Coatings for Biomedical and Healthcare Applications
Room On Demand - Session D1

Surface Coating and Surface Modification in Biological Environments

D1-1 Physical Vapor Deposition for Growth of Large Area Molecular Sensor Arrays, *N. Glavin, D. Austin, D. Moore, M. Motala,* Air Force Research Laboratory, Materials and Manufacturing Directorate, USA*;* ***Christopher Muratore (cmuratore1@udayton.edu)****,* University of Dayton, USA

Low temperature synthesis of high quality 2D materials directly on flexible substrates remains a fundamental limitation towards realization of robust, strainable electronics possessing the unique physical properties of atomically thin structures. Here, we describe room temperature synthesis of uniform, stoichiometric amorphous MoS_2, WSe_2, and other transition metal dichalcogenides and subsequent large area (>5 cm^2) photonic crystallization to enable direct fabrication of devices based on two-dimensional materials on large area flexible or rigid substrates. Fundamentals of crystallization kinetics for different monolithic and heterostructured TMDs are examined to apply this new synthesis approach for affordable, wearable devices. Example devices include photodetectors with photocurrent output and response times comparable to those fabricated via CVD and exfoliated materials on rigid substrates and the performance is unaffected by strains exceeding 5%. Flexible molecular sensors fabricated in this way detect diverse vapor phase substances with sub-ppm sensitivity. Functionalization of laser-written 2D TMD sensor transducers is also demonstrated for healthcare applications. Other devices and circuits directly written from photonically annealed monolithic TMDs thin films deposited on large area flexible substrates, with no photolithography or patterning, are also presented.

D1-2 Mesenchymal Stem Cells Response to Metal Oxide Thin Films*,* ***Phaedra Silva-Bermudez (phaedrasilva@yahoo.com)****,* Instituto Nacional de Rehabilitación Luis Guillermo Ibarra Ibarra, Mexico*; M. Fernández-Lizárraga,* Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional, Mexico*; S. Rodil,* Instituto de Investigaciones en Materiales, Universidad Nacional Autónoma de México, Mexico*; J. Garcia-Lopez, R. Sanchez-Sanchez,* Instituto Nacional de Rehabilitación Luis Guillermo Ibarra Ibarra, Mexico

Biomaterials with adequate surface properties to direct the biological response and appropriate bulk properties to meet the biomechanical requirements of bone regeneration applications are essential for orthopedic and dental implants. Mechanical and biodegradation properties are mainly determined by the bulk properties while the biological response is mainly directed by the surface properties. Thus, coatings are interesting options to tailor/functionalize the surface of mechanically adequate bulk materials, to direct the biological response towards enhanced osteoinduction and/or osteointegration. Biocompatible metal oxides such as ZrO_2, Nb_2O_5 and Ta_2O_5 are of great interest as coatings for orthopedic and dental implants. It has been shown that they decrease the biocorrosion of different materials, and they might induce adequate osteointegration and enhanced mesenchymal stem cells (MSC) differentiation towards the osteoblastic phenotype (osteoinduction), in the same way as it has been proved for TiO_2.

Thin films of TiO_2, ZrO_2, Ta_2O_5 and NO_2O_5 were deposited on Si(100) substrates as a model to study the potential of these oxide as biocompatible coatings capable of modulating the biological response. Thin films were deposited from pure metallic targets by reactive magnetron sputtering, under an Ar/O_2 (80:20) atmosphere and using RF-power. The roughness and topography of the coatings were characterized by profilometry and Scanning Electron Microscopy. The surface energy and water wettability were determined by contact angle measurements. To characterize the biological response of the oxide coatings, human MSC were independently plated on bare and oxide-coated Si(100) substrates and cultured at 37 °C, changing the culture media every three days. Cell viability and metabolic activity were assessed at different days of culture using the Calcein-AM/Ethidium homodimer fluorescent kit and the MTT-Formazan assay, respectively . To evaluate early-stage cell adhesion, cells seeded on the samples were harvested after 1 and 4 h of incubation and DNA was isolated and quantified. At 7 days of culture, cells on independent samples were fixed, dehydrated and evaluated by SEM. Potential cell differentiation to the osteoblastic phenotype was assessed at culture day 7 by immunofluorescence assays against characteristic markers of the osteoblastic phenotype such as, osteocalcin and RUNX2. Phosphatase alkaline assays in cells culture supernatants were also performed. Metal oxide coatings studied were biocompatible; however, r esults suggested that number of cells adhered on the substrate and cell differentiation were dependent on the coatings physicochemical properties.

D1-3 Behavior of a-C:H with Different fs-laser Micro-Patterns against Diamond Tip in Hyaluronic Acid*,* ***Annett Dorner-Reisel (a.dorner-reisel@hs-sm.de)****,* Schmalkalden Universtity of Applied Sciences, Germany*; S. Svoboda,* Schmalkalden University of Applied Sciences, Germany*; A. Engel,* University of Applied Sciences Mittweida*; C. Schürer,* Consultant Chemnitz*; S. Weißmantel,* University of Applied Sciences Mittweida, Germany

Surface micro-patterns like riffles, dimples, grooves can stimulate or supress special interaction with liquids and functionalize surfaces. They can act as reservoir for substances or trap undesired wear particles. In addition, laser treatment kill bacteria and clean surfaces, which is an important aspect in providing medical product to the market.

In nature, many surfaces obtain micrpatterns, like leaves of the lotus plant or cactus family.

Micro-patterns are generated on hydrogenated diamond-like carbon films by femtosecond-laser (fs-laser) irradiation (1028 nm, 220fs). Dimples with a spatial distance of 60 µm were generated. The parameters like fluence H (H: 1.71J/cm^2 or 3.70 J/cm^2) pulse repetition or duration were modified. In addition, a ripple structure (H: 3.03 J/cm^2; 220 fs) was generated. The structural changes are recorded by Raman spectroscopy earlier, while nanotribology was performed for investigating the sliding properties of the micro-patterned a-C:H surfaces. In addition to dry movement for testing the emergency operation, hyaluronic acid is used as an intermediate substance for testing the friction behaviour against a diamond tip in the present study. First impressions about potential interaction of carbon allotropes with hyaluronic acid are discussed.

D1-4 Analysis of a Drug Coated Polymer Stent with XPS and Argon Cluster Depth Profiling*,* ***David Surman (dsurman@kratos.com)****,* Kratos Analytical Inc., USA*; J. Counsell,* Kratos Analytical Ltd., UK*; M. Alexander,* University of Nottingham, UK

The application of cardiovascular stents for cardiovascular interventional therapy has emerged as the most effective method to treat coronary heart disease. Used to widen blocked or narrow coronary arteries by the insertion of a small tube into the vessels supplying blood to the heart, stents permanently allow blood to flow more freely. Cardiovascular stents were originally made from steel, however, they created issues for patients with thrombosis and hyperplasia being the usual pathological responses to the implantation of foreign devices. Despite recent advances in the field leading to the introduction of a new range of stents made from bioresorbable polymers, the undesirable problems associated with the original steel stents, such as thrombosis and hyperplasia, still remain. With these issues proving unavoidable despite the change in material, along with additional problems of overgrowth and subsequent restenosis, anti-inflammatory drugs are now loaded onto the surface of stent implants to suppress this immune response.

Here, we investigate the surface of a drug loaded polymer stent using X-ray Photoelectron Spectroscopy (XPS) and sputter depth profiling with Ar_n^+ clusters. The stents analyzed are composed of Polylactic Acid (PLA) where the outside surface has been doped with an anti-inflammatory drug. With the molecular structure of the drug being $C_{51}H_xNO_{13}$, nitrogen can be used as a marker to analyze the distribution of the drug across this stent surface. Quantitative XPS analysis concludes the drug distribution is higher on the abluminal (outer) surface than the luminal (inner) wall of the stent. Combining Argon cluster sputtering with XPS allows the distribution of the drug through the entire stent material to be fully characterized.

Conventional methods to study the effects of aging and drug mobility in these stents involve their immersion in a buffer solution for varying periods of time. Subsequent analysis of the solution with High Performance Liquid Chromatography (HPLC) can determine the extent of drug dissolution from the stent. Although this approach is accurate in determining the amount of drug dissolved, it is still unknown how much drug remains within the stent material and how it is subsequently distributed. These questions are addressed in this study where the bioresorbable stent had been immersed in PBS buffer solution for 1-3 months. Ar_n^+ cluster depth profiling of the stent materials was then used to determine the effects on simulated ageing and the propensity for the drug to migrate into the solution with time.

D1-5 Flexible Plasma Jet Source for Biomedical Applications, ***Carles Corbella (ccorberoc@gwu.edu)***, *S. Portal, L. Lin, M. Keidar,* George Washington University, USA

A new plasma source design that merges characteristics of capacitive dielectric barrier discharge (DBD) and cold atmospheric plasma jet (CAPJ) is presented. The DBD system consists of a porous ceramic material comprised between two planar electrodes. The supply of He flow, in combination with a sinusoidal voltage of ≈5 kV in amplitude and 12.5 kHz in frequency, provides a streamer that propagates beyond the DBD system. The plasma jet system can adopt different shapes with the aim of uniform surface treatment of 3D objects. Aspects like CAPJ extension, performance and lifetime of the plasma device are discussed in this paper. The composition and discharge parameters of the CAPJ are characterized by means of optical plasma diagnostics. Finally, we consider applications in plasma-based cancer surgery, as for example treatment of surgical margins. This novel source is also suitable for situations where plasma parameter adaptation to the environment (atmosphere and target surface) is required.

D1-6 INVITED TALK: Embroidery of Conductive E-Threads: Opportunities and Challenges in Healthcare, *Z. Dalisky, S. Alharbi, V. Mishra,* ***Asimina Kiourti (kiourti.1@osu.edu)***, *K. Guido,* The Ohio State University, USA **INVITED**

Rapid advances in bio-electromagnetics and flexible materials are opening unexplored opportunities in body area sensing. Next-generation wireless devices are envisioned that operate either upon or inside the human body and aim to break the state-of-the-art boundaries in terms of seamlessness, capabilities, and performance. To this end, embroidery of conductive threads (namely e-threads) is showing unprecedented potential. Technologies used to realize flexible conductors have long been reported (e.g., conductive inks, conductive fabrics, copper tape), but they exhibit numerous limitations in terms of electromagnetic and mechanical performance. By contrast, our e-textile technology brings forward numerous advantages: (a) the exhibited Radio-Frequency performance matches that of copper up to a frequency of ~4 GHz, (b) prototypes are mechanically and thermally robust, and (c) the printing resolution can be as high as 0.1 mm. Added to the above, polymer-based coatings can readily be integrated with such embroidered surfaces to serve numerous roles per applications requirements. For example, polymer-based substrates can be used to realize flexible multi-layer antennas, circuits, and transmission lines. In other cases, polymer-based superstrates can ensure biocompatibility of wireless textile-based implants or simply protect the exposed e-textile surface from corrosion and weathering. Finally, polymer-based coatings can help realize stretchable prototypes that stretch along with the polymer. Overall, embroidered e-textiles bring forward transformational opportunities in healthcare. Example applications explored to date include, but are not limited to, kinematics monitoring, medical imaging, deep brain sensing, recumbent height monitoring for infants, etc. This talk will present the current status on e-textile embroidered electronics, highlight opportunities in healthcare, and discuss challenges to be resolved in the future.

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