Tuesday Morning, October 19, 2010

Energy Frontiers Topical Conference
Room: Mesilla - Session EN-TuM

Flexible Solar Cells

Moderator: C.A. Wolden, Colorado School of Mines

8:40am **EN-TuM3 Control of the Structural, Electrical and Mechanical Bending Properties of Highly Transparent Conductive Ga-doped ZnO Films Deposited on Polyester Substrates**, ***K. Nagamoto***, *Y. Matubayashi, T. Kondo,* LINTEC Corporation, Japan, *Y. Sato, H. Makino, N. Yamamoto, T. Yamamoto,* Kochi University of Technology, Japan

In this work, we report the structural, electrical and mechanical bending properties of highly transparent conductive Ga-doped ZnO (GZO) films deposited on flexible substrates for use in electrodes for flexible devices. GZO films were deposited on polyester substrates covered with under-coat layers by ion plating deposition with direct-current arc discharge at a temperature of less than 100 degree Celsius (The glass transition temperature (T_g) of polyester substrates are approximately 120 degree Celsius). Polycrystalline GZO films with high (0002) orientation perpendicular to the substrate have obtained. The resistivity of GZO films of a 100 nm thickness on polyester substrates was 5.0 x 10^{-4} ohm-cm and the average transmittance of more than 80 % in the visible wavelength region.

The mechanical bending properties of GZO films were investigated by bend test: sheet resistance of GZO films as a function of bending diameter before and after bending was determined by Hall-effect measurement. When the substrate is bent by an external force, the outer side surface experiences tensile stress and inner side surface experiences compressive stress. The analysis of data obtained by the bend test shows that sheet resistance for GZO films at 12 mm bending diameter were 150 ohm/sq. (before bending test : 50 ohm/sq.) for compressive stress direction whereas sheet resistance was 1770 ohm/sq. for tensile stress direction. In addition, the bend test was carried out for GZO films deposited at different process temperature. GZO films deposited at lower substrates temperature exhibit improved bending performance. GZO films deposited on polymer substrates have residual stress including intrinsic stress and thermal stress caused by the difference in thermal expansion coefficient between GZO films and the substrates. The bending property of GZO films can be improved by controlling the residual stress affected by process temperature.

We developed multiple depositions to reduce polymer substrates temperature and obtained the relationship between bending properties of GZO films and process temperature.

The financial support from the Japan Science and Technology Agency is gratefully acknowledged.

9:00am **EN-TuM4 Low-Temperature Deposition of Transparent Conducting Oxides on Plastic Substrates**, ***E. Ritz***, University of Illinois at Urbana-Champaign, *T. Dockstader,* Kurt J. Lesker Company, *L. Meng, M.J. Neumann, D.N. Ruzic,* University of Illinois at Urbana-Champaign

The future of electronic devices such as touchscreen phones and large flat panel displays is bright, with their usage only becoming more prevalent in our daily lives. Such devices are dependent on transparent conducting oxides (TCOs) and their continued growth necessitates a manufacturing process that is able to deposit an inexpensive coating with high transparency and high conductivity. Operating using a dual unbalanced DC magnetron system with a secondary RF antenna running at 13.56MHz, a process has been developed that can deposit TCO films such as Indium Tin Oxide (ITO) and Aluminum-doped Zinc Oxide (AZO) without significantly heating the substrate while maintaining high transmission and electrical properties. The system utilizes two 75mm-diameter circular magnetrons with a 2-loop immersed inductive RF antenna between them in order to provide increased ionization. By adjusting RF power from 0W to 300W, ionization fraction can be increased from 20% to over 80% for unbalanced configuration as measured by a gridded energy analyzer. In addition, plasma density is increased with RF enhancement from 10^{10} cm^{-3} to 10^{11} cm^{-3}. This RF enhancement allows for substrate temperatures to remain below 100ºC while still achieving film resistivity on the order of 10^{-3}-10^{-4} Ohm-cm (measured by four-point probe method) and transparency of greater than 90% in the visible wavelengths (measured by spectrophotometery.) Low-temperature deposition expands the possibilities for substrate choice to include plastics, such as polyethylene terephthalate (PET), resulting in flexible TCO films. Adjusting process gas oxygen content (from 0-5%) and RF power allows for a means to tune the film properties to the desired transparency and conductivity. Experiments performed using ITO and 2%-doped AZO with glass and PET substrates. Plasma monitoring accomplished through use of Langmuir probe and optical emission spectroscopy. Additional film quality analysis by means of x-ray diffraction (XRD) and x-ray photoelectron spectroscopy (XPS).

9:20am **EN-TuM5 Flexible Solar Cells Based On Monocrystalline Silicon and GaAs**, ***J.A. Rogers***, University of Illinois at Urbana-Champaign **INVITED**

Solar modules that involve large colletions of small, ultrathin photovoltaic cells on thin plastic or rubber substrates offer mechanical properties (e.g. stretchability) and other features (e.g. curvilinear shapes; lightweight designs) that cannot be achieved with conventional approaches. This talk describes the use of inorganic micro/nanomaterials in systems that provide the performance of state-of-the-art, wafer-based technologies but with the mechanical properties of a rubber band. We explain the materials science and mechanics of these approaches in the context of monocrystalline silicon and gallium arsenide solar cells, and key mechanics aspects of their use in flexible and stretchable modules.

10:40am **EN-TuM9 Thin Film Photovoltaics from Nanocrystal Inks**, ***M. Law***, University of California, Irvine **INVITED**

Colloidal semiconductor nanocrystals (NCs) are metatstable objects prone to thermal and oxidative degradation driven by their large surface-to-volume ratios. The fabrication of practical electronic devices based on NC solids hinges on developing methods to prevent oxidation, diffusion, sintering and other undesirable physical and chemical changes to which these materials are susceptible. In this talk, I first describe systematic measurements of the room-temperature electron and hole field-effect mobilities of alkanedithiol-treated PbSe NC films as a function of NC size and the length of the alkane chain. These results establish a baseline for mobility trends in PbSe NC solids and have implications for fabricating high-mobility NC-based optoelectronic devices. Optical, electrical and photoelectron spectroscopy measurements are combined to monitor the room-temperature oxidation of films of PbSe NCs that are treated in solutions of short-chain thiols or carboxylic acids to produce electronically-coupled NC solids. I show that surface oxidation can be prevented by infilling NC films with thin (10-20 nm) Al2O3 layers deposited by low-temperature atomic layer deposition (ALD). ALD treatment of complete PbSe NC field-effect transistors yields high-performance devices that operate indefinitely in air. ALD infilling is a promising route to the preparation of stable, all-inorganic NC solids with tunable electrical properties, and may prove an important breakthrough in the fabrication of robust, high-efficiency quantum dot solar cells.

11:20am **EN-TuM11 Architectures for Enhanced Exciton Harvesting in Organic Photovoltaic Cells**, ***R.J. Holmes***, University of Minnesota **INVITED**

Organic semiconductors are attractive for application in photovoltaic cells due to their compatibility with lightweight, flexible substrates, and high-throughput processing techniques. Optical absorption in these materials leads to the creation of tightly-bound, mobile excitons. In order to generate photocurrent in an organic photovoltaic cell (OPV), excitons must diffuse to a dissociating, electron donor-acceptor (D-A) interface. Most organic semiconductors are characterized by exciton diffusion lengths that are considerably smaller than the optical absorption length. This trade-off between diffusion and absorption often necessitates the use of thin active layers to maximize exciton harvesting. Among the approaches that have been demonstrated to mitigate the short exciton diffusion length, the use of a D-A bulk heterojunction has been widely studied. In these structures, the D-A materials are blended to realize a large interface area for exciton dissociation. The film morphology is typically optimized by thermal annealing, which results in the formation of pathways for charge carrier collection. This talk will explore two alternate OPV architectures designed to overcome the exciton diffusion bottleneck. The first involves the use of composite donor layers that contain both a fluorescent host and a phosphorescent guest sensitizer. The inclusion of the phosphor sensitizer in the donor layer enables the population of the long-lived triplet exciton state of the fluorescent host. Diffusion via the host triplet leads to a near-doubling in the exciton diffusion length and an increase in device efficiency. The second architecture relies on the use of OPVs containing a continuously graded D-A film composition as a means to simultaneously optimize the exciton diffusion and charge collection efficiencies. In these graded heterojunction OPVs, the power conversion efficiency is observed to exceed that of comparable devices containing either planar or uniformly mixed heterojunctions. In both of these approaches, improved performance is realized by utilizing architectures that enable an increased level of control over the exciton diffusion and charge collection efficiencies.

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