# Wednesday Morning, October 4, 2000

## Organic Films and Devices
## Room 313 - Session OF+EL+SS-WeM
### Transport and Device Issues in Organic Thin Films

**Moderator:** A. Kahn, Princeton University

8:20am **OF+EL+SS-WeM1 The Transport and Injection of Positive Carriers in Conjugated Electroluminescent Polymers and their Devices***, **A.J. Campbell**,* University of Sheffield, UK, U.K.*; D.D.C. Bradley,* University of Sheffield, UK*; H. Antoniadis,* Infineon Technologies Corp. **INVITED**

Organic light emitting diodes (OLEDs) based on electroluminescent conjugated polymers are an important emerging technology with a wide range of display and lighting applications. Polyfluorene and its copolymers are considered to be amongst the most promising materials for use in commercial OLEDs. Indium tin oxide (ITO) is also the hole injecting electrode of choice in any practical device. Here we report the results of time-of-flight measurements on the transport of positive carriers in polyfluorene and its copolymers. The field and temperature dependence of the charge carrier mobility is compared to theoretical models for charge transport in disordered organic materials. We also report the results of dark injection and current density-voltage measurements on the injection of holes from differently prepared ITO contacts. The absolute injection efficiency of the contacts is calculated by comparison to trap-free, space-charge-limited current (TFSCLC). The injection efficiency is shown to vary with not only polymer ionisation potential but also with the nature of the ITO preparation (i.e. washed in solvents, exposed to an oxygen plasma, coated with a film of poly(ethylenedioxythiophene) / polystyrenesulphonic acid). The variation of the injection efficiency with temperature is also reported.

9:00am **OF+EL+SS-WeM3 Grain Boundary Effects on Electrical Transport in Polycrystalline Organic Semiconductor Thin Films***, **R.J. Chesterfield**, A.B. Chwang, K. Puntambekar, C.D. Frisbie,* University of Minnesota

The role of microstructure in electrical transport in polycrystalline thin films of organic semiconducting oligomers (e.g., pentacene, sexithiophene) has not been extensively explored. This talk describes experiments in which transport through single grain boundaries (GBs) is probed using field effect transistor (FET) structures and Kelvin probe force microscopy (KPFM). In the FET studies, closely spaced gold source and drain electrodes are connected to pairs of pentacene or sexithiophene microcrystals grown on insulating substrates, such as SiO@sub 2@. The microcrystals, or grains, share a common boundary that dominates the transport through the FET. Conduction through the GB is measured as a function of gate field and temperature, and the results are compared with a recent model by Schon and Batlogg.@footnote 1@) In the KPFM studies, a metal-coated AFM tip is used to record potential distributions across an operating microcrystal FET. The resulting images reveal where the voltage is dropped across the device and thus point to the chief bottlenecks in the current transport. In general, both the microcrystal FET and Kelvin probe experiments show that microstructure, and in particular GBs, can potentially dominate transport in polycrystalline organic semiconductor films. @FootnoteText@ @footnote 1@J. H. Schon, B. Batlogg, Appl. Phys. Letters, 74(2), 1999, 260-262.

9:20am **OF+EL+SS-WeM4 Quantum Confinement and Electron Transfer at Organic-Metal Interfaces***, **G. Dutton**, H. Wang, X.-Y. Zhu,* University of Minnesota

Electron transfer at organic-metal interfaces is important in molecule-based electronic and optoelectronic devices, such as light-emitting devices (LEDs), field-effect transistors (FETs), and molecular quantum wires (QW). We probe interfacial electronic structure and electron transfer dynamics using two-photon photoemission in model systems: thin films of hexafluorobenzene and naphthalene adsorbed on Cu(111). Electron transfer to the lowest unoccupied molecular orbitals, as well as to those mixed with image-type states, are observed. In both systems, these resonances display quantum well behavior: the electronic wavefunction is delocalized parallel to the surface but confined in the direction normal to the surface. The detailed structure and dynamics are established by dispersion measurements and by femto-second time-resolved two-photon photoemission. We believe the formation of these molecular quantum wells is a result of the strong interaction of molecular states with the metal substrate. A simple theoretical framework is developed to describe the formation of these molecular quantum wells.

9:40am **OF+EL+SS-WeM5 Chemistry and Electronic Properties at Metals (Al, Mg and Au)-Organic Molecular Semiconductor (F@sub 16@CuPc) Interfaces***, **C. Shen**, J. Schwartz, A. Kahn,* Princeton University

The fabrication of efficient and stable metal-organic contacts is exceedingly important for the optimization of organic devices such as organic light emitting diodes (OLED) and thin film transistors. Al and Mg have low work functions and are typically used as electron injecting cathode materials. Au is a mostly inert metal in contact with organic materials. F@sub 16@CuPc is a candidate for n-channel thin film transistor material because of it relatively high electron mobility. Chemistry and physical processes (e.g. interdiffusion) that take place at metal/organic interfaces have a direct impact on the electronic properties of the contacts. It is generally believed that metals deposited on organics lead to more extensive interface chemistry and broader interfaces than organics deposited on metals. In some cases, these interfaces have actually been reported to lead to drastically different electrical behavior. The interfaces fabricated in ultra-high vacuum, however, shows identical electrical behavior.@footnote 1@ We have investigated the interface chemistry, electronic structure and electrical transport in nominally symmetric metal/F@sub 16@CuPc/metal structures fabricated and tested in ultra-high vacuum. For these structures, we performed detailed ultra-violet and X-ray photoemission spectroscopy (UPS, XPS) photoemission spectroscopy measurements that suggest that the chemistry at metal-on-organic interfaces is very similar to, if not identical with, that at organic-on-metal interfaces. Using current-voltage measurements performed in vacuum, we demonstrate that carrier injection is identical from top and bottom cathodes. @FootnoteText@ @footnote 1@Role of electrode contamination in electron injection at Mg:Ag/Alq@sub 3@ interfaces, C. Shen, I.G. Hill and A. Kahn, Adv. Mat. 11, 1523 (1999).

10:00am **OF+EL+SS-WeM6 Microcontacts to Self-Assembled Monolayers with a Conducting AFM Tip***, D.J. Wold, **C.D. Frisbie**,* University of Minnesota

Molecular level electrical transport studies require innovative approaches for making electrical contacts to oriented molecules. While scanning tunneling microscopy (STM) and electrochemical methods have been used for years to study transport in surface-confined molecules, conducting probe atomic force microscopy (CP-AFM) provides an alternative approach to electrically contacting monolayer films and the formation of metal-molecule-metal junctions. In CP-AFM, a metal-coated AFM tip is placed in direct contact, under controlled load, with the material to be probed. The technique differs from STM in that the probe is positioned using normal force feedback, which decouples probe positioning from electrical measurements. Using this technique, we show that CP-AFM may be used to make mechanically stable electrical contact to SAMs of alkane thiols on Au. We have probed the current-voltage (I-V) characteristics of the resulting junctions as a function of the number of methylenes in the alkane chains and the load applied to the tip-sample contact. The ease of this technique and the fine control of the probe during measurements make CP-AFM a promising approach for studying transport through molecular junctions. Further studies of dependence on conjugation, functional group distributions, orientations, and molecular dimensions will also be discussed.

10:20am **OF+EL+SS-WeM7 White-Light-Emitting Organic EL Devices Based on Vacuum Deposited Thin Films***, **J. Kido**,* Yamagata University, Japan **INVITED**

In this paper, we describe the design and fabrication of bright and high efficiency white-light-emitting EL devices based on vacuum deposited organic thin films. In order to archive high quantum efficiency, multilayer structures are employed. White light can be generated by using two emitter layers composed of blue and yellow emitters. For the blue emitter layer, distyrylbiphenyl derivative is doped with a few percent of distyrylarylene derivative with carbazolyl groups. For the yellow emitter layer, rubrene was doped into hole-transporting arylamine derivative (NPD). Reduction of drive voltage was realized by using metal-doped electron injection layer,@footnote 1@ which is composed of electron-transporting bathophenantroline (Bphen) doped with Cs metal. Cs-doping to Bphen reduces resistivity of the Bphen film, and the contact between cathode and the Bphen layer becomes ohmic, which results in the low drive voltage. The typical device structure is ITO/NPD/yellow-emitting layer/blue-emitting/Bphen doped with Cs/Al. By optimizing the thickness of each layer and dopant concentration, the white EL devices exhibited extremely high luminous efficiency of 15 lm/W and external quantum efficiency of 4% which are the highest values reported for white organic EL devices. @FootnoteText@@footnote 1@J.Kido and T.Matsumoto, Apply. Phys. Lett, 73, 2868(1998).

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