

Wednesday Afternoon, October 30, 2013

Thin Film

Room: 102 C - Session TF+AS+NS+SE-WeA

Beam and Glancing Angle Deposition (GLAD)

Techniques

Moderator: T. Karabacak, University of Arkansas at Little Rock

2:40pm **TF+AS+NS+SE-WeA3 GLAD-ALD Core-Shell Nanorod Arrays for Solar Cell Applications**, N. Biyikli, C. Ozgit-Akgun, A. Haider, Bilkent University, Turkey, H. Cansizoglu, M.F. Cansizoglu, T. Karabacak, University of Arkansas at Little Rock

In a nanostructured photovoltaic cell, one should take into consideration the competing effects of enhanced light absorption and shorter carrier collection lengths that both lead to improved photo-conversion efficiencies, and negative effects due to the larger amounts of surface recombination events. However, a key limitation to systematically investigating this in detail originates from the disordered random network nature and the wide particle size distribution of nanostructured geometries studied in the past. In addition, most of the nanofabrication methods that can produce uniform nanostructure geometries are limited to certain material systems. Therefore, it is essential to develop innovative low-cost solar cell fabrication approaches that can provide semiconductor nanostructures of a variety of materials with uniform and optimized geometries for improving cell efficiencies. In this work, we demonstrate a novel nanostructured solar cell fabrication method using core-shell radial junction nanorod arrays, which can potentially offer superior conversion efficiencies compared to conventional planar designs. Nanorod arrays of metallic/semiconductor materials (core) were produced by utilizing glancing angle deposition (GLAD) technique. GLAD metallic nanorods were made of molybdenum (Mo) and semiconducting ones were indium sulfide (In_2S_3). For the fabrication of proof-of-concept nanostructured photovoltaic cells, we conformally coated GLAD nanorods with semiconducting metal-oxide layers (shell) of zinc oxide (ZnO) and titanium dioxide (TiO_2) using atomic layer deposition (ALD) method. Our preliminary structural, optical, electrical, and solar cell characterization results are presented.

3:00pm **TF+AS+NS+SE-WeA4 Branched Nanostructured Anodes for Dye-Sensitized Solar Cells**, W. Alayashi, K. Robbie, Queen's University, Canada

The nanostructured metal oxide layer, typically TiO_2 , that is part of the conductive electrode (anode) is the most puzzling component of Dye Sensitized Solar Cells (DSSCs). While the sponge-like morphology of the sintered-powder electrode improves efficiency by providing a high surface area scaffold for adsorption of light-absorbing dye molecules, the convoluted transport paths for photo-generated charge carriers ultimately limit achievable efficiency. Its morphology has been identified as an important efficiency-limiting aspect of TiO_2 films. A DSSC is composed of a conductive electrode (anode), a nanoporous metal oxide film such as TiO_2 , an organic sensitizing dye, a redox electrolyte, and a cathode electrode. Behaviour of the porous anode is strongly influenced by several factors: the open structure of the electrode that permits electrolyte penetration through the entire electrode, the small size of the individual colloidal particles that prevents accumulation of a large space charge, and the low intrinsic conductivity of TiO_2 . I will present a demonstration of a new type of DSSC nanostructured oxide layer based on a fractal structure (branched tree-like morphology) for the metal oxide anode, and the effect of this morphology on electron transport and thus the overall efficiency of DSSC. Different thicknesses of the tree-like morphology films are fabricated to find their influence on photovoltaic performance. The result includes a comparison of the DSSCs efficiencies that are made by Glancing angle deposition technique, conventional nanoparticulated DSSCs and highly ordered nanotube arrays.

4:40pm **TF+AS+NS+SE-WeA9 Thermal Annealing Study of Nickel Nanorod Arrays**, E. Alrashid, D. Ye, Virginia Commonwealth University

Nickel nanorods arrays were prepared on silicon (100) substrates using the glancing angle deposition (GLAD) technique. The nanorods with different lengths were then annealed in a split-top tube furnace in vacuum with Argon background. The annealing temperature was maintained at 500 °C for 30 minutes, or varied from 300 – 600 °C at a step of 100 °C. After the thermal processing, the nanorods were studied by scanning electron microscopy (SEM) and X-ray diffraction (XRD) studied. It was found that with increasing annealing temperatures, the intensity of XRD peaks for both Ni (111) and Ni (200) increased, which indicates that re-crystallization

occurs after annealing, leading to the formation of larger grain sizes. In the temperature dependent study, we found that surface melting is dominant at temperatures lower than 500 °C while coalescence of nanorods happens at 600 °C, resulting significant morphology change at high annealing temperature. The well-separated nickel nanorods join together to create a porous continuous film with interconnected pores after coalescence, which is potentially useful in the applications of catalyst support, fuel cells, and electrodes for battery.

5:00pm **TF+AS+NS+SE-WeA10 Gas Assisted Nanofabrication Using He and Ne Ion Beams: Toward Ultimate Resolution**, H.M. Wu, D. Ferranti, L.A. Stern, D.Y. Xia, Carl Zeiss

Focused ion beam systems combined with gas precursors for deposition and enhanced, selective material removal have led to many important applications. The gas field ion source (GFIS) has demonstrated its capabilities as an ultrahigh resolution (< 0.5 nm) imaging as well as a sub-10 nm nanofabrication technique using helium ion beam. Recently, the new Zeiss Orion-NanoFab microscope provides three ion beams (helium, neon and gallium) into one platform and promotes the further studies of He and Ne induced deposition and etching procedures to compare with a Ga ion beam. Because of the mass difference between He, Ne and Ga ions, the interactions of ions with precursor molecules result in different sputtering rates, implantation and deposition yields. This presentation gives an overview of our current studies using this new platform to deposit or mill nano structures with sub-10 nm resolution.

He and Ne ion beam induced metal and dielectric deposition using different precursors have been investigated extensively in our lab. The dimensions and electrical properties of these deposits are strongly dependent on the ion beam type, beam conditions and precursor gas flux. To improve the properties of deposits and minimize the ion implantation, we have been optimizing deposition conditions to increase the deposition purity and to maximize the deposition yield. We will discuss the factors that determine the ultimate resolution of deposits using He and Ne ion beams and the beam chemistry that influences the choice of gas precursors for a particular procedure and how to select between the He and the Ne ion beams to achieve the best result.

Removing material by direct He ion sputter (milling) has a resolution of a few nanometers, but a low sputter yield. The Ne ion beam offers precise nanofabrication capabilities, and 30 times higher sputter yields than the He ion beam. The implementation of chemical etching further increases the material removal process substantially and reduces the ion implantation. The effects of the ion beam conditions and etchant gas flux on the milling rate and on the gas assisted etching (GAE) enhancement have been studied and 10x enhancement has been achieved so far, compared with direct ion beam sputter.

5:20pm **TF+AS+NS+SE-WeA11 A New Type of Super Intense Cluster Beam Source based on Matrix Assembly**, R.E. Palmer, L. Cao, W.D. Terry, F. Yin, University of Birmingham, UK

Atomic clusters are attracting a great deal of attention because of their remarkable size-dependent properties and the corresponding potential applications which arise, e.g. in catalysis, nanomaterials, biochips [1][2]. However, the advancement of this field is limited by the low cluster fluxes, ~ 1nA, currently available [3]. Here we demonstrate a radical new instrument, the Matrix Assembly Cluster Source (MACS), with the potential to produce size-selected clusters in great abundance (up to ~1A, i.e. an increase of 9 orders of magnitude). In this new approach, the atoms of the desired cluster material (e.g. Au or Ag) are trapped in a thin matrix of condensed rare gas atoms (e.g. Ar). Clusters are then produced by collisions in the matrix which are driven by an atomic ion beam (such as Ar^+) in the transmission sputtering regime.

The transmission sputtering of the matrix is monitored in real time by ion-induced luminescence while the noble metal clusters produced and deposited are analyzed by aberration-corrected scanning transmission electron microscopy (STEM): the number of cluster atoms is measured by the integrated HAADF intensity [4][5]. The results demonstrate the production of Au and Ag clusters by the new method and show that the distribution of cluster size, even before mass selection, is narrow under certain experimental conditions. We find the mean size of the clusters is mainly determined by the concentration of metal atoms in the condensed rare gas matrix. The size distribution and flux of clusters also depends on the ion beam energy.

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[2] R.E. Palmer, C. Leung, *Trends Biotechnol.*, **25**, 48, (2007)

[3] S. Pratontep, S. J. Carroll, C. Xirouchaki, M. Streun, R. E. Palmer, *Rev. Sci. Instrum.* **76**, 045103 (2005)

[4] Z.Y. Li, N.P. Young, M. Di Vece, R.E. Palmer, A.L. Bleloch, B.C. Curley, R.L. Johnston, J. Jiang, J. Yuan, *Nature*, **451**, 46, (2008)

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