

## Energy Frontiers Focus Topic

Room: East Exhibit Hall - Session EN-ThP

## Energy Frontiers Poster Session

**EN-ThP1 Development of Analysis System for Evaluating Carrier Lifetime in Organic Thin Film Solar Cell.** *K. Naito*, KAST, Chuo Univ., Japan, *M. Sakai*, *H. Takei*, KAST, Japan, *K. Nakata*, KAST, Tokyo Univ. Sci., Japan, *K. Katayama*, Chuo University, Japan, *K. Takagi*, KAST, Japan, *A. Fujishima*, KAST, Tokyo Univ. Sci., Japan

Recently, photovoltaic cell is expected as new green technology replacing fossil fuel. Because of a next-generation photovoltaic cell with flexibility, portability and low cost, organic thin film solar cell (OTFSC) is currently the subject of great interest and intensive study. OTFSC is composed of organic electronic materials, which have differences in electron affinity and ionization energy, between two metallic conductive electrodes. The layer of the material with higher electron affinity and ionization potential is electron acceptor, and the other layer is electron donor. The hole-electron pairs (exciton) generated in either material, when OTFSC was photoinduced. When most of excitons reach the interface of the electron acceptor and electron donor, excitons break into carriers of electrons and holes efficiently. Electrons and holes move in the acceptor and donor, respectively. The carriers are collected by the electrode in contact with each layer. In the latest report, OTFSC has exceeded 8 percent of conversion efficiency. However, it was difficult to increase the area of OTFSC with high conversion efficiency. For instance, the conversion efficiency depended on the layer defects, which was caused by contamination of dust and H<sub>2</sub>O, oxidation and inhomogeneous coating. The defects influenced the carrier lifetime in OTFSC. Hence, the inspection technique, which was evaluated in two dimensions XY, was required to measure the carrier lifetime. The present inspection technique (Laser beam induced current method) had to contact electrodes with electric wires and pass an electric current through OTFSC. Because the carrier lifetime was measured by the decay of electric current, the value was influenced by every interface of circuitry in OTFSC. Therefore, it was necessary to detect the pure carrier lifetime in the organic semi conductivity layer. In this study, to investigate the pure carrier lifetime in the OTFSC, we developed the analysis system employing micro wave photoconductivity decay ( $\mu$ PCD). The carrier life time was discussed from the viewpoints of electrochemistry and quantum mechanics.

**EN-ThP2 Reactivation of Thermionic Electron Emission from Nitrogen Doped Diamond Films by Atomic Hydrogen Exposure.** *M. Zumer*, *V. Nemanic*, *B. Zajec*, Jozef Stefan Institute, Slovenia, *F.A.M. Koeck*, *R.J. Nemanich*, Arizona State University

Thermionic electron emission from nitrogen doped hydrogen terminated diamond film has been evaluated 18 months after it had been deposited on a 25 mm diameter molybdenum substrate by microwave plasma assisted chemical vapour deposition. A hydrogen enriched surface layer, enabling a negative electron affinity, was formed during the film deposition procedure. The initial thermionic emission current density of the aged film obtained at 500 °C and 0.2 V/micrometer electric field was stable but relatively low compared to the value measured on a freshly deposited film. The value at a base pressure of  $2 \times 10^{-7}$  mbar was  $\sim 1.4 \times 10^{-9}$  A/cm<sup>2</sup>. Such a low current density is presumed to be a consequence of oxidation, surface adsorption of contaminants and hydrogen depletion from the surface layer, all processes which proceed during ambient atmosphere exposure since the manufacturing date. Reactivation of the surface was achieved by introducing atomic hydrogen, generated by the hot filament cathode of the ionization gauge. A stable current density of  $\sim 2 \times 10^{-6}$  A/cm<sup>2</sup> (an increase factor of  $\sim 1400$ ) was achieved after exposure to hydrogen at the base pressure of  $2.2 \times 10^{-4}$  mbar for 2 hours again at 500 °C and 0.2 V/micrometer. The atomic hydrogen exposure rate was estimated by subsequent measurement of the change in optical transmittance of the tungsten phosphate glass plates. The increase in emission with hydrogen was ascribed to two effects: 1) reactivation of the surface, and 2) molecular assisted emission.

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**EN-ThP3 Self-powered Environmental Sensor System Driven by Nanogenerators.** *M. Lee*, *J. Bae*, Georgia Institute of Technology, *J.H. Lee*, Seoul National University, Republic of Korea, *C. Lee*, Korea Electronics Technology Institute, Republic of Korea, *S. Hong*, Seoul National University, Republic of Korea, *Z. Wang*, Georgia Institute of Technology

A self-powered sensor for toxic materials can be the most desirable and promising prototype of the future monitoring systems for environmental protection/detection. Wiring power-source to sensors that are placed in every corner of our surroundings not only causes a vast amount of labours, resources and budget, but also potential contamination to be produced by the batteries. Although solar energy is most attractive, it depends on the weather, season and has day and night difference. However, regardless of day and night, mechanical energy is one of the most abundant/sustainable sources practically to be utilized through piezoelectric materials. ZnO nanowires (NWs) not only have piezoelectricity, but also are environmental friendly and biological compatible, which make it a strong candidate for energy-harvesting for environmental sensors. Here, we have demonstrated a fully stand-alone, self-powered environmental sensor driven by nanogenerators with harvesting vibration energy. Such a system is made of ZnO nanowire-based nanogenerator, a rectification circuit, a capacitor for charge storage, a signal transmission LED light and a carbon nanotube-based Hg<sup>2+</sup> ion sensor. The circuit lights up the LED indicator when it detects mercury ions in water solution. It is the first demonstration of nanomaterial-based, self-powered sensor system for detecting a toxic pollutant.

**EN-ThP4 Effect of Inserting a Thin Buffer Layer on Obtainable Efficiency in n-ZnO/p-Cu<sub>2</sub>O Heterojunction Solar Cells.** *T. Minami*, *T. Miyata*, *Y. Nishi*, *J. Nomoto*, Kanazawa Institute of Technology, Japan

The effect of inserting a thin-film buffer layer on the obtainable efficiency in n-ZnO/p-Cu<sub>2</sub>O heterojunction solar cells was investigated with a transparent conducting Al-doped ZnO (AZO) thin film/Cu<sub>2</sub>O sheet structure. To improve conversion efficiency, various heterojunction solar cells were fabricated by forming an AZO/thin-film buffer layer/Cu<sub>2</sub>O structure on the front surface of thermally oxidized Cu<sub>2</sub>O sheets that function as the active layer as well as the substrate. It was found that achieving higher efficiency Cu<sub>2</sub>O-based heterojunction solar cells fabricated by depositing various thin films on Cu O sheets requires that the surface of the Cu<sub>2</sub>O sheets always be treated using a low-damage deposition technology at a low deposition temperature.

The Cu<sub>2</sub>O sheets, with electrical properties such as resistivity on the order of  $10^3$   $\Omega$ cm, hole concentration on the order of  $10^{13}$  cm<sup>-3</sup> and Hall mobility above 100 cm<sup>2</sup>/Vs, were prepared by a thermal oxidation of copper sheets under appropriate conditions. The AZO thin film and the thin-film buffer layer were prepared by a pulsed laser deposition (PLD) using an ArF excimer laser. As an example of AZO/buffer layer/Cu<sub>2</sub>O heterojunction solar cells, AZO/ non-doped ZnO (ZO)/Cu<sub>2</sub>O solar cells were fabricated by inserting a ZO thin film as the buffer layer. It was found that the obtainable conversion efficiency in AZO/ZO/Cu<sub>2</sub>O heterojunction solar cells increased markedly as the deposition temperature of the AZO and ZO thin films was decreased from approximately 300°C to room temperature (RT), i.e., non-intentionally heated Cu<sub>2</sub>O sheets. In addition, when the ZO thin films were prepared on non-intentionally heated Cu<sub>2</sub>O sheets by PLD, the efficiency ( $\eta$ ) increased considerably as the introduced O<sub>2</sub> gas pressure was increased;  $\eta$ , approximately 3 % with a ZO thin-film layer deposition at an O<sub>2</sub> gas pressure of 0.1 Pa, gradually increased as the O<sub>2</sub> gas pressure was increased up to approximately 1.2 Pa, and then decreased markedly at a pressure of approximately 1.5 Pa. The optimal thickness of the ZO thin-film layer was in the range from 30 to 50 nm. The obtained increase of  $\eta$  as the ZO film thickness was increased up to approximately 50 nm may be attributable to an improvement of film quality; in contrast, the decrease of  $\eta$  as the ZO film thickness was increased above approximately 50 nm may be attributable to the short lifetime of minority carriers in the n-ZO thin film. An AZO/ZO/Cu<sub>2</sub>O heterojunction solar cell fabricated under optimal preparation conditions exhibited an efficiency of 3.83% under simulated AM1.5G solar.

**EN-ThP5 Surface Texturing of Silicon for Solar Cells for CMOS Technology.** *A.R. Silva*, *J. Miyoshi*, *F.A. Cavarsan*, *L.P.B. Lima*, *J.A. Diniz*, State University of Campinas, Brazil

The solar cell efficiency is hardly connected with device fabrication processes, such as texturing silicon surface, which increases the surface absorption area of incident radiation on the cell and, consequently, reduces the substrate reflectance. Nowadays, solar cells based on silicon substrate are fabricated with texturing surfaces to increase the device efficiency. These surfaces are obtained by anisotropic wet etching in KOH and NaOH

alkaline solutions [1]. The disadvantage of these solutions are K<sup>+</sup> and Na<sup>+</sup> ions from KOH and NaOH, which are mobile charges in Metal-Oxide-Silicon structures. Thus, these solutions are not compatible for CMOS technology, which is used for integration circuits and devices on silicon surface. As an advantage, using these alkaline solutions, the <111> planes of silicon substrate with (100) crystallographic orientation are exposed, resulting in groups of pyramid on silicon surface. The pyramids induce many reflections and scatterings of the incident radiation, which increase the light absorption on the surface. This effect is defined as light trapping [1]. In this work, the silicon substrate texturing is carried out by an anisotropic wet etching, with an alkaline solution based on NH<sub>4</sub>OH, because this solution can form pyramids on the surface, does not release alkaline products/reagents on the silicon surface and is fully compatible with the CMOS technology. With this solution (concentration of 9%wt of NH<sub>4</sub>OH and four magnetic stirring velocities) the <111> planes of silicon substrate with (100) crystallographic orientation are exposed and these planes can form some pyramids on surface. Scanning Electron Microscopy analysis presents that these pyramids are observed all long on the surface, indicating that the wet etching was uniform on the substrate. Furthermore, the pyramid height values are between 3.5 and 7.2 μm, and the silicon etching wet rate was about of 0.7 μm/minute. The reflectance measurements show that the surfaces with and without texturing present reflectance values of about 16% and 38%, respectively. The reflectance values of about 16% with texturing are similar to the results from references [1], which have used KOH solution. This result indicated that our texturing process based on NH<sub>4</sub>OH, which is fully compatible with the CMOS technology, can be used to fabricate Si-based solar cells [2].

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**EN-ThP7 Carrier Life Time of Several Organic Photovoltaic Cells by using Micro Wave Photoconductive Decay.** *M. Sakai*, Kanagawa Academy of Science and Technology (KAST), Japan, *K. Naito*, KAST, Chuo Univ., Japan, *H. Takei*, KAST, Japan, *K. Nakata*, KAST, Tokyo Univ. Sci., Japan, *K. Katayama*, Chuo University, Japan, *K. Takagi*, KAST, Japan, *A. Fujishima*, KAST, Tokyo Univ. Sci., Japan

Recently, the importance of developing the future energy is recognized in various industries. In one of the green innovations, there are great expectations to develop organic photovoltaic cells; Dye sensitized solar cell (DSSC) and Organic thin film solar cell (OTFSC). Organic photovoltaic cells with inexpensive and low resource constraint are currently the subject of great interest and intensive study. DSSC is composed of photo-sensitized anode using molecular dye placed on a porous layer of titanium dioxide nanoparticles, and an electrolyte solution. The photo electrochemical system was known as the Grätzel cell. Electrons at the dye excited because of sunlight move into the titanium dioxide, and are collected by the electrode. On the other hands, OTFSC is composed of organic electronic materials, which have differences in electron affinity and ionization energy, between two metallic conductive electrodes. The layer of the material with higher electron affinity and ionization potential is electron acceptor, and the other layer is electron donor. The hole-electron pairs (excitons) generated in either material, when OTFSC was photoinduced. When most of excitons reach the interface of the electron acceptor and electron donor, excitons break into carriers of holes and electrons efficiently. Electrons and holes move in the acceptor and donor, respectively. The carriers are collected by the electrode in contact with each layer. In either solar cell, the carrier life time would influence the performance of the solar cell, because the carriers (electrons) move through the semiconductor and reach the electrode. Therefore, we investigated the carrier life time of several organic photovoltaic cells by using micro wave photoconductive decay (μPCD). The difference of the carrier life time was discussed from the viewpoints of electrochemistry and quantum mechanics.

**EN-ThP8 Making Molecular Multilayers using "Click" Chemistry: Growth, Characterization, and Application in p-Type Dye Sensitized Solar Cells.** *P.K.B. Palomaki*, *P.H. Dinolfo*, Rensselaer Polytechnic Institute

Bottom-up approaches to creating molecular multilayer assemblies using layer-by-layer (LbL) techniques give one the ability to tailor the surface properties of an interface through molecular control. LbL assembly methods can provide molecular level control of structure in one dimension from simple solution deposition processes. We have developed a versatile LbL fabrication method using copper(I)-catalyzed azide-alkyne cycloaddition (CuAAC) or "click" chemistry in the construction of multilayer assemblies on oxide surfaces. 1,2 These reactions occur in minutes at room temperature

allowing for the facile creation of complex, covalently attached multilayer assemblies. Multilayers containing synthetic porphyrins, perylenes, and mixtures of the two have been constructed in order to highlight the versatility of this method. The fabrication of this new type of molecular multilayer thin film will be discussed along with characterization of the photophysical, electrochemical, and structural properties. Initial results pertaining to the use of these films as light harvesting systems in p-type dye sensitized solar cells will be presented.

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**EN-ThP9 Powder-Sputtered Cu(In,Ga)Se<sub>2</sub> Thin Films: Nonstoichiometric Influences on Optical and Electrical Characteristics.** *N. Kim*, *J. Jeon*, *W. Lee*, Chosun University, Republic of Korea

The thin film solar cell efficiency of 19.2% (0.41 cm<sup>2</sup>) was accomplished by using Cu(In,Ga)Se<sub>2</sub> (NREL, 2003), which has been fabricated by using the three stage co-evaporation process. There are two general methods for Cu(In,Ga)Se<sub>2</sub> thin film fabrication: selenization after sputtering and thermal co-evaporation. The novel method of powder-sputtering was employed for the preparation of Cu(In,Ga)Se<sub>2</sub> to deposit the thin film over the large area with a good uniformity without selenization of toxic H<sub>2</sub>Se because the co-evaporation method requires very strict controls during the deposition process of Cu(In,Ga)Se<sub>2</sub> thin film. This method has the advantages of the production of target, change of stoichiometry, and easy doping of impurities. The composition of the starting powder target was changed by  $x = 0.1, 0.3, 0.5, 0.7,$  and  $0.9$  in the deposition process of Cu(In<sub>x</sub>Ga<sub>1-x</sub>)Se<sub>2</sub> thin film while Cu(In+Ga) ratio was '1'. The compositions of the starting powder target and the deposited samples with 1 μm-thickness were comparatively analyzed by electron probe microanalysis (EPMA). The crystal structure, surface morphology, optical properties, and electrical characteristics of Cu(In<sub>x</sub>Ga<sub>1-x</sub>)Se<sub>2</sub> thin films were analyzed by using X-ray diffraction (XRD), atomic force microscope (AFM), UV-Visible spectrophotometer, and a Hall effect measurement system to investigate the influence of nonstoichiometry on the characteristics. The optimized composition was selected through the comprehensive analysis of the characteristics.

**EN-ThP10 Indium-Doped CdS Thin Film by He-Ne Laser Exposure for CIGS Solar Cells.** *K. Myung*, *N. Kim*, *W. Lee*, Chosun University, Republic of Korea

Cadmium sulfide (CdS) is a direct and wide band gap (2.42 eV at room temperature) II-VI semiconductor, which is a very desirable window layer for many photovoltaic solar cells including CIGS solar cell. CdS thin film has been paid to the considerable attention due to its band gap, high absorption coefficient, reasonable conversion efficiency, stability and low cost. It is generally known that the undoped CdS thin film has the high electrical resistivity. Some impurities were employed for doping CdS to produce less resistive films. Especially, indium (In) showed the improvement of resistivity and optical transmittance when it was doped into the sputtering-deposited CdS thin film. In this study, the structural, optical, electrical, and morphological properties of indium-doped CdS thin films prepared by the effective method with He-Ne laser at room temperature. Indium was deposited on the 200 nm-thickness of CdS thin film by the sputtering method with 10 nm-thickness. He-Ne laser (632.8 nm) was exposed with a small energy by a change of exposure time. The remained indium layer was removed with the chemical solutions. The doping effects of indium on the CdS thin films were investigated by analyzing the structural, optical, electrical, and morphological properties of CdS thin films by using X-ray diffraction (XRD), Auger electron spectroscopy (AES), UV-Visible spectrophotometer, Hall effect measurement system, and atomic force microscope (AFM). AES depth profile was employed to examine the indium-doped CdS thin film with a change of He-Ne laser exposure time. The doping uniformity and amount of indium into the depth of CdS thin film was compared to the characteristics of CdS thin film. The optimization of indium-doping process was achieved to enhance the electrical and optical characteristics including resistivity and optical transmittance.

**EN-ThP11 Three-Terminal Tandem Devices for PV, TPV and CPV Applications.** *M. Emziane*, Masdar Institute, United Arab Emirates

One of the key approaches for achieving very-high efficiency for photovoltaic (PV) devices is to use, instead of single junctions, double or multi-junction devices due to an extended solar spectral coverage leading to an enhanced overall power output from the multi-junction PV devices.

In this study, we investigated two-junction solar cells based on group IV materials, i.e. Si and Ge, for top and bottom sub-cell, respectively. Unlike the conventional and widely used monolithic series-connected two-terminal device configuration that was shown to deliver a slightly lower output, these double-junction cells were assembled with three terminals and operated independently [1, 2].

The main advantages of choosing these materials and device configuration are: (i) cheapest, largest and easiest group IV substrates; (ii) extended spectral coverage leading to more photons being converted; and (iii) no current matching or the associated tunnel junctions between the two sub-cells.

We have undertaken a comprehensive modeling analysis for the device optimization and performance prediction. n/n/p as well as p/p/n device structure configurations were investigated and optimized with regard to the thicknesses and doping levels of both top and bottom active junctions that lead to the highest device performance. Due to the split of the incident solar spectrum between the top and bottom sub-cells, the latter only receives the light to which the former is transparent (mainly in the near infrared) and therefore behaves differently from the single-junction cell counterpart.

Optimal current-voltage and power-voltage characteristics were generated for individual cells together with the corresponding quantum efficiency spectra. The applications of these devices in conventional PV, concentrator PV and thermal PV were assessed and the output PV parameters were predicted as a function of the simulated operating conditions.

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**EN-ThP12 The Advantage of State of the Art DC Power Supplies Over the Pulsed DC Power Supplies for TCO Magnetron Sputtering.** P. Rozanski, P. Ozimek, M. Zelechowski, P. Lach, W. Glazek, J. Abraham, Huettinger Electronic Company, Poland

Non-pulsing DC power supplies for highly arcing processes are gaining more and more interest slowly pushing out older pulsing DC power supplies as more efficient and more cost optimal. The importance of arc management in DC power supplies is taking on a new meaning as most advanced DC generators are more and more successful in sputtering highly arcing and difficult materials, providing high deposition rates at competitive investment.

It has been developed as the answer to the market's demand to limit arc energy during an arc occurrence in sputtering. Industrial implementation has been already successfully performed with air-cooled DC power supplies that have been on the market for years. The possibility of using DC power supplies for sputtering highly-arcing materials is the result. It is the beginning of a new age in magnetron sputtering technology. Further improvement and optimization by using more efficient water cooling and faster transistors has resulted in a new generation of power supplies with state-of-the-art arc management parameters. A complementary feature of the newly-developed arc management circuitry is software that supports efficient arc handling: self-adjusting arc management settings and an internal oscilloscope.

**EN-ThP13 Photogenerated Current Enhanced by Surface Plasmon Resonance in Metal Grating.** D.J. Lee, Inha University, Republic of Korea

Photogenerated current enhanced by surface plasmon resonance excited in metal grating was confirmed in Au/p-type a-Si Schottky structures. Conduction electrons in metal absorb the incident photon of energy  $h\nu$  ( $h$  is the Planck's constant and  $\nu$  is the optical frequency) through the a-Si film, gaining enough energy to cross over the Schottky barrier into the semiconductor, where they are swept across the depletion region and collected as photocurrent under reverse bias. In addition, the surface plasmon polariton is excited in metal grating fabricated on the photoresist layer, and excited electrons will flow over the Schottky barrier. This additional photocurrent added to that directly induced by incident light and enhanced the responsivity of the photodetector.

**EN-ThP14 The Science of Precision Multifunctional Nanostructures for Electrical Energy Storage.** A. Predith, University of Maryland, College Park

Nanostructures for Electrical Energy Storage (NEES) is a five-year Energy Frontier Research Center investigating nanoscale behavior in lithium-ion

battery materials. Funded by the US Department of Energy, the Center studies the properties of composite nanostructures containing an oxide or silicon as a charge storage material and low dimensional forms of carbon as an electronic conductor or mechanical support. NEES is particularly interested in nanostructures that are precise and regularly ordered. These structures provide a unique test bed for uncovering to the science of electrochemistry at the nanoscale.

The two Science Thrusts of the Center investigate nanotubes, nanowires, and layers of MnO<sub>2</sub>, silicon, and carbon electrode materials as well as nanoporous membranes in an electrolyte. They examine the mechanical behavior, electrochemical properties, and interfacial phenomena that arise in heterogeneous material combinations. The two Enabling Thrusts of the Center develop model systems and characterization instruments for the nanoscale. Ultra high vacuum scanning probe microscopy and first principles modeling provide for the study of pristine systems, and in situ transmission electron microscopy and microelectromechanical systems are allowing members of NEES to observe electrochemical processes as they unfold.

NEES is a collaboration of 19 senior investigators, ~35 postdoctoral associates and graduate research assistants, and many staff members at six institutions. The Center integrates their perspectives to pursue a comprehensive examination of electrical energy storage using precision, multifunctional nanostructures. Members include Philip Collins (University of California-Irvine), Michael Fuhrer (University of Maryland), Sang Bok Lee (UMD), Charles Martin (University of Florida), Reginald Penner (UCI), Zuzanna Siwy (UCI), John Cumings (UMD), S. Thomas Pircaux (Los Alamos National Laboratory & Center for Integrated Nanotechnologies), Mark Reed (Yale University), Chunsheng Wang (UMD), YuHuang Wang (UMD), Kevin Leung (Sandia National Laboratories), Janice Reutt-Robey (UMD), Kevin Zavadil (SNL), Reza Ghodssi (UMD), Jianyu Huang (SNL, CINT), Robert Hwang (SNL), Gary W. Rubloff (UMD), John Sullivan (SNL, CINT), and Ashley Predith (UMD).

**EN-ThP15 Photosystem I-Based Solar Cells.** D. Gunther, D.E. Cliffler, G.K. Jennings, Vanderbilt University

The long-term success of photosynthetic organisms has resulted in their global superabundance, which is sustained by their widespread, continual mass-production of the integral proteins that photocatalyze the chemical processes of natural photosynthesis. Here, a fast, general method to assemble wet and dry solar cells composed of one such photocatalytic protein complex, Photosystem I (PSI), onto a variety of electrode substrates, including gold, nanoporous gold, and graphene is reported. The resulting PSI films consist of a protein matrix that is permeable to electrochemical mediators in a wet cell and conducting for electron transfer in a dry cell. These results demonstrate how the assembly of micron-thick coatings of PSI on non-biological substrates yields a biohybrid ensemble that manifests the photocatalytic activity of the film's individual protein constituents, and represent significant progress toward affordable, biologically-inspired renewable energy conversion platforms.

**EN-ThP16 Thickness Dependent Photo-Voltaic Effect In Ferroelectric PLZT Thin Films.** S. Kotru, H.V. Nampoori, The University of Alabama, Tuscaloosa

Ferroelectrics are emerging as potential candidate materials for energy harvesting. Among the class of ferroelectrics, Lanthanum doped Lead Zirconate Titanate (PLZT) is one which possesses high electro-optic coefficient and exhibits high optical transparency thereby makes it an attractive material for PV applications. In this work ferroelectric thin films of  $Pb_{0.95}La_{0.05}(Zr_{0.54}Ti_{0.46})O_3$  (PLZT) of various thicknesses were fabricated using chemical solution deposition method. Structural and ferroelectric properties of these films were studied using standard characterizations methods. Capacitor type solar cells were fabricated from these films using Pt as the top electrode. The IV curves were measured for each device where the thickness of PLZT film ranged from 70 nm to 350 nm. For devices, made with films less than 150 nm thickness, no PV response could be measured as an electrical contact could not be made on such films. From the PV curves measured on films with 140 to 350 nm thickness, the photocurrent density was seen to decrease from 597 to 64 nA/cm<sup>2</sup>, where as no major change was observed for the open circuit voltage. Thus thinner films are seen to enhance the PV response in ferroelectric based capacitor type solar cells.

**EN-ThP17 Nanostructure Analysis of Diamond Cold-Cathode Field Emitter, T.C. Wade, N. Ghosh, J.E. Wittig, W.P. Kang, Vanderbilt University, L.F. Allard, K. Unocic, Oak Ridge National Laboratory, J.L. Davidson, N.H. Tolk, Vanderbilt University**

Chemical-vapor-deposited diamond is an attractive material for electron field emitters because of its low or negative electron affinity, mechanical strength, and chemical inertness. Arrays of ultra-sharp diamond tips with a radius of curvature less than 5nm have been fabricated [1] and show significant improvement in emission brightness and turn-on field compared to conventional field emitters [2,3]. Irregularities in emission behavior between tips were historically attributed to anomalies in the fabrication process: "sharp" or "less sharp" tips. However, we observe large differences in electron emission thresholds between tips that appear to be equally well formed. We examine the emitter's sub-surface structure to provide insight into how surface and subsurface structure affect emission.

Cross-sectional Transmission Electron Microscopy (TEM) samples were prepared by standard Focused Ion Beam (FIB) lift-out techniques with the additional step of using a layer of EBID Pt before the ion-beam Pt deposition in order to preserve the 5 nm field emission tips. TEM images of the emitter tip cross sections were recorded with a sub-angstrom probe in a JEOL 2200FS.

The core of the emitter consists of boron-doped microcrystalline diamond with characteristic diamond cubic twinning. The graphite layers observed are likely specimen preparation artifacts, although the presence of graphitic material in these diamond emitter tips is still an open question. Crystallites on the order of 5 nm in size are evident in the nanocrystalline diamond surface layer. Final thinning using a nanomill (Fischione Co.) with low energy Ar may be the solution for removing any surface artifacts and reducing the sample thickness. Comparison of the nanostructure of emitter tips with variation in field emission characteristics will provide insight into the influence of the nanocrystalline structure on the electronic properties.

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**EN-ThP18 Microbial Fuel Cells Development on the Base of *Desulfuromonas Acetoxidans* Bacteria, O.M. Vasylyv, O.I. Bilyy, S.O. Hnatysh, Ivan Franko National University of Lviv, Ukraine**

Microbial fuel cells (MFCs) are able to capture the electrons produced during different biochemical microbial processes to generate electricity. They offer the promise of a new sustainable source of energy, produced from biodegradable and reduced compounds. Increased shortcoming of unrenewable fossil fuels causes the need for its less dependence. The enhance of use of renewable fuels requires the development of alternative sources of energy such as waste biomass for environmental benefits. MFCs investigations have attracted substantial interest in development of different devices for generating electricity and removing wastes. The development of processes that can apply bacteria of normal environmental microflora to produce electricity represents a highly effective method for bioenergy production as bacteria are self-replicating, and thus the catalysts for organic matter oxidation are self-sustaining.

Nowadays MFCs is considered to be applied as highly effective and self-sustaining model of wastewater treatment which contains energy in the form of biodegradable organic matter. At the same time wastewater contains high concentrations of xenobiotics, such as different heavy metal ions that have an overwhelming harmful effect towards all living organisms. These elements even in small concentration in the environment cause the intensive inhibition of physiological and biochemical properties of most bacteria. Despite that, some genuses of bacteria possess high toxic heavy metals resistance because of highly-efficient defensive systems functioning. There are *Ferroplasma*, *Streptomyces*, *Thiobacillus* etc.

*Desulfuromonas acetoxidans* are uncoloured gram-negative sulfur-reducing bacteria. These bacteria are considered to be used as the substrate for microbial-anode fuel cells with high electron recovery, which is more than 80%, to electric current by the interaction between processes of acetate oxidation and S<sup>0</sup> or Fe<sup>3+</sup> - reduction. Sulfurbacteria have a great effect on the biogeochemistry of aquatic environments because of their ability to reduce and precipitate toxic heavy metals compounds. It's a result of their particular binding with the final product of bacterial dissimilative sulfur-reduction - H<sub>2</sub>S, and formation of the insoluble metal sulfides. It also

serves as self-defensive mechanism of these bacteria against toxic influence of toxic heavy metal ions.

The influence of different of Ni<sup>2+</sup> and Cu<sup>2+</sup> concentrations on size distribution and relative content of *D. acetoxidans* bacteria during their life cycle on the base of cells' light scattering properties changes by the new method of measurement has been investigated. The ability of this bacteria to produce electric current in microbial-anode fuel cells under the specific cultivation condition has been shown. Particular heavy metals resistance of *D. acetoxidans* bacteria has been observed. Distribution curves of the cells' size distribution changes were in the range from 0.3 to 1.9 μm under the influence of investigated metal ions. The maximum of cells' size distribution of investigated bacteria was changed from 0.55 to 0.62 μm under the influence of 0.01-10 mM of NiCl<sub>2</sub>·6H<sub>2</sub>O and CuCl<sub>2</sub>·2H<sub>2</sub>O during five days of bacterial growth.

**EN-ThP19 Investigating CdTe/CdS/TCO Inter-diffusion by AES and XPS, L. Le Tarte, A. Barbuto, J. Courmoyer, K. Dovidenko, H. Piao, General Electric, Global Research Center**

CdTe has recently received a lot of attention as the material of choice for thin film solar cells as it converts light to electricity more cost effectively than traditional semiconductors and is compatible with manufacturing scale-up. An in-depth understanding of film composition, morphology and interface integrity is critical for CdTe thin film process development. Clear depth profiles of the buried layers by Auger electron spectroscopy (AES) and X-ray photoelectron spectroscopy (XPS) are difficult to obtain due to the rough, and thick (~3μm ± 0.5μm), upper CdTe layer. Sputtering through this layer leads to broadened depth profile interfaces which reduces information about inter-diffusion. We have developed a polishing method to thin and smooth this layer prior to analysis. In this poster we will present how this method has improved the Auger depth resolution and therefore the understanding of inter-diffusion between the CdTe, CdS and TCO layers. A novel FIB preparation method for Auger will also be discussed. XPS imaging analyses on AES sputter crater sidewalls provides additional chemical information about the buried layers and interfaces.

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