BNC Distinguished Seminar

Mixed Conduction in Polymeric Materials: Electrochemical devices for Biosensing and Neuromorphic Computing
Alberto Salleo

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11:00am – 12:00pm, BRK 1001

Bio: Alberto Salleo is currently an Associate Professor of Materials Science at Stanford University. Alberto Salleo holds a *Laurea* degree in Chemistry from *La Sapienza* and graduated as a Fulbright Fellow with a PhD in Materials Science from UC Berkeley in 2001. From 2001 to 2005 Salleo was first post-doctoral research fellow and successively member of research staff at Xerox Palo Alto Research Center. In 2005 Salleo joined the Materials Science and Engineering Department at Stanford as an Assistant Professor and was promoted to Associate Professor in 2013. Salleo is a Principal Editor of MRS Communications since 2011.While at Stanford, Salleo won the NSF Career Award, the 3M Untenured Faculty Award, the SPIE Early Career Award, the Tau Beta Pi Excellence in Undergraduate Teaching Award, and the Gores Award for Excellence in Teaching, Stanford's highest teaching award. He has been a *Thomson Reuters Highly Cited Researcher* since 2015, recognizing that he ranks in the top 1% cited researchers in his field.

Abstract: Organic semiconductors have been traditionally developed for making low-cost and flexible transistors, solar cells and light-emitting diodes. In the last few years, emerging applications in health case and bioelectronics have been proposed. A particularly interesting class of materials in this application area takes advantage of mixed ionic and electronic conduction in certain semiconducting polymers. Indeed, the ability to transduce ionic fluxes into electrical currents is useful when interacting with living matter or bodily fluids. My presentation will first discuss the fundamental aspects of how mixed conduction works in polymeric materials and then focus on two families of devices made with such materials: electrochemical transistors and artificial synapses.
1- Biosensing using electrochemical transistors: The continuous monitoring of human health can greatly benefit from devices that can be worn comfortably or seamlessly integrated in household objects, constituting "health-centered" domotics. I will describe electrochemical transistors that detect ionic species either directly present in body fluids or resulting from a selective enzymatic reaction (e.g. ammonia from creatinine) at physiological levels. Additionally, I will show that non-charged molecules can be detected by making use of custom-processed polymer membranes that act as "synthetic enzymes". Using these membranes in conjunction with electrochemical transistors we demonstrate that we are able to measure physiological levels of cortisol in real human sweat. Finally, I will show a more biomimetic approach where the sensing layer is a lipid membrane stabilized at a liquid-liquid interface, which we use to detect antimicrobial compounds. The same basic device that we use for sensing can also be used for computing.
2- Polymer-based artificial synapses: The brain can perform massively parallel information processing while consuming only ~1- 100 fJ per synaptic event. I will describe a novel electrochemical neuromorphic device that switches at record-low energy (<0.1 fJ projected, <10 pJ measured) and voltage (< 1mV, measured), displays >500 distinct, non-volatile conductance states within a ~1 V operating range. Furthermore, it achieves record classification accuracy when implemented in neural network simulations. Our organic neuromorphic device works by combining ionic (protonic) and electronic conduction and is essentially similar to a concentration battery. The main advantage of this device is that the barrier for state retention is decoupled from the barrier for changing states, allowing for the extremely low switching voltages while maintaining non-volatility. I will show that the device can rival commercial flash memory in terms of endurance and possibly switching time. When accessed with an appropriate switching device it exhibits excellent linearity, which is an important consideration for neural networks that learn with blind updates