

CHEMICAL ENGINEERING

DISTINGUISHED YOUNG SCHOLARS SERIES



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Understanding and improving the mechanical stability of solution-processable semiconductors for flexible and stretchable electronics

ABSTRACT: The primary goal of the fields concerned with solution-processable thin-film semiconductors (e.g., organic semiconductors or photoactive perovskites) is to produce devices with performance approaching that of silicon electronics, but at a greatly reduced cost. However, for these technologies to be commercially viable, significantly deeper understanding of their mechanical properties and behavior under stress is required.

For example, organic semiconductors are often believed to be as deformable as conventional plastics; however, an inherent competition between mechanical deformability and charge transport has long been observed in these materials, and achieving the extreme (or even moderate) deformability implied by the word “plastic” concurrently with high charge transport may be elusive. I will discuss the relationship between mechanical deformability and charge transport in conjugated polymers. The hypothesis that charge transport and mechanical deformability are mutually exclusive is tested, and the principal conclusions are that reducing the competition between these two parameters is in fact possible, with two demonstrated routes being: (1) incorporation of softer, insulating material into a stiffer, semiconducting material and (2) increasing disorder in a highly ordered film, but not enough to disrupt charge transport pathways. The aim of this discussion is to provide an understanding of the molecular determinants of mechanical deformability and charge transport, what morphological factors are critical for each, and how to decouple their mutual incompatibility, therefore allowing for rational design of conjugated polymeric materials for applications requiring large-area, low-cost, printable devices that are ultra-flexible or stretchable, such as organic photovoltaics (OPVs) or wearable, conformable, or implantable sensors.

Whereas organic semiconductors are ideal materials for applications where the device will undergo significant deformation, stiffer photoactive perovskites are promising materials for less mechanically demanding applications such as photovoltaics. Perovskite solar cells exhibit high efficiency, insensitivity to defects, and low fabrication cost, but their salt-like structure makes them inherently brittle, and their commercial viability requires substantial improvements in thermomechanical reliability. To address this challenge, I will also discuss a new concept in perovskite device architecture, the compound solar cell (CSC), which addresses the intrinsic fragility of these materials with mechanically reinforcing internal scaffolds. The internal scaffold effectively partitions a conventional monolithic planar solar cell into an array of dimensionally scalable and mechanically shielded individual perovskite cells that are laterally encapsulated by the surrounding scaffold and connected in parallel via the front and back electrodes. The scaffold-partitioned perovskite cells exhibited a fracture resistance 30-fold greater than previously reported planar perovskite devices while still maintaining efficiencies comparable to the planar devices. This development is a significant step in demonstrating robust perovskite solar cells to achieve increased reliability and service lifetimes comparable to c-Si, CIGS, and CdTe solar cells.

BIOGRAPHY: Adam D. Printz earned his B.S. in finance from the University of Maryland and his Ph.D. in nanoengineering from the University of California, San Diego in 2015 under the supervision of Prof. Darren Lipomi. His Ph.D. research focused on the microstructure of organic semiconductors and its effects on the mechanical properties of polymer and bulk heterojunction thin films. In 2016, he was the recipient of the Chancellor's Dissertation Medal, the highest award given to Ph.D. graduates in the Jacobs School of Engineering. Adam is now a postdoctoral scholar in the laboratory of Prof. Reinhold Dauskardt at Stanford University working on improving the stability of perovskite solar cells.

LECTURE 4:00 – 5:00 (PAA) A110
Happy Hour in Benson Hall Lobby Following

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