

Wednesday Afternoon, November 6, 2002

Organic Films and Devices

Room: C-102 - Session OF+EL+SC-WeA

Molecular and Organic Films and Devices

Moderator: N. Koch, Princeton University

2:00pm OF+EL+SC-WeA1 Recent Developments in Organic Optoelectronics, S.R. Forrest, Princeton University INVITED

The interest in organic materials for optoelectronic device applications has undergone explosive growth in the last several years. This growth has been propelled by advances in organic thin films for displays, and for low cost electronic circuits. With a few successful product introductions employing active electronic organic devices, it is possible that the "age of organic optoelectronics" has finally arrived. This talk discusses some of the recent progress in organic device technology, with an eye to the future which may include making active electronic devices with a single molecule. In particular, we discuss extremely high external emission efficiency organic light emitting devices used for displays and lighting applications. Also, similar progress in high bandwidth, high efficiency of organic photodiodes, and efficient thin film photovoltaic cells are discussed. For example, multilayer organic nanostructure photodetectors are found to have very high frequency response with detection sensitivity in the visible spectral range. Finally, we present some new ideas on organic device fabrication enabling patterning of structures on the nanometer scale in both the vertical and horizontal directions.

3:00pm OF+EL+SC-WeA4 Electron Transport in Platinum Complex Molecules: An Approach to Molecular Electronics, T.L. Schull, J.G. Kushmerick, R. Shashidhar, Naval Research Laboratory

Molecules that are highly conducting and which can be attached to metal on both sides via a functional chemical group form the basic elements of a molecular electronic device. Electron transport across different types of organic molecules are being actively investigated using different types of measuring test beds. In this paper, we present results of our electron conduction studies across a family of organo metallic molecules using a new cross-wire test bed developed recently.¹ We show that trans-platinum-bis-acetylides show good electron transport across their molecular length that are even better than the properties of the corresponding π -conjugated oligo(phenyleneethynylene) studied by several groups. The dependence of the metal ligands on the electron transport properties of materials is discussed. We have also used a simple extended Huckel Theory coupled with a Green Function approach to calculate the current voltage characteristics of these molecules. These theoretical calculations are compared with experiments.

1. J.G. Kushmerick, D.B. Holt, J.C. Yang, J. Naciri, M.H. Moore and R. Shashidhar, to be published.

3:20pm OF+EL+SC-WeA5 Organic Light-Emitting Diodes and Solar Cells with Electrically Doped Transport Layers, K. Leo, TU Dresden, Germany INVITED

In classical semiconductor technology, controlled n- and p-type doping has always been a standard technique. In contrast, organic materials for devices such as organic light-emitting diodes (OLED) are usually prepared in a nominally undoped form. We discuss results of a comprehensive study of controlled electrical doping of various thin-film molecular organic materials. The layers are prepared by co-evaporation of matrix materials with acceptor molecules and characterized by several electrical techniques. UPS and XPS measurements directly show the Fermi level shift and the reduction of space charge layer width due to increasing doping.¹ We further show that these electrical doping concepts can be successfully applied in devices. The concept of molecular doping is applicable for amorphous wide-gap hole transporting materials and allows for realizing devices with the lowest operating voltages reported so far for small-molecule devices.² The concept of controlled doping has also enabled us to prepare a semitransparent inverted OLED with outstanding performance. It features an inverted layer sequence with ITO efficiently injecting electrons into a highly n-doped layer, despite a very large energy barrier of around 1.8eV. The devices reaches display brightness of 100Cd/m² at 3.4V, which is far below any other literature result. We will also present first results on doped phosphorescent OLEDs which show that the concept of electrical doping can be extended to high-efficiency emitters. Finally, we will discuss the application of doped transport layers in solar cells. (Work done in collaboration with M. Pfeiffer, J. Blochwitz-Nimoth, X. Zhou, J. Huang, D. Qin, B. Maennig, D. Gebeyehu, A. Werner, J. Drechsel.)

¹ J. Blochwitz et al., Organic Electronics, 2, 97 (2001)

² J. Huang et al., Appl.Phys. Lett. 80, 139 (2002).

4:00pm OF+EL+SC-WeA7 Understanding Charge Transport Across Metal-Molecule-Metal Junctions, J.G. Kushmerick, R. Shashidhar, Naval Research Laboratory

Charge transport across a metal-molecule-metal junction is regulated by three factors 1) the structure of the molecule 2) the nature of the metal-molecule contacts and 3) the choice of metal electrode. We use an experimentally simple crossed-wire tunnel junction to interrogate how each of these three factors influences the current-voltage characteristics of a molecular junction. Results on symmetric and asymmetric junctions demonstrate that a specific molecular core can act either as a molecular wire or a molecular rectifier depending on its coupling to the metal electrodes. We will also show that the experimentally measured conductance of a molecular wire can be directly related to how well it's π -conjugated backbone mimics an ideal one-dimensional metal.

4:20pm OF+EL+SC-WeA8 Zero-bias Anomaly in Molecular Monolayer Tunneling, D.R. Stewart, D.A.A. Ohlberg, P.A. Beck, R.S. Williams, Hewlett-Packard Laboratories

Electron tunneling is the dominant transport mechanism in nearly all proposed molecular electronic devices. Standard tunneling theory is normally used to predict device behavior, yet few experimental investigations of molecular tunneling exist due to the difficulty in constructing high quality molecular monolayer films. We describe detailed electronic transport characterization of several planar electrode / Langmuir-Blodgett (LB) molecular monolayer / electrode systems that show a large zero-bias anomaly and an anomalous exponential temperature dependence. Single-species LB monolayers of C₂₂, C₂₀, C₁₈, C₁₆ and C₁₄ carboxylic acid alkanes were sandwiched between upper and lower platinum electrodes, with active device areas of 7-200 μ m². Current and differential conductance were measured as a function of voltage $\pm$ 1V and temperature 2-300K. Below 40K, device characteristics were constant. Surprisingly, from 40-300K device currents were exponential in temperature. A very wide $\pm$ 150mV dip in conductance was also present and temperature activated. Both results contradict standard tunnel theory, indicating that the electronic transport is not yet understood even in this simplest symmetric alkane monolayer system.

4:40pm OF+EL+SC-WeA9 Lateral Confinement of Interfacial Electrons by a Surface Dipole Lattice, X.-Y. Zhu, G. Dutton, University of Minnesota

Interface formation between molecules and a solid substrate often involves charge redistribution, the extent of which can influence a wide range of physical and chemical phenomena. In high mobility field effect transistors (FETs) based on organic single crystals, charge transport is believed to occur in one to two layers of molecules at the organic-dielectric interface. Such an interface may involve charge redistribution and dipole formation. The presence of surface dipoles may significantly alter lateral charge transport in the thin organic layer. When the interface is disordered, these surface dipoles are scattering centers for band transport. On the other hand, if the interface is ordered, there is essentially a two-dimensional lattice of dipoles. Such a surface dipole lattice should give rise to an electrostatic potential which provides periodic confinement of valence and conduction band electrons. We demonstrate this effect for image electrons on C60 thin film covered Cu(111) using angle resolved two-photon photoemission spectroscopy. Metal-to-molecule electron transfer within the first layer creates a (4x4) superlattice of surface dipoles. Such a surface dipole lattice provides lateral confinement of image electron wavefunction, effectively eliminating parallel dispersion for the n=1 image state on one monolayer C60 covered Cu(111). This is in contrast to the significant dispersion observed at higher coverages. The electrostatic potential from the surface dipole lattice is screened by additional layers of C60 molecules, thus, restoring the expected free electron behavior (parallel to the surface) for image states. Quantum mechanical simulation reproduces experimental findings and reveals the extent of wavefunction localization by the surface dipole lattice.

5:00pm OF+EL+SC-WeA10 Measurement of the Site Specific PDOS of Organic Electronic Materials via Soft X-ray Emission Spectroscopy¹, J.E. Downes, C. McGuinness, P. Sheridan, K.E. Smith, Boston University, J.A. Schlueter, U. Geiser, Argonne National Laboratory, G. Gard, Portland State University

Recent advances in the technique of soft x-ray emission spectroscopy (XES) have produced a method to directly measure the bulk elementally and, in certain cases chemically, specific partial density of states of materials. While the detailed measurement of the valence band electronic

structure of solids has traditionally been the realm of photoemission spectroscopies several problems have been encountered with the application of these techniques to organic materials. The principal issue is photon induced damage to the compound that modifies the electronic structure as it is being measured. Another is the fact that photoemission measurements probe the surface electronic structure of a material, which may or may not be representative of the bulk. We will show that the use of XES can avoid both of these problems and allows the detailed valence band electronic structure of recently developed organic electronic compounds to be measured. An overview of the technique of XES and its advantages for studying these organic compounds will be followed by specific results from several organic electronic compounds of current interest in the fields of molecular organic semiconductors, (TDATA, Alq₃, TPD, Cu-Pc etc.), and ET based conducting organic charge transfer salts, (β -(ET)₂SF₅CH₂CF₂SO₃).

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