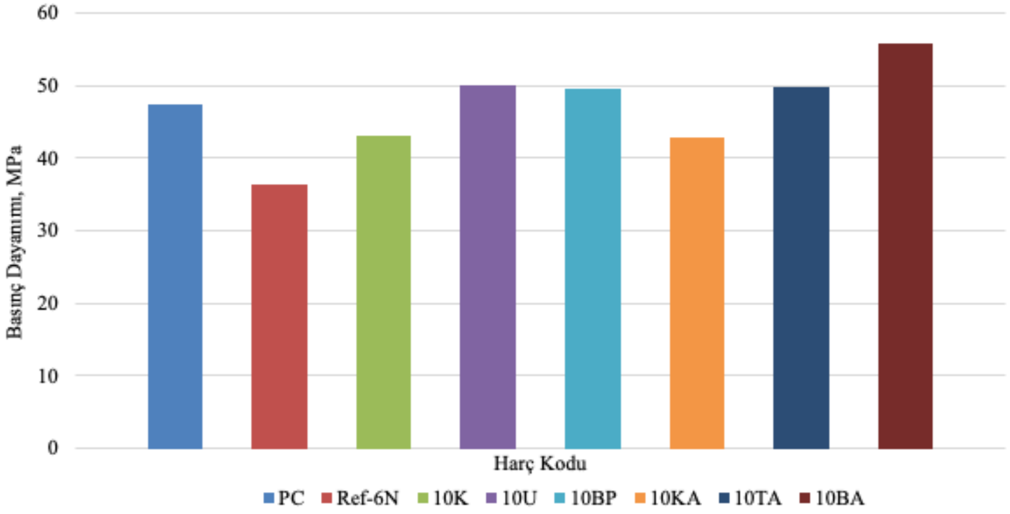
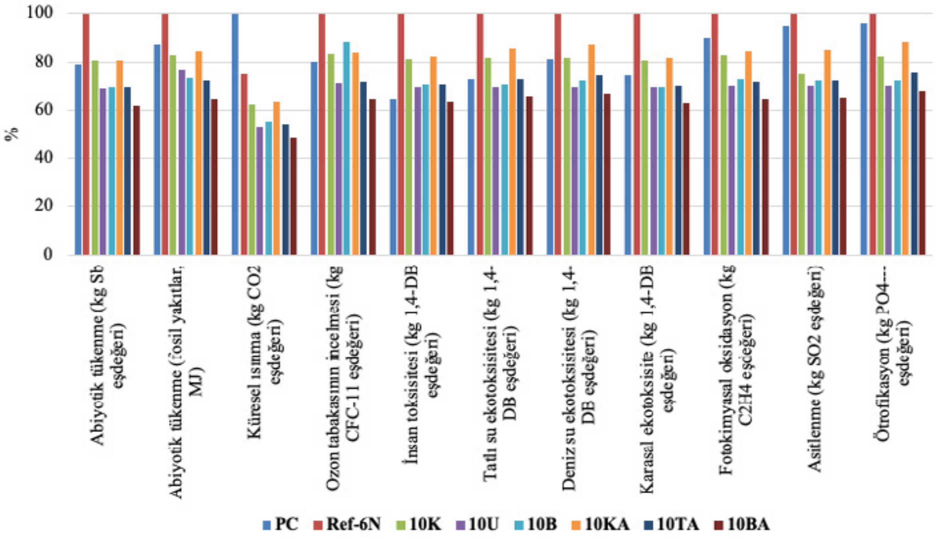
Son yıllarda artan çevresel kaygılar, çimento üretiminin yüksek enerji tüketimi ve CO_2 salımı nedeniyle inşaat sektöründe sürdürülebilir alternatif malzeme arayışlarını hızlandırmıştır. Türkiye, Paris İklim Anlaşması kapsamında 2050 yılına kadar net sıfır emisyon hedefini benimsemiş ve 2030 yılına kadar sera gazı emisyonlarını %45 azaltmayı planlamıştır. 2050 Net Sıfır Karbon Yol Haritası'na göre, yüksek enerji tüketimine sahip çimento endüstrisinin 2050 itibarıyla endüstriyel CO_2 salımlarını 50 milyon ton seviyesine düşürmesi öngörülmektedir. Bu hedeflere ulaşmak, yenilikçi, düşük karbonlu ve çevre dostu bağlayıcı sistemlerin geliştirilmesini gerekli kılmaktadır. Alkali aktive bağlayıcı sistemler çimentolu sistemlere alternatif malzemelerdir. Ancak bu sistemlerdeki çevresel yükün önemli bir kısmı alkali aktivatörlerden kaynaklanmaktadır. Bu çalışmada, yüksek fırın cürufu esaslı ve %6 oranında Na^+ içeren alkali-aktive harçlarda, geleneksel aktivatör olarak kullanılan sodyum metasilikatın (Na_2SiO_3) %10 oranında rafine (kolemanit, üleksit, bor pentahidrat) veya atık (kolemanit atığı, tinkal atığı, borojips atığı) bor mineralleriyle ikame edilmiştir. Bor minerallerinin sodyum metasilikata alternatif olarak kullanılabilirliğini mekanik performans ve çevresel etkiler açısından değerlendirilmiştir. Alkali aktive harç deneyleri 23±2°C sıcaklık ve %60±5 bağıl nem koşullarında 28 gün boyunca ortam kürüne tabi tutulan numuneler üzerinde gerçekleştirilmiştir. Basınç dayanımı sonuçlarına göre, Portland çimentolu harç (PC) 47,5 MPa ve cüruf esaslı referans karışım (Ref-6N) 36,27 MPa dayanım değerine ulaşmıştır. %10 oranında bor ikamesi yapılan harçların dayanımları, PC harcıyla karşılaştırılabilir düzeyde veya daha yüksek bulunmuştur. (%10 üleksit 50,09 MPa, %10 bor pentahidrat 49,63 MPa ve %10 tinkal atığı 49,88 MPa). En yüksek basınç dayanımı ise %10 borojips atığı içeren harçta 55,90 MPa olarak elde edilmiştir. Yaşam döngüsü değerlendirmesi, beşikten kapıya yaklaşımıyla CML-IA yöntemi kullanılarak 1 m^3/MPa fonksiyonel birimi üzerinden SimaPro Expert v9.5 yazılımı ile gerçekleştirilmiştir. Sonuçlar, bor ikameli harçların tüm çevresel etki kategorilerinde PC karışıma kıyasla daha düşük değerlere sahip olduğunu ortaya koymuştur. Küresel ısınma potansiyeli (GWP), PC harcında 17,8 kg CO_2-eq iken, %10 borojips atığı içeren karışımda 8,64 kg CO_2-eq olarak belirlenmiş ve bu durum yaklaşık %51 oranında emisyon azaltımı sağlamıştır. Benzer şekilde borojips atığı ikamesi, fosil yakıt tüketimi (AD-FF) PC'de 148 MJ'den 110 MJ'e düşerek yaklaşık %25 enerji iyileşmesi göstermiştir. Genel olarak, borojips atığı içeren harç, CO_2 emisyonu, enerji tüketimi, toksisite ve ekotoksisite kategorilerinde en düşük çevresel etkilere sahip sistem olarak öne çıkmıştır. Bulgular, bor bileşiklerinin yalnızca mekanik performansı artırmakla kalmayıp, aynı zamanda çevresel etkileri azaltıcı bir etkiye sahip olduğunu göstermiştir. Ayrıca, alkali aktive sistemlerde çevresel yükün temel olarak aktivatörden, çimentolu harçlarda ise çimento üretim sürecinden kaynaklandığı sonucuna varılmıştır.

Anahtar Kelimeler: Alkali Aktive Harçlar, Atık Bor Mineralleri, Rafine Bor Mineralleri, Yaşam Döngüsü Değerlendirmesi, Yüksek Fırın Cürufu



Harç Karışımlarının Basınç Dayanımı Değerleri (MPa)



Harç Karışımlarının Çevresel Etkilerinin Karşılaştırılması

Thermal Management Enhancement of Type-IV Hydrogen Storage Tanks Using h-BN Reinforced Composites: A COMSOL Multiphysics Study

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Type-IV hydrogen storage tanks are predominantly used in fuel-cell electric vehicles (FCEVs) due to their high strength-to-weight ratio, corrosion resistance, and superior fatigue performance. However, the rapid filling of hydrogen gas generates a significant temperature rise within the polymer liner and composite overwrap, potentially undermining structural integrity, accelerating material degradation, and compromising overall system safety. In this study, a simulation-driven thermal management approach was adopted to investigate the influence of hexagonal boron nitride (h-BN) reinforcement on the transient thermal response of a Type-IV hydrogen storage vessel. The computational analyses were conducted using the COMSOL Multiphysics® software, specifically employing the Heat Transfer in Solids and Laminar Flow modules to model the coupled thermo-fluid behavior during high-pressure hydrogen charging. A composite overwrap consisting of carbon fiber/epoxy reinforced with 3 wt.% h-BN and a polyamide liner containing 10 wt.% h-BN was evaluated under rapid-filling boundary conditions. The temperature evolution, spatial heat distribution, and peak temperature localization were systematically compared against baseline, non-reinforced materials. Simulation results reveal that h-BN-modified materials exhibit markedly enhanced thermal conductivity, enabling a more homogeneous temperature distribution and effective mitigation of hot-spot formation during rapid hydrogen loading. This improvement in heat dissipation capacity demonstrates the crucial role of h-BN as a thermally conductive additive, significantly improving thermal management efficiency and expanding the safety margins of composite hydrogen storage systems.

Keywords: Thermal Management, Type-IV Hydrogen Tank, Hexagonal Boron Nitride, Heat Transfer Analysis

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