Nanometer-scale Science and Technology Division
Room: 203 - Session NS-ThA

Biological Nanomaterials

Moderator: N.A. Burnham, Worcester Polytechnic Institute

2:20pm **NS-ThA2 Biologically-Inspired Reversible Adhesives: Where Are We Now?**, ***S. Gorb***, Zoological Institute at the University of Kiel, Germany **INVITED**

Biological hairy attachment systems demonstrate their excellent adhesion and high reliability of contact. The structural background of various functional effects of such systems is discussed in the present paper. Additionally, it is demonstrated here, how comparative experimental biological approach can aid in development of novel adhesives. Experimental studies show that the effective elastic moduli of fiber arrays and spatula-like terminal elements are low, and this is of fundamental importance for adhesion enhancement on rough substrata and for an increased tolerance to defects at the level of individual contacts. Based on the broad structural and experimental studies of biological attachment devices, the first industrial bioinspired reversible adhesive foil was developed, which adhesive properties were characterised using variety of measurement techniques and compared with the flat surface made of the same polymer. The microstructured foil demonstrates considerably higher pull off force per unit contact area. The foil is less sensitive to contamination by dust particles, and after washing with water, its adhesive properties can be completely recovered. This glue-free, reversible adhesive is applicable in dynamic pick-and-drop processes, climbing robots, and other systems even under vacuum conditions. The foil represents therefore a considerable step towards development of industrial dry adhesives based on the combination of several principles previously found in biological attachment devices.

3:00pm **NS-ThA4 Ultrastable Superparamagnetic Nanoparticle Design for Membrane Assembly and Triggered Release**, *E. Amstad*, *M. Textor*, ETH Zurich, Switzerland, ***E. Reimhult***, University of Natural Resources and Life Sciences Vienna, Austria

Application of superparamagnetic iron oxide nanoparticles as biomedical imaging contrast agents and as actuators in smart materials, e.g. for drug delivery and release, require them to retain high stability even in extremely dilute suspensions, high salt and at elevated temperatures. These requirements can only be met by steric repulsive stabilization through irreversibly binding, low molecular weight dispersants of e.g. poly(ethylene glycol) or a similarly irreversibly bound organic shell which stabilizes the nanoparticle into another matrix material.

We have recently demonstrated that we can stabilize magnetite nanoparticles which fulfil these stability criteria using self-assembling dispersants with nitrocatechol anchors (1-2). This allows us free control over the dispersant type by simple co-adsorption of dispersants to as-synthesized core Fe_3O_4 particles. Combined with independent control over the Fe_3O_4 core size in the range 3-15 nm a versatile toolbox for assembly of various smart materials and for biomedical applications has been created.

This presentation is focussed on recent results demonstrating and characterizing assembly of such nanoparticles into membranes of stealth liposomes (3). We show that there are strict requirements for the size of particles that can be assembled into lipid bilayer membranes and that a requirement for efficient assembly and actuation as well as liposome stability is to ensure stability of the hydrophobic shell surrounding the nanoparticle within the membrane. Encapsulated molecules were released multiple times by application of short bursts of alternating magnetic fields through a localized phase change in the membrane without heating of the surrounding aqueous environment. This allowed control of both timing and dose of release. The highest efficiency of release and encapsulation was obtained for irreversibly stabilized superparamagnetic iron oxide nanoparticles with diameters <6 nm inserted into the lipid membrane.

1. E. Amstad et al., Nano Lett, 9:4042 (2009)

2. E. Amstad et al., J Phys Chem C 115:683-691 (2011)

3. E. Amstad et al., Nano Lett, 11:1664-1670 (2011)

3:40pm **NS-ThA6 Nanoscale Electrical Interaction between Carbon Nanotubes and DNA**, ***Y. Cao***, *Y. Xu*, Vanderbilt University

Carbon nanotube-biomolecule hybrids have emerged as one of the most promising materials for biological and biomedical applications, such as biosensors, drug delivery, and imaging. Recently, Carbon nanotubes (CNTs) have shown the ability to protect bound DNA cargos from enzymatic cleavage both during and after delivery into cells. This ability may result from the interaction between CNTs and DNA, which makes DNA unrecognizable to enzyme binding pockets. Therefore, it is important to study the interaction between CNTs and DNA. In this work, we have developed a nanoscale optoelectronic probing system by combining highly-sensitive CNT transistors with advanced dual-trap optical tweezers to investigate the interaction between CNTs and DNA at the single-molecule level. We tightly bonded both ends of a DNA molecule with microbeads, which could be held and manipulated by optical tweezers. When the DNA molecule was moved close to a suspended CNT transistor, the negative charge from the DNA molecule would change the local electrostatic environment around the CNT. Through scanning photocurrent measurements, the electrical coupling between individual DNA molecules and CNTs could be investigated.

4:00pm **NS-ThA7 Surface Functionalization of Nanomaterials: From Heterogeneous Catalysis to Nanoparticle Drug Delivery**, ***W. Gao***, Brigham and Women's Hospital and Harvard Medical School **INVITED**

The advent of nanotechnology has vastly advanced our fundamental understandings on nanomaterials, in particular their surface properties. It has also revolutionized the way we functionalize these materials to exploit novel properties and applications. For example, metallic nanoclusters can be processed into different morphologies on support surfaces and subsequently allow desired reaction pathways to occur. In addition, a great number of metal oxides have been grown into single crystal surfaces with precisely controlled atomic arrangements. They have aided researchers to unlock principles governing the extraordinary chemical and electronic properties of oxides. Furthermore, various functionalities can be introduced to polymers and have resulted in multifunctional nanoparticles with superb surface properties. These nanoparticles can therefore overcome biological barriers and effectively deliver therapeutic agents to the disease sites. Using examples from my research in surface functionalization of metals, oxides, and polymeric nanoparticles, I would like to show how the surface functionalization of diverse materials can be guided by a common principle of understanding material structure-property relationship. The continuing effort in studying surface functionalization of nanomaterials will lead them to a brighter future in the fields of biomedicine, energy, and environment.

4:40pm **NS-ThA9 Perfluoropentane Filled Boron Doped Hollow Silica Microspheres for Ultrasound Guided Surgery**, ***A. Liberman***, *H.P. Martinez, Z. Wu, S.L. Blair, Y. Kono, R.F. Mattrey, A.C. Kummel, W. Trogler*, University of California, San Diego

The reported positive margin rate from wire localized excisions of breast cancers is approximately 20-50%; however, using radioactive seeds and a radiation detector 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 foci can be localized, and incisions are required to implant the seeds, so it is rarely employed. As a safe alternative, gas-filled hollow boron-doped silica particles have been developed, which can be used for ultrasound-guided surgery for multiple focii. The function of the boron doping is to increase the mechanical strength of the silica shell. The particles are synthesized through a sol-gel method on a polystyrene template, and subsequently calcined to create hollow, rigid microspheres. The boron doped silica shell is derived from tetramethoxy orthosilicate (TMOS) and trimethyl borate (TMB), which forms a rigid, mesoporous shell upon calcination. The microshells are filled with perfluoropentane vapor. The perfluorocarbon vapor is contained within the porous shell due to its extremely low solubility in water. In addition, the high surface tension of water may serve to seal the fluorous phase within the pores of the shell wall as water enters the outer surface of the porous shell by capillary action. Considerable testing of particle functionality, signal persistence and acoustical properties have been performed in various phantoms including ultrasound gel, chicken breast, and excised human mastectomy tissue. Furthermore, preliminary particle injection longevity studies have been performed in a rabbit animal model. *In vitro* studies have shown that continuous particle imaging time is up to approximately 45 minutes. *In vivo* studies have shown consistent signal presence even 48 hours post injection in rabbits with an injection volume of 50 µl carrying only 100 µg of particles. As a result these particles may provide a significant improvement over current methods in terms of patient comfort in having a small injection 1-2 days prior to surgery. On going studies are currently aimed at improving the understanding of the mechanism by which these microspheres are capable of producing such robust signal under color doppler ultrasound.

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