OPEN SEMINAR

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Title: Organic Semiconductor Homojunction Diodes: Mechanisms Controlling Current & Capacitance Characteristics

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Abstract: Electronic devices based on organic materials, particularly, diodes and transistors have significant technological potential due to their advantages in processibility, flexibility and costeffectiveness. The role of organic/organic & metal/organic interfaces is crucial in controlling the device characteristics. However the underlying physical mechanisms taking place at these interfaces are not well understood, and need special attention. A detailed understanding of mechanisms at the interface will help design structures and applications in the field of organic electronics.

My thesis aims to study in detail the undoped homojunction diode, which is a sandwich structure consisting of doped and undoped layer of the same organic semiconductor. Our principal focus is to demonstrate the effect of the thickness of the undoped layer on the device characteristics. The configuration of the specifically designed device under test is ITO|p-MTDATA|i-MTDATA|Al. Intrinsic layer thickness is varied from 10 nm to 100 nm so as to demonstrate the control over both forward and reverse current density-voltage (J-V) and capacitance-voltage (C-V) characteristics. The specially designed device structures for this purpose have been fabricated using a state-of-the-art automated multi-chamber Cluster tool. The prototype materials m-MTDATA and F4-TCNQ are used as matrix and dopant, respectively and the doping is achieved by co-evaporation. The devices with thin intrinsic layer showed Zener type behaviour exhibiting high current density beyond a certain reverse threshold voltage.

In order to delineate underlying mechanisms, the J-V characteristics were studied by varying the temperature from 200K to 300K. The forward bias characteristics are controlled by the high-low junction to result in nearly temperature independent ideal exponential J-V regime prior to the space charge limited regime even for samples with intrinsic layer thickness as low as 10 nm. However, the reverse characteristics are controlled by Fowler-Nordheim (F-N) tunneling at the cathode/intrinsic layer interface. The barrier controlling F-N tunneling is found to be temperature independent but sensitive to the intrinsic layer thickness. This is interpreted in the framework that the thickness of the intrinsic layer modulates the Fermi level responsible for barrier height.

The capacitance spectroscopy of m-MTDATA based homojunction and intrinsic diodes has been analyzed to investigate the physical mechanisms controlling the charge processes. The capacitance exhibits voltage dependence in reverse bias which is a signature of the defect states acting as traps. In order to investigate the defect states, temperature dependent capacitance-frequency (C-f) characteristics have been analyzed. The defect states are estimated to have Gaussian distribution and the associated parameters have been calculated. In the low thickness homojunction we are

able to probe the parameters associated with localized level in the HOMO states, demonstrating consistency with Gaussian disorder model of energetic in organic semiconductors.

In homojunction diode, having low intrinsic layer thickness (10nm), the capacitance in deep reverse bias starts decreasing nearly exponentially and goes below the geometrical capacitance (Cg) after a critical electric field inside the device. This decrease in the capacitance is interpreted on the basis of F-N tunneling of carriers. The small signal capacitance in such cases will have negative contribution which is directly related to delay time introduced by charge transport. Using F-N tunneling, the characteristics have been modeled in deep reverse bias, and the estimated barrier height matches with the values calculated from J-V characteristics. The technique also allows determination of mobility, and disorder parameters are derived through its temperature and field dependence.

The study reported in the thesis thus gives a coherent account of mechanisms underlying current and capacitance characteristics of homojunction organic diodes. We thus demonstrate determination of useful intrinsic transport and disorder parameters from such characteristics.