Improving Performance of Organic Thin-Film Transistors and Solar Cells

Dawen Li

Department of Electrical and Computer Engineering, Center for Materials for Information Technology, University of Alabama, Tuscaloosa, AL 35487

The seminar presentation focuses on two organic devices: thin-film transistors with TIPs-pentacene as active layer and heterojunction solar cells based on P3HT/PCBM material system.

Organic thin-film transistors (OTFTs) based on 6,13-bis(triisopropyl-silylethynyl)-pentacene (TIPS-pentacene) polycrystalline films are promising for low-cost flexible electronics due to their relatively high mobility, air stable, and the ability to be solution-processed at room temperature. However, TIPS-pentacene thin films severely suffer from crystal growth anisotropy, which consequently results in poor consistency of device performances. To solve this problem, silicon dioxide nanoparticles (SiO_2 NPs) (~20 *nm*) were mixed with TIPS pentacene in solution, and subsequent drop-casting of the blend solution yielded uniform film morphology with enhanced average mobility and significantly reduced performance variation. In addition, pure TIPS-pentacene thin film with uniform crystal orientation was also obtained by air flow navigation. Sharp peak in X-ray diffraction indicates great crystallinity and areal coverage of TIPS-pentacene with optimal air flow rate. The OTFTs based flow-guided TIPS-pentacene show an increase of average mobility and a reduction in the ratio of measured mobility standard deviation (μ_{Stdev}) to average mobility (μ_{Avg}).

In the heterojunction solar cell project, we have demonstrated that a small amount of a PS-b-P3HT diblock copolymer could serve as a compatibilizer to effectively improve the power-conversion efficiency of P3HT/PCBM based photovoltaic cells. At optimal concentrations, the diblock copolymer was found to induce favorable active layer morphology with interpenetrating nanoscale domains, and the enhanced P3HT crystallinity and orientation facilitate hole transport within the active layer. Quantum density functional theory calculations suggest that the interaction between PS segments and PCBM is a major driving force to control phase separation in P3HT/PCBM blends, with the PCBM attracted to the PS block, and the P3HT stacking onto the P3HT block, which leads to improvements in long-range “crystallinity”. Neutron Reflectivity (NR) results show that the addition of the PS-b-P3HT compatibilizer affects the PCBM segregation in the vertical direction, in which the PCBM accumulation near the substrate interface is reduced with a corresponding increase in the middle region of the active layer. The most homogeneous profile (no near air surface segregation) was obtained at the PS-b-P3HT concentration of 5 wt%, which we attribute to an increase in miscibility of P3HT and PCBM driven by the copolymer compatibilizer. Overall, the addition of diblock copolymers to control phase separation, crystallinity, and resultant favorable composition profile in vertical direction represents a promising way to enhance the photovoltaic properties of polymer bulk heterojunction solar cells.

Key words: organic thin-film transistors, TIPS-pentacene, SiO_2 nanoparticles, air flow navigation, heterojunction solar cells, diblock copolymer, mobility, power-conversion efficiency