Biomaterial Surfaces & Interfaces
Room Milo - Session BI-ThM

Plasma for Biomedical Applications

Moderator: David Castner, University of Washington, USA

9:00am **BI-ThM4 Fundamentals of Plasma Interactions with Biological Systems***, **Endre Szili**, R.D. Short,* University of South Australia, Australia **INVITED**

There is significant optimism that cold atmospheric plasma could play a role in the treatment of diseases and infection, particularly those that are refractory and potentially life-threatening such as non-healing chronic wounds and cancers. The medical benefits from plasma are assigned to reactive oxygen and nitrogen species (RONS) that are generated by plasma upon interaction with air and liquids. However, we still do not have a sufficient understanding of (1) what RONS are delivered by plasma, (2) the rate RONS are delivered, (3) how the RONS are perturbed by tissue and (4) how RONS interact with cellular membranes. This knowledge is essential in order to obtain a quantitative mechanistic understanding of plasma in biology and medicine. In this talk, I will discuss simple biological mimics of 3D tissue or cells membranes, which are utilized to gain new insight into the plasma generation and transport of RONS and molecular oxygen into tissue fluid, tissue and cells. Surprisingly, we discovered that plasma can directly transport RONS and molecular oxygen deep within tissue to millimeter depths and across cellular membranes without physically damaging the tissue or cell membrane. In addition, I will discuss how the combined dynamic changes in the concentrations of RONS and molecular oxygen in the biological fluid can significantly impact cell viability during and after the plasma treatment. Finally, I will discuss how the above assays can support the future development of plasma sources to deliver metered doses of RONS and molecular oxygen within tissue for treatment of diseases such as chronic wounds and cancers.

9:40am **BI-ThM6 Plasma Engineered Surface for Managing Growth Factor Release in Stem Cell Culture***, **Jason Whittle**,* University of South Australia, Australia

The surface modification of materials used in biomedical applications is one of the earliest successful applications of gas plasma treatment. Such “Tissue Culture Plastics” are the mainstay of cell culture facilities to this day.

More recently, the ability to use plasma polymerisation to engineer novel surfaces has opened up the possibility of more advanced surfaces for cell culture. Products based around this technology are now also widely available.

In our laboratory we have developed plasma deposited surfaces that bind glycosaminoglycans from solution, and which are subsequently able to bind and release growth factors and other signalling molecules into solution. The presence of these growth factors enables the culture of primary- and stem cells without the need to add these growth factors to the media formulation. The development and application of this surface in the culture of human cells will be described, in addition to some of the challenges associated with commercialisation of plasma deposited films, where better knowledge of the physics and chemistry of depositing plasmas is needed.

10:20am **BI-ThM8 Principles for Retention of Fragile Chemical Functionality Structures in Plasma Polymer Thin Films***, **Solmaz Saboohi**, B.R. Coad, A. Michelmore,* University of South Australia, Australia*; R.D. Short,* University of Lancaster, UK*; H.J. Griesser,* University of South Australia, Australia

There is a growing need for thin films which are functionalized with specific surface chemical motifs that impart new physical, chemical or biological properties. The design and fabrication of thin films with specific surface groups has the potential to provide further insights into bio-interfacial interactions as well as to yield novel coatings for products such as cell culture ware. Plasma polymerization (PP) provides a one-step, solvent-free process, irrespective of material type and format, and supports several large-scale industrial applications on the basis of advantages such as excellent uniformity and adhesion of coatings and their reproducibility. We have studied how volatile ester compounds can be plasma polymerized with retention of a high density of intact structural elements. However, in PP there usually occurs extensive fragmentation of the volatile precursor molecule ("monomer") and re-assembly of the various fragments from the plasma gas phase into a solid polymeric coating. Considerable scrambling of molecular structural elements is evident even where functional group retention has been the objective. High energy electron impact events in the plasma results in loss of specific functional groups in the plasma phase. In addition, a strong negative electric field, which develops in the vicinity of the surface, may cause positive ions to arrive at the surface with significant energy. Sputtering / reorganization at the surface due to ion impingement also results in loss of specific functional groups. Retention of chemical functional groups can be optimized by considering the pressure where the plasma transitions from the alpha to the gamma regime.[1] Operating the plasma in the collisional regime biases the deposition towards increased contributions by ions rather than neutral/radical grafting.[2] This study demonstrates that relatively complex structural motifs in precursor molecules can be retained in plasma polymerization if the chemical and physical processes occurring in the plasma phase are controlled by tuning the plasma to deliver a high flux of polyatomic ions and suitable energy of the ions to deposit films.

References

[1] Liebermann, M. A. and Lichtenberg, A. J. Principles of Plasma Discharges and Materials Processing, 2nd ed. (A John Wiley and Sons, New York), 2005.

[2] Saboohi, S.; Coad, B.R.; Michelmore, A.; Short, R.D.; Griesser, H.J. Hyperthermal Intact Molecular Ions Play Key Role in Retention of ATRP Surface Initiation Capability of Plasma Polymer Films from Ethyl α–Bromoisobutyrate, ACS Appl.Mater.Interfaces, 2016, 8, 16493−16502

10:40am **BI-ThM9 Cell-Surface Modification for Biomaterial Applications using Furfuryl Methacrylate Plasma Polymer***, **Hanieh Safizadeh**, A. Michelmore, J.D. Whittle,* University of South Australia, Australia

Cell-surfaces interaction plays a significant role in biomedical applications and cell therapies. In many cases, materials which are convenient for manufacturing biomedical devices and culture ware exhibit poor cell adhesion. Therefore, it is important to modify cell-surface interactions using surface engineering. Poly(furfuryl methacrylate) (p(FMA)) is a promising polymer surface that recently has been recognized for stem cell adhesion and proliferation due to the furan ring in its structure. However controlling the thickness and topography of surface coatings of p (FMA) is difficult, which inhibits scale-up. Plasma polymerization offers a simple, solvent-free method for coating surfaces with FMA which is substrate independent, with fine control of film thickness and topography.

Herein, FMA plasma polymer coatings were prepared with different powers, deposition times and flowrates. Furan ring retention on these surfaces has been determined using chemical analysis such as XPS and ToF-SIMS. SEM demonstrated the existence of particle aggregates under certain plasma conditions. Through judicious choice of plasma polymerization parameters the formation and quantity of the particle aggregates was reduced and the fabricated plasma polymer coatings became chemically uniform and smooth and the furan ring retention was maximized. These optimised surfaces support cell proliferation, comparable to results with tissue culture plastic, while maintaining cell fate. These findings show not only the chemistry of surfaces is important but also that surface morphology plays an important role in cell adhesion and proliferation.

11:00am **BI-ThM10 Quasi-zwitterionic Glow-Discharge Radio Frequency Plasma Coatings Reduce IgG Protein Adsorption***, **Marvin Mecwan**, B.D. Ratner,* University of Washington, USA

Introduction: Glow discharge plasma-treated surfaces have been used to create non-fouling surfaces, and can be readily applied to implants. For successful plasma polymerization it is important that the monomer of interest be easily volatilized. Zwitterionic polymer hydrogels in mice have shown to resist foreign-body reaction. However, zwitterionic polymer precursors, such as carboxybetaine methacrylate (CBMA) and sulfobetaine methacrylate (SBMA) are solids with high boiling points which would not make them ideal candidates for glow-discharge plasma treatment to coat surfaces. This study investigates the preparation of quasi-zwitterionic surfaces via glow-discharge plasma treatment prepared by the simultaneous deposition of a positively charged (allylamine or AAm), and negatively charged (acrylic acid or AAc) monomer, and its ability to act as a non-fouling surface.

Methods: Glass substrates were cleaned with MeOH in a sonication bath for 10 mins x 2. Substrates were loaded into the reactor, Ar etched (40W for 10 min), followed by a CH_4 layer (80W for 5 min). The monomer of choice—AAc and AAm—was introduced into the chamber either by itself or simultaneously and plasma deposition was carried out at 150mT pressure; 80W for 1 min (adhesion) followed by 10W for 10 mins (deposition). Samples were quenched for 5 mins before venting the chamber and retrieving coated samples resulting in 3 treatment groups: AAc, AAm and

AAc-AAm. Plasma-treated samples were washed using DI water x 3 and ESCA was used to assess coating composition before and after washing. ESCA analyses were done using an S-Probe ESCA (with monochromatic Al K-alpha X-rays focused to 800µm spot size) using survey and detailed C1s scans. Protein adsorption studies were performed using bovine IgG, and the amount of IgG adsorbed was determined by substrate based ELISA. Cytotoxicity studies were performed using NIH3T3 mouse fibroblast cells.

Results: ESCA scans of plasma-treated substrates showed absence of substrate associated peaks implying that plasma coatings on substrates are at least 10 nm thick (coating thickness will be measured using AFM). Furthermore, experimental and theoretical elemental compositions of the surfaces align well. Moreover, AAc-AAm coatings were able to reduce protein adsorption by 50% compared to untreated controls, and were non-cytotoxic.

Conclusions: The preliminary data demonstrates that quasi-zwitterionic surfaces can be successfully created, reduce IgG protein adsorption and are non-cytotoxic. Further optimization is required to reduce protein adsorption further in order to create a new generation of materials that perform efficaciously as non-fouling surfaces.

11:20am **BI-ThM11 Titanium Films Deposited by HiPIMS for Medical Applications**, *K. Thorwarth,* Empa, Switzerland*; S. Jin,* Sungkyunkwan University, Korea, Republic of Korea*; S. Gauter,* Christian-Albrechts-University Kiel, Germany*; **Joerg Patscheider**,* Empa, Switzerland

The metallization of polymer substrates by metallic titanium films provides many attractive applications, e.g. in biomedical applications. In contrast to conventional techniques in orthopaedic implants such as plasma spraying, which lead to a high thermal load of the substrates' surface and thereby to the undesired loss of surface structural feature, magnetron sputter deposited films maintain the surface topography of PEEK substrates

In this work Ti coatings were deposited on PEEK (polyether ether ketone) by chopped HiPIMS, a technique where HiPIMS pulses are decomposed into a sequence of short micropulses. The combination of these pulse trains distinctly influence the properties of titanium coatings prepared by this technique. The plasma was characterized using voltage/current measurements, optical emission spectroscopy and Langmuir probing, along with caloric measurements during deposition. The prepared coatings were examined using X-ray diffraction, scanning electron microscopy and X-ray photoelectron spectroscopy. It is shown that the pulse sequence is decisive for the applicability of Ti coatings on polymeric substrates, as it strongly influences properties such as process stability, deposition rate, morphology and thermal load during deposition, which can be improved with respect to standard HiPIMS and DC sputter deposition. The coatings' microstructure shows increased smoothening of the coating surface and shallower surface oxidation for samples deposited using chopped HiPIMS

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