Organic Electronic Materials Topical Conference
Room 327 - Session OE+EM-MoA

Organic Thin Film Devices II: Transitors and Transport

Moderator: P.E. Burrows, Princeton University

2:00pm **OE+EM-MoA1 Organic Thin Film Transistors*, T.N. Jackson,*** The Pennsylvania State University **INVITED**

Over the past several years the performance of organic thin-film transistors (OTFTs) has improved dramatically and it now appears likely that they will find application in displays or other low-cost large-area electronic applications. Small molecule materials such as oligothiophenes and oligoacenes have shown the most progress. When deposited by thermal evaporation onto substrates held at elevated temperature these materials often form thin films with strong molecular ordering; such ordering may be important for obtaining large field-effect mobility and other desirable electrical characteristics. In particular, pentacene thin films deposited at a few Å/s onto substrates held at 50 - 100 °C typically have micron-sized grains, and OTFTs using pentacene as the active layer have demonstrated field-effect mobility as large as 1.5 cm@super 2@/V-s, current on/off ratio larger than 10@super 8@, near zero threshold voltage, and subthreshold slope less than 1 V/decade; all these characteristics are similar to those typically observed for a-Si:H thin film transistors (TFTs). Polymeric semiconducting materials are also of interest since they may offer a simple path to solution-processable devices. Thin films of these materials can often be solvent cast which leads to films that are less well-ordered than evaporated small molecule films; however, field-effect mobility near 0.05 cm@super 2@/V-s has been demonstrated for alkyl-substituted soluble polythiophenes. In addition to all-organic applications, OTFTs show promise for integration with a-Si:H TFTs. The field-effect mobility of p-channel OTFTs and n-channel a-Si:H TFTs are similar and integrated organic/a-Si:H devices can provide a simple complementary circuit technology.

2:40pm **OE+EM-MoA3 Fast Electronic Transport in Organic Molecular Solids?*, N. Karl,*** Universität Stuttgart, Germany **INVITED**

The fundamental aspects of electronic charge transport in organic solids will be reviewed and some specific features of this class of materials highlighted. Examples of appropriate measurement techniques - such as time-of-flight (TOF), field effect transistor (FET), and surface acoustoelectric travelling wave (SAW) techniques - as well as of characteristic results - such as magnitude, temperature dependence and anisotropy of intrinsic charge carrier mobilities - will be presented. While ample basic knowledge has been gained from well-defined ultrahigh purity single crystals, where mobilities of several hundred cm@super 2@/Vs could be reached (see e.g. ref. 1), understanding of the electronic properties of organic thin films is often unsatisfactory. Different kinds and degrees of structural disorder, residual foreign molecules, and a sensitivity to accidental doping by ambient donor or acceptor molecules (such as e.g. O@sub 2@) frequently not only lead to ill-defined irreproducible or nonstationary properties but also to slow transport. Sample preparation under well-controlled conditions and careful sample characterization by sensitive methods of structural and trace impurity chemical analysis are the prime prerequisite not only for further progress in fundamental research, but also for the development of innovative applications. Needless to say that proper selection of material parameters, such as sufficient stability and specific molecular architecture-based functions, is necessary for designing promising molecular-electronic systems, but the complementary aspect of efficient charge carrier transport, which is a superordinated consideration in most applications, may necessitate optimization compromises. @FootnoteText@ @footnote 1@ "Organic Semiconductors" in: Landolt-Börnstein (New Series) Group III, Vol.17i, pp 106-218 (Springer-Verlag, Berlin, New York 1985).

3:20pm **OE+EM-MoA5 Soluble and Processable Oligothiophenes and Analogues as Semiconductors for Thin Film Transistors*, W. Li,*** *H.E. Katz, A.J. Lovinger, K.R. Amundson,* Bell Laboratories, Lucent Technologies

There has been rapid progress in the synthesis and fabrication of organic semiconductors for field effect transistors (FETs) useful for plastic-based electronics. Conjugated oligomers, such as oligothiophenes and their derivatives, have been shown to be effective semiconducting layers for FETs. We and others have utilized these compounds primarily as vapor-deposited solid films. Recently, our investigation has been extended to liquid phase fabrication of organic FETs. We have synthesized a series of soluble and processable oligothiophenes and related compounds. Thin film FETs cast from solutions of these compounds showed both high field-effect mobilities (ca. 0.03 cm@super 2@/Vs) and relatively high on/off current ratios (>10@super 3@). We find that the film continuity and field-effect mobility are strongly dependent on solvents and dielectric substrates used as well as other casting conditions. Detailed synthetic routes and transistor characteristics, as well as approaches to devices with higher on/off ratios will be presented.

3:40pm **OE+EM-MoA6 Field Effect Conductance of 1-6 Monolayer Thick Crystals of Organic Semiconductors***, E.L. Granstrom, T.W. Kelley,* ***C.D. Frisbie,*** University of Minnesota

We describe two types of field effect measurements on organic semiconductor single crystals that are as thin as a single molecular layer. In these studies, crystals of the semiconductors pentacene or sexithiophene are grown by vacuum sublimation onto SiO2, ranging in thickness from 1-6 monolayers with lengths and widths on the order of a micron. In one experiment, individual crystals are contacted with source and drain electrodes fabricated by electron-beam lithography; heavily doped Si underneath the SiO2 serves as a gate electrode. Field effect conductance and carrier mobility are measured as a function of temperature (30-300 K) and the number of discrete molecular layers in the crystals. We find that measurements on these thin crystals are extremely sensitive to carrier trapping and offer a potential approach to dynamic recording of the effects of individual trapping events on source-drain current. A second experiment uses a conducting atomic force microscopy (AFM) probe as a positionable source or drain contact to crystals contacted by a fixed electrode at the other end.@footnote 1@ This configuration allows variation of the source-drain separation and estimation of the organic-metal contact resistance. Resistances associated with defects, e.g., a single grain boundary between adjacent crystals may also be measured. In general, the conjunction of AFM imaging methodology with transport measurements facilitates correlation of transport properties with specific, well-defined organic semiconductor structures. @FootnoteText@ @footnote 1@Loiacono, M. J.; Granstrom, E. L.; Frisbie, C. D. J. Phys. Chem. B 1998, 102, 1679.

4:00pm **OE+EM-MoA7 Charge Injection and Transport in Organic Films*, D.K. Murti,*** Xerox Research Centre of Canada, CANADA

Charge injection and transport is important in many diverse organic electronic devices. For example, electroluminescent devices for display and organic photoreceptors for digital printers depend on injection and transport. In this presentation, the primary focus will be on the organic photoreceptor. Organic photoreceptors consist of a metal film with layers of organic photoconductor and molecularly doped polymers. Charge injection and transport at metal-phthalocyanine interfaces and phthalocyanine-molecularly doped polymer interfaces will be discussed in this presentation. In the photoinduced discharge technique, the surface is initially corona-charged and then followed by discharge of the surface potential with photogenerated carriers that are injected from phthalocyanine and transported in the tetraphenylbenzidine (TPD) doped polycarbonate film. Photoinduced discharge measurements indicate that photogenerated holes can be injected from phthalocyanine into TPD without charge trapping. Hole mobility and the electric field dependence were measured with the time-of-flight technique. In this technique, the drift of a sheet of holes injected from the phthalocyanine film is time-resolved; the transit time is determined in order to calculate the hole mobility at an applied electric field. Hole mobility showed dependence on the electric field with a mobility of about 1x10 @super -5@ cm@super 2@ / V.s at an electric field of 1x10 @super 4@ V/cm. Kelvin probe was used to determine the contact potential difference and changes in the work function of phthalocyanine and TPD. The relative work functions of phthalocyanine and TPD are 5.2 eV and 4.7 eV respectively based on Kelvin probe measurements. This indicates no barrier for hole injection as observed by photodischarge techniques.

4:20pm **OE+EM-MoA8 Localized Growth and Electrical Characterization of Polypyrrole on Temperature Programmed Microhotplates*, C. Kendrick,*** *R.E. Cavicchi, S. Semancik,* National Institute of Standards and Technology

Arrays of microhotplates fabricated at CMOS foundries have been post-processed to realize suspended, heatable structures that have previously allowed localized deposition of SnO@sub 2@ by thermally activated CVD.@footnote 1@ This work presents an electrochemical, self-lithographic technique for the growth of polypyrrole on the micromachined platforms and a study of the effect of rapid heating/cooling cycles on film conductivity during gas exposure. Electropolymerization was performed in a sealed flow cell containing Ag-pseudoreference and Pt-counter electrodes mounted directly on the chip package and filled with a solution of acetonitrile, 0.1M LiClO@sub 4@, and 50mM pyrrole. Optical microscopy indicates that polypyrrole growth begins on the Au-plated microhotplate contacts and expands laterally, forming a continuous film. The effects of NO@sub x@, NH@sub 3@, CO, H@sub 2@, and methanol vapors on film resistance have been measured for different film dopings and temperature schedules. The highest sensitivities are found for the strongly oxidizing and reducing gases NO@sub x@ and NH@sub 3@, respectively, where resistance changes have been shown to be caused by changes in carrier concentration brought about by a weak charge transfer interaction between adsorbates and the film. We show that resistance changes (@DELTA@R/Ro) due to 100ppm NO@sub x@ exposure can be increased from ~15% at 25°C to ~30% when periodically pulsing the sensor to 150°C. A similar increase in sensitivity is observed for periodic heating during exposure to NH@sub 3@. Information on analyte adsorption rates and dynamics can also be extracted from the transient resistance characteristics observed between temperature pulses. @FootnoteText@ @footnote 1@S. Semancik, R. E. Cavicchi, K. G. Kreider, J. S. Suehle, and P. Chaparala, Sensors and Actuators B 34, 209 (1996).

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