Materials Considerations and Patterning Strategies for Organic Thin-Film Electronics

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Large-area displays based on organic materials promise low-cost fabrication, lightweight construction, mechanical flexibility and durability. To truly realize the low-cost aspects of organic electronics, however, conventional high-vacuum deposition technologies – costly both in terms of instrumentation as well as operation – will have to be replaced by solution processing methodologies like inkjet printing or spin casting. This need has in turn driven the development of solution-processable organic semiconductors, and even solution-processable organic conductors.

Devices made from spun-cast organic semiconductors have previously been disappointing, with carrier mobilities (<10^{-3} cm^2/V-sec) that are too low for any practical applications, and current-voltage characteristics that are highly dependent on the processing conditions. We have recently fabricated bottom-contact thin-film transistors with spun-cast triethylsilylethynyl-anthradithiophene (TES-ADT) comprising the electrically-active channel. As-spun, the TES-ADT device characteristics are unremarkable. Subjecting the same transistors to brief solvent vapor annealing, however, improves the device characteristics dramatically. Specifically, the carrier mobility and on-off current ratio increase by more than two orders of magnitude, to > 0.1 cm^2/V-sec and > 10^4, making the performance competitive for display backplane applications. More importantly, we observe a great reduction in the threshold voltage and current hysteresis on cycling – observations that imply trap reduction at the electrode-organic semiconductor and dielectric-semiconductor interfaces, respectively. The electrical characteristics are directly correlated with changes in TES-ADT morphology and molecular orientation, as probed by optical microscopy and near-edge x-ray absorption fine structure spectroscopy.

Our efforts in solution-processable organic conductors focus on water-dispersible polyaniline (PANI) that is synthesized oxidatively in the presence of a polymeric acid dopant, with conducitivities of 0.1 – 1 S/cm. Using stamp-and-spin-cast, a patterning technique developed in our labs, we have fabricated bottom-contact thin-film transistors with PANI electrodes, which function as effectively as gold electrodes as far as on-characteristics are concerned. Examination of the linear source-drain voltage regime suggests that PANI devices exhibit markedly less contact resistance than gold devices. The potential drops at the organic-semiconductor-electrode interface measured by Kelvin probe microscopy are complemented with structural studies at the interface.

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