Advanced Surface Engineering Division
Room Oregon Ballroom 203-204 - Session SE-TuP
Advanced Surface Engineering Poster Session

SE-TuP-1 Characterizations and Drill Performance of AlCrCn Coatings Deposited by High-Power Impulse Magnetron Sputtering, *F. Yang,* National Taiwan University of Science and Technology, Taiwan*; B. Lu, J. Tsao,* Ming Chi University of Technology, Taiwan*; Y. Kuo,* National Taiwan University of Science and Technology, Taiwan*; **Chi-Lung Chang**,* Ming Chi University of Technology, Taiwan

In recent years, the production capacity of printed circuit boards (PCBs) has increased significantly resulting in an increase in the demand for micro drills, especially in the requirements of wear-resistant properties. Therefore, various PVD technologies are applied, especially the high power pulsed magnetron sputtering (HiPIMS) technology has the most potential for application, which due to the high ionization rate leads to high density and high mechanical properties of the thin film.

In this study, AlCrCN coatings were prepared via HiPIMS with four Al70Cr30 targets and two Cr targets, with a focus on the effects of carbon content and substrate bias on the microstructure, mechanical properties, and drill performance of the coatings. FE-SEM revealed the interlayers designed to improve adhesion strength from 10 N up to 58N. The highest hardness (3045 Hv) and highest adhesion force (58 N) were obtained by increasing the bias voltage (－75 V) with a carbon content of 9.4 at%. The drill test results showed better wear resistance and useful lifetime than CrAlN coating for PCBs application.

SE-TuP-2 Fabrication of FeCrAlY-Al_2O_3 Composite for Additive Manufacturing, ***Hsin-Mei Kao**, K. Son, S. Yang, N. Ghanadi, S. Pasebani, B. Paul, C. Chang,* Oregon State University

FeCrAlY is commonly utilized because of its exceptional oxidation resistance, whereas alumina ceramics are valued for their high fracture toughness, resistance to wear, and corrosion[1]. Therefore, developing Al_2O_3-FeCrAlY composites is a promising approach for engineering applications requiring high temperature and strength, such as engines, solid oxide fuel cells, thermal barrier coatings, and catalytic supports[1-2]. The production of these composite powders involves using multiple materials or phases subjected to physical or chemical treatments such as ball milling and fluidized bed chemical vapor deposition to synthesize homogeneous powders. These fabrication processes have produced many functional materials, such as ceramics, metals, and composites, which possess improved mechanical, thermal, or electrical properties[1]. However, these methods are very time-consuming and expensive.

In this study, we investigated a new method to synthesize spherical composite powders consisting of FeCrAlY powders with Al_2O_3 coatings, which are used as feedstock materials for metal additive manufacturing. Chitosan is used as a binder to hold FeCrAlY and Al_2O_3 together, and then the mixture is spray-dried into spherical composite powders. We tailored the sizes and microstructures of the FeCrAlY-Al_2O_3 composite by controlling various parameters such as material content, mixing, flow rates, and reaction temperature. By engineering these composite powders, we can improve the uniformity of material distribution and reduce powder denudation while printing complex structures using metal additive manufacturing technologies. This approach creates a bi-continuous FeCrAlY and Al_2O_3 structure after laser melting and annealing. Furthermore, Al_2O_3 acts as a templating material, which can be selectively etched away, resulting in a highly porous FeCrAlY structure with a large surface area. The composite powders' and printed structures' structure and surface properties were characterized using X-ray diffraction, X-ray 3D tomography, Brunauer-Emmett-Teller analysis, Scanning Electron Microscopy, and Energy Dispersive X-ray Spectroscopy techniques.

References

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SE-TuP-3 Avoiding Mistakes During the Nanoindentation of Coatings, ***Esteban Broitman**,* SKF B.V. - Research and Technology Development, Netherlands

Nowadays, nanoindentation has become a routinely technique for the mechanical characterization of thin films and small-scale volumes. Thanks to the development of friendly analysis software and advances in high sensitive instrumentation, it feels like the measurement and calculation of hardness and elastic modulus can be easily done by just *"the pushing of one button."* However, the consequences of easy procedures have led many researchers to multiple publications with erroneous data.

Recently, we have reviewed the nanoindentation hardness of materials at macro, micro, and nanoscale (E. Broitman, Tribology Letters, vol. 65, 2017, p. 23). Some misconceptions in the nanoindentation technique were highlighted, and solutions to errors were proposed. In this presentation, five typical mistakes in the measurement and data analysis during the nanoindentation of thin films will be critically reviewed, and the possible ways to avoid them will be discussed: 1) the wrong area selection to calculate instrumented indentation hardness; 2) the wrong data conversion from Vickers microindentation to Berkovich nanoindentation; 3) the confusion of thermal drift with creep and viscoelastic effects; 4) the wrong correlation of hardness with tip penetration; 5) the preconceptions about a direct relationship between elastic modulus and hardness.

The origins of the aforementioned mistakes will be elucidated from the lack of understanding on contacts mechanics theory, the limits and validation of the Oliver and Pharr's method, and preconceptions transmitted from generation to generation of nanoindenter users. At the whole, it will be stressed that it is not enough to know *"how to push the start button of the nanoindeter"* in order to measure the nanoscale mechanical properties of coatings.

SE-TuP-4 Plasma Deposited Si-Rich Silicon Nitride: Deposition, Characterization, thickness scaling limitation and applications in Cap/Passivation of Advanced nano Devices, ***Son Nguyen**, V. Pai,* IBM Research Division, Albany, NY*; Y. Yao,* IBM Corporation, East Fishkill Facility*; M. Rizzolo, A. Dutta, D. Canaperi,* IBM Research Division, Albany, NY*; U. Sharma,* IBM Research Division, Albany, NY (IBM Intern**)

Most current nano-electronic devices are using final composited SiNx-SiOy layer to prevent moisture penetration in final devices prior to chip packaging (1). Silicon nitride (SiNx) as a dielectric plays an important role in the semiconductor industry for many years. Si-Rich SiN have been evaluated over the years in electronic device application (2,3). With device scaling to sub-5nm dimension, both passivation and capping layers also needs to scale down to the sub-5nm thickness without compromising the following properties: 1) Excellent Oxidation and diffusion Barrier. 2) High Electrical Breakdown and Low Leakage Current. 3) High stability under thermal stress with low Hydrogen content. 4) Positive performance impacts to the passivating electronic devices including electrical and mechanical properties. 5) Conformal step coverage over high topological structure at low deposition temperature.

This work is focusing on the Si-rich SiNx as an encapsulation film and its ultrathin thickness limitation as oxidation barrier and encapsulation layers. Low-temperature (200° C -300°C) plasma enhanced chemical vapor deposition (PECVD) process was used to deposit Si-rich SiNx for encapsulation/capping of temperature sensitive nano-electronic devices. Deposition temperature impact on the Si-Rich SiNx capping film's electrical, conformality, oxidation and barrier properties of the films are evaluated with completed material compositional analysis vs film's performance. To obtain a good process at low temperature for encapsulation/capping of temperature sensitive nano-device, novel cyclic multilayers deposition/plasma treatment approach was developed. Ultrathin (3-4 nm) Si-Rich Silicon Nitride film with excellent conformality, oxidation barrier and passivation performance are achieved for passivation/capping with novel cyclic multilayer deposition/plasma treatment approach at low deposition temperature of 200 C and with > 80% conformality over high aspect ratio nanodevice structures. Carbon doped ultrathin (4 nm) SiN (SiCN) was also evaluated and achieved similar robust cap performance for nanodevice fabrication. These high-performance Si-Rich SiN and SiCN films have excellent potential for logic and memory nanodevice as passivation and capping layers.

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SE-TuP-5 Multifunctional Optical Surfaces Using Scalable Nanostructuring*,*
Iliyan Karadzhov*, J. Rombaut, C. Graham, A. Mezzadrelli, J. Arres Chillon,* Institute of Photonic Sciences (ICFO), Spain*; W. Senaratne, R. Bellman, D. Thelen, P. Mazumder,* Corning Research and Development Corporation*; V. Pruneri,* Institute of Photonic Sciences (ICFO), Spain

Current optoelectronic applications such as touchscreen displays, photovoltaic cells or lenses require surfaces that can possess multiple functions, for example, easy optical and/or electrical tunability, high transparency, self-cleaning properties, and antimicrobial properties, to name a few. Borrowing from designs found in nature such as the eyes of nocturnal insects or the lotus leaf, much progress has been made towards bio-inspired surfaces. Yet developing mass-scalable, and cost-efficient methods for fabricating multifunctional optical surfaces is still a major challenge due to the limitation of the existing nanofabrication methods that rely on traditional optical and e-beam lithography. In this talk, we review recent efforts from our group in developing optical surfaces based on the use of ultrathin metal films (UTMF) and solid-state dewetted nanoparticles (DNPs) as a scalable and lithography-free approach to confer functionalities such as high transparency, broadband and omnidirectional antireflection effect, self-cleaning properties, and antimicrobial properties.

Solid-state thermal dewetting of ultrathin metal films (Ag, Cu, Ni) has emerged as a viable strategy to obtain features down to few nanometers, therefore, it has great potential to be implemented as a fast and low-cost method in industrial scale nanofabrication. The dewetted nanoparticles on glass surfaces serve as a mask in creating nanopillars or nanoholes using dry etch process. Initial metal films thickness, temperature, and duration of the dewetting, and dry etching times are the parameters that give us morphological and optical control on the nanostructures. The structured surfaces present omnidirectional broadband antireflection effect with low scattering and have self-cleaning properties. Importantly, structures maintain their optical and wetting properties after repeated abrasion making them attractive to be used in consumer display devices. Moreover, when high aspect ratio nanopillars in fused silica are fabricated, we observe increase of the optical emissivity in the infrared range, which can be exploited for passive radiative cooling. The versatility of dewetted nanoparticles is also shown by using Cu DNPs to make transparent, antimicrobial surface.

SE-TuP-9 Investigating the Microstructure and Mechanical Behavior of the Particle-Particle and Substrate-Particle Interfaces in Cold Sprayed Coatings*,*
Tanvi Ajantiwalay*, S. Niverty, R. Kalsar, V. Joshi, A. Devaraj,* Pacific Northwest National Laboratory

During cold spray, powder particles undergo severe plastic deformation upon impact with the substrate. This results in particle flattening, oxide breakage, and metallurgical bond formation at particle-particle and substrate-particle interfaces. At smaller length scales, heterogeneity of the bond coating can create property differences, which are yet to be explored. Thus, a comprehensive understanding of local interfacial bond strength at this heavily deformed interface would assist in designing optimal cold spray processes. In this study, we investigated the microstructure and mechanical properties of zinc (Zn) cold sprayed on AZ91 magnesium (Mg) substrates via correlative microscopy and in situ micro-tensile testing.Micro-tensile dogbones fabricated using Plasma Focused Ion Beam (PFIB) were tested in a displacement-controlled mode to estimate the interfacial strength and live deformation behavior.

SE-TuP-10 Icephobic Coating Using Polymers/Silica Nanoparticles Composite via Self-Formation of Superhydrophobic Surface*,*
Aravind H. Patil, Incheon National University/ Korea Polar Research Institute, Korea (Democratic People's Republic of)*; N. Trinh,* Incheon National University, Korea (Democratic People's Republic of)*; H. Do,* Korea Polar Research Institute, Korea (Democratic People's Republic of)*; G. Seo, J. Wook Choi,* Seoul National University, Korea (Democratic People's Republic of)*; Y. Kang,* Incheon National University, Korea (Democratic People's Republic of)*; J. Lee, C. Chung,* Korea Polar Research Institute, Korea (Democratic People's Republic of)*; H. Lee,* Incheon National University, Korea (Democratic People's Republic of)

The accretion of ice has resulted in adverse impact on a variety of household, industrial, and polar research station activities. Despite significant efforts being made to prevent ice adhesion with different surfaces by developing various passive anti-icing coatings, it is still essential to enhance overall performance and durability. Herein, we report the designing of icephobic coatings through self-formation of 3D porous micro-nanostructure utilizing siloxane/fluoropolymer/silica nanoparticles (NPs). The spin coating method was used for coating PDMS/PTFE composite on aluminium (Al 6061) substrate. The excellent miscibility and adhesion in PDMS and PTFE were observed due to the secondary electrostatic interactions between H and F atoms. These interactions were supported by the density functional theory (DFT) calculations and structural studies. Moreover, the controlled addition of PTFE powder to PDMS improved the water-repellency properties, mechanical strength, and adhesion strength of the coating. The self-formation of superhydrophobic Cassie Baxter state of PDMS/PTFE composite was achieved by sprinkling SiO_2 NPs on it. The PDMS/PTFE/SiO_2 NPs composites, surface morphology images showed the formation of porous 3D micro-nanostructure that produces a highly textured surface with several trapped air pockets. These air pockets minimise the surface contact area with water droplets or ice, which enhanced the water contact angle (WCA) and reduced the ice adhesion strength (IAS). Additionally, we experimentally demonstrated that the freezing at low temperatures can be delayed by controlling the heat flow rate, interfacial contact area, and surface texture.These results suggest the feasibility of the method for a wide range of promising anti-icing applications.

*Corresponding author: hbrlee@inu.ac.kr [mailto:hbrlee@inu.ac.kr]

Keywords: Superhydrophobicity, Icephobicity, PDMS/PTFE composite, SiO_2NPs, freezing delay time

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