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High Performance Organic Field-Effect Transistors – From Single Crystal Devices to Large-area Electronics

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Organic materials present a great chemical and functional tunability, allowing for a wide range of properties of interest to both fundamental studies and potential applications. The reduced complexity processing of such materials enables their fast deposition over large-area, flexible substrates using roll-to-roll processing, inkjet printing or spray coating, allowing their production in large volumes and at low cost. But the complexity of the film microstructure yielding from solution deposition often precludes a good electrical performance. In this presentation I will focus on describing the electrical performance of pentacene and thiophene derivatives in relation to their structural degree of order. Single crystals are used to provide a well-defined structure, with minimal defects and to permit access to the intrinsic electronic properties of these materials. Several methods which allow improvement of the long-range order in organic thin-film transistors (OTFTs) will be described. The mechanism of self-patterning arising from the formation of differential microstructure on contacts and dielectric surfaces will be revealed. This results from halogen-halogen interactions between the organic semiconductor and the self-assembled monolayers (SAMs) at the surface of electrodes. We demonstrate that we can precisely control the preferential molecular orientation and tune the charge carrier mobility from 10^{-3} cm^2/Vs to greater than $1cm^2/Vs$ in the same material. Consequently, a dramatic increase in the current on/off ratio from 10^4 in the case of un-patterned transistors to 10^7 in self-patterned devices is recorded. The ability to pattern OTFTs is critical for manufacturing high-performance devices, as it reduces the leakage currents, and promotes superior electrical performance. Spray-coating is further employed for efficiently depositing organic semiconductors over large areas, without compromising the performance and fabrication costs. Properties such as mobility, contact resistance, interfacial trap-density and threshold voltage will be discussed, and the results will be correlated with structural data obtained from X-ray diffraction studies.