UC San Diego
JACOBS SCHOOL OF ENGINEERING
NanoEngineering

UC SAN DIEGO NANOENGINEERING

Wednesday, April 12, 2017
Seminar Presentation: 11:00am – 12:00pm
Cymer Conference Center, SME 248

Dr. Nicholas Melosh
Associate Professor
Department of Materials Science and Engineering
Stanford University

Heterogeneous Integration of Inorganic Devices into Biological Cells and Tissues

Abstract:
The cell's lipid membrane is one of the most vital components of a cell; the gate-keeper into and out of the cytoplasm. Studies ranging from neural activity to drug discovery to fundamental cell physiology rely upon controlling electronic or chemical flow across this barrier. Unfortunately, artificially controlling access through a lipid layer is surprisingly difficult; current techniques often involve creating holes in or puncturing cell membranes that cause cell cytotoxicity. Yet precise, non-destructive access to the cell interior can lead to an impressive range of new techniques and devices, ranging from neural-prosthetic interfaces, direct material delivery and even cell content sampling. The critical barrier is penetration of the lipid membrane itself, yet what happens when the lipid membrane interacts with nanostructures and cell-penetrating materials is still an active area of research. Here we explore how inorganic materials with high-aspect rations and nanoscale molecular functionalization influence and control this vital interface. We achieved high-efficiency chemical delivery and control by mimicking nature gap junction proteins, creating arrays of 'nanostraws'. These nanoscale (100-500 nm) diameter straws are formed based on simple water filtration membranes. We show these permit delivery or extraction of a wide variety of materials that could normally not pass through the cell wall. We have modeled the lipid bilayer failure mechanism, and show that a simple impaling mechanism is insufficient to cause rupture, but instead rely upon cellular traction forces to drive rupture. Another key challenge is how to create very large arrays of depth electrodes for brain machine interfaces. Here we present using microelectrode bundles that can be pressed against CMOS microelectronic chips, such as those used for cameras or displays. These chips are already available with more than 1 million independent pixels, thus have room to spare to record or stimulate from 100k+ electrodes. The chip architectures have similar electronics and voltage/current ranges as neural interface systems, enabling use of even off-the-shelf chips. Here we present our efforts to build and test these massively parallel interface systems, including bundle preparation and connectivity yield with the CMOS pixels. We show that a press-fit bundle connector can achieve >90% wire connectivity, and each wire can even produce physiologically relevant stimulation current or recording speed for highly dense electrical interfaces. These systems may provide a means to reach the electrode numbers and electronic readouts necessary for next-gen brain machine interfaces.

Biosketch:
Professor Melosh received his B.S. degree in Chemistry from Harvey Mudd College in 1996, then went on to do a Ph.D. in Materials Science at UC Santa Barbara working with Brad Chmelka, Galen Stucky, and Glenn Fredrickson. He worked with Professor Jim Heath at UCLA/Caltech as a post-doc from 2001-2003, and joined the Materials Science and Engineering department at Stanford University in 2003. Professor Melosh's interests include interfacing inorganic structures with biology, high-temperature energy conversion, and plasmonics. He is a Terman Fellow and Reid and Polly Anderson Faculty Scholar at Stanford University.