Protective and High-temperature Coatings
Room Town & Country C - Session MA4-1-MoA

Boron-containing Coatings I

Moderator: Martin Dahlqvist, Linköping University, Sweden

1:40pm **MA4-1-MoA-1 Focused on Synthesis; Innovative Material Solutions: Bridging Research and Application***, **Árni Sigurður Ingason [arni@greinresearch.com]**,* Grein Research ehf., Iceland **INVITED**

Grein Research is a contract research company specializing in materials development using PVD, especially focused on magnetron sputtering. Over the years the company has participated in projects involving the synthesis of various borides and in this talk, some of them will be presented. The talk will give some highlights of these research efforts, mostly focused on the synthesis and Grein's role as a partner in these projects.

2:20pm **MA4-1-MoA-3 Advanced Multicomponent Layers for High-Performance Tool Steels***, **Jorge Luis Rosales-Lopez [jrosales96@hotmail.com]**,* 16 de septembre de 1823 #96, Mexico*; Mauricio Olivares-Luna, Karen Daniela Chaparro-Perez, Luis Eduardo Castillo-Vela, Iván Enrique Campos-Silva,* Instituto Politécnico Nacional, Mexico

This study explores the application of PDCPB on AISI H13 steel (B), focusing on a novel powder mixture (GIS-T) and the influence of a double-tempering post-treatment (BR). The findings reveal paradigm-shifting insights into surface engineering:

1. The unprecedented capability of achieving a single-step borocarburizing treatment, forming a layered microstructure with a boride layer and an underlying carburized zone.
1. The preferential growth of Fe_2B, which partially suppresses the formation of the brittle FeB phase.

Microstructural and chemical analyses were conducted using scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS), and X-ray diffraction (XRD). The B condition exhibited a boride layer, diffusion zone, and carburized zone on the substrate. In contrast, the BR condition showed a thinner boride layer and diffusion zone dissolution.

According to mechanical evaluation (scratch test), the BR condition exhibited a 12% higher load-bearing capacity than the B condition before delamination of the boride layer and demonstrated nearly twice the adhesion strength of TiN coatings deposited via PVD. This enhanced practical adhesion can be attributed to a homogeneous redistribution of C and Si during double-tempering, leading to a gradual transition in mechanical properties.

These findings highlight the PDCPB process with the GIS-T powder mixture as a promising alternative for industrial applications demanding high wear resistance and strong layer adhesion.

2:40pm **MA4-1-MoA-4 Charge Trapping Behavior in BN Films Fabricated by a Reactive Plasma-Assisted Coating Technique and Their Design Strategies***, **Koji Eriguchi [eriguchi.koji.8e@kyoto-u.ac.jp]**,* Kyoto University, Japan **INVITED**

Boron nitride (BN) possesses highly desirable properties for a wide variety of industrial applications [1]. Its properties strongly depend on its microscopic structure: sp^2-bonded hexagonal (h-BN) and sp^3-bonded cubic (c-BN). For example, h-BN films are expected to be superior dielectric materials for electronic devices owing to their high dielectric breakdown field [2], whereas c-BN films have attracted considerable attention because of their high hardness [3]. Historically, using plasma-based technologies, these microscopic structures have been controlled predominantly by the energy of incident ions and the fluxes of B and other species [4]. However, crucial issues remain to be solved—namely, the degradation of dielectric breakdown lifetime for h-BN films and delamination due to residual stress in c-BN films. A fundamental understanding of the various degradation mechanisms in BN films is therefore required.

In this study, we formed BN films and their stacked structures with various bonding phases on Si substrates using a reactive plasma-assisted coating (RePAC) method [5]. After confirming their bonding networks by Fourier-transform infrared spectroscopy and optical properties by spectroscopic ellipsometry [6], we investigated the dielectric degradation of h-BN and the delamination behavior of c-BN in terms of charge trapping dynamics using Al/BN/Si devices. Characteristic charge trapping behaviors during time-dependent dielectric breakdown measurements were enhanced by the bombardment of higher-energy ions and the incorporation of impurities during h-BN film formation [7]. The presence of trapped charges was identified at the c-BN/Si interface and even within stacked BN films (h-/c-BN or c-/h-BN) [8]. In addition, film delamination was found to occur preferentially at the stacked c-/h-BN interface. Moreover, we found that time-dependent film delamination was closely correlated with the trapped charge density. These findings indicate that controlling charge trapping behaviors is key to improving the properties of BN films for various industrial applications.

This work was supported by JSPS KAKENHI (23H01728) and O.S.G. Foundation.

[1] I. Levchenko et al., Nat. Commun. **9**, 879 (2018).

[2] Y. Hattori et al., Phys. Rev. B **97**, 045425 (2018).

[3] V. L. Solozhenko et al., J. Appl. Phys. **126**, 075107 (2019).

[4] C. B. Samantaray and R. N. Singh: Int. Mater. Rev. **50**, 313 (2005).

[5] T. Matsuda et al., Jpn. J. Appl. Phys. **61**, SI1014 (2022).

[6] T. Hamano et al., Appl. Phys. Lett. **120**, 031904 (2022).

[7] Y. Asamoto et al., J. Appl. Phys. **137**, 105301 (2025).

[8] N. Oguchi et al., to be presented at the 2025 Dry Process Symposium.

3:20pm **MA4-1-MoA-6 Development of TiB_2:h-BN:a-C Based Nanocomposite Coatings with Enhanced Wear and Corrosion Resistance for Turbojet and Gas Turbine Components***, **Gokhan Gulten [gokhangulten@atauni.edu.tr]**, Banu Yaylali, Mustafa Yesilyurt, Ali Emre, Yasar Totik,* Atatürk University, Turkey*; Justyna Kulczyk-Malecka, Peter Kelly,* Manchester Metropolitan University, UK*; Ihsan Efeoglu,* Atatürk University, Turkey

Turbojet and gas turbine engines operate under severe thermo-mechanical and chemically aggressive conditions where simultaneous control of friction, wear, and corrosion is essential. This study reports the design and synthesis of a solid-lubricating nanocomposite architecture based on TiB_2:h-BN:a-C deposited by closed-field unbalanced magnetron sputtering (CFUBMS) driven by a hybrid HiPIMS + pulsed-DC power setup. The coating concept employs the synergistic combination of hard TiB_2 domains (load-bearing), hexagonal BN (lamellar solid lubricant, thermal stability), and amorphous carbon (low shear, transfer-film formation). To promote enhanced substrate adhesion and gradient stress accommodation on aerospace alloys (Inconel 718 and Ti-6Al-4V), a thin Cr adhesion layer and a CrN transition layer are incorporated. A Taguchi L9 experimental design is employed to map the influence of TiB_2 target voltage, N_2 flow, duty cycle, and working pressure on structure–property relationships. Comprehensive characterization includes XRD, Raman and XPS, SEM cross-sections, nanoindentation, scratch testing, and pin-on-disk tribometry at room and elevated temperatures. Electrochemical performance is assessed by potentiodynamic polarization and EIS to quantify corrosion resistance. The hybrid power delivery enhances ionization and adatom mobility, producing dense microstructures and superior adhesion. Process–structure–property correlations reveal reduced friction, improved wear resistance, and enhanced corrosion protection, establishing TiB_2:h-BN:a-C coatings as promising candidates for extending component life and reducing maintenance in advanced propulsion systems.

4:00pm **MA4-1-MoA-8 Energy Efficiency in Pulsed-DC Powder-Pack Boriding: A Sustainable Approach to Surface Hardening of Metallic Materials***, **Ivan E Campos Silva [icampos@ipn.mx]**,* Instituto Politecnico Nacional, Mexico **INVITED**

Boriding has emerged as an efficient thermochemical treatment to enhance the wear and corrosion resistance of metallic materials. The resulting boride layer, characterized by its exceptional hardness and outstanding thermal and chemical stability, outperforms nitrided, carburized, and PVD-coated surfaces. However, conventional powder-pack boriding still faces critical challenges (mainly the need for long treatment durations and high temperatures ((≥850 °C)) to achieve protective boride layers (50–75 µm thick). These conditions result in high energy consumption and increased production costs, limiting its industrial sustainability.

The pulsed-DC powder-pack boriding offers a sustainable alternative to conventional method by drastically reducing energy usage and processing time. This technique employs an electric field generated by a power source and a polarity-switching device connected to electrodes immersed in a powder mixture together with the metallic specimen. Remarkably, successful treatments have been performed at lower temperatures (600–750 °C) and shorter durations (up to 1.5 h), producing boride layers with excellent wear and friction performance—an unprecedented advancement in the field of solid boriding media and aligned with the principles of sustainable manufacturing.

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