Surface Engineering - Applied Research and Industrial Applications
Room Town & Country A - Session IA-ThP
Surface Engineering – Applied Research and Industrial Applications Poster Session

IA-ThP-2 Interface-Engineered Grain Boundary Diffusion for Enhanced Coercivity, Corrosion Resistance, and Thermal Stability in Thick NdFeB Magnets with Efficient Rare-Earth Utilization, ***Ching-Chien Huang [huangcc@nkust.edu.tw]***, National Kaohsiung University of Science and Technology, Taiwan

Grain boundary diffusion (GBD) has emerged as a powerful interface engineering strategy to enhance the magnetic performance and environmental durability of sintered NdFeB magnets. This study presents a single-stage GBD process utilizing dysprosium (Dy) vapor adsorption, followed by subsequent aging treatment, to overcome coercivity degradation and thermal instability in thick-section magnets. By precisely controlling the diffusion temperature between 940 and 950 °C and the duration from 8 to 16 hours, significant improvements in intrinsic coercivity ($_iH_c$) were achieved. For samples with thicknesses of 5.5 mm and 6.5 mm, $_iH_c$ increased to 25.78 kOe and 25.06 kOe, corresponding to enhancements of 34.06 % and 30.32 %, respectively. These improvements enabled a magnetic grade transition from N44H to G42UH without compromising remanence (B_r) or maximum energy product ($(BH)_{max}$). Microstructural analysis using glow discharge optical emission spectroscopy (GDOES) and field-emission electron probe microanalysis (EPMA) confirmed uniform Dy enrichment at grain boundaries and the formation of thermally stable $(Nd, Dy)_2Fe_{14}B$ intergranular phases, supporting deep and homogeneous diffusion. Electrochemical evaluation via Tafel polarization revealed substantial reductions in corrosion current density and increased polarization resistance, indicating enhanced grain boundary chemical stability. The proposed method enables simultaneous enhancement of coercivity, thermal stability, and corrosion resistance. This interface-focused strategy provides a scalable and resource-efficient solution for fabricating high-performance NdFeB magnets for electric vehicles, offshore wind turbines, and aerospace applications.

IA-ThP-3 Advanced Coating Solutions for High-Pressure Injectors under Bioethanol Fuel Conditions, *Sung Chul Cha,* Hyundai Motor Group- Hyundai Kefico, Republic of Korea*; Jongkuk Kim,* KIMS, Republic of Korea*; Kyoung Il Moon, Hae Won Yoon,* KITECH, Republic of Korea*; Chang Ha Park, Dong Sik Kim,* ATF, Republic of Korea*;* ***Gi-Hoon Kwon [kgh9900a@kitech.re.kr]***, KITECH, Republic of Korea

This work presents the results of a ta-C coating developed by Co. ATF for injector balls, offering high hardness and superior corrosion resistance in bioethanol fuel environments. In the 2035 automotive trend, the use of biofuels is expected to continue expanding. Therefore, ensuring the durability of next-generation powertrain components for biofuel applications is essential. Conventional SiO-doped diamond-like carbon (DLC) coatings, 1.8-2.2 µm thick with 22-25 GPa hardness and 300 °C heat resistance, fail under bioethanol exposure due to delamination and severe corrosion of counterpart components. To overcome these limitations, a tetrahedral amorphous carbon (ta-C) coating was developed in collaboration with a domestic research institute and an industry partner. The ta-C coating, with a total thickness of 1.5-1.6 µm, features a two-layer structure consisting of a Ti bonding layer and a ta-C functional layer deposited using filtered cathodic vacuum arc (FCVA). It exhibits a hardness of 64-68 GPa, bonding strength rated HF1, and heat resistance up to 400 °C. Corrosion resistance was validated under aggressive conditions, including exposure to hydrochloric acid and ethanol, demonstrating superior performance compared to SiO-DLC. Additionally, both coatings were compared in a complex severe test sequence involving high-temperature exposure at 400 °C, subsequent corrosion, and friction/wear testing. The ta-C coating consistently outperformed SiO-DLC across all evaluations. These results indicate that ta-C coating offers strong potential for application in biofuel-compatible injector systems.

IA-ThP-5 Nanolayers Based on Ti/TiN, Zr/ZrN, and Cr/CrN in Multilayer PVD Systems: Tribological and Micro-impact Response, ***Daniel Toboła [daniel.tobola@kit.lukasiewicz.gov.pl]***, Łukasiewicz Research Network – Krakow Institute of Technology, Poland*; Ben D. Beake,* Micro Materials Ltd., UK*; Łukasz Maj,* Institute of Metallurgy and Materials Science of Polish Academy of Sciences, Poland*; Tomasz Liskiewicz,* Manchester Metropolitan University, UK*; Cezary Drenda,* AGH University of Krakow, Poland

Advanced transition–metal nitride coatings are widely employed to enhance the durability and functional performance of components operating under severe contact conditions, particularly in machining and forming. Among these, Ti/TiN, Zr/ZrN, and Cr/CrN multilayer architectures have gained significant attention due to their favorable combination of hardness, wear resistance and good adhesion. Despite extensive studies on their mechanical properties, a comprehensive comparison of their tribological and micro–impact responses – especially under dynamic loading remains limited.

This work investigates the wear mechanisms, frictional behavior, and micro–impact durability of $(Ti/TiN)_{25}$, $(Zr/ZrN)_{25}$, and $(Cr/CrN)_{25}$ coatings deposited by arc-evaporation on hardened M2 steel substrate. Reciprocating tests were performed under 2N load and sliding frequency of 5 Hz to evaluate friction coefficient evolution, wear scars morphology, and counterbody interactions. Micro–impact experiments, conducted using a cyclic loading, enabled the assessment of crack initiation and propagation pathways, and coating deformation modes.

The lowest CoF values were recorded for the $(Zr/ZrN)_{25}$ system, which was over 2.2 times and 43% lower, respectively for $(Cr/CrN)_{25}$ and $(Ti/TiN)_{25}$ coatings. These results directly correlated with the lowest values of the volume of removed material.The wear scars for the Zr/ZrN-based variant were dominated by the abrasive wear mechanism.

Acknowledgments

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IA-ThP-6 Cathodic-Driven Alkalization and Interfacial Reaction Competition in Cathodic-Excess MAO of AZ31B Magnesium Alloy, ***Shih-Yen Huang [f08525129@g.ntu.edu.tw]***, *Yueh-Lien Lee,* National Taiwan University, Taiwan

Micro-arc oxidation (MAO) with cathodic bias has been shown to modify discharge behavior and improve corrosion performance of magnesium alloys. However, under cathodic-excess operation (cathodic input exceeding anodic input), the coating/substrate interfacial growth coatings would be different, indicating that interfacial reactions are shifted compared with balanced bipolar conditions. In aluminum MAO, cathodic-excess bipolar conditions have often been associated with discharge softening and improved coating compactness, and the underlying interfacial chemistry has been discussed in detail in terms of phase evolution and reaction pathways. In contrast, for magnesium MAO, excessively high cathodic input is frequently reported to cause coating delamination or peeling, and the explanation is commonly limited to intensified hydrogen evolution and associated mechanical disruption at the interface.

In this research, AZ31B magnesium alloy was treated by bipolar MAO under cathodic-excess conditions with balanced total charge (Q_c:Q_a = 1:1) but higher cathodic current density ($|J_c|$:J_a = 4:3).The voltage–time response and surface roughness exhibited a soft-sparking-like trend compared with aluminum MAO; however, the corrosion resistance decreased under these cathodic-excess conditions. Cross-sectional observations revealed a non-uniform coating/substrate interface with locally uneven microstructure, suggesting that the interfacial growth pathway changes when excess cathodic current density is introduced. These results indicate that hydrogen evolution alone cannot fully explain the interfacial instability under cathodic-excess MAO on magnesium. The observations are consistent with cathodic-driven changes in local alkalization and OH^--involved interfacial reactions, which alter coating growth and lead to reduced corrosion resistance despite the moderated voltage behavior. To further evaluate this hypothesis, the NaF concentration in the electrolyte was increased. The higher fluoride availability stabilized coating formation and increased the low-frequency impedance by approximately one order of magnitude compared with the baseline electrolyte, supporting the importance of competitive interfacial chemistry beyond hydrogen evolution under cathodic-excess operation.

IA-ThP-7 In-Situ Diffusion-Induced Micro-Carburization of SAE 4140 Steel: Tailoring Surface Integrity and Torsional Resistance via Controlled-Atmosphere Heat Treatment*, **Te-Kang Tsao [tktsao@nkust.edu.tw]**,* Dep. of Mechanical Engineering, National Kaohsiung University of Science and Technology, Taiwan*; Wen-Hao Chiu,* Department of Mechanical Engineering, National Kaohsiung University of Science and Technology, Taiwan

Surface engineering plays a critical role in enhancing the structural reliability of high-strength steels subjected to severe mechanical loading. In this study, an in-situ diffusion-induced micro-carburization approach was developed by modulating atmospheric carbon potential (Cp) during the austenitization stage of a conventional quench-and-tempering (Q&T) process. SAE 4140 steel was treated at 840 °C for 1 h under controlled carbon potentials (0.3, 0.4, and 0.8 wt.%). Under the 0.8 wt.% Cp condition, a diffusion-controlled carburized martensitic surface layer approximately 40–50 μm thick was formed without requiring an additional carburizing cycle. Microstructural characterization and hardness profiling revealed a graded surface structure with hardness exceeding 800 Hv, while the tempered martensitic core retained bulk toughness. The experimentally measured hardness gradient showed strong agreement with carbon diffusion profiles predicted using Fick's second law, confirming the diffusion-driven formation mechanism. Residual stress analysis indicated a 21% reduction in detrimental surface tensile stress (from 182 to 144 MPa), attributed to differential transformation kinetics between the carbon-enriched layer and the core during quenching. Mechanical validation under torsional loading demonstrated a 22% increase in maximum torque capacity (from 273 to 334 Nm). Finite element simulations employing the Cockcroft–Latham criterion further revealed that the graded layer acts as a high-strength energy barrier, elevating the cumulative strain energy density threshold required for crack initiation. Although a marginal reduction in torsional fatigue life was observed due to increased surface brittleness and torsional fretting fatigue (TFF), the results demonstrate that in-situ micro-carburization provides an effective strategy for diffusion-based surface engineering. The proposed approach integrates surface modification directly into standard heat treatment, offering a scalable and cost-efficient alternative to discrete coating or vacuum-based processes for high-performance, torque-loaded steel components.

IA-ThP-8 Influence of the Parameters of Producing Oxide Coatings on Aluminum Tapes on Their Structure and Insulating Properties*, **Aleksander Iwaniak [aleksander.iwaniak@polsl.pl]**, Andrzej Posmyk, Łukasz Bąk, Adrian Krysiak,* Silesian University of Technology, Poland

The windings of most electromagnet coils, transformers and electric motors are made of copper wires. Due to the high price and high density of this element, work is underway to replace copper wires with aluminum tapes. The windings of the timing actuators of combustion engines, the windings of linear motors and transformers, and the windings of electric motors for individual drives of electric vehicles could be made of insulated aluminum tapes, which would result in a reduction in their weight and price.

The conducted research determined the possibility of shaping the insulating properties of oxide coatings by selecting the electrolyte chemical composition and oxidation parameters. The microstructure of the produced anodized oxide layers was examined and their breakdown voltage was measured to determine their dielectric strength.

Studies have shown that adding glycerin to an H2SO4 electrolyte allows the formation of an anodic coating with the same breakdown voltage as an electrolyte without glycerin, while using three times less electricity. Continuous oxide layers were obtained. These layers could be used as electrically insulating coatings in windings.

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