Biomaterial Interfaces
Room: Hall B - Session BI-TuP

Biomaterials Interfaces Poster Session

BI-TuP2 Monocyte Adhesion to Protein Functionalized Nanopatterns, ***A.S. Andersen***, *D.S. Sutherland*, Aarhus University, Denmark

Through a biofunctionalized nanopattern proteins are presented in circular nanopatches, which can range from 66nm-3µm in size. These protein nanopatches are used to study cell binding, specifically in regards to ligand clustering. Monocytes are the precursors for our body's macrophages, the scavenger cells, which for example help during inflammation and to remove apoptotic cells. Monocytes are found in the blood and needs to be recruited to sites of inflammation. This happens in four stages, rolling, binding, diapedesis and migration. The focus of this research is in the first two stages. During binding an integrin, LFA1, on the monocyte binds to its ligand, ICAM1, on the epithelial cells and it is known that these form focal adhesions (FA). The size of the FA, needed to get a strong binding, is not known. This research uses a nanopattern (1), biofunctionalized through a serial protein deposition (2) mimicking FA ICAM1 patches. The binding of THP1 cells to 100-800nm sized ICAM1 nanopatterns will be shown. It illustrates a cut off in size where the cell binding disappears indicating that there is a crucial size of FA for monocytes to adhere.

Further, results showing a protein nanopattern made inside a microfluidic channel are presented. The nanopattern consists of circular gold covered holes 800nm in diameter, in a PLL-g-PEG covered SiO2 surface. The gold holes have been biofunctionalized through a serial protein deposition which gives an oriented antibody pattern, with the possibility to change to any protein with a FC domain attached. The microfluidic setup will allow for cell studies under flow and opens up the opportunity to mimic the flow conditions found in the blood stream during cellular adhesion, which have been shown to be an important factor in monocyte adhesion.

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BI-TuP3 Ultrasound Imaging, Gamma Scintigraphy and HIFU Therapy with Perfluorocarbon Loaded Iron-Silica Nanoshells, ***A. Liberman***, *Z. Wu, C. Barback, R. Viveros, S.L. Blair, D. Vera, L.G. Ellies, R.F. Mattrey, W.C. Trogler, A.C. Kummel*, University of California San Diego

The reported positive margin rate from wire localized excisions of breast cancers is approximately 20-50%; however, by preoperatively injecting a radioactive seed into the tumor under CT guidance, the excision rate is halved because the surgeon can constantly reorient the dissection to place the seed in the center of the specimen. Unfortunately, radioactive seed localization has several safety challenges, only single focus can be localized, and incisions are required to implant the seeds, so it is rarely employed. As an alternative, gas-filled hollow Fe-doped silica particles have been developed, which can be used for ultrasound-guided surgery even for multiple foci. The function of the Fe doping is to render the silica shells biodegradable. The particles are synthesized through a sol-gel method on a polystyrene template, and calcined to create hollow, rigid nanoshells. The Fe-doped silica shell is derived from tetramethyl orthosilicate and iron ethoxide, which forms a rigid, nanoporous shell upon calcination. The nanoshells are filled with perfluoropentane vapor or liquid. The flourous phase is contained within the shell due to its extremely low solubility in water. *In vivo* particle longevity studies have been performed in tumor bearing mouse models show signal presence up to 10 days post injection. To study biodistribution, nanoshells were functionalized with DTPA and radiolabeled with ^{111}In and then imaged by γ-scintigraphy. Scintigraphic imaging and γ-counting confirm that particles undergoing IV delivery to tumor bearing mice will passively accumulate in the tumors which may allow for tumor detection and therapuetic applications. The nanoshells break under acoustic excitation to release gas pockets which increase acoustic energy absorption and reduce acoustic cavitation threshold. Therefore they may also be employed as a sensitizing agent in high intensity focused ultrasound (HIFU) therapy. Traditional ultrasound agents which can be used as a HIFU senstizing agent pose several potential drawbacks such as poor *in vivo* persistence (mins) and high risk during continuous perfusion. Preliminary *in vivo* HIFU ablation studies show that few particles are needed in order to develop a sensitizing effect to HIFU thereby substantially reduce the amount of HIFU exposure necessary to achieve an ablative effect. It was found that nanoshells systemically adminstered to breast tumor bearing mice could be cavitated by HIFU 24 hrs after administration. This cavitation caused liquification within the focal volume of the HIFU which contained the nanoshells within seconds. This may potentially allow for a larger area to be ablated in less time with less power.

BI-TuP4 Development of Nanofibrous Meshes as Smart Dressings for the Healing of Chronic Wounds, ***M. Abrigo***, *S.M. McArthur, P. Kingshott*, Swinburne University of Technology, Australia

Diabetic, pressure, venous and arterial ulcers are a large social, economic and healthcare burden. These chronic non-healing wounds show delayed and incomplete healing processes exposing patients to high risk of infection. Chronic wound care currently focuses on dressings capable of preventing microbial infiltration and keeping a balanced moisture and gas exchange environment. The design of dressings that combine the necessary morphological and physical requirements for wound healing with the value-added capability to address optimal cell responses and impair bacterial proliferation represents a major challenge in wound care.

Polymeric nanofibrous meshes are good candidates as wound dressings and cell scaffolds due to their high surface area, micro-porosity and non-woven structure. Electrospinning is used for the fabrication of these structures because it is a simple, cost-effective and reproducible process. Moreover, electrospinning enables fibres of synthetic and natural polymers to be combined as multifunctional dressings capable of addressing a range of wound challenges.

In this study, a range of different synthetic polymers (Poly-lactic acid, Poly-glycolic acid and Polycaprolactone) have been blended and the parameters of the electrospinning process (such as spinning rate and electric field intensity) optimized to achieve a nanofibrous membrane. The morphological properties of the electrospun meshes have been analysed by three-dimensional optical profiler, Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM). As the first step to understand microbial infiltration and control in wound dressings, a number of studies have been completed using *E. Coli*, *P. Aeruginosa*, *S. Aureus* in an effort to understand how the morphological and structural properties of the electrospun meshes influence bacterial attachment, proliferation and growth.

BI-TuP5 Lipid Interactions with Plasma Polymers, ***H.J. Askew***, *S.M. McArthur*, Swinburne University of Technology, Australia

The cell membrane encases and protects cellular components and plays an important role in transport, signalling and disease . Studying membrane behaviour is a challenging task due to the complexity and scale on which these processes occur. Supported lipid bilayers (SLBs) have provided researchers with stable and reproducible platforms to recreate cell membrane environments. The planar structure of the model means a variety of patterning techniques can be employed to recreate membrane architecture on both a micro and nanoscale. In particular pre-patterned substrates are of great interest as they eliminate complications associated with preserving membrane integrity during patterning. Plasma polymers provide a versatile method of creating thin films with a variety of different surface chemistries. In this work we explore the behaviour of plasma coatings in aqueous conditions and the use of plasma films for creating patterned SLBs using vesicle collapse. A variety of micropatterned surface chemistries were formed using commonly used plasma polymers such as allylamine and acrylic acid combined with standard UV photolithography techniques. Characterisation of film behaviour and bilayer formation was conducted using a variety of techniques including ellipsometry, quartz crystal microbalance with dissipation (QCM-D), confocal microscopy and atomic force microscopy (AFM). This study adds to the currently limited literature considering plasma film behaviour in aqueous conditions. Plasma coatings provide a versatile technique for micropatterning SLBs and have advantages over other commonly used techniques such as microcontact printing which suffers from PDMS contamination. Further optimisation of the plasma patterning process may yield increased resolution and chemistries to aid the development of increasingly complex SLB systems.

BI-TuP6 Pseudomonas Aeruginosa Biofilm Formation Mechanisms on Highly Ordered Micro and Nano-sized Colloidal-based Patterns, ***H. Pingle****, P.Y. Wang,* Swinburne University of Technology, Australia*, C.B. Whitchurch,* University of Technology Sydney, Australia*, P. Koegler, S.M. McArthur, P. Kingshott*, Swinburne University of Technology, Australia

Pseudomonas aeruginosa is an opportunistic pathogen with life threatening complications for hospitalised patients needing catheters or other medical devices when it forms biofilms on the surface of that device. Each year almost 16,000 catheters related blood stream infection cases are found in USA only, with estimated mortality rates ranging from 12% to 25% even with use of uncompromising antibiotics. Some research has shown that extra-cellular DNA is involved in *Pseudomonas aeruginosa* biofilm formation but the actual part it plays in initiating attachment and how it helps bacteria to form multicellular biofilms is unknown. New surfaces are therefore seriously needed to understand the exact mechanisms and prevent biofilm formation. We use a novel approach for making chemical micro and nano patterns on material surfaces with the help of self-assembled colloidal particles used as masks for creating advanced material surfaces. Recently we have prepared binary colloidal assembly of different crystal structure over a wide range of size ratios (Y=small/large) from 0.01 to 0.2 by tuning Y during assembly and characterised the surface using Scanning Electron Microscope (SEM). We found that zeta potential and size ratio are critical for self-assembly crystal formation. When zeta potential over -30 mV resulted in crystal structure formation. Beyond this range, disordered structure or particle-particle adsorption was found. The crystals are used as masks against gold and plasma polymer deposition to create chemical patterns on the surface that are used for immobilising of eDNA to study how *Pseudomonas aeruginosa* attaches to surfaces and form biofilms.

BI-TuP7 Quantification of the Adhesion Strength of the Diatom *Navicula perminuta* in a Microfluidic Assay, ***M. Alles****, C. Christophis,* University of Heidelberg, Germany*, M.E. Callow,* University of Birmingham, UK*, M.H. Grunze,* University of Heidelberg, Germany*, A. Rosenhahn*, Ruhr-University Bochum, Germany

In recent years Fouling-Release (FR) technologies have been significantly improved and can be considered as an environmental benign approach against marine biofouling [1]. FR coatings refer to those coatings on which microorganisms adhere only weakly allowing their release by low shear stresses present e.g. at the hull of a cruising ship. To study cell adhesion strength on different substrates quantitatively, a microfluidic shear force assay was developed [2-3]. After an attachment phase, the adhesion strength of cells can be measured by detaching them from substrates using a stepwise increased flow across 6 orders of magnitude starting with very low shear forces of 0.01 dyn·cm^{-2}. With this device we can determine both, the fraction of adherent cells and the critical shear stress which is necessary to remove 50% of the adherent cells. Diatoms are frequently observed biofoulers and prevalent on fouling-release coatings commercially used [4]. In the presented work we tested the effect of different incubation conditions and attachment geometries on the attachment strength of the marine diatom *Navicula perminuta*. Furthermore we used chemically different substrates to determine if adhesion strength of *Navicula* is changed on potential foul-release chemistries. By this microfluidic approach, inert chemistries can readily be discriminated from surfaces with low foul release properties and the high sensitivity allows revealing even subtle differences in adhesion caused by a change in surface properties.

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BI-TuP9 Bacterial Deposition of Patterned Cadmium Sulfide Thin Films, ***K.E. Marusak****, S. Payne, Y. Cao, L. You, S. Zauscher*, Duke University

The need for new energy harvesting techniques increases, and research in photovoltaics is becoming more and more essential. In particular, there has been a growing research effort focused on "green" manufacturing techniques, including the use of bacteria to precipitate semiconducting nanoparticles. We argue that *E. coli* has tremendous potential in the fabrication of patterned cadmium sulfide thin films for solar cell applications. Here we capitalize on the ability of genetically engineered *E. coli* to precipitate cadmium sulfide nanoparticles, through the expression of the Treponema denticola cysteine desulfhydrase gene,[1] and we show that these genetically engineered *E. coli* have the ability to form patterns and monolayers on silica, glass, and indium tin oxide. Furthermore, we discuss the properties of the deposited cadmium sulfide nanoparticles and films, where we have used X-ray photoelectron spectroscopy, FTIR spectroscopy, X-ray diffraction, and scanning electron microscopy.

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BI-TuP10 Lipid Membranes as Dynamic Templates for the Assembly of Inorganic Nanoparticles, ***P. Bao****, G.R. Heath, J. Roth, B. Johnson, M. Cheetham, R.J. Bushby, S.D. Evans*, University of Leeds, UK

Supported lipid bilayers have found widespread use a model system for the investigation of basic properties of cell membranes, as well as for the development of diagnostic assays and in biosensing [1-3]. The potential of supported lipid bilayers however is still not fully realised considering the possibility of fine tuning the surface charge, fluidity, and organisation at the molecular level. In this work we have been interested in using the dynamic nature of the planar membrane as a substrate to support the crystallisation of monolayers gold nanoparticles. Two different methods of crystal formation have been investigated. In the first negatively charged gold nanoparticles were attached to a neutral lipid bilayer via cholesterol anchors and concentrated via the application of an electric field within the plane of the membrane [4-8]. This resulted regions of high nanoparticle density. We describe results of electric field annealing and the role of nanoparticle concentration on the structures formed. In the second approach we first created a bilayer displaying a phase-separation, into liquid ordered and discorded regimes and containing a small fraction of positively charged lipid. Interestingly the gold nanoparticles spontaneously assembled on the liquid ordered regimes to form quasi-crystals of nanoparticles.

The presentation will describe our combined fluorescence microscope and atom force microscope (AFM) studies on these systems and the role of temperature on assembly formation as well as the mechanism related to the crystallisation. Our results may inspire a wider application lipid bilayers as dynamic structures for the directed assembly of inorganic materials.

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BI-TuP14 Biocompatible Hydrogel Materials - Surface Properties and Deposition Comparison of Commercially Available Contact Lenses, ***K.A. Wygladacz****, D.J. Hook, S.E. Norton*, Bausch and Lomb

Hydrogel contact lenses are ophthalmic devices designed to correct refractive errors. Wettability, modulus, friction, oxygen permeability, and topography are some of the factors that influence lens comfort and performance. In addition, elimination of deposition of proteins and lipids on the lens surface from the tear fluid is of particular interest as it may influence contact lens surface wettability and impact comfort negatively. Thus, the surface chemistry and morphology of a durable and biocompatible hydrogel material should be carefully fashioned.

The objective of this research was to understand the properties of modern daily disposable contact lens materials. The surface composition, morphology, wettability and protein/lipid uptake of worn and unworn nesofilcon A and delefilcon A hydrogels were examined by X-ray Photoelectron Spectroscopy (XPS), Atomic Force Microscopy (AFM), and Captive Bubble (CBCA). Lenses from 5 healthy adults were examined after 4 hours of continuous wearing. A Dimension ICON AFM was used to characterize the unworn and worn hydrogels. Topography, peak to valley, and roughness (RMS) were recorded. AFM phase lag was used to evaluate lipid/protein deposition. Multipoint XPS spectral analysis was performed to establish the spatial distribution of elements over a large area of the hydrogel. CBCA was done to compare the wettability of unworn lenses.

AFM and XPS characterization revealed significant surface chemistry and morphology differences between worn and unworn lens materials. XPS mapping showed a uniform distribution of the identified elements on the

surface of unworn nesofilcon A and also detected the presence of a coating on delefilcon A. Unworn nesofilcon A exhibited a smooth featureless surface morphology with RMS of 1.9 ± 0.2 nm while unworn delefilcon A showed clear presence of a branched surface coating (RMS = 14.2 ± 5.5 nm) with peak to valley as deep as 61.4 ± 18.8 nm. It was established that the wear process changes the contact lens material morphology. The changes observed in the case of worn nesofilcon A were minor, while those observed for worn delefilcon A were quite pronounced. Both daily disposable materials attracted lipid/protein deposits. The topography of worn nesofilcon A was uniform and it was not altered by wear. The branched surface coating of delefilcon A collapsed during 4 hours of wear on eye and was no longer detected by AFM. In addition, delefilcon A attracted more deposits than the nesofilcon A. Topography and phase lag AFM imaging of worn deleficon A did not detect any areas that would be lipid/protein deposit free. In terms of stability and lipid/protein deposition nesofilcon A was superior.

BI-TuP15 Nanoscale Topographical Control of Graphene Architecture by Replication of DNA Nanostructures, ***Y.K. Moon***, Sungkyunkwan University, Republic of Korea

Graphene is a very fascinating material because of its unique mechanical and electronic properties. One of the major challenges for graphene is to control its electronic structure in a designed manner for various device applications. To control the electronic structure and unit size of graphene nanostructures, various approaches have been reported, including fabrication of graphene nanoribbons, chemical functionalization of graphene, control of strain applied to graphene by stretching or bending and nanoscale control of three-dimensional (3D) topography of graphene. Among these, the 3D topographical control of graphene showed interesting phenomena such as a pseudo-magnetic field, which was observed in 3D strained graphene on Pt nanobubbles by scanning tunneling microscopy. The 3D topographical control of graphene at the nanoscale level is quite difficult because graphene intrinsically prefers a two-dimensional (2D) structure. Although graphene with local 3D topography was reported to exist in the form of nanobubbles on a Pt (111) surface, ripples on CVD graphene, and corrugated structures on double strand deoxyribonucleic acids (ds-DNAs), there are limits to the geometrical shapes that can be constructed.

It is not possible for graphene itself to produce the designed 3D structures except by creating artificial defects in graphene. Designed templates with nanometer-scale precision are thus required to make various 3D graphene structures in a controlled manner. DNA nanotechnology has provided a platform to construct artificially designed nanostructures which were self-assembled with precisely controllable and programmable nanoscale features with the aid of oligonucleotide recognition. Here, we demonstrate that the nanoscale 3D topography of graphene can be controlled in a designed manner by using artificially designed DNA nanostructures with a high degree of geometrical freedom. Two DNA nanostructures, a one-dimensional (1D), five-helix ribbon (5HR) structure and a 2D double-crossover (DX) lattice, were self-assembled in a solution during annealing. After formation of DNA nanostructures, the samples were deposited on a mica surface. CVD graphene, which was grown on a Cu foil, was transferred onto the DNA nanostructures on the mica surface; during this process, graphene nanostructures were successfully replicated from DNA nanostructures. After the successful production of the designed 3D topography of graphene replicated from DNA nanostructures, we further studied its thermal stability. The influence of temperature on its topography and electrical properties was verified by atomic force microscopy (AFM) and a four point probe, respectively.

BI-TuP16 The Effects of Glycation on Serum Proteins' Affinities for Hemin, ***A.R. Mercer-Smith***, *M.S. Johal*, Pomona College

Non-enzymatic glycosylation is the process by which sugars covalently bond to proteins, potentially altering their structure and function. We investigated the change in affinity of physiologically-relevant proteins for hemin, a small iron containing molecule when it was incubated for two weeks with three sugars: glucose, fructose, and glyoxal. The formation of protein-heme complexes was measured using a Quartz Crystal Microbalance (QCM). We hypothesize that as the protein's exposure time to sugar increases, less hemin will bind to the protein. A decrease in the protein's binding affinity for hemin can negatively impact the protein's ability to transport hemin, which can even lead to free hemin in the blood. Free hemin may lead to higher rates of bacterial infection as some bacteria may use it as a micronutrient.

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