Duke UNIVERSITY | PRATT SCHOOL of ENGINEERING

TALK ABSTRACTS

FRONTIERS 2014

EXPLORE THE LATEST RESEARCH ADVANCES AT DUKE UNIVERSITY

BENJAMIN WILEY, PHD

FLEXIBLE, TRANSPARENT, CONDUCTING NETWORKS OF METAL NANOWIRES

Abstract: There is an ongoing drive to transform rigid, glass-based flat-panel devices (e.g., displays, solar cells, organic LEDs) into flexible devices on plastic substrates in order to improve flexibility, reduce weight, and reduce cost. The high cost, brittleness and slow coating process (<0.01 m/s) of the standard transparent conducting material, indium tin oxide (ITO), is limiting realization of these goals. This presentation will discuss the replacement of ITO with networks of metal nanowires. Metal nanowires can be produced in scalable, solution-phase syntheses, and can be coated from liquids at high rates (>1 m/s). Nanowire networks can be flexed more than 1000 times with no change in their conductance, can be made from earth-abundant metals (Cu, Ni), can carry high currents (0.5 A/cm2), can be rendered stable against oxidation and have equivalent optoelectronic properties as ITO. Nanowire networks can thus enable the production of low-cost, highly robust flexible electronics. This work is patent pending.

C. WYATT SHIELDS IV

ELASTOMERIC PARTICLES FROM SILICONE GELS FOR ACOUSTOPHORETIC BIOSEPARATIONS

Abstract: We have developed a class of elastomeric particles comprised of silicone materials with tunable mechanical properties and narrow size distributions. These particles are prepared from nucleation and growth methods, thus providing intrinsic scalability that can greatly exceed the production rates of microfluidic-based approaches. Their programmable acoustic behaviors afford the elastomeric particles the ability to experience forces that allows their rapid separation from cells in acoustic standing waves. As a leading example, we show these particles can be functionalized with biomolecules to specifically capture proteins, viruses or rare cell populations for continuous sorting in acoustic fields. Patent for this technology is currently pending.

VRAD LEVERING

ACTIVE SURFACES FOR CONTROL OF BIOFOULING

Abstract: Surface biofouling, the unwanted accumulation of material, biomolecules, cells (including microbes) and attaching organisms (referred to as a biofilm) upon submersed surfaces, is a devastating problem in many industrial, military and medical applications. Biofouling in industrial and military applications requires greater than $15 billion to manage annually. Biofilms in medical applications cost 100's of millions to manage annually, while also causing patient injury and contributing to the rise of antibiotic resistant bacteria. We have developed active surface technologies to control biofouling and demonstrated dramatic results for control of both medically and maritime-relevant biofouling. Patents for the general new biofouling control technology and the anti-biofilm medical catheter technology are pending.

JEFFREY GLASS, PHD

CARBON NANOSTRUCTURES FOR ELECTRODE APPLICATIONS: FROM MINIATURE MASS SPECTROMETERS TO ENERGY STORAGE

Abstract: This presentation will provide a review of research in the presenter's laboratory related to carbon nanotube and graphenated carbon nanotube growth, characterization and device development. Laboratory capabilities in the area of ALD (atomic layer deposition) of oxides will also be reviewed if time allows. Primary application areas of interest involve electrodes for disinfection, energy conversion, energy storage, neural stimulation and miniature-mass spectrometry. Graphene and carbon nanotubes (CNTs) are fascinating materials due to their exceptional properties and potential use in applications ranging from high frequency electronics to energy storage devices. A hybrid structure consisting of graphene foliates protruding from the sidewalls of aligned multi-walled CNTs has been developed in the presenter's labs. The graphenated-CNT (g-CNT) structures are deposited via microwave plasma enhanced chemical vapor deposition and characterized using electron microscopy, Raman spectroscopy, and electrochemical techniques. These structures have enhanced capacitive properties due to the density of exposed graphene edges in a three dimensional framework. Electrochemical impedance spectroscopy has indicated that the weight specific capacitance for the g-CNTs is ~5x that of similar CNTs without the graphene foliates. Pulsed charge injection measurements demonstrated approximately a 7x increase in capacitance per unit area. These improvements in capacitance indicate this new material is promising for a variety of electrode applications including energy storage and catalysis.

Acknowledgement: Funding from various sources is gratefully acknowledged, including NSF, NIH, DARPA, DOE, Gates Foundation, and the Department of Homeland Security. Management of the laboratory and research projects is enabled by the efforts of Drs. Charles Parker, Jason Amsden and Qing Peng. The numerous graduate students who have conducted the research discussed in this presentation are also gratefully acknowledged.

ASHUTOSH CHILKOTI, PHD

TRANSLATING MOLECULAR BIOENGINEERING FROM THE LAB TO THE PATIENT

This talk will highlight recent work from my laboratory that illustrates the clinical translation of molecular bioengineering technologies for point-of-care clinical diagnostics and drug delivery. I will discuss a point-of-care diagnostic that we have developed, in which all reagents are printed and stored on a "non-fouling"—protein and cell resistant—polymer brush. The D4 assay, involves four sequential events: (1) Dispense (droplet of blood); (2) Dissolve (printed reagents on chip); (3) Diffuse (across surface); and (4) Detect (binding event). Examples of quantitative dose-response from whole blood and the integration of the assay with a smart phone compatible detector will be presented. In the area of drug delivery, I will highlight two technologies that are ready for commercialization. In the first design, I will discuss a general method, attachment-triggered self-assembly of recombinant peptide polymers, that packages small hydrophobic molecules into soluble polymer nanoparticles. Because many cancer chemotherapeutics are insoluble small molecules with poor bioavailability, this approach has great utility to increase the solubility, plasma half-life and tumor accumulation of many cancer chemotherapeutics. In the second example, I will discuss a new approach for PEGylation of proteins and peptide drugs, by growing a poly(ethylene glycol) (PEG)-like polymer from the surface of protein and peptide drugs to yield a well-defined protein-polymer conjugate with greatly improved circulation and tissue distribution as compared to the unmodified protein, and thereby improving its clinical performance.

GABRIEL P. LÓPEZ, PHD

SIMPLE ASSAYS FOR PROTEASES

Abstract: The precise and accurate detection of proteases is an important tool for both disease diagnosis and drug discovery. Toward application to both needs, we have developed a rapid, inexpensive, highly precise, yet simple protease assay based on protease-dependent precipitation of genetically engineered polypeptides that form nanoscopic micelles. In this assay, cleavage of a soluble peptide segment containing a specific protease-recognition sequence from the engineered peptide induces transition of the small micellar particles to large aggregates, resulting in increased turbidity. Protease concentration can be accurately determined by the time dependence of appearance of turbitity. As an example using this technology, we can precisely quantify matrix metalloproteinase (MMP) presence in buffer and human serum. In addition, we have also developed a low cost prototype instrument for point-of-care diagnostics. Patent for this technology is currently pending.

ALVIN R. LEBECK, PHD

HARNESSING DATA PARALLEL HARDWARE FOR SERVER WORKLOADS

Abstract: Addressing the increasing computational demands for high-volume, high-velocity big data workloads is a challenge that must be addressed across all areas of computer science and engineering. This talk focuses specifically on systems software to exploit the rapid advances in high throughput accelerators (e.g., GPGPUs) to provide the computational resources required to meet the increasing demands of big data workloads.

Our work builds on the observation that server workload execution patterns are not completely unique across multiple requests/queries. We present a framework for high throughput servers that can exploit similarity across requests/queries to improve server throughput and energy efficiency by launching data parallel executions for request cohorts. Prototype implementations of the SPECWeb Banking and a k-nearest neighbor workload (web search) using our framework on NVIDIA GPUs shows that significant performance, efficiency and cost of ownership benefits can be achieved by using cohort-based servers for high throughput scenarios.

THEOPHILUS BENSON, PHD

IMPROVING BIG DATA ANALYTICS WITH SOFTWARE DEFINED NETWORKING

Abstract: Although there is tremendous interest in designing improved networks for big data analytics data centers, very little is known about the network-level traffic characteristics of current data centers. In this talk, I will present MicroTE, a system that leverages insight from a large data study that I conducted on Microsoft's Data centers. MicroTE improves performance by using Software Defined Networking to exploit the short-term predictability of data center traffic. I will show that MicroTE performs close to the optimal traffic engineering solution. Finally, I will conclude by presenting initial results from ongoing work, NaPS, that seeks to integrate Software Defined Networking with big-data frameworks, such as Hadoop. NaPS improves Hadoop's performance by providing visibility into the network and thus allowing Hadoop to make more efficient decisions in a network aware manner.

CHRIS DWYER, PHD

INTEGRATED NANO-MOLECULAR SYSTEMS ENABLED BY DNA SELF-ASSEMBLY

Abstract: This research addresses the question of how to design and fabricate efficient nano- and molecular-scale computational substrates for bringing computation into new domains. This requires a long-term vision and the many challenges along such a trajectory demand that there is sufficient near- and mid-term utility to warrant such work. Thus, we are investigating the near-, mid- and long-term horizons that are uniquely enabled by DNA self-assembly yet align with the long-term vision of building sophisticated nano- and molecular-scale computers. In the near-term our efforts aim to address fundamental questions in building a new class of devices and circuits based on resonance energy transfer (RET). In the mid-term, DNA self-assembly will have impact by enabling fused molecular-scale sensing and computation which can operate in many physical environments. Our long-term goal is to overcome the fundamental physical limitations of top-down computer manufacturing and develop self-assembled molecular-scale substrates for highly parallel computing.

To do this, we use self-assembling DNA nanostructures which offer a unique ability to create arrangements of single molecules with complex and controllable patterns. Recent advances in DNA nanotechnology have enabled new application domains at the molecular-scale (i.e., 0.1 – 10nm) that remain inaccessible by traditional lithographic methods. For example, it is now possible to pattern single molecules with sub-nm precision in complex, aperiodic 2D and 3D patterns on discrete, near-micron scale nanoscale objects. Few technologies have sufficient resolution to reproduce such structures and even fewer can produce them in the numbers that molecular self-assembly can, i.e., ~10^15 structures or more per run (i.e., in 4-8 hrs). DNA self-assembly can also scale to industrial capacity by leveraging existing infrastructure and manufacturing in the biotechnology and pharmaceutical industries which already use large quantities of custom DNA and derivatives. Thus, the barrier to industrial adoption of DNA self-assembly is low.

This work will explore a new nanoscale technology for computing based on single molecule optical devices called chromophores. In isolation, a given chromophore absorbs photons of a specific wavelength and emits photons at a lower energy, longer wavelength, as first characterized by Stokes. However, when appropriate chromophores are placed a few nanometers apart, i.e., within the near-field, the energy of an absorbed photon can be transferred to a neighboring chromophore through the well-known process of resonance energy transfer. This process provides the theoretical foundation for the creation of RET circuits which can implement, e.g., pass gates (both inverting and non-inverting), memory elements and valves which operate on near-field, tightly bound optical excitons. Through DNA self-assembly we have begun to build and characterize RET circuits for use in information processing, storage and biological application domains.

ALEXANDER HARTEMINK, PH.D

BIG DATA AND THE GENOME REVOLUTION

Abstract: When people think about high-throughput DNA sequencing technology, they might imagine the landmark sequencing of the 3 billion nucleotides of the human genome. Since the sequence of the human genome is now known, what is left to sequence?

For starters, every person on the planet has a different genome, and when mutations arise that cause cells to proliferate into cancerous tumors, knowing the specific alterations in the genome sequence can help guide personalized treatments.

Second, we are embarking on the process of sequencing the literally millions of different species in an effort to understand their evolutionary relationships.

Third, and the focus of my group's research, high-throughput DNA sequencing technology can be used not just to tell us which nucleotides make up a genome, but also how that genome is functioning within cells: how it is being dynamically interpreted, regulated, transcribed, and replicated. These kinds of applications lead to large heterogeneous data sets that must be integrated into holistic models of genome function, which in turn, requires large-scale computation as well as principled statistical machine learning.