Surface Engineering - Applied Research and Industrial Applications

Room Sunset - Session G4

Pre-/Post-Treatment and Duplex Technology

Moderators: Hiroshi Tamagaki, NIRO (The New Industry Research Organization), Wan-Yu Wu, Da-Yeh University, Chris Stoessel, Eastman Chemical Company, Inc., USA

10:00am **G4-1 Mechanical Pretreatment before Electroplating of Aluminium Alloy AlSi12***, E Uhlmann,* ***Robert Jaczkowski****,* Technische Universität Berlin, Germany

Electroplating is a coating process which is used to increase the durability of workpieces or to change their appearance. To form a high adhesive bonding between the coating and the workpiece, its surface has to meet certain requirements achieved by a comprehensive pretreatment. The conventional pretreatment process chain consists of different steps to increase the roughness and the surface tension of the workpieces. For this process chain chemicals are used, which are harmful to the environment and health, besides their high costs.

The complexity of the pretreatment and coating process chain differs depending on the used workpiece material. Particularly challenging to coat are Aluminium-Silicon alloys. During the conventional pretreatment of these casting alloys, the Silicon phase enriches on the surface of the workpieces and has to be removed in an additional process step using nitric acid.

This study compares alternative mechanical pretreatment processes for AlSi12–workpieces prior to electroplating. The investigated processes are conventional grinding, double face grinding with planetary kinematics, lapping and dry ice blasting. Subsequent to the structuring, the workpieces are cleaned by carbon dioxide snow blasting. The investigation of the different surface structures and their properties, like roughness, surface tension and wetting behaviour, allowed the determination of their impact on the adhesive strength of the coating by empirical modelling.

By structuring the surfaces of the workpieces they could be coated by electroplating. As a result, the chemicals used in the conventional pretreatment could be substituted. Especially the creation of surfaces, which could be wetted homogenously, showed a satisfactory adhesive strength of the applied coatings. Concluding the study, a comparison of the economic performance of the mechanical and conventional pretreatment processes is created, which confirms the profitability of the mechanical pretreatment for small batch sizes.

10:20am **G4-2 Microstructure Characterization and Mechanical Properties of Gradient AlCrSiN hard Coatings Using Ternary Alloy Targets***, Y Chang,* ***Liang-Chan Chao****,* National Formosa University, Taiwan

Transition metal nitride coatings based on Cr and Al, such as CrN and CrAlN have been attracting great interest for industrial applications as protective coating materials due to their high hardness, impact resistance and thermal stability. CrAlN coatings show high hardness and high thermal stability together with excellent oxidation resistance. However, the properties of the CrAlN coatings may be further improved by addition of Si. The addition of Si suppresses the grain growth and refines it. In this study, AlCrN and AlCrSiN coatings were deposited onto high-speed steels and tungsten carbide tools using AlCr and ternary AlCrSi alloy targets in a Cathodic-arc evaporation (CAE) system. During the coating process of gradient AlCrSiN, CrN and AlCrN were deposited as interlayers to enhance adhesion strength between the coatings and substrates. By controlling the different negative bias voltages and cathode currents, the AlCrSiN via compositional grading and plasma etching possessed different microstructures and mechanical properties. The microstructure of the deposited coatings were investigated by field emission scanning electron microscope (FE-SEM) and field emission gun high resolution transmission electron microscope (FEG-HRTEM), equipped with an energy-dispersive x-ray analysis spectrometer (EDS), Glancing angle X-ray diffraction was used to characterize the microstructure and phase identification of the films. Mechanical properties, such as the hardness and young's modulus, were measured by means of nanoindention. The adhesion strength of the coatings was evaluated by a standard Rockwell indentation test. A ball-on-disc wear test was conducted to evaluate the tribological properties of the deposited coatings. In order to evaluate the impact fatigue behavior of the coated samples, an impact test was performed using a cyclic loading device with a tungsten carbide indenter as an impact probe. The design of AlCrSiN coatings were anticipated to increase the hardness, toughness, thermal stability and impact resistance by optimizing the coating architecture.

10:40am **G4-3 Integrated Shot Peening, Plasma Nitriding and Gradient PVD TiAlSiN Coating on AISI H13 Molds for Al Die Casting***, Venice* ***Mascariñas****,* University of the Philippines, Philippines*; D Quinto,* Beta Nanocoating Philippines Inc., Philippines*; A Salvador,* University of the Philippines, Philippines

Surface engineering that combines processes of a) external shot peening b) plasma nitriding and c) PVD coating – b) and c) comprising duplex treatment done in a continuous process in a commercial PVD cathodic arc machine – has proven to significantly improve the service lifetime of AISI H13 steel molds used for aluminum die casting. Microhardness profiles measured across a spherical taper section (calotte scar) gave a hardness of 2900 $HV_{0.05}$ for the 5 µm TiAlSiN-based multilayer coating while the hardness of the substrate gradually decreased from 1300 $HV_{0.05}$ at the surface across the 40 µm nitrided depth to 600 $HV_{0.05}$ of the base steel. XRD, SEM-EDS analyses confirmed the presence of $Fe_{2-3}N$ and CrN phases within the nitrided diffusion layer of the H13 steel. Shot peening effected by alumina particle microblasting resulted in enhanced nitriding. Rockwell indentation tests at different loads were utilized to compare the adhesion of TiAlSiN coating on the plasma nitrided and non-nitrided H13 samples. Coating removal along circumferential cracks was observed on the non-nitrided sample at 100 kg and 150 kg loads compared to no coating removal on the duplex-treated H13 steel at these loads. The mechanisms of performance improvement of duplex treated H13 molds subjected to thermal fatigue and tribological wear can thus be attributed to the synergies of 1) a high-temperature wear-resistant hard coating, 2) a nitrided layer of increased hardness and in compressive residual stress that inhibits cracking and gives higher load support to the coating against plastic deformation and delamination, and 3) prior shot-peening that enhances nitrogen diffusion during plasma nitriding.

11:00am **G4-4 Effect of Nano-penning Surface Texturing on Self-clean Function***, Nicolas Coniglio,* Arts et Métiers ParisTech d'Aix-en-Provence, Laboratory of Mechanics, Surface and Materials Processing (MSMP-EA7350), France*; S Mezghani,* Arts et Métiers ParisTech de Châlons-en-Champagne, Laboratory of Mechanics, Surface and Materials Processing (MSMP-EA7350), France*; M El Mansori,* Arts et Métiers ParisTech d'Aix en Provence, Laboratory of Mechanics, Surface and Materials Processing (MSMP-EA7350), France*; J Cabrero,* Saint Gobain, CREE, France

Surface texturation at micro and meso scales play an important role in applications where cosmetic, aesthetic and clean functionalities are specified. We are hence dealing with a multiscale surface, in which texturing and texture have a larger influence because they are scaled differently. In this research paper, an experimental method is illustrated to highlight the important effect on the anti-fingerprinting performance (i.e. surface hydrophobicity) rated in term of surface wettability. We examine first, in detail, the wetting response of surfaces textured on aluminum alloy 6063 plates using nano-peening with a range of processing parameters. Roughness was measured by atomic force microscopy (AFM) over a 100 x 100 µm² surface. In addition, the surface wettability was quantified by measuring the contact angles of different liquids using the sessile drop method according to the norm AFNOR EN 828. The calculation takes into account the wetting behavior of the textured surfaces at different scales. A correlation was made between the micro-scale roughness and the macro-scale apparent solid surface energy.

11:20am **G4-5 Hard Coating and Surface ModificationTechnologies for Piston Ring***, Hideaki Kamiyama,* Nippon Piston Ring Co., Ltd., Japan **INVITED**

The technology that achieves abrasion resistance and low friction is essential for improving the product features and the added value of slide members, which are used under severe conditions such as in a high-temperature and high-speed environment. Typically, abrasion resistance and low friction are achieved with the use of the deposition technique, which involves coating of a material surface with a hard coating, and/or the modification technique, which hardens the material surface itself.

A piston ring is an engine component fitted into the groove cut in a piston (piston groove), and moves in a reciprocating motion with the piston inside a cylinder. Specifically, a piston ring has two different surfaces: a surface that contacts the cylinder (peripheral surface), and a surface that contacts the piston (slide faces, or inside surface). These surfaces contact different materials, and different functions are required for these surfaces. It is accordingly very important to have possession of not one but many surface treatment techniques.

The deposition technique used for piston rings often uses chrome plating by a wet process, and CrN, and TiN coating by a dry process (Arc Ion Plating, AIP). Gas nitriding and salt bath nitriding are two processes commonly used for surface modification. Though the deposition and surface modification techniques are often used by themselves, these techniques are also used in combination depending on engine specifications.

In this lecture, we introduce a technology based on both deposition and surface modification, along with the recent composite technology.

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