Topical Symposia
Room California - Session TS2-1
Thermal, Cold, and Kinetic Sprayed Surface Coatings

Moderators: Pylin Sarobol, Sandia National Laboratories, USA, Charles Kay, ASB Industries, Inc., USA

9:00am **TS2-1-4 Thermally Sprayed Alumina and Ceria-doped-Alumina Coatings on AZ91 Mg Alloy***, **Sanjeet Kumar,*** ITMMEC, Indian Institute of Technology Delhi, India*; D Kumar, J Jain,* Indian Institute of Technology Delhi, India

Present study deals with the development of ceramic based coatings for Mg alloys using thermal spray technique, where Al_2O_3 is doped with CeO_2. Coatings characteristics and other responses were measured using microindenter, nanoindenter, scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), X-ray Diffraction (XRD) and tribometer. The tribological response is evaluated in terms of specific wear rates and coefficient of friction under lubricated reciprocating sliding condition for different loads and speeds. Ceria doped alumina coatings showed improved responses. The elastic modulus and nano-hardness of CeO_2 doped alumina coating was ~13% and ~53% higher than alumina coating, respectively. Under high load and velocity conditions, ceria doped coating showed ~40% reduction in specific wear rate. Also, the results suggest that ceria doping has helped in lowering the coefficient of friction during sliding. One may attribute this to the development of a new intermetallic phase.

9:20am **TS2-1-5 Langmuir–Blodgett Colloidal Assembly: Challenges and Solutions***, H Nie,* Donghua University, China*; **Jiaxing Huang,*** Northwestern University, USA

LB assembly has been routinely used in research labs for nearly a century for preparing molecular and colloidal monolayers. Volatile, water-immiscible solvents are convenient for spreading, but they have also been a "pain" in terms of colloidal stability, processability and chemical safety, making scaled up applications difficult. The use of water-miscible spreading solvents would avoid all of these problems, but it tends to lose most materials to water subphase due to intermixing, making such LB colloidal assembly ineffective and hard to standardize or reproducible.

This dilemma can be solved by electrospray spreading, in which the small volume of the microdroplets is readily depleted during initial spreading, leaving no extra solvent for mixing. As is demonstrated with several prototypical colloidal systems, electrospray allows high-yield, high-throughput spreading of colloidal materials on water surface using environmentally benign, water-miscible solvents (even water itself), which liberates this century-old technique from many constrains related to material processing and significantly expands its scope. Electrospray apparatus can be readily automated and fully integrated with existing LB systems, which should help to standardize this technique and scale it up from LB assembly to LB manufacturing.

9:40am **TS2-1-6 Mechanical Properties of Thermal Spray Coatings on Carbon-fiber-reinforced Plastic***, **Reinhard Kaindl,*** Joanneum Research, Austria*; M Kräuter,* Graz University of Technology, Austria*; P Angerer,* Materials Center Leoben Forschung GmbH (MCL), Austria*; W Stöger,* SECAR Technology GmbH, Austria*; M Traxler,* BVT Beschichtungs- und Verschleißtechnik GmbH, Austria*; J Lackner, W Waldhauser,* Joanneum Research, Austria

Due to exceptional properties like high strength and low weight carbon-fiber-reinforced plastic (CFRP) replace steel and aluminum in aerospace and automotive applications. However, the stability of CFRP against mechanical wear, corrosion and thermal load is limited. Thermal spray coatings are routinely used for the protection against extensive wear and/or high temperature, e.g. in power plant turbines, aircraft engines or on pulp rolls in the paper industry. The highly complex relationship between cohesion and adhesion, mechanical properties, structure and composition of course strongly influences the functionality of the compound substrate-coating material. In this contribution, scratch test derived cohesion of thermal spray oxide coatings on CFRP materials and influences of thickness, substrate and coating system will be presented.

Yttrium-stabilized zirconia (YSZ), titanium-aluminum (TiAl) and aluminum-silicon (mullite) coatings with a thickness between 0.15 and 1.4 mm were deposited by thermal spraying on a variety of CFRP materials. Scratch tests were performed using an Anton Paar micro scratch head on cross-sectioned samples embedded in resin. The tests were done with constant loads of 4, 8, 12, 16 and 20 N, scratch length 2 mm, at a speed of 2.4 mm/min with a 100 µm Rockwell C diamond indenter. Images of the cone fracture area were taken immediately after scratching and projected cone areas in µm^2 were calculated.

All cone fractures originated in the coating, confirming that the cohesion was tested. The projected cone area increases with increasing load, in most cases linear but depending upon thickness, substrate and coating system also discontinuous and exponential. This suggests the existence of different failure mechanisms. The lowest areas were observed for a coating thickness around 0.5 mm, both thinner and thicker layers resulted in increased values and decreased cohesion, respectively. The CFRP substrate seems to influence the mechanical properties of the coating. Highest cohesion was found for epoxy and phenolic resin systems. For other systems like sheet moulding compound (SMC), high temperature resins and ceramic particles in the CFRP matrix decrease of cohesion was observed. Differences were also observed for the three coating systems: the highest cohesion was found for TiAl, followed by mullite and YSZ. This is confirmed by the very low, non-economic deposition rates for YSZ during spraying.

In conclusion, scratch tests at constant load allow achieving best functionality against wear and abrasion of thermal spray coatings on CFRP materials by characterizing the cohesion and influences of thickness, substrate and coating system.

10:00am **TS2-1-7 Developments in the Understanding of the Fundamental Growth Mechanisms of Aerosol Deposition***, **Scooter Johnson,*** Naval Research Laboratory, USA*; D Park,* Korean Institute of Material Science, Korea*; Y Park,* Pukong National University, Korea*; D Schwer, E Gorzkowski,* Naval Research Laboratory, USA **INVITED**

Aerosol deposition is an emerging technologically relevant technique to produce thick polycrystalline films at room temperature. While there have been many materials deposited by this method; including, ceramic, metallic, and even organic compounds for a wide range of applications there is still a very poor theoretical understanding of the mechanics of the film growth. The current theory of film growth is postulated to occur by a mechanism of fracture and plastic deformation of the solid particle as it impacts with the substrate and/or as-deposited particles. This talk will provide an overview of the current understanding of the theory and practice of aerosol deposition along with a comparison between recent experimental results that attempt to correlate film growth, material properties, and deposition parameters.

10:40am **TS2-1-9 Aerosol Deposition as a Method of Room Temperature Thick-Film Deposition***, **Jesse Adamczyk**, P Sarobol, A Vackel, T Holmes,* Sandia National Laboratories, USA*; P Fuierer,* New Mexico Institute of Mining and Technology, USA

Creating thick (>5 µm) films of ceramics and metals typically requires high temperatures or reactive environments, limiting the integration of film/substrate materials possessing drastically different melting points. Thick films of both ceramics and metals can be deposited, using traditional thermal spray techniques. However, particle melting/solidification and splatting lead to a unique microstructure containing splat boundaries, porosity, oxide inclusions, and non-stoichiometric oxide formation. Moreover, melting/solidification can lead to loss of volatile elements, original crystal structure, and associated desired properties (e.g. BaTiO3 will lose its perovskite structure and associated dielectric properties after going through melting/solidification in a plasma spray process). The Aerosol Deposition (AD) process is being utilized to create readily integratable, high density thick-films of ceramics and metals on a variety of substrates at room temperature. In the AD process, thick-films are produced by spraying micron to submicron sized particles out of a nozzle and onto a substrate within a low vacuum chamber. AD takes advantage of the low pressure within the vacuum by allowing sprayed particles to maintain velocity and consolidate in solid-state (no melting/solidification), into a film on impact with the substrate and subsequent film. AD also takes advantage of the small particle size and the ability of ceramic and metallic particles to plastically deform and bond as coatings. Potential applications of aerosol deposition being investigated include direct applied Multi-Layered Ceramic Capacitors (MLCC), electrically conductive electrodes, thermally and chemically resistant barrier coatings, and electrically insulative films.

This work is supported by Office of Electricity and Laboratory Directed Research and Development Program at Sandia National Laboratories. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed

Martin Corporation, for the U.S. DOE's National Nuclear Security Administration under contract DE-AC04-94AL85000.

11:00am **TS2-1-10 Residual Stress Measurement of Aerosol Deposited Films**, ***Andrew Vackel***, *J Adamczyk, T Holmes, P Sarobol,* Sandia National Laboratories, USA

Aerosol Deposition (AD) is a room temperature, solid state coating process for synthesizing thick films, where sub-micron to micron sized powder is accelerated by a carrier gas through a nozzle towards a substrate within a vacuum environment, forming a coating by particle consolidation. The use of small particles and the reduced drag and bow shock from a vacuum environment allows for normally brittle materials, such as ceramics and carbides, to plastically deform and adhere to the substrate. One of the unique benefits of the AD process is the ability to deposit materials that typically have high melting temperatures or metastable phase compositions at room temperature, allowing material integration that would otherwise be prohibited by the need for high temperatures for processing. Additionally, thermal stress due to expansion mismatches between coating and substrate is eliminated. However, there is still a large degree of residual stress within AD films, due largely to the high kinetic energy impact of particles as the main consolidation mechanism for coating deposition. This talk will explore the use of in-situ substrate curvature measurement to calculate the deposition and residual stresses experienced by different materials in the AD process and how they relate to processing parameters, such as nozzle design, particle size, and process gases, in an effort to better understand and characterize AD coatings.

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11:20am **TS2-1-11 Microstructure and Properties of Room Temperature, Aerosol Deposited, Thick $BaTiO_3$ Dielectric Films**, ***Pylin Sarobol***, *A Vackel, J Adamczyk, T Holmes, M Rodriguez, J Griego, H Brown-Shaklee,* Sandia National Laboratories, USA

$BaTiO_3$ based dielectrics are being explored for high temperature stable capacitor applications to enable high power electrical switching devices. The high sintering temperature of $BaTiO_3$ (T>1000°C) often prevents successful integration with low melting point substrates such as glass, metal, or plastic. In this work, we demonstrate integrated high density $BaTiO_3$ based thick films at room temperature utilizing a novel, solid-state deposition process, Aerosol Deposition (AD). In AD process, high velocity submicron particles impact, deform, and consolidate as coatings on room temperature substrates under vacuum. The aerosol deposited $BaTiO_3$ film crystal structure, grain size, residual strain, and dielectric properties were investigated. Preliminary results showed an in-plane crystallographic strain in our AD films were determined to be ~1% by XRD analysis, which corresponds to an approximate compressive stress of 1GPa. The impact of this significant crystallographic strain on dielectric properties will be discussed. The ability to deposit dielectrics at room temperature will further enable the design, fabrication, and integration of high capacitance devices.

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11:40am **TS2-1-12 Dielectrics Produced via Aerosol Deposition**, *E Patterson,* ASEE, USA; *S Johnson,* ***Edward Gorzkowski,*** Naval Research Laboratory, USA

Aerosol deposition (AD) is a thick-film deposition process that can produce layers up to several hundred micrometers thick with densities greater than 95% of the bulk. The primary advantage of AD is that the deposition takes place entirely at ambient temperature; thereby enabling film growth in material systems with disparate melting temperatures. The bonding and densification of the film and film/substrate interface are thought to be facilitated by local temperature rise, high pressure, and chemical bonding during deposition, which leads to a dense nano-grained microstructure. In this talk we present results on the deposition of dielectric and ferroelectric materials deposited by aerosol deposition including the effect of processing parameters on the resultant material properties.

Topical Symposia
Room California - Session TS2-2
Thermal, Cold, and Kinetic Sprayed Surface Coatings

Moderators: Pylin Sarobol, Sandia National Laboratories, USA, Charles Kay, ASB Industries, Inc., USA

1:30pm **TS2-2-1 Influence of Bondcoat and Substrate Chemistry on Lifetime in Suspension Plasma Sprayed Thermal Barrier Coatings*, Mohit Gupta*,** *N Markocsan,* University West, Sweden*; X Li,* Siemens Industrial Turbomachinery AB, Sweden

A Thermal Barrier Coating (TBC) system is designed to protect gas turbines from high temperatures and harsh environments. Development of TBCs allowing higher combustion temperatures is of high interest since it results in higher fuel efficiency and lower emissions. It is well known that nano-structured TBCs produced by Suspension Plasma Spraying (SPS) have significantly lower thermal conductivity as compared to conventional systems due to their very fine porous microstructure. However they have not yet been commercialised due to low reliability and life expectancy of the coatings.

Lifetime of a TBC system is highly dependent on bondcoat and substrate chemistry as it influences the interdiffusion characteristics and growth rate of Thermally Grown Oxide (TGO) layer. To enhance the lifetime of TBCs, fundamental understanding of relationships between bondcoat-substrate chemistry, TGO growth rate, and lifetime is essential. The objective of this work was to study the effect of TGO growth rate on lifetime in SPS TBC systems by changing bondcoat and substrate materials. Experimental NiCoCrAlY bondcoat powders with different aluminium activity were investigated. High velocity air fuel spraying was used for bondcoat deposition while axial-SPS was used for yttria stabilised zirconia topcoat deposition. Lifetime was examined by thermal cyclic fatigue and thermal shock testing. The failure mechanism in each case will be discussed.

1:50pm **TS2-2-2 *a*-Oxide-Induced Grain Growth in Ligand-Free CZTS Nanoparticle Coatings*, Stephen Exarhos*,** *E Palmes, R Xu, L Mangolini,* University of California, Riverside, USA

Cu_2ZnSnS_4 (CZTS) is a material of interest for application as the photo-absorber layer in polycrystalline thin film photovoltaic (PV) devices due to its earth abundant, inexpensive, and nontoxic constituents. We have developed a highly scalable synthesis technique for the controllable formation of surface-ligand-free CZTS nanoparticles using aerosol spray pyrolysis. Further, we have developed scalable techniques to generate uniform large-grained polycrystalline thin films from nanoparticle coatings. High quality PV absorber layers are unattainable by sintering our ligand-free particles using traditional methods. We have found that a simple annealing step at moderate temperature (200-300 ºC) in air results in the formation of a thin oxide layer at the particle surface. Powder processed in this manner shows significantly enhanced grain growth kinetics after high-temperature annealing in a low-pressure sulfur atmosphere in concert with alkali incorporation. Most importantly, using these particles and the oxidizing technique, we avoid the introduction of carbon to the system which invariably facilitates the formation of a fine-grain carbon-rich layer between the substrate and the large-grained absorber layer in previously reported nanoparticle-derived films. We also observe structural and compositional inhomogeneity from grain-to-grain in these annealed films, a result previously reported by our group to be found in alternatively processed CZTS films, which allows us to infer possible unknown mechanics of grain growth in the material system. We present extensive characterization of these particles and films in order to understand the role an amorphous oxide layer and phase evolution may play in enhancing grain growth in CZTS nanoparticle coatings.

2:10pm **TS2-2-3 CaviTec HVOF Coatings for Protection against Cavitation Erosion*, Sébastien Lavigne,*** Polytechnique Montreal, Canada

CaviTec® is an alloy known for its high resistance to cavitation. Under cavitation conditions, this material exhibits a long incubation period before erosion sets-of, and a low erosion rate is observed afterwards. During the incubation period, the material absorbs energy, and a structural transition takes place. In the present work, Cavitec powders were prepared by water atomization followed by HVOF thermal spray. Compared to the bulk alloy, the coatings exhibit a relatively poor cavitation resistance and no incubation period. The defects present in the coatings (intersplat boundaries, pores etc) initiate cracks during erosion, leading to the removal of dense CaviTec particles. However, by ball milling the powder at high energy prior to deposition, the cavitation resistance can be improved by a factor of 2. Moreover, deposition at high velocity leads to a much higher cavitation resistance comparable to that of other well-known cavitation resistant HVOF coatings: For instance, a lower erosion rate than that of WC-CoCr HVOF coatings was achieved, and a longer incubation period than that of Stellite-6 was observed.

2:30pm **TS2-2-4 Experimental and Numerical Investigation on Fracture Toughness of Plasma-sprayed TBCs using a Modified Three-point Bending Method*, Jianguo Zhu,*** Jiangsu University, China

Determination of interfacial properties of thermal barrier coatings (TBCs) is very important for designing and evaluating the durability of TBCs. In this work, the adhesion of thermal spraying coatings deposited on a NiCoCrAlY bondcoat by the APS process was investigated experimentally. A modified three-point bending test was adopted to initiate and propagate the topcoat/bondcoat (TC/BC) interfacial crack. The fracture surfaces were examined, and images show that the crack plane was just on the TC/BC interface. Furthermore, the displacement and strain fields of the TC/BC interface were obtained using the digital image correlation (DIC) method, and the crack length was accurately determined. Based on the experimental results, the critical strain energy release rate G_c for crack initiation was calculated with Irwin-Kies formula, and the G_c for crack propagation was inversely determined by a finite element model. Results indicate that the G_c can be reliably obtained theoretically and numerically.

2:50pm **TS2-2-5 Process Induced Real-time Residual Stress Measurement of Thermal Spray Coatings***, W Choi, C Jensen, S Sampath,* ReliaCoat Technologies, LLC, USA*;* ***Andrew Vackel,*** Sandia National Laboratories, USA **INVITED**

Thermal spraying (TS) represents a flexible and highly efficient method of materials processing, and applications of protective coatings. Over the last several decades, the thermal spray process has emerged as an innovative and unique means for processing and synthesizing from low melting plastics to complex multi-component alloys and refractory ceramics. TS coatings find extensive applications including, but not limited to aerospace, energy generation, paper and pulp, biomedical implants, earth moving machinery, automotive industries for from thermal barriers for heat shielding to wear/corrosion resistance and reclamation. Despite significant advances in process and materials technology, limitations in coating reliability and repeatability have prevented expanded applicability of thermal spray coatings and, in particular, the use of thermal spray coatings in *prime reliant functions*. One major obstacle to obtaining greater coating performance, repeatability and reliability is the inability to measure relevant coating properties, and to do so in real-time within the production environment.

ReliaCoat Technologies has developed In-situ Coating Property (ICP) sensor, based on bi-layer thermo-elastic beam curvature solutions during and after coating deposition for real time extraction of residual stress evolution, deposition dynamics, and the onset of stress-relief cracking. The sensor distinguishes variation in process condition through resulting residual state of stress and elastic modulus. This real time residual stress analysis can comprehensively be related to both in-flight particle state (temperature and velocity) and booth operational parameters (cooling, spray distance, and deposition rate). Furthermore, monitoring of the residual stress evolution provides a qualitative indication of the stored energy in the layer owing to the intersplat bonding strength (cohesion) and work hardening due to impact (hardness), as well as, energy relief mechanisms including micro/macro cracking, poor cohesion, yielding or creep. Thus, the ICP sensor enables rapid process parametric optimization for design-relevant coating properties within the spray booth.

3:30pm **TS2-2-7 Metallization and Selective Metallization of Silver by Spraying*, Koen Staelens,*** Jet Metal Technologies, France

Jet Metal Technologies (France) introduces a green alternative for metallization processes like PVD, electroplating or evaporation.

Two chemical solutions, an oxidant containing the metal salt of the metal that the user wants to deposit, the other the reducing agent, are both water based, solvent, Pd ànd CMR free. Using compressed air and a double nozzle spraying paint gun, the reducing and oxidising agent are simultaneously sprayed onto the substrate surface, starting an oxido-reduction reaction and instantly forming a thin metal layer. The end result of this reaction is a dense and high adherent metallic film on the substrate surface.

The technology is applied on many substrate geometries (small or big, easy or complex, 2D or 3 D shape) and basically all substrate material choices, whether it is an electrically conducting or non-conducting surface. The range of substrates goes from metals, metal alloys, over glass, textiles, ceramics, silicon, leather to a long list of plastics and composites to even wax. The only prerequisite is linked with the use of water based solutions: in order realize an evenly well distributed metal layer over the surface, a good substrate wettability is needed which can be achieved via a pre-treatment step (flaming, plasma or corona). Once the required layer thickness is reached, spraying deionized water stops all reactions and the substrate is dried with the help of compressed air, so no for a curing step.

By adding one more step to the above described process, a selective, conductive pattern can be realized: an alkali sensitive organic ink, used as a negative mask, is printed on the substrate with an ink jet printer. As the oxidant and reducing agent have a pH >10, a loss of adhesion of the printed ink is achieved. During the final step of the process (spraying with deionized water) the ink layer is removed, leaving only metallization where there was no ink printed: a selective coating is achieved, and the result is the exact opposite of the pattern designed with the ink.

Today the technology is used on industrial scale in many application areas where Ag is used. In decorative applications like cosmetic bottles & caps, spirit bottles but also in functional applications like anti-bacterial applications, EMI shielding (500 nm Ag gives 65-70 dB between 10 MHz–10 GHz), intermediate conductive layer (150 nm Ag on a non-conductive surface gives enough electrical conductivity to be followed by electroplating, powder coating, electroforming,).

And with the selective metallization technology the manufacturing processes of e.g. antennas, PCB’s, … can be simplified.

Topical Symposia
Room Grand Exhibit Hall - Session TSP

Symposium TS Poster Session

TSP-1 Improved Electron Field Emission Characteristics of Amorphous Carbon Film Embedded with Graphene Nanocrystallites, *K Sun, L Yang,* Xi'an Jiaotong University, China; ***Dongfeng Diao,*** Shenzhen University, China

With excellent mechanical, chemical, and electronic properties, carbon-based thin films have drawn much attention as field emitter candidates in the past few years. Since amorphous carbon (a-C) films don't have outstanding characteristics on s and emission currents, metals are often doped in a-C films to improve the field emission characteristics . Graphene exhibits lower s and larger emission currents, but the emitters are easy to be destroyed under high voltages. Therefore, embedding graphene nanocrystallites in the surfaces and interior structures of a-C film s could be a potential method to improve field emission characteristics of a-C films.

In this study, a-C films and graphene sheet embedded carbon (GSEC) films ware prepared in electron cyclotron resonance (ECR) electron irradiation with different electron irradiation energy. Then the surface morphologies and structures of films were characterized by scanning electron microscope (SEM) and transmission electron microscope(TEM). The field emission currents were measured with a parallel plate capacitor setup. The results showed that GSEC films had a better field emission property than a-C films. The formation of graphene nanocrystallite lowered the work function and increased the local field enhancement factor on the surfaces, and enhanced the conductivity in the interior structures. The research highlighted that graphene nanocrystallite structures embedded in amorphous carbon films have an important role in electron field emission.

TSP-2 Zirconium Carbide Based Self-Healing Ceramics, ***Angela Yang,*** University of North Texas, USA; *P Petry,* University of Rouen, France; *I Hammood, R Reidy, S Aouadi,* University of North Texas, USA

Self-healing ceramics are novel materials that have the ability to restore mechanical properties of cracked materials through annealing. This research focuses on the self-healing ability of zirconium carbide based nano-composites. Zirconium carbide is a stable compound and is commonly used in harsh environments, such as those encountered in space and aerospace applications. A Vickers Hardness Tester was used to inflict small diamond shaped cracks in the sample. The sample was then self-healed through heating at 1100°C for four hours and analyzed using scanning electron microcopy and x-ray diffraction to determine the chemical and structural changes that occurred at the crack site. Three sample compositions were tested for their self-healing ability in this study, namely $ZrC/SiC/Y_2O_3$, $ZrC/Al_2O_3/Y_2O_3$, and $ZrC/Si_3N_4/Y_2O_3$. Sintered and unsintered samples of the same composition were compared to each other. The sintered samples were heated to 1000°C for three hours. The introduction of Fe_2O_3 to $ZrC/SiC/Y_2O_3$ interestingly was found to yield tubular whiskers when sintered.

Topical Symposia
Room California - Session TS1
Biointerfaces

Moderators: Jinju Chen, Newcastle University, Tianyu Zhang, Montana State University, USA

8:00am **TS1-1 The Investigation of Mechanisms about Bacteria-Hydrogels Interactions*, Nehir Kandemir*,** *W Vollmer, N Jakubovics, J Chen,* Newcastle University, UK

The structure and function of eukaryotic cells, like mammalian cells, can be regulated by altering their micromechanical environment such as alteration of their microenvironment stiffness. However, little work has been done for prokaryotic cells, like bacteria, which may be affected by similar interactions. In addition to this, bacterial cells are exposed to large forces from osmotic pressure differences and their microenvironment, but quantitative measurements of their mechanical properties have been limited. In this study, the aim is to investigate how physical factors (e.g. mechanical properties of the microenvironment), and chemical factors (e.g. chemical composition) would affect bacteria-material interactions and the bacteria cell mechanics. For this purpose, different mechanical characterisation techniques were adopted to extract the mechanical properties of *Escherichia coli* (Gram negative) and *Staphylococcus epidermidis* (Gram positive) encapsulated in agarose hydrogels made with different media. In addition, finite element simulations and theoretical models were employed to reveal more physical insights. Our study has demonstrated that the structure and properties of the microenvironment considerably affect the extraction of mechanical properties of the encapsulated cells. Such findings will help the further understanding of bacterial cell-materials interactions, which would have great potential impact in various healthcare industries.

8:20am **TS1-2 How Nanostructure on Ti Alloy Surface would Affect Bacterial Adhesion and Biofilm Formation?*, Yunyi Cao,*** Newcastle University, UK*; B Su,* University of Bristol, UK*; S Chinnaraj, N Jakubovics, J Chen,* Newcastle University, UK

Titanium and its alloys have been widely used in biomedical devices and surgical implants due to their excellent mechanical properties and good biocompatibilities. One of big issues for these Ti-based medical devices is bacteria induced infection and inflammation because biomaterial implant surface is also favorable for bacterial adhesion and biofilm formation. This would result in device retrieval and additional surgery, which will significantly affect the patients and increase the financial burden of national health services. To eliminate bacterial adhesion and biofilm formation, different nanostructures such as nanotexture and nanospikes were created on the titanium alloy implant surfaces. In order to understand how these nanostructures would affect bacterial adhesion and biofilm formation, a typical clinical relevant bacteria *Staphylococcus epidermidis* was cultured on these two nanostructured surfaces and the polished titanium surface (control sample). Both the initial bacterial adhesion and the biofilms grown on these surfaces for 3 days were analyzed. We found that both nanotexture and nanospikes enable to kill the bacteria and significantly inhibit biofilm formation compared to the control sample. Such an effect is even more significant for nanospike surfaces. This is possibly due to the high aspect ratio of the nanospike structures. To further reveal the mechanisms of this, some preliminary computational simulations based on interaction energy between bacteria and material surfaces were adopted.

8:40am **TS1-3 First Contact: Surface Sensing, Motility Appendages, and Hydrodynamics in Bacterial Interactions with Surfaces*, Gerard Wong,*** California NanoSystems Institute, UCLA, USA **INVITED**

Bacterial biofilms are integrated communities of cells that adhere to surfaces and are fundamental to the ecology and biology of bacteria. The accommodation of a free-swimming cell to a solid surface is more complex than simply modulation of cell adhesion. We investigate the interplay between motility appendages, molecular motors, hydrodynamics, and exopolysaccharide production near the surface environment using state of the art tools from different fields that are not usually combined, including theoretical physics, community tracking with single cell resolution, genetics, and microbiology. Themes such as *surface sensing*, multi-generational signaling via secondary messengers, subsequent downstream motility consequences, and the subsequent *onset of microcolony organization* via interactions between appendages and exopolysaccharides will be discussed.

9:20am **TS1-5 How Surface Physical Properties of Polymer Carrier Materials would Affect Wastewater Biofilm Formation?*, Sam Charlton,*** *M Brown, R Davenport, J Chen,* Newcastle University, UK

Biofilms are ubiquitous naturally occurring biological populations encased within an extracellular polymeric substance (EPS) matrix which adhere to substrates within aqueous environments. It was reported that various surface properties and features (e.g. roughness, surface energy, topography, surface chemistry and surface charge) would affect biofilm formation. However, most of these studies are focused on single species biofilms with lack of studies on wildtype multispecies biofilms. Therefore, in this study we investigated how the physical properties of various polymer materials (such as HDPE and PVC) would affect wildtype wastewater biofilm formation. It demonstrated that surface roughness, surface topography and hydrophobicity would affect biofilm growth rate, biofilm microstructure and bacteria community as well as biofilm mechanics. Such finding is important for understanding the interactions between mixed species and material surfaces. It will also potentially have significant impact on nitrification efficiency for wastewater treatment industries.

9:40am **TS1-6 Evaluating the Electrochemical Corrosion and Immune Cell Activation Behaviour of Nano-crystalline Thin Films of Chromium Nitride Prepared by Reactive Magnetron Sputtering*, SaeedUr Rahman,*** *A Ogwu, A Crilly,* University of the West of Scotland, UK

We investigated the potential of nano-crystalline chromium nitride thin film implant coatings to reduce the corrosion process and minimise the immune cell response in-vivo faced by patients with osteoarthritis. The films are prepared by reactive magnetron sputtering and characterised for grain growth by scanning electron microscopy. The chemical structure of the prepared films are characterised by X-ray photoelectron spectroscopy and Raman spectroscopy. The nano crystalline structure of the coatings which contributes to their phagocyte activation was probed by x-ray diffraction and radial distribution function analysis. We investigated the presence of surface chemical constituent entities on the coatings with XDLVO surface energy analysis and Kelvin probe contact potential difference/ work function measurements to establish the presence of hydrophobic surface chemical entities on the prepared films. The corrosion susceptibility of the films was investigated in saline solution. Our initial investigation includes open circuit potential measurements (OCP) over several hours, Tafel plots and Potentiodynamic polarization. The coatings show good corrosion resistance against pitting corrosion but could be improved further through a microstructural growth mode switch to eliminate potential pin-holes due to a columnar growth mode. The columnar Volmer-Weber growth mode observed by scanning electron microscopy is suspected to underlie the corrosion behaviour of the coating. The initial in vitro immune cell activation was investigated using peripheral blood mononuclear cells (PBMC) cultured on coated and uncoated control surfaces. Supernatants were collected at various time points and simulation conditions. There was a statistical significance ($P<0.01$) in the secretion of the inflammatory cytokine, interleukin 6 (IL-6), between the chromium nitride coated and the uncoated control surface. The results of our current in-vitro investigation based on corrosion and cellular response tests confirm the potential promise for the application of chromium nitride coatings prepared by reactive magnetron sputtering in orthopaedic implant applications.

10:00am **TS1-7 The Graphene Oxide Biopolymers (Polystyrene Sulfonate, PSS and Heparin), and PEDOT were Electrochemically Polymerized in the SUS316L Stainless Steel*, HuiMing Tsou,*** *T Liu,* Ming Chi University of Technology, Taiwan

In this study, the graphene oxide (GO), biopolymers (polystyrene sulfonate, PSS and heparin), and PEDOT were electrochemically polymerized in the SUS316L stainless steel, which could produce an anti-fouling surface to avoid the restenosis of the blood vessels. The negative charge of GO, PSS and heparin would exclude the negative charge of protein and platelets to achieve the purpose of anti-fouling and anti-clotting. Furthermore, we also add the surfactant (SDS) in the electrochemically polymerization process. The result shows that the surface energy would decrease with the SDS addition to form the hydrophobic surface. The lower surface energy surface would enhance the ability of anti-fouling and anti-clotting. In conclusion, we have developed an excellent anti-fouling surface by using GO, PSS, heparin and SDS, which could be applied in the eluting stent. The hemocompatibility, biocompatibility, and drug controlled release would be studied detail in the future.

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Choi, W: TS2-2-5, 3
Crilly, A: TS1-6, 6
— D —
Davenport, R: TS1-5, 6
Diao, D: TSP-1, **5**
— E —
Exarhos, S: TS2-2-2, **3**
— F —
Fuierer, P: TS2-1-9, 1
— G —
Gorzkowski, E: TS2-1-12, **2**; TS2-1-7, 1
Griego, J: TS2-1-11, 2
Gupta, M: TS2-2-1, **3**
— H —
Hammood, I: TSP-2, 5
Holmes, T: TS2-1-10, 2; TS2-1-11, 2; TS2-1-9, 1
Huang, J: TS2-1-5, **1**
— J —
Jain, J: TS2-1-4, 1
Jakubovics, N: TS1-1, 6; TS1-2, 6
Jensen, C: TS2-2-5, 3
Johnson, S: TS2-1-12, 2; TS2-1-7, **1**
— K —
Kaindl, R: TS2-1-6, **1**
Kandemir, N: TS1-1, **6**
Kräuter, M: TS2-1-6, 1
Kumar, D: TS2-1-4, 1
Kumar, S: TS2-1-4, **1**
— L —
Lackner, J: TS2-1-6, 1
Lavigne, S: TS2-2-3, **3**
Li, X: TS2-2-1, 3
Liu, T: TS1-7, 6
— M —
Mangolini, L: TS2-2-2, 3
Markocsan, N: TS2-2-1, 3
— N —
Nie, H: TS2-1-5, 1
— O —
Ogwu, A: TS1-6, 6
— P —
Palmes, E: TS2-2-2, 3
Park, D: TS2-1-7, 1
Park, Y: TS2-1-7, 1
Patterson, E: TS2-1-12, 2
Petry, P: TSP-2, 5
— R —
Rahman, S: TS1-6, **6**
Reidy, R: TSP-2, 5
Rodriguez, M: TS2-1-11, 2
— S —
Sampath, S: TS2-2-5, 3
Sarobol, P: TS2-1-10, 2; TS2-1-11, **2**; TS2-1-9, 1
Schwer, D: TS2-1-7, 1
Staelens, K: TS2-2-7, **3**
Stöger, W: TS2-1-6, 1
Su, B: TS1-2, 6
Sun, K: TSP-1, 5
— T —
Traxler, M: TS2-1-6, 1
Tsou, H: TS1-7, **6**
— V —
Vackel, A: TS2-1-10, **2**; TS2-1-11, 2; TS2-1-9, 1; TS2-2-5, **3**
Vollmer, W: TS1-1, 6
— W —
Waldhauser, W: TS2-1-6, 1
Wong, G: TS1-3, **6**
— X —
Xu, R: TS2-2-2, 3
— Y —
Yang, A: TSP-2, **5**
Yang, L: TSP-1, 5
— Z —
Zhu, J: TS2-2-4, **3**