

Thursday Afternoon, November 13, 2014

Electronic Materials and Processing

Room: 314 - Session EM2-ThA

Hybrid and Organic Electronics

Moderator: Sean King, Intel Corporation, Rachael Myers-Ward, U.S. Naval Research Laboratory

4:00pm **EM2-ThA6 Innovating Organic Electronics and Photonics, Bernard Kippelen**, Georgia Institute of Technology **INVITED**

Printed organic electronics, a technology based on organic semiconductors that can be processed into thin films using vacuum processing or conventional printing and coating techniques, has been the subject of active research and development over the past decades. A range of solid-state devices, including organic light-emitting diodes (OLEDs), organic field-effect transistors (OFETs), photodiodes, and solar cells, have been demonstrated with this new class of materials. However, despite a steady progress in performance, many challenges remain and further scientific and technological advances are required before this emerging technology can unleash its full potential.

In this talk, we will review recent advances both in materials and device architectures in a series of organic semiconductor devices. First, we will present progress in organic light-emitting devices with an unconventional architecture that yield current efficiencies of 200 cd/A at a luminance of 1000 nits and 100 cd/A at 100,000 nits. Next, we will discuss a new organic field-effect transistor geometry that yield unprecedented environmental stability and allows for continuous reversible sensing in aqueous media. In a third part, we will discuss recent advances in organic photovoltaic devices. A new method to produce air-stable low work function electrodes as a substitute for Ca will be presented. This method is based on surface modification by water-soluble polymers that physisorb to the surface of various conductors and lead to large surface dipoles that shift the vacuum level (> 1 eV) reducing the injection or collection barrier for electrons. We will show that these advances in interface modification can be used to design organic solar cells with novel architectures that can overcome some of the economic hurdles of current approaches and accelerate the deployment of these technologies. We will show that the current-voltage characteristics of organic solar cells can be modeled with engineering-inspired equivalent circuit models. Strategies based on transfer lamination will be presented that allow for a drastic reduction of parasitic shunt effects, enabling solar cells with unprecedented dynamic range. Finally, we will discuss how to minimize the environmental footprint of organic electronic technologies.

4:40pm **EM2-ThA8 Role of Light Scattering in Hybrid Solar Cells, James Dorman, M. Noebels, T. Pfadler, J. Weickert, L. Schmidt-Mende**, University of Konstanz, Germany

Hybrid solar cells, with an inorganic/organic interface for charge separation, have been extensively investigated in the past decade in order to replace the expensive Si based technology with an inexpensive alternative. Typically, these devices incorporate a mesoporous TiO₂ film which is decorated with dye molecules and filled with a hole transport material, to conduct the electrons and holes, respectively. Recently, devices with an liquid electrolyte have been able to reach up to 13% conversion efficiency. However, the TiO₂ mesoporous films used for solid state dye sensitized solar cells and hybrid solar cells have a limited light absorption due to thickness of the film (500 nm – 2 μ m) required for efficient charge transportation. An elegant approach to increase the light absorption is to induce “defects” within the mesoporous film, causing light to scatter within the active layer of the device. In this work, we combine the commonly used 25 nm particles with other nanostructures, including 200 nm TiO₂ particles, TiO₂ nanowires, and Sn doped nanowires, all of which produce light scattering due to their dimensions and disorder within the active layer. Through this approach, we are able to correlate an improvement in conversion efficiencies of around 25 % to the light scattering. Furthermore, the incorporation of these nanowire structures increases the mobility of the electrons, allowing for increased charge extraction and reduced recombination. These two phenomena can be simultaneously engineering due to the crystallinity of the “defects” within the films and the cascading conduction bands produced with the incorporation of the doped TiO₂ wires. The extent of the reduction in recombination is quantified through photovoltage decay and impedance spectroscopy measurements and compared to the standard mesoporous TiO₂ devices.

5:00pm **EM2-ThA9 The Structure and Energetics of the Calcium / Phenyl-C₆₁-butyric Acid Methyl Ester Interface, James Lownsbury, C.T. Campbell**, University of Washington

The vapor deposition of metal films onto the surfaces of organic semiconductors, especially fullerene derivatives and π -conjugated polymers, plays an important role in the fabrication and long-term stability of organic electronic, optoelectronic and photovoltaic devices. Nevertheless, the strength and structural details of metal-organic bonding at such interfaces is not well known. We report here measurements of the interface structure and adsorption energies of calcium metal films grown by vapor deposition on phenyl-C₆₁-butyric acid methyl ester (PCBM). PCBM is a much studied electron acceptor material used in a vast array of organic electronic devices, most notably organic photovoltaics, and Ca metal is often used as the cathode material for such devices due to efficient electron collection at the cathode-active layer interface. Structural details of the interface and the morphology of the evolving metal film were measured using low-energy ion scattering spectroscopy and X-ray photoelectron spectroscopy. The energetics of interfacial bonding were measured using an adsorption microcalorimeter which is unique in the world, and which has been applied previously to the adsorption of Ca on common and well-researched electron donor materials including derivatives of poly(phenylene-vinylene), polyfluorene, and polythiophene. Spin-cast PCBM samples were prepared under nitrogen environment and transferred to our ultrahigh vacuum chamber without exposure to atmosphere. There, a pulsed beam of calcium atoms was directed at the sample surface. By simultaneously measuring the heat of adsorption and the sticking probability of the metal atoms as a detailed function of metal coverage, we obtain interfacial bonding energies for Ca on PCBM.

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5:20pm **EM2-ThA10 Controlling the Electronic Structure of Organic Semiconductors via Doping, Antoine Kahn**, Princeton University **INVITED**

Typical organic (molecular and polymer) semiconductors (OSC) used in organic light emitting diodes, field-effect transistors or photovoltaic cells have energy gaps upwards of 1.5-2 eV and have very low conductivity due to the exceedingly small density of “free” carriers and the localized nature of these carriers. Chemical doping has proven to be an extremely powerful tool for controlling the electronic structure of these materials, in particular for improving charge carrier injection at contacts. This talk will review recent developments in the area of chemical doping of OSCs [1,2]. The reducing or oxidizing power of a number of n- and p-type organic dopants are reviewed, along with their impact on the electronic structure and conductivity of both vacuum- or solution-processed OSC films. In particular, the talk will outline recent work aimed at passivating, or compensating, deep electronic gap states, or traps, which are due to structural or chemical imperfections and profoundly affect interface energetic and carrier transport [3]. The process implies the control of ultra-low concentrations of dopants just sufficient to fill traps states and render them inactive, without adding significant densities of “free” carriers in the system. Impact on device characteristics will be reviewed [4].

[1] C. K. Chan et al. *Org. Elect.* **9**, 575 (2008)

[2] G. Song et al. *Adv. Mat.* **24**, 699 (2012)

[3] S. Olthof et al., *Phys. Rev. Lett.* **109**, 176601 (2012)

[4] S. Olthof et al., *Appl. Phys. Lett.* **101**, 253303 (2012)

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