Biomaterial Surfaces & Interfaces
Room Naupaka Salon 6-7 - Session BI-WeM

Soft Surfaces and Biofunctional Coatings

Moderator: Tobias Weidner, Aarhus University, Denmark

8:40am **BI-WeM-3 Surface Micropatterning Techniques for Reconstituting Functional Neuronal Networks in Culture**, ***Hideaki Yamamoto***, *A Hirano-Iwata,* Tohoku University, Japan **INVITED**

Nerve cells in culture take irreplaceable roles in molecular and cellular neuroscience. However, the fact that neurons form random connections, which are substantially different from the actual brain, has limited the wide application of cell culture in systems-level studies.

Surface modification combined with microfabrication has a high potential to circumvent this limitation of cell culture technology in neuroscience [1-2]. By patterning biomolecules that scaffolds cellular growth, a glass coverslip can be functionalized so that growth of primary neurons can be controlled extrinsically, at the level of both individual cells [3-5] and cell populations [6]. Taking advantage of the cell micropatterning technology, we reconstitute functional neuronal networks of rat cortical neurons and investigate how meso-scale connectivity among neurons determines network dynamics. We focus on the modular organization of brain networks, characterized by the presence of densely-connected subsystems, i.e., modules, that are weakly interacting with each other [7]. Analysis of spontaneous neural activity by fluorescence calcium imaging shows that an atypical dynamics of the cultured networks, characterized by a bursting activity that is highly-synchronized across the whole network, is suppressed by the induction of modular organization in the networks. Increasing the degree of modularization causes the networks to generate activity patterns that are spatiotemporally more complex. Our results demonstrate that surface micropatterning expands the cell culture system as a unique tool to model and study the structure-function relationships in living neuronal networks.

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9:20am **BI-WeM-5 Inhibiting Bacterial and Fungal Growth *via* Biomimetic Nanopillared Surface Structuring**, ***Rachel Rosenzweig***, *V Ly, K Perinbam, M Marshall, E Pearlman, A Siryaporn, A Yee,* University of California, Irvine

Bacterial and fungal contamination occur in our everyday lives from food spoiling, oral disease, appliance clogging, and industrial naval and aviation fuel-line dependent transportation. More perilously, human pathogenic bacteria and fungi often contaminate medical device surfaces leading to 1.7 million annual nosocomial infections in the US alone. Such infections result in 99,000 annual deaths and $20 billion in healthcare costs. Current solutions that are declining in efficacy due to antimicrobial resistance (AMR) include chemical antimicrobials applied topically to or impregnated onto devices and implants. The rise of AMR has created an urgent need for alternative strategies. In this work, the physical antimicrobial effects of nanoimprinted polymer surface structures inspired by insect wing nanotopography are investigated.

Natural nanopillared surface structures found on dragon fly and cicada wings have been found to cause bacterial cell lysis, yet their possible effect has not been studied when applied to eukaryotic filamentous fungi. In this work, AMR prokaryotic bacteria, *Pseudomonas aeruginosa*, and clinical isolates of AMR eukaryotic filamentous fungi, *Aspergillus fumigatus* and *Fusarium oxysporum*, were cultured on flat and engineered biomimetic nanopillared surfaces on a material often used in medical devices, *viz*., poly(methyl methacrylate). Surfaces of nanopillared arrays with varying periodicities of 200nm, 300nm, 500nm, and 600nm were fabricated using nanoimprint lithography. Notably, this surface structuring technique is a low-cost and scalable lithographic method translatable to flat and curved surfaces. Cell growth and survival were measured using fluorescence microscopy of GFP tagged bacteria and fungi with propidium iodide DNA stain to indicate compromised cell membranes. The cell-nanosurface interface was further analyzed with scanning electron microscopy. A decrease in *P. aeruginosa, A. fumigatus,* and *F. oxysporum* cell growth and an increase in cell death were observed on the biomimetic nanopillared surfaces compared to the flat. This work presents the first demonstration of a scalable, nanostructured, antimicrobial surface against both drug resistant prokaryotic bacteria and eukaryotic fungi. This biofunctional coating can be applied to a broad range of applications in healthcare, industrial transportation, and environmental conservation.

9:40am **BI-WeM-6 Chemo-enzymatic Pathways for Sustainable Terpene-based Polymeric Materials**, ***Arne Stamm***, *L Fogelström, P Syren, E Malmström,* KTH Royal Institute of Technology, Sweden

Polymers play an essential role in everyday life as materials in automotive, packaging and electronics and as compounds in medicine. Nevertheless, the finite supply of fossil fuels leads to an increased need for development of more sustainable materials from renewable sources. Renewable natural products from forestry, especially hemicellulose and terpenes, offers a highly versatile platform for green building blocks. By using Nature's own biofunctionalizations, enzymes can be used as green catalysts for the valorization of abundant terpenes from pine-wood extractives. Enzymatic biotransformations enable mild processes for "activating" inert molecular building blocks in a highly controlled manner to afford renewable monomers. By combining *in vitro* synthetic biology and polymer chemistry, we have generated a novel class of bio based polymers, star ting from a naturally abundant terpene found in wood. Specifically, the terpene sobrerol, which can be achieved both enzymatically and by traditional organic chemistry, represented a promising starting compound for the preparation of such bio based monomers. Sobrerol consists of a multiple substituted cyclohexene unit, containing secondary and tertiary hydroxyl functionalities. The functionalities of sobrerol enable certain chemical modifications, whereas the cyclic structure provides hardness in subsequent polymeric products. Especially, the stereoselective methacrylation of the secondary hydroxyl group constituted a suitable monomer for radical polymerization. We were able to demonstrate that the enzymatic functionalization under benign conditions showed superior properties concerning yield, stereo selectivity and workup procedures of the methacrylated sobrerol (SobMa). Further, SobMA could be polymerized using both traditional and enzymatic procedures enabling a completely green route from a natural abundant product to a highly versatile polymer. Due to the remaining functional groups in the side chain, polySobMA provides a variety of possibilities for post-functionalization reactions and crosslinking. Polymeric films were obtained by crosslinking reactions using either the ene-, or the hydroxyl functionality of the sobrerol unit and their properties evaluated. Thus, the unaffected second functionality could be used for a broad range of further modifications to produce tailor-made polymer films targeting different fields of application. In conclusion we were able to present that the use of enzymatic or chemo-enzymatic processes is an ideal approach to convert terpenes into highly versatile polymeric coating materials.

10:20am **BI-WeM-8 Chemical Surface Modification of Carbon Nanostructures Towards Biological Applications**, ***Mildred Quintana***, Universidad Autónoma de San Luis Potosí, México **INVITED**

The unique combination of properties of carbon nanostructures, such as high specific surface area, chemical stability, mechanical strength, flexibility, high electrical and thermal conductivity, and tunable band gap and shape, make them ideal materials for the development of a number of bio-applications including biosensors [1], photodynamic therapy agents [2], and active surfaces for cellular growth [3]. However, for applicability several problems arise, including scalability, dispersibility, stability, and reproducibility. Several authors have proposed chemical functionalization as a feasible solution to render carbon nanostructures dispersible in many solvents, comprising water, and readily for its integration in hybrids materials [4]. Furthermore, by performing chemical organic reactions on carbon nanostructures, it is possible to exactly adjust the interfacial properties to increase biocompatibility [5] or to prompt lipid membrane translocation [6]. In this work, I will describe our recent efforts on the chemical functionalization of carbon nanotubes and graphene towards the development of SERS biosensors, photodynamic therapy agents and active surfaces for cellular growth. The importance of the tailored design of the chemical surface of the nanostructure for the desired application will be extensively discussed.

References

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11:00am **BI-WeM-10** ***Roles of Anodic Oxide Layer on the Improvement of Cellular Response of Titanium Implant*** *,* ***Naofumi Ohtsu****, T Kuji, M Hirano,* Kitami Institute of Technology, Japan

Anodic treatment of titanium (Ti) has been used to improve its biocompatibility. The process leads to the formation of TiO_2 layer and the layer growth can be controlled by varying the processing voltage. Concomitantly, the surface roughness increases accompanying with the layer growth. Some researchers have believed that the enhanced biocompatibility through anodization is derived from the chemical property of TiO_2 itself, whereas other groups have insisted that the roughness increase relates with the biocompatibility. To obtain the valuable clue regarding this argument, in the present study, we prepared a TiO_2 layer with different roughness through the anodization in H_3PO_4 electrolyte with various voltages ranging from 5 to 500 V and thermal oxidation at 723 K in air. Thereafter, surface roughness and cellular response were compared to discuss the dominant property contributing the enhancement.

The surface image of the anodized substrates, observed by SEM, revealed that the surface roughness increased with increasing the voltage. To investigate the cellular response, MC3T3-E1 cells, an osteoblast-like cell line, were seeded on the sample surface and cultivated for 72 h, after which the numbers of the attached cells were counted. The numbers of the cells on the anodized surfaces were larger than those on an untreated and the thermally oxidized surfaces, whereas the difference depending on the processing voltage was hardly observed. Ii was conjectured that the enhanced biocompatibility is due to the anodized TiO_2 itself, of which surface property is different with that of TiO_2 prepared by thermal oxidation.

11:20am **BI-WeM-11 (Electro)Chemically Synthesis et Characterization of New Coating having N-Halamine Groups giving them Regenerative Antibacterial Properties***,* ***Vincent Humblot****, N Nazi,* LRS - CNRS Sorbonne Université, France*; C Debiemme-Chouvy,* LISE - CNRS Sorbonne Université, France

In the presence of moisture, surfaces are an ideal support for the development of biofilms containing bacteria that can be pathogenic. This poses a real public health problem, economic or even environmental in view of the use of biocides to fight against this phenomenon. The first step in the formation of a biofilm is the adsorption of molecules, especially proteins, followed by the colonization of surfaces by bacteria.

The goal of this study is the development of **new regenerative antimicrobial coatings**, **containing haloamine (or N-halamine) functions(> N-Cl or> N-Br)** that have oxidative properties due to the degree of oxidation +I [(a,b)]. N-halamines are broad-spectrum biocidal groups; due to their mode of action, i.e. oxidation, bacteria should not develop resistance, unlike after repeated use of antiobiotics. The protection of surfaces with N-halamine compounds requires the immobilization of amine, amide or imine functions that will be transformed into haloamine either during synthesis or by post-treatment in the presence of NaOCl or NaOBr.

In this study, we will present a new approach of gold surfaces functionalization with the use of a biopolymer: **polydopamine**. The synthesis of the polymer has been implemented with two original approaches: a chemical and an electrochemical synthesis. We will present a comparative study of both chemical and electrochemical polymerisation and functionalization of gold surfaces characterized by means **of PM-RAIRS, XPS and (E)-QCM surfaces techniques**. The control of the polymer thickness shows a clear dependence of the antibacterial response with the degree of chlorination or bromination. Finally, the simple regeneration of the biocidal surfaces will be presented together with the biocidal activity upon re-use of the surfaces.

(a) Antimicrobial *N*-halamine polymers and coatings: A review of their synthesis, characterization and applications. F. Hui, C. Debiemme-Chouvy, *Biomacromolecules* **2013**, 14, 585-601. (b) N-halamine coating formed via the electroreduction of *in situ* generated diazonium cations: toward antimicrobial surfaces. S. Gao, H. Cachet, C. Debiemme-Chouvy. *Surf. Interface Anal*. **2016**, 48, 630-635.

11:40am **BI-WeM-12 Effect of Salts on Friction of Zwitterionic Polymer Brush: Molecular Dynamics Simulation***,* ***Shuichi Uehara****, Z Liu, N Miyazaki, Y Ootani, N Ozawa, M Kubo,* Tohoku University, Japan

In recent years, concentrated polymer brush (CPB), which is constructed by grafting polymers onto a substrate at high density, has been developed [1]. Especially, zwitterionic CPB produces ultra-low-friction surface and has biocompatibility in aqueous environment. Thus, zwitterionic CPB has attracted much attention for application to a low friction material as artificial joints. Recently, experiment showed the friction force of zwitterionic CPB decreases with increasing ionic strength for salts [2]. However, the details of this mechanism are still unknown because the in-situ observation is difficult. For enhancing the performance of zwitterionic CPB as a low friction material in biological applications, it is important to understand the effect of salt existing in biological environment. Thus, computational simulation is required.

In the present study, we performed molecular dynamics friction simulation between CPB and Au tip to elucidate the effect of salts on friction force of zwitterionic CPB. In the CPB model, 9 zwitterionic polymer chains of 10 monomers were grafted to a silicon (111) substrate (area, 5.75nm×5.98nm) via covalent bonds. For comparison, we prepared two systems: with salts (80 KCl) and without salts. Both system of CPB solvated in 6000 water molecules.

At a low load (up to 10 MPa), zwitterionic CPB with salt showed lower friction force than system without salts. This result is qualitatively consistent with experimental data [2]. The mean square displacement of water in the system with salts is lower than that in system without salts. This result suggests that waters in the system with salts have higher viscosity. Whereas, we find that zwitterionic chain with salts is harder to move in the sliding direction than system without salts. Therefore, we revealed that the binding of salts to polymer chain made polymer chains hard to collapse in spite of increasing viscosity of waters. Thus, zwitterionic CPB with salt reduced contact area between Au tip and polymer chains. Our previous study showed that the reduction of contact area of CPB in friction interface leads to low friction [3]. On the other hand, at a high load (20 MPa), the friction force of zwitterionic CPB with salts and system without salts were comparable. This is because salts desorb from inner layer of zwitterionic CPB due to the severe load. Therefore, to enhance performance of zwitterionic CPB as a low friction material, it is necessary to design of CPB so as to hold salts which make CPB hard to collapse in the severe load.

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