Thin Films
Room Makai - Session TF-WeE

Microstructure & Surface Morphological Evolution in Organic & Inorganic Films

Moderator: Satoshi Hamaguchi, Osaka University, Japan

6:20pm **TF-WeE3 Understanding Organic-Organic Quasiepitaxy*, Richard Lunt,*** Michigan State University, USA **INVITED**

The presence of excitons in organic materials offer new opportunities for low-cost photovoltaics and electronic systems and provide prospects for unique energy science and applications. In this talk I will review our understanding of organic quasepitaxy. I will then discuss our demonstration of the growth of ordered organic-organic hetero-quasieptiaxial supperlattices, composed of incommensurate organic semiconductors with sustained registry grown from the bottom up via a new step-edge nucleation driven growth mechanism. By probing a range of molecular pairings with in-situ and real-time diffraction, we further uncover driving forces that can broadly enable this type of growth, which are completely distinct from the requirements of inorganic epitaxy. It is well known that crystalline order, orientation, and quantum confinement of highly anisotropic organic semiconductors can significantly alter the properties and performance of organic electronics. Thus, these demonstrations can enable entirely new photophysical phenomena and provide opportunities for manipulating energy in a variety of excitonic structures.

7:00pm **TF-WeE5 Characterization of Aluminum Nitride Grown by Atomic Layer Epitaxy with real time Grazing Incidence Small Angle X-ray Scattering*, Virginia Anderson,*** *N. Nepal, S.D. Johnson,* US Naval Research Laboratory, USA*; Z.R. Robinson,* The College at Brockport SUNY, USA*; A. Nath, A. Kozen,* US Naval Research Laboratory, USA*; A. DeMasi,* Boston University, USA*; J.K. Hite,* US Naval Research Laboratory, USA*; K.F. Ludwig,* Boston University, USA*; C.R. Eddy, Jr.,* US Naval Research Laboratory, USA

A focus area of research on III-nitrides attempts to lower the growth temperature of films, because molecular beam epitaxy and metalorganic chemical vapor deposition (MOCVD) must be done at relatively high temperatures to produce a high quality material. As an example, aluminum nitride MOCVD takes place at over 1000°C. Tunable band gaps, high breakdown voltages, and piezoelectric properties are attractive qualities of aluminum nitride films, and thus motivate the search for alternate fabrication methods. Atomic layer epitaxy (ALE) of GaN, AlN, and InN films have been shown at temperatures far below that required for MOCVD. [1] Further exploration of the growth parameters of these films is underway. Research during the actual growth process allows much more information on early stages of film deposition, and eliminates many of the *ex-situ* issues with surface oxidation upon sample removal from the reactor. The X-ray photons available at some synchrotrons allow insight into the growth process from grazing incidence small angle X-ray scattering (GISAXS), a technique that can be carried out at ALE pressures and is extremely sensitive to surface morphological evolution.

The work presented will describe film growth of aluminum nitride using trimethylaluminum and a nitrogen/argon or hydrogen/nitrogen/argon plasma. Based on *ex-situ* examinations, aluminum nitride ALE on MOCVD GaN at 500°C was previously seen to exhibit single crystal character, with a full-width at half maximum of 670 arc-seconds. [2] Work presented here describes results on changing the temperature and the plasma conditions for ALE AlN. The substrates were sapphire and the growth took place at Brookhaven National Laboratory and at the Cornell High Energy Synchrotron Source in a custom reactor designed to facilitate GISAXS monitoring during growth.

These results suggest that surface feature distances are related to the final quality of the aluminum nitride films. Samples grown at 350-400°C have higher impurities than samples grown at 450-500°C, and GISAXS shows closer features at the lower temperatures. In addition, holding the flow constant and changing the nitrogen to argon ratio resulted in changes in the atomic species present in the plasma source, and changes in nucleation and growth behavior.

References:

1 N. Nepal et al., *Thin Solid Films* **589** 47 (2015)

2 N. Nepal et al., *Appl. Phys. Lett.* **103** 0 82110 (2013)

7:40pm **TF-WeE7 Study of Structural Phase Transitions during Growth of Tetracene and Pentacene Films on H/Si(001) via NEXAFS and AFM*, Xiaorong Qin,*** *J. Shi,* University of Guelph, Canada*; T. Regier,* Canadian Light Source, Canada*; D.T. Jiang,* University of Guelph, Canada

To understand the formation of organic thin films and substrate influences to the molecular structures, we investigated the orientation of polyacene molecules (i.e., tetracene, pentacene) on hydrogen-passivated Si(001) as a function of coverage, using polarization-dependent C1s near-edge x-ray absorption fine structure spectroscopy (NEXAFS). Molecular films were prepared via vacuum molecular beam deposition, and in situ NEXAFS measurements were performed on the films of different coverage (from 0.2 ML to 12 ML). We report that under the film growth condition, at the early stages of the film growth the average orientation of the molecules is largely disordered. Clear upwards tilting of the molecules start when coverage exceeds a significant portion of a monolayer. With further increasing the film coverage to around 3-4 ML, a structural phase transition occurs, leading to the average molecule tilting angle around the bulk value. We conclude that, in both tetracene and pentacene growth, after the coverage of 3-4 ML, the molecules adopt the organization similar to that in the bulk-phase structure due to strong the self-assembly effect and less influence from the molecule-substrate interface. Atomic force microscopy (AFM) imaging of the films was carried out ex situ to show the morphology of the surfaces at different coverage. The film formation mechanisms and their impact to the charge transport properties of the film will be discussed.

8:00pm **TF-WeE8 RF-Sputtering Reactive used for Depositing Thin Films CdS:O*, Juan Luis Pena Chapa,*** *M. Loeza-Poot, I. Rimmaudo,* CINVESTAV-IPN Unidad Merida, Mexico*; I. Riech Mendez,* Universidad Autónoma de Yucatán, Mexico*; R. Mis Fernandez, V. Rejon Moo,* CINVESTAV-IPN Unidad Merida, Mexico

We present the effects of the variation oxygen concentration in the thin films of CdS:O deposited by RF-Sputtering. This kind of thin film was studied with the purpose to be used as a window layer in a solar cell. The films were deposited on Corning glass substrate (area 1 in^2) from a ceramic target of CdS with 99.99% purity, in an atmosphere of mixture of gases Ar + O2. Deposition was performance at room temperature with a working pressure of 25 mTorr and a sputtered power of 40 Watts. Films with different oxygen content were prepared with a variation of the oxygen concentration in a range from 1% to 1.5% with respect to the total pressure . The structural and morphological properties were characterized by using X-ray Diffraction (XRD) and field emission scanning electron microscopy (FE-SEM), respectively. The diffraction patterns showed that samples prepared with oxygen concentration less to 1.1% are crystalline and present the hexagonal CdS (h-CdS) structure, while samples with oxygen concentrations greater than 1.1% are amorphous, all crystalline films were oriented preferentially (002). Also we observed a decrease in the crystallite size in a range from 5.9 nm to 4.3 nm, which can be correlated in the micrographs. SEM images show that is possible to obtain nanostructure thin films of CdS varying the grain size in a range from 20nm to 70nm, the grain size decrease as the oxygen percentage raises, all samples present high uniformity.

ACKNOWLEDGEMENTS: This work has been supported by CONACYT-SENER (México) under projects CeMiESol 207450/P25 and CeMiE-Sol 207450/P26. M. Loeza-Poot acknowledges CONACYT-Mexico for scholarship (number 556332) in the Applied Physics Department of CINVESTAV-Merida. . Measurements were performed at LANNBIO CINVESTAV-Mérida, supported from projects FOMIX-Yucatán 2008-108160, CONACYT LAB-2009-01 No. 123913 and CB2012/ 178947. The authors gratefully acknowledge to D. Huerta and Wiliam Cauich for technical support, and to L. Pinelo as secretarial assistant.

8:20pm **TF-WeE9 Spatio-Time-Resolved Cathodoluminescence Study of Thick III-polar and N-polar InGaN*, Zakaria Al Balushi,*** *J. Redwing,* The Pennsylvania State University, USA

InGaN quantum wells (QWs) have been well established as active layers in LEDs and laser diodes. Recently, there has been interest in the growth of thick InGaN to serve as strain-reducing layers for deep-green and red emitters. The growth of thick layers is, however, challenging. The miscibility gap between InN and GaN leads to InGaN phase separation and indium clustering. In addition to low indium incorporation at high growth temperatures, a high density of V-pits are observed in InGaN films grown in the III-polar direction. Alternatively, the growth of films in the N-polar direction offers advantages that are attractive for the growth of thick InGaN. N-polar growth enables higher indium incorporation and V-pits are

less favorable to form. Despite these advantages, limited studies on thick N-polar InGaN films have been reported. This is because N-polar InGaN grown by MOCVD typically suffer from high densities of hexagonal hillocks that originate from low quality N-polar GaN templates. Therefore, in order to assess the quality of thick N-polar InGaN films, it is necessary to probe the local structure and optical properties of high quality grown films.

In this study, we compare the structural and optical properties of thick III-polar and N-polar InGaN. Both III-polar and N-polar InGaN growth was carried out by MOCVD under identical conditions (130 nm, 780°C, 300 Torr, V/III=2450) on high quality GaN base layers. The N-polar InGaN films were free of hexagonal hillocks and exhibited a reduced RMS roughness of 0.66 nm in comparison to the RMS roughness of 2.30 nm for III-polar InGaN. High resolution XRD, SIMS and EDX measurements revealed higher indium incorporation in the N-polar films (13%) when compared to III-polar InGaN (7.5%). From PL measurements, two distinct peak emissions located at different depths of the film were observed for both film polarities, one peak originating from a pseudomorphically strained region and the other from a partially relaxed region. To further investigate the optical properties of InGaN films, we performed both steady state and time-resolved cathodoluminescence mapping of the III-polar and N-polar films at room and liquid helium temperatures. From CL measurements, distinct emission from indium clusters and threading dislocation around V-pits were observed in III-polar InGaN films. In the case of N-polar InGaN, CL emission was homogenous across the film surface. With the combination of spectroscopic techniques, this study elucidates the differences in the luminescence in thick InGaN as a function of film polarity and gives new insights into possible mechanisms of luminescence quenching commonly observed N-polar InGaN.

8:40pm **TF-WeE10 3D Image of Coating and Diffusion Species*, Lei Zhang,*** Shenyang National Laboratory for Materials Science, Institute of Metal Research, Chinese Academy of Science, China

Morphology, composition and crystallography are three common objects for microanalysis in material science. The developments of 3D techniques in material microanalysis facilitate researchers to explore in 3D space. 3D chemical analysis is of important in 3D microanalysis family but need to be improved and promoted. Combining 2D imaging in lateral with sputtering in depth, layered SIMS imaging can be reconstructed in 3D. Detailed 3D-SIMS analysis of interfaces between phases, such as concentration change and inhomogeneity of diffused species near interface, provide diffusion information between coating and substrate with new view. Such 3D-SIMS technique become a useful and popular tool to generate full-view images in 3D space for various specimens with layered or complex structure from inorganic, organic and biological research. It provides a wealth of composition information and gives deep insights that cannot easily be attained in other interfacial analysis.

Normal approach in 3D-SIMS can display the species in layered or complex structure. However, detailed analysis of interfaces between phases, such as concentration change and inhomogeneity of diffused species near interface, attract more attention that need to be explored. For example, diffused interface is expected to be a sign of solid bonding for the safety of coating service life. New 3D imaging approach is developed to separate the diffused species through the interface. In terms of the ion imaging of CsAl+ in diffusion region, diffused Al at the interface between the ceramic coating and Zircaloy substrate were investigated in both as-deposited and annealed states.

The new analytics toolkit to resolve diffused species is a key evaluation to develop coating layer on alloys. The new method based on 3D-SIMS analytics is expected to provide diffusion information between coating and substrate with new view. It will continue to advance and gives more information about the formation of diffusion interface which facilitate the interface analysis from variety of research interest.

References

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