Amgen Seminar Series in Chemical Engineering

in

Cherry Auditorium, Kirk Hall, 1 PM

Presents on September 29, 2016

Electronic, Optical, and Magnetic Neural Interfaces

By

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Mammalian nervous system contains billions of neurons that exchange electrical, chemical and mechanical signals. Our ability to study this complexity is limited by the lack of technologies available for interrogating neural circuits across their diverse signaling modalities without inducing a foreign-body reaction. My talk will describe neural interface strategies pursued in my group aimed at mimicking the materials properties and transduction mechanisms of the nervous system. Specifically, I will discuss (1) Fiber-based probes for multifunctional interfaces with the brain and spinal cord circuits; (2) Magnetic nanotransducers for minimally invasive neural stimulation; and (3) Active scaffolds for neural tissue engineering and interrogation.

Fiber-drawing methods can be applied to create multifunctional polymer-based probes capable of simultaneous electrical, optical, and chemical probing of neural tissues in freely moving subjects[1]. Similar engineering principles enable ultra-flexible miniature fiber-probes with geometries inspired by nerves, which permit simultaneous optical excitation and recording of neural activity in the spinal cord allowing for optical control of lower limb movement[2]. Furthermore, fiber-based fabrication can be extended to design of scaffolds that direct neural growth[3] and activity[4] facilitating repair of damaged nerves.

Molecular mechanisms of action potential firing inspire the development of materials-based strategies for direct manipulation of ion transport across neuronal membranes. For example, hysteretic heat dissipation by magnetic nanomaterials can be used to remotely trigger activity of neurons expressing heat-sensitive ion channels. Since the alternating magnetic fields in the low radiofrequency range interact minimally with the biological tissues, the magnetic nanoparticles injected into the brain can act as transducers of wireless magnetothermal deep brain stimulation[5, 6]. Similarly, local hysteretic heating allows magnetic nanoparticles to disrupt protein aggregates associated with neurodegenerative disorders[7].

References

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Polina Anikeeva received her BS in Physics from St. Petersburg State Polytechnic University in 2003. After graduation she spent a year at Los Alamos National Lab where she worked on developing photovoltaic cells based on quantum dots. She then enrolled in a PhD program in Materials Science at MIT and graduated in January 2009 with her thesis dedicated to the design of light emitting devices based on organic materials and nanoparticles. She completed her postdoctoral training at Stanford University, where she created devices for optical stimulation and electrical recording from neural circuits. Polina joined the faculty of the Department of Materials Science and Engineering at MIT in July 2011, where she is now a Class of 1942 career development associate professor. Her lab focuses on the development of flexible and minimally invasive materials and devices for neural recording, stimulation and repair. Polina is also a recipient of NSF CAREER Award, DARPA Young Faculty Award, and the TR35 among others.

This series at the University of Rhode Island is made possible through the generosity of Amgen, West Greenwich, R.I.

Refreshments provided by the Joseph Estrin Endowment.