

“Biomaterials in Medicine and Personal Care”

**May 1, 2008
1:00 pm to 6:30 pm**

**Douglass College Student Center
Rutgers University
New Brunswick, New Jersey**

Organized by NJACS Polymer Topical Group

Sponsors:



Biomaterials in Medicine and Personal Care

1:00 pm to 6:30 PM, May 1, 2008

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New Brunswick, New Jersey**

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- 12:00 noon Registration
1:00 pm Welcome and opening remarks
1:10 pm **From Willow Bark to PolyAspirin: History, Discovery and Innovation”**
Dr. Kathryn Uhrich (Rutgers)
1:45 pm **“Functionalized Biomaterial Systems for Bone Tissue Engineering”**
Dr. David Kaplan (Tufts Univ.)
2:20 pm **“Biocompatibility Evaluation of Biomaterials”**
Dr. Richard Hutchinson and Dr. Thomas Barbolt, (Johnson & Johnson)
2:45 pm Break & Poster Viewing
3:40 pm **“Biomimetic Approaches To Detect Pathogens With Antibody-Conjugated Peptide Nanotubes”**
Dr. Hiroshi Matsui (CUNY)
4:15 pm **“Human Tropoelastin as a Bioactive Polymer”**
Dr. Burt Ensley (DermaPlus, Inc.)
4:50 pm **“Novel Absorbable Polymers for Biomedical Applications”**
Dr. Rao Bezwada (Bezwada Biomedical, LLC)
5:25 pm Social & Poster Viewing
Dr. Bin Wei (ICI National Starch and Chemical), organizer and presiding
6:30 pm Drawing for Door Prizes

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Speakers

From Willow Bark to PolyAspirin: History, Discovery and Innovation

Kathryn Uhrich

Dept. of Chemistry & Chemical Biology, Rutgers University

Abstract

Degradable polymers based on polyanhydrides are essentially polymeric prodrugs; the polymers hydrolytically degrade into salicylic acid, just as aspirin hydrolyzes into salicylic acid upon ingestion. This talk describes medical applications where the polymer serves as a temporary barrier that degrades into therapeutically active molecules such as non-steroidal anti-inflammatory drugs (NSAIDs) and concurrently releases admixed antimicrobials. We build upon our progress with salicylate-based polymers to create new NSAID-based polymers (PolyNSAIDs) that simultaneously reduce inflammation, control pain, and eliminate bacteria to not only address periodontal indications, but also deep bone infections, restenosis, and other related inflammatory diseases. More recently, we've expanded our program to include PolyAntibiotics and PolyAntiseptics useful for simultaneously controlling pain, inflammation and infection.

Bio for Kathryn Uhrich

Dr. Kathryn Uhrich is a Professor of Chemistry at Rutgers University. She received a B.S. degree (1986) in Chemistry at the University of North Dakota, and Ph.D. degree (1992) in Organic Chemistry from Cornell University [Prof. Jean Frechet]. Before moving to her present post at Rutgers in 1995, she held post-doctoral positions at AT&T Bell Laboratories [Dr. Elsa Reichmanis] in 1992 and Massachusetts Institute of Technology [Prof. Robert Langer] in 1993-95. The focus of her current research is the synthesis and characterization of biocompatible polymers for medical and dental applications, mainly drug delivery and tissue engineering. Specifically, three different polymeric systems are being investigated: (i) hyperbranched, water-soluble polymers that encapsulate, then release, hydrophobic drugs; (ii) polymers that biodegrade into aspirin-like components to locally reduce inflammation and pain; and (iii) micropatterned polymeric substrates for evaluation of nerve cell growth mechanisms.

Her research is funded by National Institutes of Health, National Science Foundation as well as various foundations and corporations. Kathryn received the Johnson & Johnson Discovery (1996), Hoechst Celanese Innovative Research (1996 and 1997), and National Science Foundation CAREER (2000) awards for her research and elected a Fellow in the American Institute for Medical and Biological Engineering (2003). She is co-founder of Polymerix (2000), recipient of the 2003 recipient of New Jersey's "Best Life Sciences/Healthcare Company". Her recent awards include the Thomas Alva Edison patent award (2003), New Jersey's Outstanding Scientist in Biomedical Research (2004), ACS-sponsored Buck-Whitney award (2005) and the NY Academy of Sciences Blavatnik Award for Young Scientists (2007). Currently, she is co-Director of an NSF IGERT program on "Biointerfaces" (2004-present).

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Functionalized Biomaterial Systems for Bone Tissue Engineering

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Abstract

The improved understanding of cell-matrix interactions has provided new direction to the design and study of biomaterial scaffolds to direct cell and tissue outcomes both in vitro and in vivo. The ability to deliver appropriate topography, structure and chemistry to cells to direct their fate is emerging as a useful strategy relevant to functional tissue formation. Toward this goal, we utilize fibrous protein scaffold systems (e.g., collagens, silks) and control material features during biosynthesis, assembly and processing. The ability to tailor the protein matrix structure, morphology and chemistry leads to new insight into modes to control cell fate, and thus tissue outcomes. Strategies employed to gain insight into the relationships between protein material features and cellular responses include genetic engineering, as a route to add new chemical functions, selective chemical decorations of silk proteins to alter cell interactions, and processing alterations as a route to impact the self-assembly of the protein polymers and thus the material structure and morphology. These chemical/biochemical/materials processing routes to the modification of the parent protein polymer or its macromolecular organization can be combined to gain control of the chemistry, morphology and structure of the biomaterials formed. Key strategies in ongoing studies include processing in all aqueous environments with control of crystallization and thus material properties, composite formation to combine useful features from different biomaterial formats, and the formation of organic-inorganic composites with control of the interface between these components. The combination of chemical modification tools with processing options leads to an expanded family of protein polymers for biomaterials utility. The ability to vary features in this way provides control of degradation lifetimes, cell signaling, biomechanical properties and many related features critical to optimized cell and tissue functions. Specific examples from the above studies will be reviewed in the context of bone tissue engineering.

Bio for Dr. David Kaplan

David Kaplan is the Endowed Stern Family Professor of Bioengineering, and Professor & Chair of the Department of Biomedical Engineering at Tufts University. He also holds faculty appointments in the Tufts University School of Medicine, the Tufts University School of Dental Medicine and the Department of Chemistry. His research focus is on biopolymer engineering to understand structure-function relationships, with emphasis on studies related to biomaterials and functional tissue engineering. He has published over 400 papers and edited eight books. He directs the NIH P41 Tissue Engineering Resource Center (TERC) that involves Tufts and Columbia University, and the Bioengineering and Biotechnology Program at Tufts University. He serves of the editorial boards of six journals and is Associate Editor for the journal *Biomacromolecules*. He has received a number of awards for teaching, including the Henry and Madeline Fischer Faculty Award – Tufts University (2006). He was Elected Fellow, American Institute of Medical and Biological Engineering in 2003, received the Society for Biomaterials Clemson Award for contributions to the literature in 2007, and the State Massachusetts Columbus Discovery Award in 2007.

Biocompatibility Evaluation of Biomaterials

Dr. Richard Hutchinson and Dr. Thomas Barbolt
Ethicon, Inc., A Johnson & Johnson Company

Abstract

When biological systems are exposed to materials, the system responds in various ways. Some of these responses reflect the intended use of the biomaterial, and others do not. When assessing the biocompatibility of a medical device, the unintended biological responses are considered, and if these are compatible with the biological system, the material is considered “biocompatible”. The unintended responses are weighed against the intended benefit in a biocompatibility risk assessment.

The evaluation of biocompatibility relies heavily on international standards published under the ISO 10993 series, and endorsed by the FDA in general program memorandum G-95. These standards prescribe a framework for selecting biocompatibility tests based on the type and duration of tissue contact, and provide guidance on the methods for conducting these tests. When considering the biocompatibility of combination drug/device products, the standards for pharmaceuticals (ICH S6 and M3) are considered as well.

The threshold of toxicological concern is a concept gaining acceptance. It refers to the level of exposure at which there is no appreciable risk of toxicity, and can be derived without compound specific toxicity information, or specific structural information. This threshold has applications in risk assessment, setting detection limits and cleaning validations among others.

Bio for Dr. Rich Hutchinson & Dr. Thomas Barbolt

Dr. Rich Hutchinson received his DVM from Texas A&M University and his PhD in the Department of Veterinary Anatomy. His dissertation was titled: The Cellular and Molecular Mechanism of Gossypol Toxicity. Rich is a diplomat of the American Board of Toxicology, licensed to practice Veterinary Medicine in two states, and has authored more than 45 citations. He serves on several international standards boards including service as the co-chair of the US delegation developing the recently published series of standards on the risk assessment of animal materials in the manufacture of medical devices (ISO 22442). He also serves as the chair for the working group establishing a harmonized Threshold of Toxicological Concern for medical devices. He is presently a Research Fellow in the Preclinical Sciences Group of ETHICON, a Johnson and Johnson Company.

Dr. Thomas Barbolt received his BS in Biology from LeMoyne College and his PhD in Experimental Pathology and Toxicology from Albany Medical College, and has been certified in Toxicology by the American Board of Toxicology since 1981. Tom has published 71 abstracts/publications in peer-reviewed journals relating to colon carcinogenesis, animal models of human disease, the toxicologic pathology of a variety of pharmaceutical and biotechnology products, and implantable medical devices. He has participated as a member of the International Standards Working Groups for ISO 10993 developing Guidelines for the Biological Evaluation of Medical Devices. Recent activities have included the development of antibacterial sutures, wound closure devices, surgical mesh, and internal adhesives and sealants. He is presently a Distinguished Research Fellow in the Preclinical Sciences Group of ETHICON, a Johnson and Johnson Company.

Biomimetic Approaches To Detect Pathogens With Antibody-Conjugated Peptide Nanotubes

Hiroshi Matsui

Dept. of Chemistry, Hunter College, City University of New York

Abstract

Robust trace-level detection of viruses is crucial to meet urgent needs in fighting the spread of disease or detecting bioterrorism events. We are developing two approaches to detect pathogens rapidly with high specificity, high selectivity, and low detection limit. First approach is to detect viruses utilizing fluorescent antibody nanotubes. When viral pathogens were mixed with these antibody nanotubes, the nanotubes rapidly aggregated around the viruses to form a networking structure. Trace quantities of viruses such as herpes simplex virus type 2, influenza type B, Adenovirus Type 3, and simian virus 40 were detected on attomolar order by changes in fluorescence and light scattering intensities associated with aggregation of dye-loaded antibody nanotubes around viruses. High specificity of each antibody nanotube toward its targeted virus was demonstrated by quantifying concentrations of multiplex samples. This antibody nanotube assay detects targeted pathogens within 30 minutes after incubation with antibody nanotubes. This antibody nanotube assay could fill a pressing need to detect and quantify viruses both rapidly and sensitively. Second approach is to detect and identify the stains of viruses by AC capacitance. As viruses were trapped between electrodes, the capacitance change was observed and these capacitance values were characteristic to the types of viruses. The control experiments indicate that dielectric properties of capsid proteins and envelope glycoproteins significantly influence overall dielectric constants of viruses. Because those capsid proteins and glycoproteins are characteristic of the virus strain, this technique could be applied to detect and identify viruses at the single virion level using their distinct capacitance spectra as fingerprints without labeling. Since this detection system is evolving toward lab-on-chips, we also discuss how the complex electric circuit-like detection platform can be fabricated from antibody nanotubes which were precisely immobilized on substrates via biomolecular recognition.

Bio for Dr. Hiroshi Matsui

Professor Hiroshi Matsui is currently an Associate Professor (tenured) in the Department of Chemistry at City University of New York, Hunter College. After he received B.S. degree in Chemistry at Sophia University, he worked at DuPont. Then, he moved back to academia and he completed M.S. degree in Materials Sciences & Engineering at Stanford University. After obtained Ph.D. degree in Physical Chemistry at Purdue University, he served as a Postdoctoral Fellow at Columbia University. His researches in the areas of Bionanotechnology; Biomimetic material synthesis, Bio-Electronics, and Biosensing are currently funded by the Department of Energy, the National Science Foundation, the National Institute of Health, and the Food and Drug Administration. His research projects are to fabricate electronics, sensors, and medical imaging/therapeutic systems by self-assembling protein and peptide on surfaces by using their molecular recognition function. Professor Matsui was awarded the National Science Foundation Faculty Early Career Development Program "CAREER" Award in 2002. He was elected as a Frontier Member in the National Academy of Engineering in 2003 and also elected as an organizer for the Frontier Meeting of the National Academy of Engineering in 2006. Professor Matsui was awarded Japan Society for the Promotion of Science Fellow in 2006. His research has a high impact on sciences and engineering, and it was covered by various media (NBC news, World Nanotechnology newsletter (<http://nanotechweb.org/articles/news/2/12/5/1>), Nature Materials, Crain's New York Business, New Scientist, and Food Ingredient News). His recent report about the peptide nanowire fabrications became a Most-Accessed Article for the third-quarter of 2007 in *Journal of the American Chemical Society (JACS)*, the report about the development of peptide nano-reactors was the top 10 most accessed article in 2006 in *Supramolecular Chemistry*, and the report about collagen-like triple helix peptides was selected as a hot paper in *Angewandte Chemie International Edition* in April 2007

Human Tropoelastin as a Bioactive Polymer

Dr. Burt Ensley
DermaPlus, Inc.

Abstract

Human tropoelastin is a major component of the skin and other structures such as arteries and veins that require elasticity. Tropoelastin is synthesized *in vivo* as a monomer and is efficiently polymerized by cross linking at lysine residues while it is excreted into the extracellular matrix. Unlike most proteins, tropoelastin is highly polymorphic and at least 9 different versions have been described in the scientific literature. We have identified at least 15 new forms of tropoelastin through analysis of mRNA extracted from human skin fibroblasts.

The significance of most tropoelastin polymorphisms and their impact on characteristics such as polymer elasticity, tensile strength and degree of crosslinking are generally unknown. Researchers have been able to establish relationships between certain tropoelastin forms and deleterious changes in arterial characteristics in humans. These observations suggest that at least some elastin polymorphisms can have an effect on the function of the resulting polymer.

The recent ability to produce tropoelastin in useful quantities and multiple forms will aid in the identification of physical and chemical properties of individual tropoelastin isomorphs, combinations of isomorphs, and combinations with other monomers. These unique and complex polymers could have valuable applications in wound healing and even tissue and organ regeneration.

Bio for Dr. Burt Ensley

Burt Ensley, Ph.D., is founder of DermaPlus, Inc.; a New York City-based Biotechnology Company involved in wound healing and skin care. His professional career began in 1981 when Amgen, Inc., a start-up biotech firm in Thousand Oaks, California, hired him. Amgen now has 40,000 employees and \$12 billion in annual revenue.

In 1989, Dr. Ensley left Amgen to serve as director of advanced technologies for Envirogen, Inc. From 1993 to 1999, he was President and CEO of Phytotech, Inc., and from 1999 to 2004, he was CEO of NuCycle Therapy, Inc.

Dr. Ensley's professional affiliations include Fellowship in the American Academy of Microbiology, Business Advisory Board of The Bio5 Institute at the University of Arizona; Board of Trustees at the Biotechnology Council of New Jersey; Board of Directors of the Natural History Museum at the University of Kansas; the American Association for the Advancement of Science; the American Society for Microbiology; service on the National Research Council Committee on Catalysis; and the Biology Directorate Advisory Committee of the National Science Foundation.

He holds a Ph.D. degree in Microbiology from the University of Georgia (1979), his Master's degree in Biology from the University of New Mexico (1976), and Bachelor's degree in Biology from the University of New Mexico (1974). Dr. Ensley has 22 publications in the peer-reviewed scientific literature since 1990 and holds 16 issued US patents.

Novel Absorbable Polymers for Biomedical Applications

Rao S Bezwada

Bezwada Biomedical LLC, 15-1 Ilene Court
Hillsborough, NJ 08844

Abstract

What monomers are to polymers, biomaterials are to medical devices. Bringing technologically differentiated and therapeutically diverse absorbable medical devices in the market requires innovative biomaterials that can transform existing medical devices. To that end, this presentation will focus on novel absorbable technology platform developed by our company. Key aspects along with potential applications of each subset of our absorbable technology platform including polyurethanes, poly(aminoacids), poly(NSAID), polyesters, and polyamides will be presented. Furthermore, distinctive characteristics and applications of novel degradable monomers such as isocyanates, amines, functionalized drugs, functionalized natural products, functionalized phenolics, functionalized triclosan, unsymmetrical aromatic ether diacids and hydrolysable linkers and crosslinkers will be discussed. Innovative technology behind these revolutionary monomers and polymers will enable us to make novel absorbable medical devices that can fulfill the unmet needs of the healthcare community.

Bio for Dr. Rao S. Bezwada

An accomplished scientist and entrepreneur, Rao S Bezwada established Bezwada Biomedical, LLC, an innovation driven start-up research company with operations in USA and India, focused on developing and commercializing a range of novel biomaterials that represent platform technology for generation of next generation bioabsorbable medical devices and therapeutic applications. A PhD in Chemistry from Stevens Institute of Technology, Dr Bezwada is a leading expert on bioabsorbable polymers and bioabsorbable polymer based technologies with more than 25 years of leadership and research experience in medical device industries including 20 years at Ethicon (a Johnson & Johnson Company) prior to establishing Bezwada Biomedical in 2003. Dr Bezwada's strong sense of commitment towards improving the health and quality of life is attested by his original research contributions with critical applications in health care. Specifically, while at Ethicon his research and development efforts led to the launch of number of products including Monocryl, a new ultra limp synthetic absorbable suture with total worldwide sale of more than 800 million dollars since its launch in 1993 and current annual sale of 60-80 million dollars. In recognition of his invention, development and commercialization of Monocryl, Johnson & Johnson Corporation awarded him the highly prestigious Johnson Medal and Philip B Hoffman Research Award. Furthermore, Dr Bezwada is a prolific inventor with more than 72 issued US Patents. Moreover, he has made a visible impact in the field of polymer sciences and Biomaterials by authoring several scholarly articles published in international scientific journals, along with numerous well received presentations attended by leaders in the field of biomaterials in international and national meetings including the American Chemical Society and Society for Biomaterials.

Posters

1. Engineering Microbial γ -Poly(glutamic acid) with Controlled Molecular Weight and Polydispersity for Biomedical Applications

Asya Bakhtina¹, Delroy Coleman¹, Xiaoyan Zhang¹, Wenhua Lu¹, Wenchun Xie¹ and Richard A. Gross¹

*INSF-I/UCRC Center for Biocatalysis and Bioprocessing of Macromolecules,
Department of Chemical and Biological Sciences, Polytechnic University, Six
Metrotech Center, Brooklyn, NY 11201*

γ -Poly(glutamic acid) or γ -PGA is a naturally occurring homopolyamide. It is water soluble, biodegradable, edible (found in Japanese natto) and non-toxic in humans. Furthermore, γ -PGA has numerous pendant acid groups allowing its facile modification. This enables γ -PGA to be tailored for a number of medical applications including drug delivery, tissue engineering, biosensors, diagnostics, bio-separations and medical adhesives. Through microbial biosynthesis, γ -PGA is obtained in high purity and quality.

Unfortunately, during biosynthesis, γ -PGA is often obtained with a rather broad molecular weight distribution. In this study results are presented on strategies to tailor γ -PGA molecular weight average and polydispersity values.

2. Hybrid Nanostructures Based on Self-assembled Peptide Fibrils for Bone Tissue Engineering Applications

Aysegul Altunbas¹, Nikhil Sharma¹, Joel P. Schneider², Darrin J. Pochan¹

*Department of Materials Science & Engineering¹, Chemistry & Biochemistry², University
of Delaware, Newark, DE*

In an effort to design materials that will perform their intended functions under physiological conditions, self-assembled peptide hydrogels constitute an important class. One such peptide, designated MAX1, consists of alternating valine (hydrophobic) and lysine (hydrophilic) residues flanking a central diproline turn sequence that adopts a β -hairpin conformation in solution and forms a physically crosslinked hydrogel that has a fibrillar nanostructure. These hydrogels form self supporting structures that shear thin upon application of shear and then recover to their original elastic modulus on cessation of shear. In an attempt to create novel hierarchical structures with MAX1 peptide assemblies for bone tissue engineering studies, surface functional groups on the exterior of these fibrils have been utilized. Sol gel chemistry was applied to create a thin layer of silica around the peptide fibrils. This process involves the transition of a hydrogel with a water content of about 99% to a rigid porous mass. The significance of silica is accentuated with its ability to nucleate calcium phosphate during biomineralization which results in bond formation between bone and biomaterial. Structural characterization and rheological properties of these hybrids will be presented.

3. Acetylation of PAMAM Dendrimers for siRNA Delivery to Cancer Cells

Carolyn L. Waite^{*}, Sarah M. Sparks[‡], Kathryn E. Uhrich[‡], and Charles M. Roth^{**‡}
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The advancement of gene silencing via RNA interference is limited by the lack of effective siRNA delivery vectors. Rational design of polymeric carriers has been complicated by the fact that most chemical modifications affect multiple aspects of the delivery process. In this work, the extent of primary amine acetylation of generation 5 poly(amidoamine) (PAMAM) dendrimers was studied as a modification for the delivery of siRNA to U87 malignant glioma cells. A linear decrease in cytotoxicity was observed upon primary amine acetylation. To evaluate the siRNA delivery by acetylated PAMAM and subsequent gene silencing dynamics, U87 cells stably expressing d1EGFP were analyzed using flow cytometry. We observed that a modest fraction (approximately 20%) of primary amines can be modified while maintaining the GFP silencing ability comparable to unmodified PAMAM, but higher degrees of amine neutralization notably reduced the gene silencing efficiency of PAMAM-siRNA polyplexes. This trend might be explained by a marked reduction in endosomal buffering capacity of dendrimers upon amine acetylation which counteracted the increase in siRNA unpackaging. These findings demonstrate the importance of carefully tuning modifications of PAMAM dendrimers in order to reduce cytotoxicity without compromising cellular delivery of siRNA.

4. Organization and Evaluation of Primary Cardiomyocytes Seeded on Three-Dimensional Polyurethane Scaffolds

Danielle N. Rockwood¹, Robert E. Akins², Jr., Kimberly A. Woodhouse³, Joanna D. Fromstein³, Ian Parrag³, D. Bruce Chase⁴, and John F. Rabolt¹

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Electrospinning is a process by which small diameter polymer fibers can be produced to form three-dimensional fibrous matrices. The technique requires relatively simple equipment and can be applied to many different polymer systems. The work presented here focuses on the use of a biodegradable polyurethane as a substrate to seed and orient primary rat cardiomyocytes. The chemical architecture of this polymer contains hydrolyzable groups and enzymatic cleavage sites to promote *in vivo* degradation. The degradation of electrospun (ES) mats of this polyurethane was evaluated in the presence of chymotrypsin. We found that the polymer degraded slowly

over one month of incubation which will allow the cells to develop into tissue before the scaffolding completely degrades.

A particular advantage of the electrospinning process is the ability to align the fibers. In this work, we show that the orientation of the fibers determines the organization of cardiomyocytes in culture. Specifically, cells were seeded on scaffolds of isotropic and anisotropic polyurethane as well as on control tissue-culture-polystyrene (TCPS) dishes. Viability assays indicated that the ES-polyurethane was non-toxic and supported cell attachment. Immunofluorescent labeling of the cells showed that the cardiomyocytes oriented themselves to the long axis of the underlying fibers. For isotropic mats, this means that the cells appeared disorganized, much like cells seeded on TCPS. In contrast, cardiomyocytes inoculated on the aligned mats were all oriented in the same direction. This conformation of aligned cardiomyocytes is similar to the organization seen *in vivo* and suggests that ES-polyurethane may be a useful scaffold for cardiac tissue engineering.

5. Factors in Characterization of Ex-Vivo Performance of Biosurgical Materials

Elizabeth Vailhe* and Christopher DeFelice

Tissue adhesives find use in wound closure, internal surgical procedures and as hemostats. Studies show that bioadhesives may have varying performance depending on the intended target tissue. For example, an adhesive may have better peel performance when adhering to small intestine vs. dura due to inherent differences in the mechanical and physical properties of the tissues. Also, in the evaluation of tissue adhesives, freshly harvested tissues are the most relevant to clinical applications; however, sometimes it is difficult to obtain and test experimental samples to mimic freshly harvested tissues, and therefore preserved tissue is used. The effect of storage conditions on the ability of the preserved tissue to mimic freshly harvested tissue is not well known.

To address the above questions, a series of ex-vivo experiments have been conducted in our laboratory. First, porcine intestine, dura, pericardium and skin were used as model tissues for the experiments. Then, different treatment conditions were selected: freshly harvested, 24-hour aged in phosphate buffered saline at 37°C and formalin-fixed tissue. Cyanoacrylate and a proprietary polymeric adhesive were applied on the tissue substrates and their adhesion performance was characterized by T-peel testing, failure mode analysis and contact angle measurements.

The study showed that regardless of the tissue adhesive used, the fresh intestine samples had the weakest bond strength while the fixed tissue had the highest bond strength. It was found that the tissue dehydrates upon storage resulting in altered interfacial and chemical properties limiting the ability to mimic freshly harvested tissue.

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6. SELF-ASSEMBLING NANOSTRUCTURES WITH PREDEFINED GEOMETRIES VIA NATURE-INSPIRED DESIGN APPROACH

Erinc Sahin^{1,2,3}, Kristi L. Kiick^{2,3}, Thomas P. Beebe, Jr.¹

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2- Department of Materials Science, University of Delaware, Newark, DE 19711

3- Delaware Biotechnology Institute, University of Delaware, Newark, DE 19711

Nature-inspired materials design to form self-assembling structures is a powerful approach since it mimics evolutionarily perfected properties: high specificity and multivalency-induced strength of macromolecular interactions in living systems.

In our study, we aim to use nucleic acid conjugated helical polypeptides as building blocks to obtain well defined two- and three-dimensional self-assembling materials with predefined distances and angles between certain functional groups.

The control of functional group placement in the proposed macromolecular assemblies will offer sensitivity to heavy metals and toxins in the environment, which may prove useful in designing tools and devices such as highly specific filters or scavengers.

Characterization of the association of both the individual assembly units and the assembled structures will permit fundamental understanding of the thermodynamic and kinetic parameters that control the final architecture, which will allow implementation of additional designs.

7. ENVIRONMENTAL STRESS-DRIVEN EVOLUTION OF PROTEOME-WIDE SHIFTS IN ISOELECTRIC POINTS

Erinc Sahin^{1,2,3}, Kristi Kiick^{2,3}, and Thomas E. Hanson^{3,4}

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The efforts to increase the yield of recombinant expression of *de novo* designed proteins lead to the discovery of a surprising pattern pointing to environmental stress driven evolution of proteomes: *The amino-acid composition of proteins in acidophiles*

and alkaliphiles is under selective pressure which directs their proteomes toward a pI that is the opposite of environmental pH.

Our analysis also suggested the significance of salt concentration, temperature and presence of a host-association as environmental driving forces in addition to pH.

The discovery and understanding of this evolutionary phenomenon may prove useful in selection of appropriate host organisms to achieve high-yield expression of rationally designed proteins with biotechnologically important properties that are incompatible with current expression systems.

8. Influence of Various Polymers on the 3-D Arrangement of Human Hair Fiber Assemblies

F. Zisa and R. McMullen

International Specialty Products, Wayne, NJ, US

Hair body is one of the most important attributes for the hair care consumer. It is a complex phenomenon that describes the 3-dimensional state of one's hair and often alludes to the overall mechanical properties of the hair fiber assembly. Several single fiber properties are thought to be responsible for hair body and include curvature, friction, stiffness, diameter, cohesion, or weight of the individual fibers that comprise the hair fiber assembly.¹⁻² In addition, many hair styling polymers in the personal care industry are utilized to modify hair body. In this study, we investigated the structure-property relationships for hair fiber assemblies treated with an assortment of structurally distinct polymers. This was accomplished utilizing a 3-dimensional LASER stereometer, which allows for the collection of a surface plot of the hair fiber assembly and the subsequent calculation of volume, which is a key component of hair body. The stereometer was constructed with a two-dimensional x-y translational stage and a Smart Sensor LASER device. The Smart Sensor permits the measurement of distance from the LASER to the fiber assembly, while the translational stage provides a 2-dimensional grid, thus allowing for the collection of height data for the entire bundle of hair.

One of the challenges when examining hair volume is the treatment and preparation of the hair fiber assembly prior to measurement with the 3-dimensional LASER stereometer. In our studies, we incorporated several techniques for the preparation of the hair fiber assemblies, which will be discussed. We will also provide 3-dimensional images of hair assemblies and offer an interpretation for the calculated volume of space occupied by a given hair tress.

References

- [1] C. Robbins, *Chemical and Physical Behavior of Hair*, 3rd ed., Springer-Verlag, New York, 1994.
- [2] D.L. Wedderburn and J.K. Prall, "Hair product evaluation: From laboratory bench to consumer and back again," *J. Soc. Cosmet. Chem.*, 24, 561-576 (1973).

9. Tunable Affinity Ligands : A New Approach to Affinity Chromatography

Les Beadling¹, Manu Sebastian Mannoor², Teena James² and Bill Braunlin^{1,3}

The success of solid-phase biopolymer synthesis has opened the door for the facile synthesis of chain molecules, including mixed oligomers, that cannot be synthesized in living systems. Tunable Affinity Ligands (TALs) are a class of such chain molecules that are rationally designed to partition among conformational states with binding affinities that can be modulated in response to environmental stimuli. In the construction of nucleotide-based TALs, for example, non-natural bases and linkers with a variety of designed chemical functionalities can be incorporated into either natural or unnatural backbones. Synthetic polymer chains can be inserted between polynucleotide regions to provide flexible hinge regions with tunable target binding and release properties. Reactive chemistries can be used to incorporate a diverse array of functional groups, including amino acids, oligopeptides and a variety of synthetic polymers. TALs can be designed with regions that are neutral, zwitterionic, negatively and/or positively charged with target-specific implications. In this poster we will describe the utility of TALs for the separation of high-value target proteins. A unique feature of these separations is the ability to bind and elute under mild, non-denaturing conditions. The combination of our application-directed molecular technology with convective interaction media provides a powerful tool for analytical and preparative applications involving the separation of biologically important peptides, proteins, macromolecular complexes and cells.

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10. Multi-Component Nanoparticles for Combined Fluorescence, Optical and Magnetic Resonance Imaging

Marian E. Gindy and Robert K. Prud'homme.

Chemical Engineering, Princeton University, E-Quad, Olden Street, Princeton, NJ 08544

Recent advances in synthesis strategies for the fabrication of nanoscale contrast agents has lead to significant advancements in the understanding of biological processes at the molecular level, the development of better diagnostic tools, and the ability to accurately monitor drug uptake for improved drug dosing. Nanocrystalline materials such as fluorescent-doped silica nanoparticles, quantum dots and paramagnetic nanomaterials have overcome many of the early limitations associated with conventional organic dye

contrast agents, including poor photostability, low quantum yield and insufficient biological stability. However, challenges in the controlled and reproducible synthesis of biocompatible, bioinert nanomaterial contrast agents remain unmet.

In this work, we demonstrate the successful preparation hybrid nanoparticles for multi-modal imaging applications. Block copolymer nanoparticles successfully encapsulating organic fluorescent dyes, metal nanostructures and superparamagnetic materials are prepared for use in combined fluorescence, optical and magnetic resonance imaging applications. The nanoparticle preparation process, termed Flash NanoPrecipitation, relies on the controlled self assembly of incorporated agents and subsequent stabilization by a biocompatible amphiphilic block copolymer to yield highly stable nanoparticles with controlled size (50-300 nm), narrow particle size distributions, specific component composition, and high loading efficiencies. Because the process herein described relies solely on the control of mixing and aggregation timescales, and not on intrinsic physical properties of imaging components, it is anticipated that it can be expanded to include a wide variety of novel contrast agents, yielding nanoparticle formulations for integrated drug delivery and imaging applications.

11. Evaluation of Tissue Holding Strength for Different Suturing Techniques in Human and Animal Models

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Surgery involves closing a wound or incision in muscle, fascia, fat, skin, etc. Although great progress has been made in developing alternative wound closure devices such as adhesives, sealants, tapes and staples, sutures continue to be the materials of choice in surgery. There are generally two types of suturing patterns used to close a wound or incision (i.e., interrupted and continuous suture patterns). The holding strength of the suture determines the effectiveness of a sutured wound closure. To evaluate tissue-holding strength of a suture, various models or media (such as animal tissue, human cadaver, or synthetic materials) may be used. Few studies compare the holding strength of an interrupted suture pattern to a continuous suture pattern in tissue models.

We conducted a series of studies to determine the holding strength of a polydioxanone suture used to close an incision. The main purposes of this study was to determine if animal tissues could be used to replace human tissue in the early phase of the development of new sutures. In this study, interrupted and continuous suture patterns were used to close incisions in human cadaver and porcine tissues. During testing, tissues were held in a special fixture that was designed in-house. An Instron mechanical tester was used to measure breaking strength. The relationship between the number of sutures and loops and the tissue holding strength was evaluated. Failure mechanisms were determined. Results from the two tissue models were compared. This study showed the possibility of using porcine tissue to determine tissue-holding strength with sutures. The main findings of the study are summarized as follows.

1. For both interrupted and continuous suture patterns, both human and porcine tissue models yielded similar trends between the tissue holding strength and the number of interrupted sutures placed, or number of loops in a continuous suture pattern.
2. For the interrupted suture pattern, the holding strength increased as the number of the interrupted sutures increased in conformance with the following equation: $s_i = a + b \ln(n_i)$, where s_i is the holding strength, n_i is number of interrupted sutures, and a and b are constants.
3. For the continuous suture pattern, the holding strength increased as the number of the loops increased in conformance with the following equation: $s_c = ce^{dn_c}$, where s_c is strength, n_c is number of loops, and c and d are constants.
4. Failure is a gradual process.
5. For the interrupted suture pattern, most failures occurred first at the knot.
6. For the continuous suture pattern, failure occurred at the knot or in the middle of the strand.
7. During testing, some minor tissue damage was present that did not impact on the testing.

12. Characteristics of Electrospun Collagen Membranes for 3D Cancer Models

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Electrospun collagen matrices resembling architecture of a native tissue offer 3D *in vitro* models to study cell phenotype in relation to the matrix organization. In cancer research *in vitro* 3D tissue culture models for drug screening are becoming more popular than conventional monolayer of cells growing on tissue culture polystyrene (TCP). Moreover, the development of tissue engineered culture models based on the composition of the native extracellular matrices mimicking *in vivo* environment is vital for cancer research and this is an area of growing interest.

We are currently investigating physical characteristics of the three-dimensional (3D) electrospun collagen matrices and how they influence biological properties of metastatic prostate cancer cells (C42B) *in vitro*. These tissue-like constructs more realistically mimic the structure and functions of prostate cancer cells in native tumors than a traditional monolayer of cells, providing *in vivo*-like responses to therapeutic agents. They also allow study of cell-cell, cell-matrix interactions, as well as influence of the microenvironment on cell attachment, proliferation, apoptosis and gene expression.

Electrospun collagen membranes were produced from a variety of solvents and their mixtures. This allowed us to investigate solvent effect on fiber size, morphology, and molecular structure. The effect of applied electric field on fiber morphology and fibrillogenesis was also investigated. The resulting fibers (micrometer and nanometer in diameter) with specific morphology and surface topography were designed to recreate 3D extracellular matrix of prostate cancer tissues; and were further characterized using AFM, SEM, CD and Raman spectroscopy. These fundamental studies provided us valuable strategies to control electrospinning process.

In vitro cell studies revealed that the electrospun collagen membranes support normal morphogenesis and growth of C42B cells by enhancing their clustering phenotype and survival rate under various drug treatments. Such favorable interactions between C42B cells and fibrous collagen matrices result from their physical characteristics that have been thoroughly evaluated. This knowledge was applied toward development of *in vitro* pharmacological assay for testing of novel anti-neoplastic therapeutics. Hence, electrospun collagen membranes are being seen as promising candidates for a variety of biomedical applications such as drug sensitivity assays, high-throughput screening, and *ex vivo* culturing for clinical diagnostics and regenerative medicine.

13. Modulating Rigidity of Self-Assembled β -Hairpin Peptide Hydrogels via Photopolymerization

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Self-assembly of rationally designed β -hairpin peptides is a promising approach to construct robust functional biomaterials. Towards this goal, a 20-amino acid peptide (MAX 1) was designed to undergo an intramolecular folding event to form an amphiphilic antiparallel β -hairpin that intermolecularly self-assembles to form β -sheet rich stimuli responsive hydrogels. The gel consists of a network of well-defined fibrils formed by intermolecular hydrogen bonding and hydrophobic association of the folded β -hairpin peptides. In the self-assembled state, the fibril consists of a bilayer formed in an ordered fashion due to the stacking of the individual hairpins directly on top of each other, minimizing exposure of the hydrophobic side chains to water. However, during the self-assembly process, irregular hydrophobic facial associations may also occur resulting in packing defects creating nucleation sites for nascent fibril growth, thus forming non-covalent interfibril junctions that serve to crosslink the gel. In addition to the interfibril crosslinks, simple fibril entanglements also help define the gel nanostructure. The number of interfibril crosslinks and fibril entanglements formed as a result of self-assembly define the material rigidity at the macroscopic level. To modulate the material rigidity, we prepared β -hairpins that display dienes along the solvent exposed side of the

fibril so that the fibrils of the hydrogel can be covalently crosslinked via photopolymerization. In addition to forming self-supporting hydrogels at physiological conditions, these hydrogels also possess the ability to self-heal following application of high shear. Photopolymerization of the self-healed peptide hydrogels resulted in a two-fold increase in rigidity. Trigger-induced folding and self-assembly, photopolymerization, and material properties assessed by circular dichroism and oscillatory rheology will be presented. Designing materials in this fashion, where the mechanical properties can be controlled, has potential applications in tissue engineering and drug delivery.

14. Architecture Effects on the Binding of Cholera Toxin B Pentamer by Polypeptide-Based Glycopolymers

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Multivalent interactions between oligosaccharides and saccharide receptors occur in a wide range of biological events, such as the initial recognition of pathogens and viruses during host infections, inflammation response, cell communication and adhesion. Various inhibitors and effectors have been synthesized to mimic these multivalent binding between receptors and ligands, however, the determinants for designing polymeric inhibitors or effectors of these interactions have remained somewhat obscure, and polymers with well-defined architectures are therefore required to illustrate effective parameters in multivalent ligand design. In this work, a series of α -helical glycopolypeptides, with well-defined architectures and precise control of the presentation of pendant saccharides, were synthesized via a combination of protein engineering methods and chemical coupling. The homogeneity, secondary structures, and the hydrodynamic volume of these polypeptides and glycopolypeptides were characterized via SDS-PAGE, ¹H NMR, circular dichroic spectroscopy and gel permeation chromatography. Binding to the cholera toxin B pentamer (CT B₅) subunit was evaluated via direct enzyme-linked immunosorbent assay (DELA). Inhibition enhancements observed for the recombinant helical glycopolypeptides suggests the potential for optimizing binding through appropriate control of polymer conformation and architecture.

15. Heparin-containing hydrogels for modulating growth factor delivery and endothelial cell responses

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The ability to engineer biologically active materials has advanced dramatically in the last few years. Glycosaminoglycan hydrogels designed for the delivery of therapeutic proteins, such as growth factors, is one of the most important areas of recent development. In this study, *in situ* crosslinkable and degradable heparin-containing hydrogels were designed for the binding and controlled release of growth factors, and tested as an ECM mimetic materials for modulating endothelial cell responses. The gelation times and elastic moduli of these gels could be tuned by alternating the chemical and physical properties of the materials.

Cell studies indicates that the proliferation and migration of human umbilical vein endothelial cells (HUVECs) could be modulated by variations in the mechanical properties of hydrogels. Vascular endothelial growth factor (VEGF), which is released from hydrogel, significantly stimulates the spreading and migration of HUVECs on the hydrogel. HUVECs spreads and migrates faster on hydrogels with higher moduli ($G' = 2,200$ Pa) than gels with lower moduli ($G' = 500$ Pa). This system may therefore provide an ECM mimic matrix for manipulating the local environment and response of endothelial cells (EC) in the engineering of EC-derived structures.

16. Study of Glutamate Release from Rat Hippocampus Neurons Using Microelectrode Array

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Glutamate is the main excitatory neurotransmitter in central nerve system. It is directly related to many neurologic diseases. However, the mechanism of glutamate release from neurons is not yet well understood. Here, we designed a device based on a gold microelectrode array to study glutamate release from rat hippocampus neurons cultured on the device. Gold electrodes modified with poly(acrylic acid) brushes, to which glutamate oxidase was attached, have shown good sensitivity and fast response time towards glutamate. The gold electrode array was insulated by silicon oxide. A positively charged polymer brush was patterned on the silicon oxide layer and the patterns were arranged to go across gold electrodes to guide neurons to grow over the electrodes. Neurons have shown good processing on such a positively charged polymer brush. Such integrated device can be very useful for *in situ* study of exocytosis in neurons.

17. Early-Times of β -Hairpin Self-Assembly and Hydrogelation

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Triggered hydrogelation of MAX 1 peptide ($\text{NH}_2\text{-(VK)}_4\text{-V}^{\text{D}}\text{PPT}\text{-(KV)}_4\text{-CONH}_2$) proceeds through peptide intramolecular folding into β -hairpins and immediate self-assembly into branched clusters of well defined (uniform, 3 nm cross section), semi-flexible, β -sheet-rich nanofibrils. Cryogenic transmission electron microscopy indicates that dangling fibrils extend from one growing cluster to another and lead to early, intercluster communication in solution. At the apparent percolation threshold, the dynamic shear modulus measured by oscillatory rheology ($G'(\omega), G''(\omega) \propto \omega^n$) and the field-intensity autocorrelation function measured by dynamic light scattering ($g_1(\tau) \propto \tau^{-\beta'}$) show power-law behavior with comparable critical dynamic exponents ($n \approx 0.47$ and $\beta' \approx 0.45$). Finite interpenetration of percolating clusters with smaller clusters, along with permanent intercluster entanglements, increase the network rigidity. The self-assembly of MAX 1 peptide will be compared and contrasted with the assembly of other biopolymeric networks in literature.

A Chemspeed automated, parallel synthesis platform has been used successfully to synthesize a library of polymers, using the RAFT technique. Approximately 85 polymers were synthesized in parallel (one run) per day. The materials subset exhibits a range of thermal properties.

B. Polymer Swelling Characteristics and Protein-Polymer Interaction Studied with the QCM-D Technology

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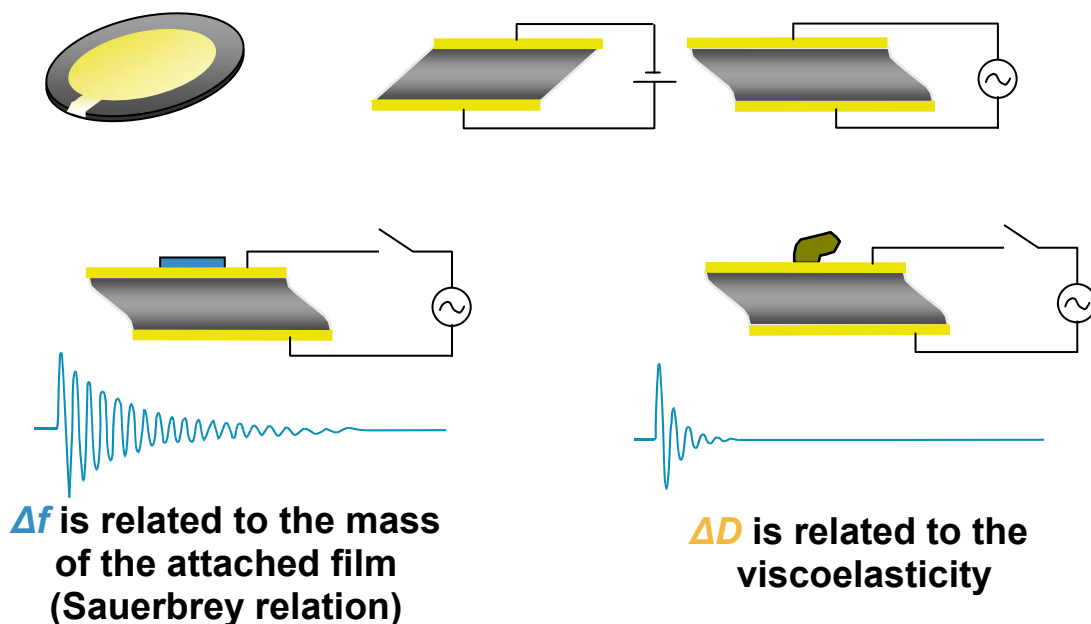
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Recently, there has been an increasing demand of analytical tools for the characterization of interaction between biological molecules and polymeric materials due to its broad scientific interest and great commercial importance. Applications and products developed from this field of study include medical implants, drug delivery formulations, biosensors and biofilms.

Quartz Crystal Microbalance with Dissipation monitoring (QCM-D), a nanomechanical acoustic-based analytical technique, is a novel tool to analyze binding events and reactions occurring at a wide variety of biointerfaces. With QCM-D, simultaneous measurement of resonance frequency change (ΔF) and energy dissipation change (ΔD) is performed by periodically switching off the driving power of oscillation of the sensor crystal and recording the decay of damped oscillation as the adsorption and/or structural changes takes place at sensor crystal surface. While change in frequency provides information about mass changes, dissipation (D) provides structural information about the viscoelastic properties of adsorbed films in real time.

In the present poster we show the real-time analysis of hydrogel swelling, polyelectrolyte multilayer assembly and protein adsorption to biomaterials using QCM-D.

QCM-D ping principle



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“FUNCTIONAL PACKAGING THROUGH CHEMISTRY”

This symposium is presented by the *Polymer Topical Group* of the North Jersey Section of the American Chemical Society. It features presentations contributed by leading scientists from both academia and industry. The event is intended to bring the local polymer science community up-to-date on the advancements in the chemistry relating to packaging, in a range of applications such as pharmaceuticals and vaccines, food packaging, electronic devices, and many other exciting areas.

This event also features presentations, posters and networking opportunities of interest to diverse professionals involved in the functional packaging industry. Whether you are from academia or industry, this is a good opportunity for you to showcase your research, network with other people and contact possible employers and clients.

In addition to posters focusing on packaging, general polymer posters are being solicited. We are looking for poster submissions relating to polymer research in diverse areas such as green polymers, advanced polymeric materials, polymer characterization, etc. *Any registered conference attendee may sign up to present a poster on any polymer-related topic.*

We look forward to seeing you at this symposium and hope that you would take advantage of the scientific and networking opportunities it offers. Updated information will be available in late August at the PTG website [<http://www.njacs.org/ptg.html>].

PRELIMINARY PROGRAM

Time: 1:00 pm to 6:30 PM, October 29, 2008 (Wednesday)

Location: NJIT Campus Center, Newark (NJ), Grand Ballroom

ORGANIZER: Dr. Tamal Ghosh (tamal@alumni.stevens-tech.edu)

CO-ORGANIZERS: Dr. Bin Wei (ICI National Starch and Chemical bwei01@gmail.com) and Dr. Ankur S. Kulshrestha (BD Medical, Ankur_Kulshrestha@bd.com)

Keynote Talk: Challenges in sustainable packaging (Dr. Bob Kimmel, Clemson U.)

New developments in biodegradable polyester for packaging applications (Mr. Tony Gioffre, Novamont)

Oxygen and moisture vapor barrier coatings (Dr. Derek Illsley, Sun Chemical)

The polymer supply chain and the impact on extractables and leachables in pharmaceutical container closure systems (Dr. Michael Ruberto, Ciba)

Temperature monitoring in pharmaceutical cold-chain (Mr. Oumer Salim, Wyeth Biotech)

Evolution of electronic packaging and its demands to materials (Dr. Allison Xiao, ICI National Starch)

POSTER SESSION & MIXER

ORGANIZER: Dr. Bin Wei (ICI National Starch and Chemical) (bwei01@gmail.com)

EXHIBITS & COMMERCIAL POSTERS

ORGANIZER: Dr. Nicole Harris (Sun Chemical) (nicole.harris@sunchemical.com)

Directions: Can be found at the NJIT website (<http://www.njit.edu/about/visit/gettingtonjit.php>)

Registration: Members: \$40; Non-members: \$50; Students: \$25; free for NJIT students and staff with ID

Early registration and poster submission deadline is October, 15, 2008. Fees increase after that date and late poster submissions may not be listed in the program and might not be accepted due to equipment limitations. Online registration will start in late August <http://www.njacs.org/ptg.html> OR send your full contact information along with a check for the appropriate amount made payable to NJACS-Polymer Group to Dr. Willis B. Hammond, Treasurer, NJACS-PTG, 128 Center Ave., Chatham, NJ 07928.

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