Materials Science & Engineering Seminar Series

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Mechanical properties of organic semiconductors: Toward robust and intrinsically stretchable electronics

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The term “plastic electronics” masks the wide range of mechanical behavior possessed by films of π-conjugated (semiconducting) small molecules and polymers. Mechanical compliance can be influenced strongly by differences in structure that appear minor. For example, poly(3-heptylthiophene) (P3HpT) is an order of magnitude more elastic than is poly(3-hexylthiophene) (P3HT). There is also an apparent trade-off between electronic performance and mechanical compliance in films of some of the best-performing conjugated polymers and polymer-fullerene blends, which fracture at tensile strains not significantly greater than those at which conventional inorganic semiconductors fail. The design of materials that can be deformed significantly would facilitate roll-to-roll production, mechanical robustness for potable applications, conformal bonding to curved surfaces (i.e., for implantable biomedical devices), and would enable large-scale solar farms based on ultrathin organic modules that can survive forces of the outdoor environment. This seminar describes my group’s efforts to understand and control the structural parameters that influence the mechanical properties of modern conjugated polymers. Our conclusions include the strong effect of the side chain in determining the elasticity, ductility, and adhesion of polymers and their blends with fullerenes, and how this effect can be predicted by theory. Ultra-compliant materials are used for the first time in solar cell that can be stretched and conformed to hemispherical surfaces without damage. We also describe the synthesis of all-conjugated, segmented copolymers, along with stretchable fabrics of semiconducting nanowires, whose goal is to maximize both electronic properties and mechanical compliance. Mechanical, electronic, and spectroscopic evidence suggest that compliance and electronic performance need not be in competition, and could inform the engineering of the next generation of semiconducting polymers for mechanically tough, ultra-flexible, and stretchable applications.

Darren J. Lipomi earned his bachelor’s degree in chemistry with a minor in physics from Boston University in 2005. Under Prof. James S. Panek, his research focused on total synthesis and heterogeneous catalysis for efficient asymmetric synthesis. He earned his PhD in chemistry at Harvard University in 2010, with Prof. George M. Whitesides, where he developed unconventional, green approaches to fabricate nanostructures for electronic and optical applications. From 2010 – 2012, he was an Intelligence Community Postdoctoral Fellow in the laboratory of Prof. Zhenan Bao at Stanford University, where his research was directed toward increasing the mechanical compliance of organic photovoltaic devices. He is now an assistant professor in the Department of NanoEngineering at the University of California, San Diego. The interests of his research group include the mechanical properties of organic semiconductors for robust and stretchable devices, and green chemistry and nanoengineering. His research is supported, in part, by the AFOSR Young Investigator Program and the NSF BRIGE program.

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