Electronic Materials and Processing
Room 309 - Session EM-TuA

Growth and Characterization of ZnO

Moderator: T.J. Coutts, National Renewable Energy Laboratory

2:00pm **EM-TuA1 Expanding Thermal Plasma Deposited ZnO Films: Effect of Al Doping on the Thin Film Growth**, ***I. Volintiru***, *M. Creatore,* Eindhoven University of Technology, The Netherlands*; J.L. Linden,* TNO Science and Industry, The Netherlands*; M.C.M. Van De Sanden,* Eindhoven University of Technology, The Netherlands

Zinc oxide (ZnO) films have been extensively studied in the past decade due to their advantages over other transparent conductive oxides (TCOs) such as large exciton binding energy, possibility of wet chemical etching, non-toxic precursors, and low-cost production. For specific applications, a good control of the ZnO film electrical and optical properties, as well as the surface morphology (e.g. high roughness needed for light trapping within solar cells) is necessary. In this work, both undoped and Al-doped ZnO films are deposited on crystalline Si and glass substrates using an argon-fed expanding thermal plasma in which oxygen, diethylzinc (and trimethylaluminium for Al doping) are admixed downstream. The in-situ real-time spectroscopic ellipsometry (SE) and atomic force microscopy (AFM) performed on undoped ZnO point out towards a linear roughness development (about 10% of the film thickness) starting from 10 nm film thickness. Moreover, both AFM and X-ray diffraction (XRD) measurements indicate a polycrystalline film growth above 10 nm. The influence of Al doping on the ZnO film electro-optical properties, surface morphology and crystallinity obtained from Hall, in-situ SE, AFM and XRD, respectively, will be presented.

2:20pm **EM-TuA2 Carbon Passivation Effect in ZnO Thin Film**, ***X. Li***, *S. Asher, C.L. Perkins, B.M. Keyes,* National Renewable Energy Laboratory*; S. Limpijumnong,* Suranaree University of Technology, Thailand*; S.B. Zhang, S.-H. Wei, T.J. Coutts, R. Noufi,* National Renewable Energy Laboratory

Carbon impurity is commonly found in thin films fabricated by metal-organic chemical vapor deposition (MOCVD). The role of carbon in undoped and nitrogen-doped ZnO thin films was studied experimentally and theoretically to understand the possible compensation effect of carbon. ZnO thin films were fabricated by low-pressure MOCVD using diethylzinc and oxygen precursors. Nitrogen doping was achieved with nitric oxide (NO) gas. High levels of carbon incorporation were observed in the ZnO film, especially for nitrogen-doped ZnO film. Fourier transform infrared (FTIR) spectroscopy observed the possible C-H@sub x@ (x=1, 2, and 3) defect complex in the unintentionally doped ZnO film. Both FTIR and X-ray photoelectron spectroscopy observed the possible N-C defect complex in the nitrogen-doped ZnO. The first-principles calculations predict that the N-C defect complex is 1+ charge state. Therefore, the existence of carbon and the N-C defect complex could compensate the nitrogen acceptor species.

3:20pm **EM-TuA5 Direct Formation of Nanoporous ZnO Networks by MBE**, ***S.M. Durbin***, *W.C.T. Lee, R.P. Millane, R.J. Reeves,* University of Canterbury, New Zealand*; Z. Liu, S. Ringer,* University of Sydney, Australia*; F. Bertram,* Otto-von-Guericke-University Magdeburg, Germany

Porous semiconductors have captured significant attention in the past decade, both as a result of visible luminescence from silicon structures and due to the potential for creating surface-active devices such as gas sensors. Porous networks of these materials are generally formed in conjunction with some form of anodic etching procedure, although some arc processing has been reported as well. In contrast, we have observed the direct formation of large-scale multi-level nanoporous ZnO networks grown using an RF plasma-assisted molecular beam epitaxy (RF-PAMBE) technique without the need for etching or other postprocessing. Elemental Zn was evaporated using a standard effusion cell, and active oxygen was supplied using an Oxford MDP21 plasma source with alumina components in the plasma chamber. In-situ reflection high-energy electron diffraction exhibited patterns consistent with c-axis oriented single crystal growth on the GaN/sapphire template. Initial estimates indicate a porosity of at least 20% based on analysis of field emission scanning electron microscopy images, which also show feature sizes on the order of tens of nanometres and pores of approximately 100 nm in diameter. Cross-sectional transmission electron microscopy confirms the presence of a porous network on top of a 20 nm thick continuous ZnO layer. Low temperature photoluminescence reveals a broad feature near the bandedge of ZnO, which is near the short wavelength limit of the measurement apparatus. The driving mechanism underlying the formation of the nanoporous layer is unclear, but may be related to preferentially-oriented surface features formed on the GaN buffer layer. This work is supported in part by the MacDiarmid Institute for Advanced Materials and Nanotechnology, and the University of Canterbury.

3:40pm **EM-TuA6 STM Study of Gold Nanoparticles on ZnO Film Annealed at Different Temperature**, ***R.S. Aga***, *A. Ueda, W.E. Collins, R. Mu,* Fisk University

ZnO nanowires are promising for photovoltaic applications. In addition, ZnO film may also be used as a transparent electrode. Direct growth of ZnO nanowires on ZnO film via gold nanoparticles may then provide a better transport of photogenerated charges from the nanowire to the electrode. Thus, it is important to understand the effect of thermal treatment on the microstructure and electronic properties of gold nanoparticles deposited on ZnO film. In this work, we use STM to study spin-coated gold nanopaticles on ZnO films annealed at different temperatures. The films were grown by electron beam deposition. Our results may be useful in optimizing nanowire properties as well as improving nanowire connectivity to the electrode.

Author Index

Bold page numbers indicate presenter