A Durable Bendable Superhydrophobic Surface with Anti-icing, Anti-condensation, and Weathering-resistant Properties

by Xinghua Wu | Guangdong University of Technology

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Anti-condensation, Anti-icing, Bendable, Durable, Superhydrophobic, Weathering-resistant

Superhydrophobic coatings are highly desirable for anti-condensation, anti-icing, and anti-fouling applications. Nevertheless, designing a functional coating with durable anti-icing properties and bendability remains a major challenge. Here, we explored a design strategy to develop a durable and bendable superhydrophobic coating with excellent anti-icing, self-cleaning and weathering-resistant properties based on glass powders and aluminum powders. Specifically, anodic oxidation were used to provide selective oxidation of the coating layer. The obtained hierarchical coatings exhibit outstanding bendability, imparting durable superhydrophobicity. The superhydrophobic coatings maintained superhydrophobicity after sandpaper abrasion and sandblasting test. Significantly, the superhydrophobic coating exhibited excellent anti-condensation, anti-icing properties, and good weather resistance. This work illustrates the possibility of designing long-lasting and bendable superhydrophobic coatings with glass powders and aluminum powders for outdoor applications.

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Advanced Polymer Composite Electrolyte Film towards All Solid-State Li Metal Batteries

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Keywords: Lithium metal batteries, ion conductivity, poor electrolyte/electrode interface, solid polymer electrolytes

Lithium metal batteries with solid polymer electrolytes have attracted extensive attention, due to the high energy density and the intrinsic safety. However, the low ionic conductivity of solid polymer electrolytes and the poor electrolyte/electrode interface have hindered their wide utilization. To address these critical challenges, a strong Lewis acid additive, is introduced into the traditional polyethylene oxide (PEO) based polymer electrolyte, facilitating the lithium salt dissociation and increasing its ion conductivity by 190% (1.2×10^{-3} S cm^{-1} at 60 °C). Furthermore, a lithium fluoride rich interfacial layer is in-situ formed, suppressing the lithium dendrite growth and continuous side reactions of PEO matrix. Benefited from our rational design, the symmetric battery with the modified electrolyte exhibits much longer cycling stability (over 3600 h) than that of the pure PEO/LiTFSI electrolyte (550 h). More impressively, the $LiFePO_4$ full cell with the composite electrolyte displays a much higher Coulombic efficiency (98.4% after 150 cycles) than that of the electrolyte without the aluminum fluoride additive (63.3% after 150 cycles) at a high voltage window of 2.4 - 4.2 V, demonstrating the improved interfacial and cycling stability of solid polymer lithium metal batteries.

Short BIOGRAPHY

Dr. Yuxin Tang is a professor in Fuzhou University and Qingyuan Innovation Laboratory. He obtained his BS and MS degrees at the Nanjing University of Aeronautics and Astronautics in 2006 and 2009, respectively, and graduated from Nanyang Technological University (NTU) with a Ph.D. in Mater science (2013). After postdoctoral training in NTU, he joined Institute of Applied Physics and Mater Engineering at the University of Macau as an assistant professor in 2018-2020. His research is the development of advanced electrolytes and electrode materials towards high-performance energy storage devices.

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Assessment of Nickel-Plating Processes for Corrosion Protection of Copper Substrate

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Keywords: Copper corrosion prevention, electroless nickel, immersion nickel, nickel electroplating, salt spray test

Copper substrates are integral components in various industries, necessitating effective corrosion protection methods. In this study, we assess four nickel-plating processes—immersion nickel, high-phosphorus electroless nickel, chloride nickel, and sulfamate nickel—to determine their efficacy in safeguarding pure copper substrates against corrosion. Industry requirements dictate that the nickel coating thickness should be kept below 1 micron, with the objective of achieving the thinnest possible coating while ensuring robust corrosion resistance. Additionally, the plated copper substrates must pass the 8-hour salt spray test (ASTM B117) without exhibiting signs of corrosion, tarnishing, or color change.

Our findings reveal varying degrees of corrosion resistance among the evaluated nickel-plating processes. Immersion nickel and high-phosphorus electroless nickel fail to meet the industry requirements, as corrosion is observed on the copper substrates following the 8-hour salt spray test. While chloride nickel plating demonstrates promising corrosion protection, instances of color change are noted on some samples, raising concerns about its suitability for certain applications. In contrast, sulfamate nickel plating emerges as the standout performer, with ultra-thin nickel layers (<0.5 micron) exhibiting exceptional corrosion resistance. Notably, copper substrates plated using sulfamate nickel plating withstand the 8-hour salt spray test without any signs of corrosion or color alteration, meeting the stringent industry requirements for corrosion protection. Electrochemical analysis was carried out to investigate the mechanism behind the varied corrosion resistance of nickel coating from different nickel-plating processes. Overall, our study underscores the importance of selecting the appropriate nickel-plating process to ensure optimal corrosion resistance of copper substrates. Sulfamate nickel plating, with its ability to provide ultra-thin yet highly effective nickel coatings, offers a promising solution for industries seeking reliable corrosion protection for their copper components.

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Bio-based photocurable polyurethane resin incorporating polydimethylsiloxane for self-healing and antifouling coating applications

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Keywords: Photocurable acrylic-polyurethane; Chitosan; Hydrophobicity; Sustainable; Antifouling coating

Silicone elastomer coatings have attracted considerable attention due to their excellent hydrophobicity, outstanding fouling release ability, and drag-reduction properties. Chitosan is a naturally derived biodegradable polymer known for its abundance, sustainability, and ease of chemical modification. Herein, a bio-based polyurethane with chitosan and polydimethylsiloxane elastomer via condensation is reported. This work presents the design of a photocurable polyurethane coating capable of environmentally friendly, customizable, and efficient self-healing for antifouling coatings. The hydroxyl groups in chitosan and the urethanes form hydrogen bonds with the substrate, resulting in a significant improvement in the adhesion strength of the coating. Furthermore, the cross-linking structure formed through the photocuring reaction also substantially enhances the mechanical properties, hydrophobicity, and corrosion resistance in a salty environment. The prepared coatings exhibit autonomous self-healing at both room temperature and saline conditions, which is attributed to the large number of dynamic interactions of hydrogen bonds in the polymer. The novel design has the potential to enhance the resistance of silicone coatings to biofouling and mechanical forces, making it promising for high-performance antifouling coatings in a marine environment. Meanwhile, the biodegradable elastomer coating is very beneficial for sustainable and environmentally friendly materials in the field of antifouling coating.

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Bond layer materials for environmental barrier coatings

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Environmental barrier coatings, bond layer, corrosion, oxidation

Continuous fiber reinforced SiC ceramic matrix composites (SiC/SiC) has the potential application in the next generation aero-engine. However, its performance dramatically decreases at high temperature in moisture environment. Environmental barrier coatings (EBCs) was proposed to protect SiC/SiC composites. In the triple-layer structured EBCs system, the low melting point of Si bond layer inhibits the upper-temperature-limit of EBCs. Here in this talk, the HfO_2-doped Si and newly developed temperature resistant bond layer materials were introduced. Their oxidation/corrosion behavior and microstructure evolution at high temperature in air and/or moisture were systematically investigated. Their mechanisms were deeply studied.

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Comparative study of cold spraying Ti3Al powder and laser post-annealing of cold sprayed Ti+Al blends for obtaining intermetallic coatings

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Cold gas dynamically spray (CGDS); Laser annealing; Ti-Al intermetallides

Comparative study of cold spraying Ti_3Al powder and laser post-annealing of cold sprayed Ti+Al blends for obtaining intermetallic coatings.

During the study, the intermetallic Ti_xAl_y coatings were obtained by cold spraying technology. For this purpose, two approaches were implemented: intermetallics synthesis with self-propagating high-temperature synthesis controlled by laser radiation in a cold-sprayed Ti+Al mechanical blend, and immediate cold spraying of commercially available Ti_3Al powder. In both cases the XRD analysis showed the presence of Ti_3Al phase. The cold sprayed and laser treateted coatings were subjected to the analysis with the optical microscopy, SEM (equipped with EDX) and hardness. The results of both approaches were compared and the preference of synthesis intermetallics in-situ is demonstrated. The optimal parameters for cold spraying and laser radiation were determined and its influence on coating microstructure is discussed.

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Deicing performance based on piezoelectric materials coupled with a porous coating.

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Porous coating; Low interfacial toughness; Piezoelectric vibration; Coupling; De-icing energy consumption

Icing on material surfaces often has a negative impact on daily life, and nature-inspired superhydrophobic and superlubricating coatings can effectively address the icing problem. However, their widespread application is hindered by the limited area affected by icing. It has been discovered that low interfacial toughness coatings have a unique ability to induce ice crack expansion and fracture, which shows great potential for large-area deicing applications. In this study, considering the urgent need for high-efficiency and low-energy anti-/deicing technology, the first step is to investigate the phenomenon of ice crack expansion under applied stress through observation and simulation of the process of crack initiation and growth in the ice layer. This will help clarify the mechanism behind surface ice layer removal. The porous coating is effectively prepared through a phase separation and multi-step curing process, and its non-wettability, mechanical properties, and anti-/de-icing performance are comprehensively evaluated. A porous coating coupled with a piezoelectric material vibration de-icing strategy is proposed, and a systematic study on the factors affecting the effectiveness of piezoelectric vibration de-icing is conducted to clarify the optimization method for reducing energy consumption in the organic coating/piezoelectric vibration integrated anti-/de-icing system.

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Depletion of metallization pads in Sn-xAg-0.5Cu micro joints with different surface finishes

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Ag content, Au/Pd(P)/Ni(P), IMC, Sn-Ag-Cu, micro joint, pad's consumption

Sn-Ag-Cu series of Pb-free alloys have been widely used in microelectronic packaging for over a decade since July 1st, 2006 due to the European Union's Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS) directive. The Cu content in commercial Sn-Ag-Cu alloys generally ranges from 0 wt.% to 1 wt.% and the Ag content is predominantly in the range of 3–4 wt.% based on the considerations of low melting temperature and high mechanical properties. At the current stage, the cost effectiveness has motivated the development of low-Ag-content Sn-Ag-Cu alloys in consumer electronics. However, the effect of Ag content on the solderability, specifically on the pad's consumption during soldering, has rarely been investigated previously in the literature. In this study, the consumption of metallization pads, including Cu and Au/Pd(P)/Ni(P), and the growth of intermetallic compounds (IMCs) in Sn-*x*Ag-0.5Cu micro joints (x = 0–4 wt.%) after soldering reaction were investigated via scanning electron microscopy (SEM) and electron probe X-ray microanalysis (EPMA). The results showed that the metallization pad's consumption, especially for the Cu pad, and the IMC growth strongly depended on the Ag content in Sn-*x*Ag-0.5Cu. The correlation among pad's consumption, IMC growth, and Ag content will be discussed in this study.

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Development of TiAlCuN Coatings with high erosion, cavitation and antibacterial properties for Marine Applications

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Physical vapor deposition; Hard coating; Nitriding; doping; Marine Application.

In marine hydrodynamic systems, metal components face significant threats from cavitation, sand erosion, and bacterial fouling. Although TiAlN hard coatings have been well developed to combat wear and corrosion, they still hardly satisfy the diverse requirements for marine environments. In this study, we have successfully developed a Cu-doped TiAlCuN coatings with controlled existence through periodically addition near the topmost surface. The TiAlCuN coatings possess excellent erosion-corrosion resistance and antibacterial property against *E. coli* with an antibacterial rate of 99.68 %. Furthermore, we have systematically studied the performance of duplex surface treatments combining plasma nitriding and TiAlCuN coatings. The duplex treated surface not only exhibits high load-bearing capacity, coating adhesion, mechanical properties and corrosion resistance, but also demonstrates the superior performance against cavitation erosion in both distilled water and simulated sea water conditions. The interfacial behavior has been thoroughly investigated and a possible ‘denitriding - nitriding’ alloying mechanism is proposed. These findings not only offer practical solutions for enhancing the marine properties of metal parts but also provide insights into design for PVD nitride coatings.

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Eco-friendly bio-epoxy coatings for corrosion-resistant and easy-cleaning applications

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: eco-friendly; bio-epoxy coating; corrosion; easy-cleaning

Corrosion and contamination of engineering metals and alloys can cause serious problems to the functionality and aesthetic appearance of pipelines, bridges, highways, vehicles, and even home appliances, leading to public safety hazards and economic loss. Epoxy resin has been widely applied as a protective coating due to its excellent properties. However, the raw material for industrially available epoxy, bisphenol A (BPA), is derived from fossil resources. BPA is proven to be harmful to the human endocrine system. Therefore, a sustainable and bio-based green epoxy resin would be ideal to replace the fossil-derived epoxy. In this work, an eco-friendly bio-epoxy coating without volatile organic solvents was fabricated by introducing nanoparticles, (3-glycidyloxypropyl) trimethoxysilane (GLYMO) into the isosorbide-based epoxy resin and hydroxyl-terminated polydimethylsiloxane (PDMS). A superhydrophobic bio-epoxy coating was achieved with a contact angle of around 153° by optimizing the coating formulation. Meanwhile, a slippery liquid-infused porous surface (SLIP) coating was obtained by infusing silicone fluid to the optimal superhydrophobic bio-epoxy coating, exhibiting an extremely low sliding angle below 1°. Both the superhydrophobic and SLIP coatings exhibited good water repellency and corrosion resistance. Electrochemical measurement results showed that the two produced coatings have a decrease of 1-2 orders of magnitude in the corrosion current density and a positive shift from −0.306 V to −0.265 V and −0.282 V in the corrosion potential as compared to the bare substrate. Furthermore, the SLIP coating was enhanced to display better easy-cleaning performance and proven to function well after the weathering resistance test.

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Effect of electrolyte additives on the microstructure of phosphoric acid film formed on the surface of A36 steel using Plasma Electrolytic Oxidation method

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Keywords: Additive, Electrolyte, Phosphate film, Plasma Electrolytic Oxidation

This study will explore the use of plasma electrolytic oxidation to form a phosphoric acid film on the surface of A36 steel, which use trisodium phosphate (Na3PO4) as the main electrolyte. Additives such as sodium percarbonate (Na2CO3) and aluminum sulfate (Al2(SO4)3) were added to improve the electrolyte. Experiments were conducted on plasma electrolytic oxidation of A36 steel surface under different voltages, the same current and time, different electrolyte concentrations and temperatures. The experiment result shows, when the concentration of 0.067M trisodium phosphate (Na3PO4) is mixed with 1M aluminum sulfate (Al2(SO4)3) as the electrolyte, and the temperature is room temperature, using a fixed voltage of 50V, a current of 1.6A, and a time of 30 minutes, the surface can be obtained Hardness value is larger. When an electrolyte mixed with a concentration of 0.067M trisodium phosphate (Na3PO4) and a concentration of 1M aluminum sulfate is used, and the electrolyte temperature is 80°C, the voltage is 200V, the current is 1.6A, and the experiment is 30 minutes, the surface roughness is the smallest and the surface is the smoothest.

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Effect of interface state on capacitance-voltage characteristics of CdZnTe crystals after surface oxidation

by Xiao-yan Liang | Ji-jun Zhang | Lin-jun Wang | Jia-hua Min | Shanghai University | Shanghai University | Shanghai University | Shanghai University

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: C-V characteristics, CdZnTe, Interface state density, Passivation interface

CdZnTe crystals are important materials for the preparation of room-temperature X-ray and gamma-ray detectors because of their high atomic number, large forbidden band width and high resistivity, which are widely used in nuclear safety, environmental protection, medical imaging and astrophysics. The TeO_2 layer generated on the surface of CdZnTe crystals is intended to reduce electronic noise and prevent crystal aging. However, the interface state existing between the TeO_2 passivation layer and the CdZnTe semiconductor can also have an important impact on the device. Especially, the influence of interface states on capacitance voltage (C-V) characteristics deserves further research, as C-V characteristics are sensitive to the distribution of interface traps, which is beneficial for quantifying interface state density, improving interface quality, and enhancing device performance.

In the paper, it was found that the interface state of TeO_2/CdZnTe exhibits a capacitance hump phenomenon in the depletion region of the C-V curve, which is affected by factors such as substrate doping concentration, frequency, interface state density, and energy level position based on numerical simulation studies. Then, the influence of these factors on the capacitance curve under experimental conditions is investigated. The results showed that the experimentally measured hump capacitance gradually decreased with increasing frequency, agreeing with the simulation results. To study the effect of different interface state densities on capacitance curves, CdZnTe chips were vacuum annealed and it was found that the capacitance value decreased after annealing. The conductivity method was used to calculate the interface state density before and after annealing, and it was found that the interface state density significantly decreased after annealing. This confirms that the decrease in interface state density will promote the reduction of hump capacitance. Therefore, vacuum annealing can effectively reduce the interface state density between TeO_2/CdZnTe and improve the interface quality of CdZnTe devices.

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Effect of MoS2 nanoparticle incorporation on microstructure and wear resistance of self-lubricating ceramic coatings fabricated on 2A50 aluminum alloy by plasma electrolytic oxidation

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: 2A50 aluminum alloy; micro arc oxidation; molybdenum disulfide; wear resistance; Nanocomposites

Self-lubricating ceramic coatings were fabricated on 2A50 aluminum alloy substrate using plasma electrolytic oxidation (PEO) in silicate-based electrolyte solution with MoS_2 nanoparticle addition. The effect of MoS_2 incorporation on microstructure and wear resistance of the composite ceramic coatings was investigated by regulating the concentration of MoS_2 nanoparticle. The microstructure, phase structure, composition and wear resistance of the self-lubricating ceramic coatings were characterized by SEM, XRD, EDS, profilometer and ball-disc friction and wear tester. The results show that the breakdown voltage increased with the increasing of MoS_2 concentration. The prepared ceramic coatings are mainly composed of α-Al_2O_3, γ-Al_2O_3, MoS_2, and Mullite phases. The cross-sectional EDS mapping results show that MoS_2 nanoparticles were evenly distributed in Al_2O_3 matrix. When the concentration of MoS_2 nanoparticle is 4 g/L, the prepared ceramic coating exhibit a smooth and compact surface. After friction and wear test, the protective lubricant film formed between ceramic layer and counter parts is the largest and the average friction coefficient is the lowest, about 0.2. The wear amount was the lowest (about 0.53×10^{-9} $cm^3\cdot N^{-1}\cdot m^{-1}$). It can be concluded that Al_2O_3/MoS_2 nanocomposite coatings successfully formed on 2A50 aluminum alloy by plasma electrolytic oxidation in MoS_2 nanoparticle-containing solution, and the coatings exhibited self-lubricating features such as antifriction and wear resistance.

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Effect of propynol on nickel coating on battery steel shell and its mechanism of action

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Keywords: Nickel□Proynylol□Stress within the plating□Battery steel case□Corrosion resistance

The corrosion of the mild steel shell of the secondary battery during the long-term service is one of the key factors for the performance degradation. Nickel plating on mild steel surfaces is an effective way to prevent corrosion and stop battery short circuits and air leaks. Experiments show that adding propynyl alcohol to Watt plating solution can refine the coating grains, control the coating stress, and increase the corrosion resistance of the coating. The surface morphology, preferred orientation and grain size of the coating were studied by XRD, EBSD, SEM, EDS and other tests on the coating. The addition of propynol can increase the lattice distortion of nickel atoms during the electroplating process, so that the stress in the coating increases with the increase of the amount of propynyl alcohol added on a macroscopic scale. In terms of corrosion resistance, with the addition of propynyl alcohol, the corrosion resistance of the coating first increases and then decreases, which may be related to the fact that propynyl alcohol can enhance the preferential orientation of nickel (111) within a certain range, and beyond this range, it is related to the preferential orientation of nickel (200), and the influence of the addition of propynyl alcohol on the grain size is proposed. The steel plates obtained by electroplating with different contents of propynyl alcohol in the plating solution were used as battery shells for lithium battery assembly tests, and the influence relationship and mechanism of the plating on the battery performance were proposed.

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Effect of Zinc-Nickel Plating Bath Composition and Plating Parameters to Control Nickel Content for Corrosion Prevention

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Keywords: Zinc plating, corrosion prevention, electrochemical analysis, nickel plating, zinc-nickel alloy plating

Cadmium (Cd) and zinc (Zn) plating are widely used in automotive and aerospace industries for corrosion prevention in high-strength steel structures, but Cd’s toxicity and Zn’s inferior corrosion resistance pose environmental and performance challenges. Zinc-nickel (Zn-Ni) plating, with approximately 13 wt.% Ni, offers a promising alternative with superior corrosion and wear resistance, along with reduced hydrogen embrittlement. However, adoption faces hurdles like cost and plating complexity. This study focuses on formulating cost-effective plating baths for Zn-Ni deposition with targeted nickel content. Optimization of parameters, including bath composition, temperature, and current density, aims for uniform coatings with 10-16 wt.% Ni. Chloride-based acidic baths are found suitable, with Ni content affected by bath Zn/Ni ratio, temperature, and current density.

Results reveal the intricate relationship between plating parameters and coating properties. Increasing bath Zn/Ni ratio reduces Ni content, while higher temperature increases it. Current density affects deposition rate and Ni content, less significantly under certain conditions. Corrosion resistance is evaluated through electrochemical analysis, offering insights into coating performance in harsh environments. This research contributes to understanding and applying Zn-Ni plating as an environmentally sustainable alternative to Cd and Zn coatings, offering enhanced corrosion protection for high-strength steel structures.

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Effects of silicon content on the characterization of (CrTaWSi)Nx thin films

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Mechanical properties

In this study, (CrTaWSi)N_x films were deposited on Si wafers and 304 stainless steel (AISI 304) substrates by reactive direct current magnetron cosputtering. The nitrogen flow ratio (f = [N_2/(N_2+Ar)]) was adjusted at 0.4. The powers applied to CrW and Ta targets were 100 W and 50 W, respectively. The process variable was the Si target power, set at 0, 50, 75, 100, and 125 W, which formed $(Cr_{0.38}Ta_{0.15}W_{0.47})N_{0.55}$, $(Cr_{0.38}Ta_{0.12}W_{0.39}Si_{0.11})N_{0.68}$, $(Cr_{0.33}Ta_{0.11}W_{0.35}Si_{0.21})N_{0.64}$, $(Cr_{0.32}Ta_{0.10}W_{0.33}Si_{0.25})N_{0.71}$, and $(Cr_{0.31}Ta_{0.10}W_{0.31}Si_{0.28})N_{0.76}$ films, respectively. The influences of Si content on the structural, mechanical, and antioxidative properties of (CrTaWSi)N_x films were evaluated. The $(Cr_{0.38}Ta_{0.15}W_{0.47})N_{0.55}$ and $(Cr_{0.38}Ta_{0.12}W_{0.39}Si_{0.11})N_{0.68}$ films formed an FCC solid solution, whereas the films with high Si contents exhibited an amorphous phase. The addition of Si resulted in increases in hardness and elastic modulus from 25.3 and 289 GPa for $(Cr_{0.38}Ta_{0.15}W_{0.47})N_{0.55}$ to 30.5 and 304 GPa for $(Cr_{0.38}Ta_{0.12}W_{0.39}Si_{0.11})N_{0.6}$, films, which was attributed to the formation of a nanocomposite structure. Further increasing the Si content to 21–28 at.% resulted in the formation of amorphous structures accompanied by a lower hardness of 15.6 GPa and elastic modulus of 226 GPa. The oxidation behavior of (CrTaWSi)N_x films at 600 ^oC in air and low oxygen-containing atmospheres were investigated for applications on glass molding technologies.

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Effects of thickness ratio on phase structures, mechanical properties, and oxidation resistance of CrSiN/WSiN bilayer films

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Keywords: bilayer films, mechanical properties, oxidation resistance

The high oxidation resistance of CrSiN films and high hardness of WSiN films inspired the fabrication of CrSiN/WSiN bilayer films. In this study, CrSiN/WSiN bilayer films of approximately 1 μm with various thickness ratios were deposited through direct current magnetron cosputtering. Cr, Si, and W targets were used to sequentially deposit Cr interlayer, WSiN sublayer, and CrSiN sublayer. The thickness ratios of WSiN to CrSiN sublayer were set as 1.3, 2.7, 3.8, and 4.7, respectively, by adjusting the deposition times of individual sublayers. The effects of thickness ratio on the film's phase structures, mechanical properties, and oxidation resistance were investigated. These CrSiN/WSiN bilayer films exhibited a mixture of face cubic centered and amorphous phase. The hardness and elastic modulus values of these CrSiN/WSiN bilayer films increased from 11.3 to 17.7 GPa and from 235 to 268 GPa, respectively, with increasing the thickness ratio of the WSiN sublayer, which were accompanied with successively increased H/E ratio and elastic recovery. The oxidation resistance of these CrSiN/WSiN bilayer films was evaluated after annealing at 600–800°C in ambient air.

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Engineered Phase Differences between HiPIMS Power and Substrate bias for Improved Mechanical Properties of TiN and CrN

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Keywords: Chromium Nitride, HiPIMS, Substrate Bias, Thin Films, Titanium Nitride

Conventional magnetron sputtering, often limited by its ionization rate, typically employs a DC substrate bias to enhance Ar+ bombardment, improving film qualities such as hardness, density, and adhesion. However, this method leads to high compressive residual stress and risk film peel-off. The complexity increases in High Power Impulse Magnetron Sputtering (HiPIMS), characterized by significantly higher plasma density, where the influx of ions during the process may overwhelm the DC bias voltage of the substrate. Our research utilizes HiPIMS for TiN and CrN deposition, employing DC, synchronous pulsed, and phase-different subtracts bias allows for fine-tuning ion intensities and energies impacting the substrate and the growing film. This approach impacts crucial film characteristics such as crystallinity, grain size, residual stress, and adhesion. The study reveals that in both TiN and CrN films, DC subtract bias attracts the most ions from the plasma to the substrate, resulting in films with the lowest surface roughness, smallest grain size, and denser structure, thereby enhancing resistance to deformation and corrosion. However, these films also show larger residual compressive stress and poorer adhesion. In contrast, applying synchronous pulsed subtract bias leads to a slight decrease in ion intensity, which results in increased surface roughness, larger grain size, and reduced film density. These films demonstrate lower resistance to deformation and corrosion but improved adhesion due to decreased residual stress. For phase-different subtract bias, TiN films with a phase difference of 100 μs maintain deformation resistance comparable to direct current biased films, but with lower residual stress and improved adhesion. Conversely, CrN films under phase-different biasing conditions do not show significant improvement in mechanical properties, indicating a more substantial effect of phase-different pulse bias on materials with higher ionization rates, like Ti.

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Enhancement of Photoelectrochemical Performance by Air-based Sputtering Deposition of N-TiO2/TiN(O) Multilayer Films

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: N-doped TiO2, air-based sputtering; multilayer; TiN, photoelectrochemical system

Ti-N-O films with various N/O ratios, exhibiting numerous intriguing physical and mechanical properties, were fabricated using a facile air-based sputtering technique. Traditionally, pure N2 and O2 have been employed as reactive gases to produce such films during sputtering, necessitating a high vacuum environment. However, employing air as the reactive gas instead can significantly reduce processing time and costs. XRD patterns of the deposited films reveal a transition from cubic TiN(O) to crystalline TiNxOy, amorphous TiNxOy, and subsequently predominantly N-doped TiOx with increasing air/Ar ratio. Furthermore, the resistivity of the films can be controlled from conductive to semiconductive, and then to dielectric, while the light transmittance shifts from opaque to translucent and nearly transparent. This facile air-based sputtering technique can also facilitate the production of multilayers in a single batch process. In a photoelectrochemical system, integrating the films comprising a semiconductor layer absorbing the light source to generate carriers and a conductive layer aiding in carrier separation and transmission is imperative. Through the multilayer design, the photoelectrochemical response performance improved significantly. The N-TiO2/TiN(O) multilayer film design yielded an optimal photocurrent density of nearly 1000 μA□cm-2, surpassing values reported in the relevant literature.

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Enhancing corrosive wear resistance and antibacterial ability of Ti6Al4V by laser clad CrMoNbW high-entropy coating with adding copper

by Xiulin Ji | Shantou University

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Laser cladding ; high entropy alloy ; tribocorrosion ; corrosive wear ; antibacterial property

To improve the corrosive wear resistance and the antibacterial performance of Ti-6Al-4V alloy (TC4) in body fluids, the CrMoNbW high-entropy alloy (HEA) coating was laser-cladded on TC4 with copper addition. This study explores copper addition as a materials design approach for simultaneously improving the hardness, corrosion resistance, lubrication performance, and corrosive wear resistance of the HEA coating. To melt tungsten-containing powder, high laser power was applied, leading to an obvious dilution and forming a Ti-rich CrMoNbWCu coating. The microstructure of the CrMoNbW coating is mainly composed of the BCC and Laves phases. With 5~10 wt% Cu addition, the Laves phase increased for the reaction between HEA and copper. Meanwhile, more HCP phases were presented in the Ti-rich matrix since more HEA elements were exhausted with copper to form the Laves phase. Furthermore, copper addition favors the Ti-rich matrix transforming from HCP to BCC. The electrochemical analysis showed the copper addition is advantageous to improve the corrosion resistance of the HEA coating. The tribocorrosion tests in 0.9% NaCl solution at 37±0.5 °C proved that the copper addition is beneficial to decreasing the friction coefficient and the wear rate was reduced significantly. Particularly, the wear rate of TC4 is 23.44×10^{-5} mm^3 m^{-1} N^{-1} under 1 N, which is approximately 69 times higher than that of HEA-Cu10 coating (0.34×10^{-5} mm^3 m^{-1} N^{-1}). The primary wear mechanism of TC4 is adhesive wear accompanied by abrasive wear. However, the wear mechanism of the HEA-Cu coatings is corrosive wear. Furthermore, the anti-S.aureus antibacterial tests showed that the antibacterial rates of the HEA coating can be enhanced by 10 wt.% copper addition from approximately 51% to 88%, displaying excellent antibacterial properties. Therefore, the CrMoNbW-10% Cu coating has a strong prospective application for titanium artificial joint implants.

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Enhancing the Initial Nucleation Behavior of ALD-Iridium Thin Films via a Surface Pretreatment Process

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Atomic layer deposition, Impurity-free, Iridium, Low resistivity ultra-thin metal film, Surface pretreatment

Iridium (Ir) has low figure of merit($\rho_0 \times \lambda$) and high melting temperature properties, so it has been recently spotlighted as a very important copper (Cu) alternative interconnect material in next-generation semiconductor devices. In particular, in the case of depositing a thin film using atomic layer deposition (ALD) technology, it can be expected to deposit extremely thin film with conformal, uniform and excellent step coverage characteristics even in a very complex structure or a trench structure of several nm dimension due to the inherent self-limiting characteristic of ALD. In this regard, ALD-Ir is considered as one of the most suitable metallization process for the application of advanced semiconductor interconnects. Therefore, considerable efforts have been conducted to develop a reliable ALD-Ir process having improved film qualities. And, ALD-Ir process with excellent thin film properties such as low electrical resistivity and negligible oxygen impurities was recently reported using Tricarbonyl (1,2,3-η)-1,2,3-tri(tert-butyl)-cyclopropenyl iridium ($C_{18}H_{27}IrO_3$ or TICP) precursor and oxygen [1]. However, in the case of this TICP precursor, it was difficult to deposit extremely thin and continuous Ir films on the hydroxyl-terminated oxide layer due to its long incubation delay.

Therefore, in this study, a method for depositing a very thin, uniform and continuous ALD-Ir thin film with low resistivity even on oxide materials was explored by reducing the incubation period and promoting nucleation using DIPAS, as a Si-based precursor. In addition, the nucleation behavior as well as film properties of ALD-Ir on the oxide material were systemically compared and analyzed according to the surface pretreatment conditions, and finally, ALD-Ir thin film with excellent properties on the oxide surface was obtained.

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Evolution of Microstructure and Bioactivity Properties of Sol-gel HA Coating Hydrothermal Treatment with a Magnetic Field

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Keywords: bioactivity, coatings, hydroxyapatite, magnetic field, sol-gel

Sol-gel hydroxyapatite-based (HA) coatings is a promising material for bone repairing and transplantation depending on its excellent biocompatibility and osteoconductivity. While hydrothermal treatment is one of the most commonly used post-treatment methods. In this work, the sol-gel HA coating has been hydrothermal treated in SBF at 200°C with and without a 300mT magnetic field. The microstructure, chemical and phase composition, and bioactivity of the coatings have been investigated. The content of bone-like apatite and weight gain of the coatings hydrothermal treated with and without the magnetic field are increased with the extension of treatment time. With the application of the magnetic field, crystallization degree of the hydrothermal treated coating is much higher. After 7 days hydrothermal treatment, the coatings treated with the magnetic field has the better biological activity and biological stability during the vitro activity test (a 14 days immersion in SBF at 37°C). The weight and the content of bone-like apatite of the coatings treated with the magnetic field is more stable during the immersion. The effect of magnetic field on surface energy is the main reason to promote the wetting of SBF on the coating that is conducive to the ion exchange between SBF and HA. Then the stability of the coatings has been enhanced during the hydrothermal treatment with the magnetic field. Hydrothermal treatment with a magnetic field is an effective post treatment method to enhance the bioactivity of HA.

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Experimental and theoretical study on mechanical and high temperature performances of CrHfNbTaTiCxNy high entropy coatings

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: CrHfNbTaTiCxNy high entropy coatings, Double glow plasma surface alloying, Elastic mechanics, Thermodynamic models analysis, tribological performance

The present paper is focused on understanding of relationships between structure, composition, mechanical and high-temperature performances of the CrHfNbTaTiC_xN_y high entropy coatings. The coatings were produced using double glow plasma surface alloying. It was found that CrHfNbTaTiCN coating demonstrated better high temperature wear resistance compared to CrHfNbTaTiC/N coating. The CrHfNbTaTiC_xN_y high entropy coatings revealed a graded microstructure and graded composition, which strongly affected tribological performance of the coatings. The calculated elastic mechanics obeys the rule of mixture, whereas Vickers hardness is slightly larger than the average value of constituent binary carbides. Thermodynamic models analysis exhibit the CrHfNbTaTiCN show relatively better thermal stability at high temperature. In addition, tribological tests show at 600 ℃ and 700 ℃ the high-entropy carbonitrides coating always show lower wear rate due to the formation of dense metal-oxidation layer, as well as the low coefficient of thermal expansion obtained by the theoretical calculation. And the wear rate values of CrHfNbTaTiC_xN_y coating at 700 ℃ uniformly lower than that at 600 ℃, owing to the wear mechanism changed from abrasive wear at 600 ℃ to adhesive wear at 700℃. The present research will be valuable for understanding and designing of high-entropy ceramics coatings.

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Exploring plasma treatment for durable transparent superhydrophilic surfaces

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Abstract ID: 10106
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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Superhydrophilic, anti-fogging, durability, plasma treatment, transparency

Fabricating superhydrophilic surfaces is crucial for various practical applications, including anti-fogging and water harvesting. However, the inherent challenge lies in its susceptibility of superhydrophilic surfaces to organic contaminations and/or change of the surface chemical state, leading to the loss their superhydrophilicity through hydrophobic recovery. Current fabrication methods for transparent and durable superhydrophilic surface are often costly and complicate. This study explores the use of plasma treatment, involving the ionization of gas into plasma to treat glass slides and prepare superhydrophilic surfaces. Setting the gas flow rate at 15 cc/min and plasma power at 300 W, we systematically investigate the impact of different plasma treatment parameter, such as the gas source and treatment time, to identify optimal conditions. The plasma-treated surfaces were analyzed in terms of water contact angle, surface morphology, roughness, and chemical states to investigate the effects of varying plasma parameters. Optimal treatment parameters are identified as 5 min for oxygen plasma, and 10 min for forming gas (5% H_2 + 95% N_2). Surfaces treated under these optimal conditions exhibit sustained superhydrophilicity for one week. And their anti-fogging applications are also examined. The characterization results reveal that plasma treatment has minimal impact on surface morphology and transmittance. In addition, the surface roughness of glass slides only changed slightly. However, the chemical state of the surface has evidently changed. With treatment time increasing, the C content decreased drastically and then remain stable. Furthermore, the binding energy of Si experiences left chemical shift until reaching a constant value, and the Si/O atomic ratio experiences first increase and then decrease before becoming stable. Through comparison of XPS analysis of superhydrophilic glasses and their counterparts after losing superhydrophilicity, the reason of superhydrophilicity is elucidated. This work provides valuable insights for the facile production of durable superhydrophilic surfaces and effective prevention of superhydrophilicity degradation.

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Exploring the mechanical properties and corrosion resistance of hydrogenated metal carbide coatings grown by reactive superimposed HiPIMS-MF deposition system

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Superimposed high power impulse magnetron sputtering, hydrogenated metal carbide coatings, middle frequency, plasma emission monitoring, target poisoning ratio

Transition metal carbide coatings have been widely studied due to their outstanding high hardness, high wear resistance, good corrosion resistance, and low coefficient of friction. In this work, three hydrogenated metal carbide protective coatings were grown by a superimposed high power impulse magnetron sputtering (HiPIMS)- middle frequency (MF) deposition system. The target poisoning status of Cr, Ti, and W targets was controlled using a plasma emission monitoring (PEM) system by adjusting the gas flow ratios of Ar and acetylene (C_2H_2), respectively. The hardness, adhesion, and tribological properties of coatings were explored. The corrosion resistance of selected hydrogenated metal carbide coatings was evaluated in 0.1 M H_2SO_4 solution. The crystalline metal carbide phases were transformed into amorphous phases when the target poisoning ratio of coatings was higher than 70%. The effects of target poisoning ratios on the mechanical properties and corrosion resistances of three hydrogenated nc-CrC/a-C:H, nc-TiC/a-C:H, and nc-WC/a-C:H coatings were discussed.

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Formation of Si-Based nanostructure on the AlSi10Mg manufactured by SLM.

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: AlSi10Mg, Nanostructure, SLM(Selective Laser Melting)

Nanostructures on a metal have many advantages such as modification of wetability, increase the surface ratio to volume, etc. To apply these advantages to various metals, numerous researchers have studied the formation of nanostructures on various metals. SLM process is a type of the additive manufacturing. SLM process has been in the spotlight, because SLM process has many advantages such as excellent strength, quick manufacturing. etc. Moreover, SLM process efficiently manufactures complex three-dimensional shapes of metallic structure and facilitate prototype manufacturing. Nanostructure formation in SLM-based metals would apply the advantages of nanostructures in more fields. Therefore, numerous researchers have studied micro-nanostructure formation on the SL M-Based metal.

In this study, we formed nanostructures like a mesh on the AlSi10Mg manufactured at various inclination such as 0°, 15°, 30°, 45° by SLM through facile method. This method was conceived in a crystal structure in which silicon is distributed like a mesh in SLM-based aluminum. The nanostructures are made up of silicon. Moreover, mechanism of nanostructure formation was identified. The formation of nanostructure on SLM-Based AlSi10Mg in this study was successfully applied to three-dimensional shapes such as TPMS(The six triply periodic minimal surface).

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Hybrid-biotaxonomy-like self-training reinforcement deeping learning to predict treatment of Au/Ag nanoparticles on ZnO nanorods

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Au/Ag nanoparticles, ZnO nanorods, deeping learning, reinforcement learning, self-training

Photosensitized materials enabling the production of green hydrogen from water and sunlight are continuously designed, e.g., ZnO nanostructures coated by photosensitized nanoparticles, which employ the light-to- exciton to realize photoelectrochemical water splitting. In this regard, we established a hybrid-biotaxonomy-like machine learning (ML) model based on generative reinforcement learning (Reinforcement learning) algorithm model flow of self-training (semi-supervised learning) to investigate the a multi-layer coating of noble metal nanoparticles (NMNPs) on ZnO nanorods. Meanwhile, we understood the physical properties of every NMNP coating layer by exploiting the multivariate normal distribution method and the concept of phylogenetic nomenclature from evolutionary developmental biology.

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Improving Oil Lubrication Effectiveness of Ti-Ti Tribopair by Thermal Oxidation

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Friction, Lubrication, Thermal oxidation, Titanium, Wear

Titanium and its alloys are notorious for their poor tribological properties under sliding contact motions. They are also well known to be difficult to lubricate. Conventional lubricants such as engine oils fail to lubricate titanium effectively. Coating and thin film technologies have been shown to be effective in enhancing the tribological properties of titanium, particularly under dry sliding conditions. However, there have been limited studies on the effect of tribological coatings in improving the lubrication behaviour of titanium tribopairs. In this study, thermal oxidation was used to produce an oxide layer and an oxygen diffusion zone on commercially pure titanium (CP-Ti), and the oil lubrication behaviour of several treated and untreated Ti-on-Ti tribopairs were studied and compared under boundary lubrication conditions. These include (1) untreated Ti-on-untreated Ti (Ti-Ti) pair, (2) treated Ti-on-treated Ti (TO-TO) pair, and (3) untreated Ti-on-treated Ti (Ti-TO) contact pairs. The results show that the engine oil indeed failed to lubricate the Ti-Ti tribopair, which experienced high and unstable friction with large amounts of wear from the contacting bodies. Thermally oxidizing both contacting bodies was very effective in improving the lubricity of the TO-TO tribopair, resulting in low and smooth friction and much reduced wear rates by 3 orders of magnitude. The oil lubrication characteristics of the TO-TO tribopair was similar to that of steel-steel tribopair. Thus, after thermal oxidation treatment, titanium can be lubricated effectively by conventional oil lubricants. The friction and wear mechanisms and the beneficial effects of thermal oxidation in forming and retaining the trbofilm under oil lubrication are discussed in the paper.

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Influence of Particle Surface Wettability on Dielectric Properties in Epoxy Resin - SiO2 Composites

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Dielectric properties, Epoxy resin composites, Particle wettability, Surface treatment

Incorporating particles such as inorganic oxides into epoxy resin is a well-established strategy to enhance the dielectric properties of materials used in the electrical and electronics industry. Prior research has indicated that the interface between fillers and polymer matrix plays a significant role in determining the final properties of composites. However, the fundamental principles governing this effect have not been thoroughly explored. This study aims to fill this gap by evaluating how the surface wettability of SiO_2 micro particles influences the interface and the dielectric properties of epoxy resin composites. Surface modification by introducing fluoride groups was applied to alter the wettability of SiO_2 particles from hydrophilic to superhydrophobic. The contact angle of these particles was tested to confirm the effectiveness of the modification. Then epoxy resin-SiO_2 composites incorporating 5 wt.% SiO_2 particles with different wettability were prepared. Dielectric tests, including measurements of permittivity and resistivity, along with electrical tree growth tests, were conducted on these composites. Distinct dielectric properties were observed between these two sets of composites. A significant increase in resistivity was observed in epoxy resin with superhydrophobic SiO_2. Additionally, their permittivity and dielectric loss slightly increased due to the formation of voids or imperfect interfaces. Difference in electrical tree growth patterns further demonstrated the influence of filler wettability on dielectric performance. These findings suggest that controlling the surface wettability of SiO_2 particles in epoxy resin significantly influences the dielectric properties of the material, offering a novel approach to designing advanced composites for electrical insulation applications.

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Influence of Si3N4 on Molten Salts Corrosion Resistance of Sealing Treated APS YSZ Coatings by AlPO4-based Composite Sealing Agent

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: YSZ, molten slat corrosion, plasma spray, sealing treatment

Corrosion failure of thermal barrier coatings (TBCs) system will be generated during the service process of hot section components, such as turbine blades, vanes, and combustion chambers, for the generation vanadate or sulfates by the impurities in the low-quality fuel at high temperature. While, sealing treatment is an effective way to restrain this corrosion of the TBCs. In this work, $AlPO_4$ composite sealing agent with various Si_3N_4 content are employed to seal the plasma sprayed YSZ TBCs. The microstructure, phase composition and corrosion resistance of the coatings with and without sealing treatment in Na_2SO_4 + V_2O_5 molten salt at 1200℃ have been investigated. After sealing treatment, the porosity of the coating is reduced and a protective film is formed on the surface of the coating. The thickness and weight change rate of the corrosion layer of the sealed coating were significantly lower than those of the untreated coating. With the increase of Si_3N_4 content, the corrosion degradation degree of the coating is decreased. During the corrosion process, the composite sealing agent hinders the entry of molten salt and the formation of corrosion products. Deeper and smaller cracks and pores filled by the generated SiO_2, and the volume expansion caused by the formation of SiO_2 further prevents $SO_4^{2-}$and V_2O_5 from reacting with Y_2O_3. Thereby the molten slat corrosion resistance of the YSZ coating is improved.

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Integrated design and performance research of stealth and anti/de-icing composite structure

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: anti/de-icing, composite structures, electrothermal film, grid structure, stealth metamaterial

In recent years, with the continuous development of the aviation industry, the aircraft is under threat with the enemy's multi-dimensional radar detection and surface icing during high-altitude flight, affecting combat survivability and flight safety. Therefore, exploring composite structures with both stealth and anti/de-icing functions has become a current research focus. This study firstly utilized multi-walled carbon nanotubes (MWCNT) to fabricate an electrothermal film, which was arranged in a periodic grid design to enhance its wave transmission performance while also ensuring effective surface anti-icing properties. And then the carbonyl iron powder/silicone rubber composite material was used to design the wave-absorbing stealth metamaterial. The results showed that when MWCNT content increased to 30 wt%, the maximum steady-state temperature of the film reached 160 ℃ and the heating rate reached 1.341 ℃/s, indicating the film had excellent thermal cycling properties. Also, the wave transmittance of the gridded electrothermal film in the 2-18 GHz frequency band was greater than 50%, particularly higher than 80% in the 2-8.88 GHz frequency band. In addition, the prepared stealth metamaterial had an absorption rate greater than 90% in the 1.3-18 GHz frequency band, corresponding to 173% fractional bandwidth, and had polarization insensitivity and wide-angle wave absorption performance. Finally, the stealth and anti/de-icing composite structure was systematically evaluated and the coupling mechanism of the gridded electrothermal film layer and stealth metamaterial layer was revealed.

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Investigating the Impact of Laser-Induced Periodic Surface Structures on the Microstructure and Properties of Metallic Surfaces

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Laser-Induced Periodic Surface Structures; microstructural; material properties

Laser-Induced Periodic Surface Structures (LIPSS), as a means of adjusting surface properties, can be used to enhance the surface performance of materials or components in various industrial applications, including medicine, optics, tribology, biology, and more. However, there is limited reporting on the microstructural evolution of the metal alloy matrix during the processing of LIPSS. This presentation will cover the concurrent impact on the microstructural evolution of metal alloys during laser processing of LIPSS structures. Additionally, the talk will discuss how the microstructural evolution of metal alloys during LIPSS processing influences material properties.

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Investigation of Tin-Doped Hydroxyapatite Thin Films

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Investigation, Propoerties, Sol-gel, Spin coating, Thin Films

In this work, we report the production of tin-doped hydroxyapatite (Sn-HAp) thin films for the first time. The films were prepared using a combination of the sol-gel, spin coating and high-temperature treatment at 500˚C with varied concentrations of tin (Sn) and spin rate. The thin films were subjected to advanced research methods such as scanning electron microscopy (SEM) to investigate their morphology, topography, and fractures along with approximate thickness values; X-ray energy dispersive spectroscopy (X-ray energy spectroscopy) to determine their chemical composition; atomic force microscopy (AFM) to measure their topography and roughness; sitting water droplet method to determine the water contact angle values; and spectroscopic ellipsometer to investigate the optical properties of the fabricated materials. The results obtained showed the formation of a continuous film with craking was obtained with Sn successfully incorporated. The introduction of Sn ensured an efficient adsorption of electromagnetic radiation as compared to pristine hydroxyapatite. The results obtained from this investigation allude to the fact the thin films produced are suitable for application as coatings for biomedical implants.

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Investigations of CrN/TiO2 coatings obtained in the hybrid PVD/ALD process on 316L steel substrates

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: 316L steel, ALD, Corrosion resistance, Hybrid coatings, PVD

Chromium nitride CrN is a coating material deposited by physical vapour deposition (PVD) to achieve both improved wear and corrosion resistance. However, in aggressive environments, such corrosion protection may not be sufficient. As a result of natural microstructural defects in the coating, such as microcraters, among others, the aggressive environment may come into contact with the substrate and consequently initiate and develop corrosion. In this study, the influence of parameters was investigated to obtain a TiO2 layer using the ALD technique. In a hybrid PVD/ALD coating on a substrate made of austenitic 316L steel, a TiO2 layer (ALD) was used as the sealant for the CrN coating (PVD). The TiO2 ALD layers were tested at a constant temperature of 200°C, deposited in a variable number of cycles, in the range of 200 to 1000 cycles. Structural investigations were carried out using scanning electron microscopy SEM and atomic force microscopy. Electrochemical properties were investigated using potentiodynamic spectroscopy and electrochemical impedance spectroscopy (EIS) in a 3.5% NaCl solution. Hybrid coatings (PVD/ALD) with titanium oxide deposited at 500 ALD cycles were found to have the best corrosion resistance. The polarisation resistance for this coating is Rpol=58 kΩ×cm² and the corrosion current density icorr=194×10-9 A/cm². In comparison, the corrosion resistance of single PVD (CrN) coatings is characterised by Rpol=12 kΩ×cm² and icorr=704×10-9 A/cm², and the corrosion resistance of the substrate without coating is Rpol=11 kΩ×cm² and icorr=541×10-9 A/cm². The corrosion mechanisms were investigated by observing the surfaces of the samples after corrosion testing by scanning electron microscopy SEM.

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Isostructural soft ceramic and superhard metallic Ti1-x-yMoxNy coatings fabricated via high-through magnetron sputtering

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: ThinFilms2024
Symposium: 3. Surface Treatment & Protection (STP)
Keywords: TiMoN coatings, dynamic Hall-Petch strengthening, plasticity, superhard, toughness

Chemical composition and microstructure are two key factors governing mechanical properties including hardness and toughness. However, the hardness and/or toughness mechanisms related to microstructure response during deformation remain less understood. Inspired by the VEC (valence electron concentration)-CEC (core electron count) solid solution hardening-toughening theory, a series of $Ti_{1-x-y}Mo_xN_y$ coatings were fabricated via a high-throughput deposition method, through which we are able to tune the composition and microstructure of the coatings. The resulting coatings are from soft (with hardness <10 GPa) to superhard (48 GPa) as Mo content rises while N content dramatically decreases to below 20 at%, as a result of much higher deposition rate and energy of Mo compared to Ti. The massive increment of hardness comes from enormous densification as Mo content become higher. More importantly, the superhard exhibit concurrent highest toughness characterized by high H/E value ~0.1 and metal-like ductility featured by apparent plastic pile-up at the edge of cube corner indent. The metallic features of the coatings are further verified by increasing fraction of Mo-Mo metallic bonding in XPS results. With strong metallic characteristic, dislocations are active in the extremely fine nanograin (24.9 nm), imparting high plasticity of the coatings. Simultaneous activities of nanoscale dislocation debris casues further grain size refinement down to 7 nm, giving rise to dynamic Hall-Petch strengthening. This work opens up new approach towards designing hard-yet-tough protective coatings.

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Knowledge-based Development of PVD Multicomponent and Nanoscale Multilayer Protective Hard Coatings

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Abstract ID: 10090
: ThinFilms2024
Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Hard coating; Mechanical property; Thermal stability; Multicomponent; Multilayer

Continuous advancements in surface engineering applications necessitate the development of novel material solutions that provide enhanced properties and performance. To achieve this, designs for advanced multifunctional materials can be systematically generated and confirmed through the use of physical vapor deposition (PVD). The continuing trend of the machining industry towards higher efficiency and productivity results in further increasing cutting velocities and feed rates. The tribological problems of machining tools for molding and cutting have triggered the development of protective AlTiN and AlCrN hard coatings. In recent years, a new class of nano-coatings has greatly benefited material scientists, providing them with an even more effective set of tools for engineering thin film design. This is achieved by combining the multilayer concept with new coatings that possess precise structural ordering at the nanoscale.

In this talk, the speaker will discuss the latest advancements in durable and wear-resistant thin films using the multilayer coating technique. A brief overview of the research on multilayers and dive into description of the current state-of-the-art in nanoscale multilayer thin films is provided. It is known that adding Si and B to coatings can effectively enhance their mechanical properties. Through combing the characteristics of Si and B, multicomponent and multilayer AlCr(X)N and AlTi(X)N coatings were prepared, and their thermal stabilities at high temperature up to 900 °C and 1000 °C were studied to align with the requirements of high-temperature applications. In addition, multicomponent high-entropy alloys (HEA) have been attracting significant research interest with good wear resistance and corrosion resistance. Our research group use cathodic arc deposition to synthesize the HEA and HEA nitride (HEAN) coatings, and the development of HEAN thin films will be discussed. The gradient, multilayered, and nanocomposite hard coatings show significantly improvement of the lifespan of cutting tools for difficult-to-cut materials.

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Laser surface texturing of SS304 substrate for improving coating adhesion performance

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: ThinFilms2024
Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Coating adhesion, Nanosecond pulsed fibre laser, SS304, Surface texturing

Laser surface texturing is a potential value-added process for improving the sol-gel coating adhesion through producing well-controlled surface profile patterns. This would replace currently used coating adhesion improving sand blasting that suffers from a number of disadvantages (dust generation, need to clean work piece after process, embedding of sand particles that reduces yield). In this paper, laser surface texturing on stainless steel (SS304) plates have been investigated with 1,06 um 100W ns pulsed fibre laser. Optimum laser process parameters and surface patterns have been identified in terms of the induced texture feature profile, surface roughness (Ra, Rz), and the coating adhesion performance on the textured SS plates. The performance of the sol gel coating on the laser textured SS plates were evaluated and discussed in terms of coating adhesion, surface hardness, IEC scratching resistance, corrosion resistance, in comparison with sandblasting process. The developed process has the potential to be applied in improving the reliability and lifetime of the sol-gel coated SS-based components and/or products.

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Lattice damage and optical properties in Nd:YLF single crystal induced by H ion irradiation

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Abstract ID: 10252
: ThinFilms2024
Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Ion irradiation; Waveguide; Single-mode

The neodymium doped Yttrium Fluoride has emerged as one of the most valuable functional-materials in fabrication of integrated devices, which transmits extends from ultraviolet to infrared. In this work, the neodymium doped yttrium fluoride crystal was irradiated by H ion at energy of 300 keV and fluence of 5.6×1016 ions/cm2. After H ion irradiation, the single-mode planar waveguide structure was fabricated. Elastic collisions between the irradiated H ions and target nuclei were reconstructed using SRIM software. The near-surface lattice structure change and damage were studied using the displacement per atom, X-Ray diffraction, and micro-Raman spectroscopy techniques. The related optical properties induced by the structural changes, including the absorption bands and refractive index profiles, were investigated. The waveguide characteristics at 633nm were studied by prism coupling and end-face coupling methods. The electrical properties of neodymium doped yttrium fluoride crystal before and after H ion irradiation at room temperature were evaluated by semiconductor parameter analyzers.

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Manufacture, Microstructure, and Mechanical Properties of Refractory Metal Nitride Coatings

by Y.C. Chang, Y.H. Liao, S.Y. Hsu, Y.C. Liu, Z.X. Lin, Y.H Yang, K.Y. Liu, W.C. Hsu, J.Y. Hsu, and F.B. Wu | National United University

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: HiPIMS, RMN coatings, input power, mechanical behaviour., microstructure, multiple phase

Refractory metal nitride, RMN, coatings have been developed for semiconductor, microelectronics, communication devices, and surface protections, due to their extraordinary characteristics and excellent performance. The microstructure, composition, phase, and structural feature of the RMN films were manipulated through fabrication parameter control, such as input power, inlet gas mixture, layered feature, and building layer thickness ratio. Versatile microstructures and phases, from amorphous, preferred orientation, nanocrystalline, nanolayered, and columnar structures were manufactured for comparison. The lower input power density less than 0.005 kW/cm^2 by radio frequency magnetron sputtering, RFMS, and/or higher N_2/Ar inlet ratio led to the amorphous phase for TaN and MoN films, while medium RFMS power around 0.01 kW/cm^2 and high power impulse magnetron sputtering, HiPIMS, over 0.5 kW/cm^2, triggered the formation of stable multiple phase feature. The binary RMN films, including MoHfN, MoTaN, and MoWN, were also investigated to figure out the effect of additive elements on the mechanical behaviour of the MoN protective layers. The MoHfN coatings showed a Mo-N dominated microstructure and solid-solution strengthening, while stable multiple phase structure were observed for the MoTaN and MoWN layers. The significant growth of WN columnar crystals both in width and length with W addition promoted its hardness and anti-wear behaviour. Strategically designed nanolayered RMN assemblies, like amorphous/crystalline TaN, amorphous/preferred-orientation MoN, and MoN/MoSiN coatings, were put into practice to extract the superior mechanical properties of RMN films. Testing results showed that the cut-off of continuous growth of through-layer columnar structure was realized and the nanolayered RMN films with intact interfaces exhibited tougher responses against mechanical failure.

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Mechanical properties of single phase (Cr1-x,Vx)N thin films

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Abstract ID: 10434
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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Chromium vanadium nitride, Hard coating, Pulsed laser deposition, Transition metal nitride

Chromium nitride (CrN) has attracted attention as a hard coating material due to its high hardness, corrosion resistance, wear resistance, and anti-oxidation. Vanadium nitride (VN) is also a hard coating material, and the mechanical properties of Cr-V-N ternary materials system in which VN is added to CrN to improve wear resistance have also been reported. However, in these reports, the grain sizes differ from each other and secondary phase such as Cr_2N and V_2N are also included. In this work, single phase $(Cr_{1-x,}V_x)N$ thin films were prepared and its mechanical properties were investigated in the absence of additional factors such grain size and secondary phase that could affect the hardness.

$(Cr_{1-x,}V_x)N$ thin films were deposited on MgO(001) single crystal substrates by pulsed laser deposition (PLD). The properties of thin films were compared with those of pure CrN(x = 0) and VN(x = 1) thin films. The composition of the thin films were determined by a combination of 2MeV He^{2+} Rutherford backscattering spectroscopy and X-ray fluorescence analysis. It is displayed that compositional ratio, x = 0, 0.12, 0.20, 0.61 and 1 and metal to non-metal ratio, (Cr+V)/N was 1.00±0.05 in all thin films. The phase identification of thin films were performed by X-ray diffraction, and it was confirmed that all the films were 002 oriented single phase $(Cr_{1-x,}V_x)N$ thin films and epitaxially grown on MgO(001) substrates. It was also confirmed that the presence of Cr_2N and V_2N were not detected. The hardness and Young's modulus of thin films were evaluated by nanoindenter. At x = 0.12, the hardness of the $(Cr_{1-x,}V_x)N$ thin film was 19% higher than that of CrN. Young's modulus also improved by 10% at x = 0.20. From these results, we conclude that the hardness increase in $(Cr_{1-x,}V_x)N$ was due to solid solution hardening.

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Micro/nanostructure-based surface modification of TiAl6V4 manufactured by selective laser melting process

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Abstract ID: 10143
: ThinFilms2024
Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Micro/nanostructure, Selective Laser Melting, TiAl6V4, slippery liquid-infused porous surface, superhydrophilic, superhydrophobic

The SLM (Selective Laser Melting) process is a technology for additive manufacturing complex metal parts. In addition, SLM processes are highly utilized in modern industries, and the types of metal powders available have also increased. This study is to develop a micro/nanostructure manufacturing method for medical TiAl6V4 manufactured by the SLM additive fabrication method. The SLM process is suitable for manufacturing medical artificial implants because it is possible to manufacture customized parts. However, it is known that the limitations of implants are lack of bone adhesion and some internal infections due to the surface. In order to improve these limitations, the micro/nanostructure manufacturing method was optimized for selective surfaces because microorganism adhesion, binding force to tissues, and bacteria prevention function are required depending on the contact area.

Micro/nanostructure fabrication of SLM TiAl6V4 was performed by etching through H_2SO_4 and oxidation using an aqueous NaOH 3M solution. The loss of materials and the imbalance of micro/nanostructure were prevented by optimizing etching/oxidation process conditions. In addition, the contact angle of SLM TiAl6V4 was measured to be less than 10 degrees and had superhydrophilic. After HDFS coating, the surface turned into superhydrophobic, and a high contact angle of 150 degrees or more was measured. Lubricant krytox was then applied to TiAl6V4 to complete the slippery liquid-infused porous surfaces (SLIPS).

Although several application-based studies have been conducted in modern industries using surfaces with various wet properties, these surface modification studies are rarely applied to TiAl6V4 fabricated by SLM process. In this work, we present various wettability modification methods for TiAl6V4, including superhydrophilic/hydrophobic surfaces and SLIPS formation.

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MULTIFUNCTIONAL SURFACES WITH SUPERWETTABILITY FOR MULTIPHASE SEPARATION

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: ThinFilms2024
Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Membrane; Separation; Wettability; Fiber; Coating

Inspired by the superhydrophobic lotus surface in nature, superwettability has attracted a lot of interest and attention in both academia and industry. In this present, theoretical models and fabrication strategies of superhydrophobic surfaces have been discussed in detail. The strategies for constructing fabric surfaces with an anti-wetting property are categorized and discussed based on the morphology of particles coated on the textile fibre. Such superwettability surfaces are demonstrated with promising self-cleaning, oil/water separation, self-healing, UV-blocking, photocatalytic, anti-bacterial, and special adhesion performances. Correspondingly, potential applications have been illustrated for multiphase separation. In each section, representative studies are highlighted with emphasis on the special wetting ability and other relevant properties. Finally, the problems and future challenges for practical applications were briefly discussed.

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Personal Information.

Dr. Yuekun Lai is a Fujian province “Minjiang Scholar” professor at the College of Chemical Engineering at Fuzhou University, China. Currently, He served as the Editor of Chemical Engineering Journal and section Editor-in-Chief of Polymers. His research interests focus on bioinspired functional films with special wettability, energy and environmental materials. He is selected as the 2018-2023 Clarivate Highly Cited Researchers, the recipient of 2016 Journal of Materials Chemistry A (JMCA, RSC) Emerging Investigators, 2019 Advanced Materials Interfaces (AMI, Wiley) Hall of Fame, 2023 Class of Influential Research (I&ECR, ACS) award, and has published more than 200 peer-reviewed SCI papers with over 20000 citations (H-index 82) and 6 book chapters.

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Novel biodegradable Ti-Ca-P based conversion coatings on medical magnesium alloy to improve corrosion resistance

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Abstract ID: 10411
: ThinFilms2024
Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Biocompatibility, Conversion coating treatment, Medical magnesium alloy, Simulated body fluid, Ti-Ca-P-based coating

Magnesium alloys have recently been attracting attention as a degradable biomaterial. They have advantages including non-toxicity, biocompatibility, and signifying them as one of the potential biodegradable implants. However, the fast degradation of magnesium and its alloys restricts its clinic application. Therefore, advanced developments on the surface modification of novel medical magnesium alloy composite materials were proposed on the requirements of clinical applications and modification technologies.

This study aims to utilize surface modified technology for medical magnesium alloy implants with uniformly stable biodegradation and bone healing. Advantages from this technology for magnesium break through the current medical magnesium alloy composite materials technical obstacles. The innovations of this study as following:

1. Ti-Ca-P-based coating can provide some degrees of protection from corrosion in the simulated body fluid and stimulate the attachment and differentiation of bone cells. The present study employed chemical conversion coating method to fabricate bioactive Ti-Ca-P-based coating on novel medical magnesium alloy composite materials.
2. After conversion coating treatment, the Ti-Ca-P-based coated medical magnesium alloy composite materials was characterized by SEM/EDS and its corrosion resistance was evaluated by polarization curves, EIS, and hydrogen evolution measurement in simulated body fluid (Hank balanced salt solution, HBSS).

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Preparation of Janus Particles with Large Wetting Contrast via Interface Assembly and UV Irradiation

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Abstract ID: 10005
: ThinFilms2024
Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Janus particle; Wetting state

Named after the Roman two-faced god, Janus particles are a class of materials that contain more than one property. Janus particles possess a great potential for a vast number of applications. However, despite decades of established research, the lack of commercialization of Janus particles is mainly hindered by the inability of existing methods to attain sufficient yields. In this work, we report methods to produce large quantity of Janus particles with contrasting wettabilities via a destructive technology through UV irradiation of particles with pre-functionalized coatings. Prior to the UV treatment, the particles are anchored at an interface. Semiconductor metal oxide particles are used due to their photocatalytic activity, which enable reactive species to be generated on the irradiated surface during the photodegradation process. Different alkylsilane-type surface functionalizations ranging from oleophilic-hydrophobic, oleophilic-superhydrophobic, to amphiphobic could be photodegraded. Owing to the unidirectional nature of light, only particle surfaces exposed to the light are photodegraded, leading to the recovery of the particles' intrinsically amphiphilic surface. This leads to the formation of Janus particles, which contain typically hydrophilic and hydrophobic surfaces. The obtained Janus particles are characterized based on their differences with unfunctionalized particles and fully-functionalized particles. A variety of techniques, including contact angle analysis, thermogravimetric analysis, Fourier transform infrared spectroscopy, electron microscopy, and self-assembly in immiscible systems have been employed.

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Preparation of phosphate superhydrophobic, superoleophobic, and superoleophobic adhesive coatings

by Cheng Zhenjun | Norwest University

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: phosphate superoleophobic adhesive phosphate coatings

Superhydrophobic materials have been widely studied for their unique properties such as self-cleaning and anti-icing. Most of the superhydrophobic coatings are difficult to fill with superhydrophobic, superoleophobic, and superoleophobic adhesive at same time. In this paper, nano silica particles modified by perfluorodecyltrimethoxysilane were introduced into the phosphate system. The phosphate anti bonding coating has good adhesive properties, with a water contact angle of 161 ° and a rolling angle of 2.4 °. with a oil contact angle of 150 °. And the wettability, microstructure, chemical composition, mechanical properties, wear resistance, conductivity, anti bonding performance, and compatibility between the coating and propellant were studied. It can been found micro nano porous structures and low surface energy with enough F elements are the key factor for the superhydrophobic, superoleophobic, and superoleophobic adhesive properties.

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Progress of surface engineering research on wear resistance of nuclear fuel cladding tubes

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Abstract ID: 10593
: ThinFilms2024
Symposium: 3. Surface Treatment & Protection (STP)
Keywords: nuclear fuel cladding□HTHP□Fretting wear □Surface Coating

The nuclear fuel cladding is exposed to high temperature, high pressure, high flow rate and strong radiation for a long time. The fuel rod has punching multi-form, multi-degree of freedom and multi-phase micro-amplitude movement with respect to the lattice, and the abrasion damage has become one of the bottlenecks restricting the improvement of the nuclear safety level. Deeply conduct systematic research around the fuel rod fretting abrasion, a key scientific challenge for nuclear safety, and reveal the research progress of fuel cladding wear resistance surface engineering under high-temperature and high-pressure water chemical environment, multi-dimensional composite motion mode and complex contact form coupling.

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Raman Spectroscopy Determination of Structures and Properties of 2D-M1-xM'xX2 and 2D-MX'2xX2(1-x) alloys

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Abstract ID: 10249
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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Raman Spectroscopy, coordination number., layered transition-metal dichalcogenides

The layered transition-metal dichalcogenides of MX_2 (M: transition metal atom; X: chalcogen atom) have attracted the attention of materials scientists in recent years due to their unique optoelectronic properties, defect engineering, and potential applications for integrated nano systems. Recent research progress in 2D ternary semiconductors has shown that their band gaps can be tuned gradually by changing their doping concentrations along with their structural, electronic, and optical properties. To further optimize the performance there is a need to characterize the structures of D-$M_{1-x}M'_xX_2$ and 2D-$MX'_{2x}X_{2(1-x)}$ alloys.

In our study, we employed an approach connecting the Raman shift frequency directly to the bond parameters for 2D-$M_{1-x}M'_xX_2$ and 2D-$MX'_{2x}X_{2(1-x)}$ alloys. By quantitative analysis of the Raman spectra of the monolayer 2D-$M_{1-x}M'_xX_2$ and 2D-$MX'_{2x}X_{2(1-x)}$ alloys, it was found that doping of large atoms resulted in an elongation of the bond length, an increase in the equivalent coordination number, and enhancement of the binding energy. The doping of small atoms led to a contraction of the bond length, a decrease in the equivalent coordination number, and a weakening of binding energy [1]. These results not only provide a theoretical guidance for the experimental measurements, but also widen the application range of the Raman spectroscopy.

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Recent Development in Interface Modification for Dissimilar Materials Joining

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: dissimilar materials, interface enhancement, laser surface treatment, mechanical properties

Dissimilar materials joining has been considered as promising technology for lightweight manufacturing in the fields of aerospace and automotive industries. It is challenging to enhance interface strength for dissimilar materials joining. This talk will cover our recent advancements in dissimilar materials joining, including metal-to-metal and metal-to-polymer joining technologies, with the emphasis on interface modification. Both metallurgical bonding and mechanical interlocking methods will be discussed. Moreover, fundamental mechanism of individual laser technique will be discussed to explore its capability for practical applications.

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Robust and photothermal polyurea coatings with self-repairing ability for anti-icing/de-icing and long-term corrosion protection

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Icephobic coating, Photothermal, Polyurea, Robustness, Self-repairing

Ice formation and accumulation on the surfaces of aircraft, wind turbines, and boat hulls result in serious economic losses and catastrophic accidents. Photothermal icephobic surfaces have the potential to become ideal anti-/de-icing materials due to their passive icing delay, low ice adhesion, and active photothermal de-icing performance. However, fabricating photothermal icephobic coatings with robustness and self-repairing ability remains a significant challenge. In this study, a robust and photothermal polyurea coating (RPPC) that shows rapid photothermal self-repairing, excellent mechanochemical durability, exceptional passive anti-icing and active de-icing was prepared by combining polyurea matrix, photothermal materials, and a deliberate lubricant agent. The surface morphology, chemical composition, wettability, mechanochemical robustness, photothermal anti-/de-icing, and anti-corrosion performances of RPPC were studied by various techniques and methods. The surface temperature of the fabricated RPPC can rise to 65.7 ℃ under 1 sun and achieve rapid self-repair. In addition, ice did not form on RPPC even at -10 ± 1 ℃ under 1 sun and photothermally de-frost (194 s) and de-ice (395 s). RPPC remained icephobic even after 3000 Taber abrasion cycles, 50 icing/de-icing cycles, 72 h UV radiation, and 72 h acid/alkali immersion. Furthermore, RPPC maintained excellent long-term anti-corrosion performance due to its photothermal self-repairing properties. This robust and photothermal polyurea coating with self-repairing properties paves the way for new-generation materials for aerospace, marinas, transportation, and other industrial and commercial applications with potential icing and corrosion concerns.

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Simulation-assisted design and optimization of patterned surfaces for enhanced water harvesting efficiency

by Chen Xingyu | Wei Lan | Chen Zhong | Nanyang Technological University | Nanyang Technological University | Nanyang Technological University

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Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Water harvesting, hydrophilicity/hydrophobicity, simulation, surface patterning, wettability

The imminent global water shortage crisis, with a projected two-thirds of the world's population facing water shortages by 2025, has intensified the need for innovative freshwater collection methods. This study investigates water condensation behaviors through a combination of simulations and lab experiments conducted on surfaces with single and patterned wettabilities. Glass slide surfaces were functionalized by a cost-effective, vacuum-free, and scalable sol-gel process with different wettabilities and roughness to lay a foundation for this research. Atmospheric water harvesting efficiency was quantified using a Peltier cooling stage and an analytical weighing balance. To gain a deeper understanding of the condensation findings, the surface energies were measured and calculated using a contact angle goniometer, while the morphologies of diverse surfaces were characterized by FESEM and AFM. Observations of trade-offs in single surfaces between droplet transportation (preferably on hydrophobic surfaces) and growth (preferably on hydrophilic surfaces) highlighted the importance of surface patterning. To delve deeper into the working mechanisms, a multi-faceted approach was employed, integrating experiments with Molecular Dynamics (MD) and Python simulations. MD unveiled water vapor nucleation behaviors on different wetting surfaces and under electric fields. The integration of MD data into Python facilitated the visualization of condensation at the micron level and enabled precise calculations of harvesting efficiency on diverse patterned surfaces. Validation through the fabrication of patterned surfaces, using hydrogen/nitrogen plasma treatment covered by 3D-printed masks with various sizes and shapes, affirmed the practicality of our findings. This study provides valuable scientific insights for designing future surface patterns for atmospheric water harvesting.

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Solid-liquid-ice interface for aircraft anti/de-icing materials

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: ThinFilms2024
Symposium: 3. Surface Treatment & Protection (STP)
Keywords: Icephobic; Interfacial behavior; Multifunctional materials; Liquid-repellent surfaces; Anti-icing materials; Micro/nano roughness.

In recent years, the advancement of learning algorithms has shifted the focus of molecular simulation from icing processes to more complex predictions of anti-icing material properties. However, hindrances still exist in the rational design of high-performance anti-icing materials. The interfacial interaction behavior between pre-icing droplets and solids highlights the importance of incorporating special micro/nano structures into efficient anti-icing materials. When certain interface conditions fluctuate, it may lead to unavoidable icing. To combat this irresistible process, ultra-low ice adhesion and integrated active/passive anti-icing materials are used. By review the generation and transformation of these interface phenomena, summarize the various methods for designing anti-icing materials.

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Study on low-temperature plasma nitriding and properties of carbon steel with structural defects induced by fast multiple rotation rolling

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Abstract: In this paper, the surface defects of 45 steel were induced by the fast multiple rotation rolling (FMRR). The low-temperature plasma nitriding was then processed on the surface of 45 steel at 480℃ for 4h, 6h, and 8h, respectively. After that, the corrosion behavior of the nitriding layer was investigated. The results show that structural defects such as high-density dislocations, amorphous phase, and deformation twins appear in the surface layer of 45 steel after FMRR. Moreover, the surface grain deformation is observed within the depth of 100 μm. Nanograins were also produced in the surface layer with a mean size of 10 nm. After low-temperature plasma nitrification, nitrogen compound layer was formed on the surface of 45 steel with an average depth of 4μm, 6μm, and 8μm, respectively. The main phases of the nitrogen compound layer are Fe_3N, Fe_4N, and $Fe_{24}N_{11}$. Besides, after low-temperature plasma nitrification, the surface of 45 steel obtained the simultaneously enhanced microhardness (270 HV-650 HV) and the corrosion resistance (E_{corr}=-500mV). The structural defects and nanostructures in the surface layer after FMRR provide more energy and structural conditions for the subsequent low-temperature plasma nitriding, which has the potential of the protection of some marine devices with higher abrasion performance requirements.

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Study on the wear resistance and thermodynamic stability of (MNbTaZrTi)N (M=Cr, Hf) high-entropy nitride coatings at elevated temperatures

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One of the major challenges faced by high-temperature titanium alloy components in applications is wear. Designing and preparing a highly wear-resistant and oxidation-resistant coating remains a longstanding technical challenge. In this study, (MNbTaZrTi)N (M=Cr,Hf) high-entropy nitride coatings were developed on the basis of the (TaNbZr)N system using first-principles calculations. The effects of Cr and Hf on the phase stability and performance of nitride ceramics were systematically investigated. Additionally, (MNbTaZrTi)N high-entropy nitride coatings were prepared on titanium alloy surfaces using the double-glow plasma surface alloying technique, followed by high-temperature friction and wear tests. The study indicated that the introduction of Cr and Hf further improved the mechanical properties and thermodynamic stability of nitride ceramics. The (MNbTaZrTi)N high-entropy nitride ceramics exhibited better comprehensive performance at high temperatures. Furthermore, the mixed transition metal oxides at high temperatures significantly enhanced the friction performance of titanium alloy surfaces, reducing the wear rate by an order of magnitude in the ball-on-disc friction test at 700°C (~ 10^{-5} mm^3/N•m). This study will provide valuable guidance for the design and development of new wear-resistant and oxidation-resistant high-entropy nitride ceramic coatings.

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Surface defect engineering on the improvement of photoelectrocatalytic performance

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Keywords: biomass valorization, photoelectrocatalysis, surface catalytic efficiency, surface defect, water splitting

Surface defect engineering stands out as a potent strategy for enhancing the performance of photoelectrocatalysts, promising significant advancements in energy and environmental applications. This abstract delves into the transformative potential of point defects, such as vacancies and atom doping, in improving efficiency and selectivity in photoelectrocatalytic applications such as water splitting and biomass valorization. Our investigation of BiVO4 and Fe2O3 photoanode materials revealed that element doping or introducing vacancies can effectively facilitate charge transfer on the photocatalyst surface. This process introduces novel reactive sites, amplifies reactivity, and increases their numerical abundance, consequently enhancing the surface catalytic efficiency of the water oxidation reaction. Building upon these insights, we demonstrate the synergistic benefits of tungsten-titanium dual doping, leading to the development of highly efficient bismuth vanadate materials with notable improvements in charge separation efficiency and a reduction in the surface reaction barrier energy of water oxidation. Moreover, we highlight the pivotal role of advanced characterization techniques in elucidating the structural, morphological, and electronic changes induced by surface defects. In-situ electrochemical characterization of the surface states indicates that element doping or vacancies can indeed introduce reactive sites on the photocatalyst surface. Furthermore, surface defects may also contribute to enhancing the product selectivity of biomass-based feedstock oxidation to value-added chemicals. For instance, our research suggests that oxygen vacancies in hematite play a crucial role in controlling the selectivity of glucose to formate. We discuss the mechanisms supported by surface defects through Density Functional Theory (DFT) calculations. This nuanced understanding not only broadens research horizons in surface point defects but also enables the design and optimization of efficient and sustainable photoelectrocatalytic systems, thereby driving forward the transition towards a greener and more technologically advanced future.

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Surface Integrity Enhancement of Metallic Coatings Produced by Direct Energy Deposition

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Keywords: Cold-Working, Hammer Peening, Inconel 718, Laser-Cladding, Protective Coating, Surface Integrity Enhancement

Surface engineering and protective coating has been attracting increasing attentions in recent years along with the requirement for sustainable eco-system. Out group has been focusing on fundamentals of surface enhancements and coating with various technologies, ranging from atomic layer deposition, chemical/physical vapor deposition, to direct-ink writing, plasma electrolytic oxidation, and direct energy deposition (e.g., laser cladding and twin-wire arc spray). IN this invited talk, we will be presenting our recent research observations on robotic hammer peening of laser-cladded Inconel 718 coatings.

Inconel 718 coatings deposited by laser-cladding (LC) on low-alloy steel substrate have been grinded followed by robotic hammer peening (RHP). White layer (WL) consisted of nanograins, smaller than 100 nm, has been observed on the surface accompanied with a deformation layer (DL) underneath after grinding and RHP. By increasing the RHP strength (i.e., both the impact energy and the dent overlap), the residual tensile stress (RTS) measured by X-ray diffraction from the surface of the coating has been monotonically reduced and eventually converted to residual compressive stress with increased in-plane anisotropy, which was accompanied with monotonically increased surface hardening up to 40.5 HRC. Grain deformations have been induced in the WL and DL, they are dominated by twinning and slipping, respectively. In terms of depth-dependent distributions of low-angle (< 15°) grain boundaries and hardening, the effective cold-working thickness induced by the RHP process is over 1000 mm, which is close to the thickness of a single-pass LC deposition. Onset of porosity closures occurred upon the RHP process, especially in the near-surface regions. These findings shed light on integrity enhancement for additive manufacturing of metal alloys by LC-based techniques through introducing interpass RHP process.

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Surface modifications of Mg rare earth alloys by high current pulsed electron beams

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Keywords: High current pulsed electron beam (HCPEB); Surface modification; Mg rare earth alloys; Corrosion

High current pulsed electron beam (HCPEB) treatment is a recently developed technique for surface modifications of metallic materials [1]. The pulsed electron beam induces non-equilibrium processes, such as rapid heating, melting and evaporation, followed by fast cooling in the surface layers of treated materials. As a result, improved surface properties of materials, often unattainable with conventional surface treatment techniques, can be achieved. In this work, several Mg-Rare earth alloys were chosen to be treated by HCPEB with the aim of improving their surface properties [2-4]. The microstructure, composition and phase components in the surface layers before and after HCPEB treatments were carefully characterized. It is shown that Mg-RE intermetallic phases in the treated surface layer were dissolved during the HCPEB treatment and nano-precipitates formed after treatment, leading to the homogenization of chemistry and microstructures in the surface layer. Property measurements showed that microhardness increased in the surface layer and corrosion resistance were significantly improved after HCPEB treatments under proper parameters.

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Surface problems and improvement of modified tungsten used in nuclear fusion reactor

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Keywords: Nuclear fusion; Divertor; Plasma facing materials; Modified tungsten; Application

The plasma facing materials related problems must be resolved in engineering and commercial uses for future fusion reactors. The divertor is one of the critical components in the nuclear fusion device. The plasma-facing components of the divertor have to withstand the synergy of the strong heat flow from the high-temperature plasma, the strong particle flow and the strong neutrons, which will not only cause damage to the plasma-facing materials, produce impurities, pollute the plasma, and cause plasma energy radiation loss and reduced plasma confinement performance, while the recirculation of fuel particles trapped on the wall directly affects plasma density control.

The main function of the divertor is to discharge the heat flow of the main plasma and the inadequately reacted plasma and the reaction product helium ash. Tungsten (W) is considered as one of the most promising candidates for plasma-facing materials in future nuclear fusion devices due to its merits of high melting point, high thermal conductivity, low sputtering rate and low deuterium/tritium retention. However, W has poor oxidation resistance, and following the loss-of-coolant accident (LOCA) accompanied by vacuum chamber rupture, neutron-irradiated W rapidly oxidizes and sublimates, exposing the fusion device to the risk of nuclear radioactive leakage. In view of the future fusion reactor with the characteristics of higher thermal load, longer pulse and high energy neutron irradiation, the steady-state control of plasma and plasma-facing materials interaction still faces severe challenges, and it is urgent to develop and study higher performance plasma-facing materials of divertor. A variety of studies have been reported on the preparation of tungsten materials and their modification and performance evaluation. The author summarizes the composition, microstructures and performances of modified tungsten to be applied in the future nuclear fusion reactor.

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Surface treatment and interface control of compound semiconductor-based materials for electronic devices

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Keywords: dielectric, hard x-ray photoelectron spectroscopy, nitride, oxide, surface passivation

With the miniaturization of electronic devices, surface and interface treatments are becoming increasingly important in the formation of interfaces between dissimilar materials. In addition, photoelectron spectroscopy with different X-ray energies is a useful technique for the evaluation of surfaces and interfaces at the nanoscale. In this talk I will introduce surface passivation of nitride and oxide semiconductor materials and functional enhancement by interface control.

One of the problems in the application of GaN in devices is its high vacancy density and associated dangling bonds. The fabrication of high performance/high reliability GaN based devices requires the development of a method to passivate such defects. As an alternative, F has been proposed as an element that could terminate the dangling bonds. This approach has been investigated for Si and Ge. We apply F-based termination and dielectric materials to nitride semiconductors. As a result, the effects of NF_3 or F_2 gas annealing on epitaxially grown GaN and its interface with sputtered Pt have been studied using hard X-ray photoelectron spectroscopy (HAXPES). Annealing of GaN and Pt/GaN samples in an NF_3 atmosphere resulted in the appearance of prominent F 1s peaks and chemically shifted Ga 2p peaks, indicating the efficient formation of Ga-F_x species not only in the bare GaN surface but also in the Pt/GaN interface, even when the NF_3 treatment was performed after Pt deposition. In contrast, F_2 annealing also resulted in fluorination of the GaN surface and non-fluorination of the Pt/GaN interface. The results of this study suggest that NF_3 treatment is an effective post-processing method for fluorination of GaN-based systems before or after metal deposition.

In the talk I will also present HAXPES studies on stacking structures of oxide based materials for electronic devices.

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The investigation of laser conditions on the surface properties for AZ31 Magnesium Alloys

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Keywords: Conversion coating, Corrosion resistance., Laser surface treatment, Magnesium Alloys

his research explores a novel green and efficient surface treatment process for magnesium-aluminum alloy through laser modification, eliminating the need for substantial acidic or alkaline waste solutions. The study incorporates a manganate passivation treatment system to investigate the growth and corrosion prevention mechanisms of the resulting surface film. The impact of process conditions on the growth mode of the surface film is systematically examined, with adjustments made to the chemical conversion solution and process parameters to align with industrial application requirements.

Results indicate that laser treatment of AZ31 magnesium alloy surfaces effectively removes oxides, slightly increases surface roughness, and induces grain refinement. The corrosion current density decreases significantly, and a smoother surface morphology is achieved. Laser-treated specimens demonstrate the ability to rapidly form a manganate conversion film with fewer and denser pores. Optimal laser parameters yield a more complete and dense conversion film, enhancing the corrosion resistance of the magnesium alloy, as evidenced by a 45-fold reduction in corrosion rate and minimal corrosion spots after a 72-hour salt spray test. The study extends its application scope by simulating large-scale magnesium alloy component surface treatment processes. Laser-treated magnesium alloys, when subjected to brush coating conversion solutions, form a passivation film, further highlighting the versatility and applicability of laser treatment in improving corrosion resistance. Overall, this research contributes valuable insights into the development of eco-friendly and efficient surface treatment methodologies, with laser modification showing significant promise for enhancing the corrosion resistance of magnesium alloys in various industrial applications.

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The Potential of Kapok Fibers as Customizable Sorbents with Reduced Secondary Waste

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Keywords: adsorption, conducting polymers, kapok

Kapok fibers are low-economic-value fibers that are endemic in South Asian countries like the Philippines. Kapok fibers are light and buoyant, with naturally high surface area owing to their tubular structure. Such a structure presents an advantage when applied to remove and recover various pollutants in wastewater. Additionally, kapok fibers are a renewable resource and biodegradable, which could limit the amount of secondary waste generated by the adsorptive removal of contaminants. This work presents the different surface modifications performed on kapok fibers to produce customizable adsorbents targeting different pollutants, from heavy metals (Cu, Pb), dye (methylene orange, methylene blue), oils, and organic solvents. Adsorbing polymers, such as polyacrylonitrile and polyaniline, were deposited on the surface of kapok fibers to reverse their wetting properties from hydrophobic to hydrophilic. This leads to adsorption capacities of about 90 mg/g for Cu and methylene blue. Semiconducting oxides, such as TiO2 and ZnO, were also added to allow the photodegradation of dyes under UV irradiation, leading to a 20% increase in performance. The kapok fibers were also modified with calcium stearate, resulting in adsorption capacities up to 4000% of its weight. We will also present our preliminary results on the applicability of these fibers in marine oil spills, as well as the treatment of spent kapok fibers by biodegradation.

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Zn2TiO4-ZnO Heterostructure Fabricated by Unilateral Diffusion on Titanium to Achieve Dual Functions of Osteogenesis and Preventing Bacterial Infections

by Ihsan Ullah | Weizuo | Huaqiong Li | The Affiliated Xiangshan Hospital of Wenzhou Medial University | The Affiliated Xiangshan Hospital of Wenzhou Medial University | Wenzhou Institute, University of Chinese Academy of Sciences

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Keywords: Antibacterial, Biocompatibility, Thermal diffusion, Titanium oxide, ZnO nanorod, implants

Implant-associated infection and lack of osseointegration are the major causes of orthopedic implant failures. Herein, a crystal-damage-free method of nanoengineering has been proposed to endow conventional Ti-based implants with antibacterial and osteogenic properties. To this end, the hydrothermally grown ZnO nanorods on Ti samples were polymerized with polydopamine (PDA) and decorated with titanium oxide thin shells, where core ZnO was unilaterally diffused into the TiO_2 nanoshell for the fabrication of thermodynamically stable Zn_2TiO_4 heterostructure. The PDA layer was employed as a sacrificial template to construct the hybrid Zn_2TiO_4 structure within a thin carbon layer. This designed hybrid nanorods not only induced the osteogenic performances of MC3T3-E1 cells but also exhibited excellent antibacterial ability against *S. aureus* and *E. coli* bacteria, which are attributed to the physical penetration of nanorods, slow Zn^{2+} release, as well as the different sensitivity of osteoblasts and bacteria to the surrounding microenvironment. Similarly, the *in vivo* studies also revealed that the duplex ZnO@TiO_2-6 nanorods can eradicate the peri-implant bacteria (90%) and the elicited inflammatory response is limited. In contrast, the Ti implants are short of bacteria-killing capability and the ZnO nanorods are antibacterial but pro-inflammatory, both of which after implantation will lead to thick fibrous encapsulation and numerous inflammatory cells within. Altogether, the ZnO@TiO_2-6 nanorods constructed on Ti can provide sufficient anti-infective and osteogenic properties simultaneously, hence holding great potential for the development of advanced orthopedic and dental implants.

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