Electronic Materials and Processing

Room: 612 - Session EM+NS-MoA

Semiconductor Nanostructures for Electronics and Optoelectronics I

Moderator: N. Gergel-Hackett, National Institute of Standards and Technology

2:00pm **EM+NS-MoA1 Effect of Organic and Inorganic Capping Agents on Optical Properties of CdS Nanoparticles**, ***N. Hullavarad***, *S. Hullavarad*, University of Alaska Fairbanks

Vast research interest on the synthesis and characterization of II-VI semiconductor nanoparticles for size-dependent optical properties and their potential applications in optoelectronic devices is developed over the few years. A blue shift in the energy is observed due to the quantum confinement effect as the dimensions of nanoparticles approach the Bohr radius of exciton. Size tunable properties of nanoparticles give an opportunity for various photonic applications which might find restrictions because of nonradiative recombinations due to surface defects. Organic and inorganic capping agents are used to stabilize and passivate during the synthesis of nanoparticles in order to overcome these kind of difficulties associated with the nanoparticles. Cadmium sulfide (CdS) is an important II-VI semiconducting material having a direct band gap of 2.42 eV. However, when synthesized chemically through a bottom-up approach by the capping method, the narrow band gap material can be grown with enhanced band gap in the ultraviolet region. In this paper, the synthesis of CdS nanoparticles through a simple, inexpensive and straightforward method will be discussed. The synthesis of CdS nanoparticles using organic and inorganic capping agents by chemical colloidal method will be discussed. The capping agents used are thioglycrol, mercaptoethanol, 1-6 heaxnedithiol and tetraethyl orthosilicate (TEOS) and tetraethyl orthotitaniate (TEOT). It is observed that nature of optical absorption spectra changes depending on the capping agents for CdS nanoparticles synthesized under same parameters. The effect of capping agent on the photoluminescence and UV absorption will be discussed in the light of metal induced defects. The thioglycerol capped CdS nanoparticle sample will be taken as a special case to study the effect of X-ray irradiation.

2:20pm **EM+NS-MoA2 Initial Metallization and Transition Metal Diffusion in ZnO Single Crystals, CVD-Grown Epi-films, and Nanostructures**, *S. Rangan*, ***S. Katalinic***, *R. Gateau, D. Hill, R.A. Bartynski, P. Wu, Y. Lu*, Rutgers University

Transition metal doped ZnO is a promising candidate room temperature dilute magnetic semiconductor for spintronic applications. In previous studies of MOCVD-grown epitaxial ZnO films and nanostructures, either ion-implanted or diffusion doped with Fe or Mn, we have observed that these two metals exhibit significantly different diffusion properties. To explore whether this is an inherent property of ZnO or if it is related to non-ideal aspects of the films or nanostructures, we have studied the initial stages of Mn, Fe, and Cu metallization of the single crystal ZnO(0001)[Zn-terminated] and (11-20) surfaces, as well as MOCVD-grown epitaxial films [for which the (11-20) surface is exposed], using scanning tunneling microscopy and spectroscopy (STM and STS). The subsequent diffusion of these metals into the oxide upon annealing to various temperatures was studied with ion scattering spectroscopy. The as-prepared surface of the epitaxial film shows the same nanoscale morphology as the single crystal (11-20) surface, organized in row-like structures tens of nm in width and 2 - 4 nm in height. While Cu deposition results in well defined islands, all three surfaces exhibit apparent disruption upon Fe deposition, even at room temperature. The surfaces exhibit substantial morphological changes on the nm length scale, with a significant change in terrace widths and a significantly smaller fraction of atomic height steps. Upon annealing, Cu islands become mobile and coarsen, but the underlying ZnO structure is not strongly affected. In contrast, with Fe present on the surface, significant coarsening and roughening of the substrate occurs even at the modest annealing temperature of 200C, and this effect is enhanced upon annealing to 400 C. A comparison of the diffusion of Fe and Mn into the single crystals and the film will be presented. Initial results suggest that uptake of metals into the epi-film is predominantly determined by the properties of the (11-20) surface that terminates the film.

Support for this work from NSF grant 0224166 is gratefully acknowledged.

2:40pm **EM+NS-MoA3 Electron Spin Dynamics in Colloidal ZnO Quantum Dots**, ***K.M. Whitaker***, *D.R. Gamelin*, University of Washington

Conduction band electrons in colloidal ZnO quantum dots have been prepared photochemically. This presentation will describe the use of electron paramagnetic resonance (EPR) spectroscopy to probe the spins of these conduction band electrons. Spectroscopic g-values for 3-7 nm diameter nanocrystals containing single S-shell conduction band electrons have been determined. Room-temperature ensemble spin dephasing times for these electrons were estimated from EPR linewidth analysis. The effects of electron-nuclear hyperfine interactions on T_2^* were investigated systematically by varying the concentration of ^{67}Zn (I = 5/2) ions synthetically. A clear relationship between T_2^* and nuclear spin concentration was observed and will be discussed.

3:00pm **EM+NS-MoA4 Characterization of Ion Beam Deposited Quantum Dots Thin Films from Colloidal Solution**, ***Y. Tani***, *S. Kobayashi, H. Kawazoe*, HOYA Corporation, Japan

Distinctly monodispersed core/shell structured semiconductor nanocrystals (NCs) quantum-dots (QDs) prepared by chemical synthetic methods in liquid solutions are fascinating fluorescent materials because of efficient saturated chromatic luminescence. In the consideration of applications to light emitting flat panel displays, ready-synthesized NCs can be expected to be pieces of a light emitting component being deposited on a heterologous large areal polycrystalline or amorphous substrates, in contrast with a restrictive conditioned Stranski-Krastanov mode QDs. However, it has been a daunting challenge to form an organic-free luminescent QD structured film from the wet QDs, which are stably dispersed in an organic solvent or water with hundreds of ligand molecules on their surface. We developed a very low energy NC ion beam deposition technique,[1] which is capable of forming QD ion beam from the colloidal solution to deposit fluorescent thin films without significant organic contamination. In present study fabrications of high efficient luminescent QD structured thin films from CdSe/ZnS colloidal NC source are demonstrated. Semiconductor device requires a compatible technology with the colloidal source and a high-vacuum deposition process for simultaneous pursuit of a preservation of NC configuration and an exclusion of the organics derived from the ligand and solvent. An electrospray technique was employed for a soft ionization process to obtain nanocrystalline ions. From the requirement of a transportation of the ultraheavy ions and a nonequilibrium deposition, a supersonic flow with a speed of 1.1×10^3 m/s was formed with a free jet nozzle arrangement attaching a differential pumping system, which also works as a neutral molecular evacuator. Furthermore, for preventing the depositing films from an exposure with lighter ions such as the ones originated from the organic solvent and surfactant, ion optics including an energy analyzer are applied. Microstructural observations and chemical composition analysis evidenced that the deposited film has a closely packed polycrystalline structure with less organic contamination. Its photoluminescence spectrum reproduces the original distinct single peak spectrum from the colloidally dispersed NCs. The NC ion with kinetic energy of 0.1-0.4 eV/atom provides appropriate energy dissipation for a deposition of NCs.

[1]S. Kobayashi et al Jpn. J. Appl. Phys. 46 (2007) L392.

3:40pm **EM+NS-MoA6 Interdiffusion during Growth of Self-Assembled InAs/InP Quantum Dots by Chemical Beam Epitaxy: A Combined Experimental and Theoretical Study**, ***C. Dion***, *P. Desjardins,* École Polytechnique de Montréal, Canada, *N. Shtinkov,* Université d'Ottawa, Canada, *M.D. Robertson,* Acadia University, Canada, *F. Schiettekatte,* Université de Montréal, Canada, *P.J. Poole, S. Raymond*, National Research Council, Canada

The formation of atomically sharp interfaces during the epitaxial growth of heterojunctions is a challenging task since atomic intermixing between the different materials is often unavoidable due to the relatively high growth temperatures involved. This effect has been found to be particularly important during the growth of self-assembled quantum dots (QDs) for which evidence of highly alloyed structures have been reported by several authors for a wide variety of semiconductor systems.[1] In the present work, we investigate intermixing during the growth of self-assembled InAs/InP QDs by chemical beam epitaxy. Using a careful combination of photoluminescence (PL) and transmission electron microscopy (TEM) measurements as well as tight-binding (TB) calculations, we have devised a procedure that enables an unambiguous assignment of QD heights (h_{QD}) and composition to the observed PL transitions. PL spectra from ensembles of QDs are characterized by distinctive peaks which can be attributed to the ground state emission of QD families having the same thickness in terms of an integer number of monolayers (ML).[2] Consequently, QDs electronic

transitions are analogous to those of quantum wells and can be analyzed accordingly. TB calculations were performed by assuming (i) $InP/InAs_{1-x}P_x/InP$ structures of varying P concentration ([P]) with abrupt interfaces and (ii) InP/InAs/InP structures with P diffusion concentration profiles described by the diffusion length L_D. Both calculation frameworks lead to similar, realistic descriptions of the as-grown material. However, the above procedure yielded two solutions sets of (h_{QD} : [P] or L_D) compatible with experimental results. In order to determine which solution set is the most suitable, they were used as input data in a Bloch-wave simulation of TEM image contrast providing a sequence of contrasts versus h_{QD}. A unique solution set was compatible with observed TEM data, therefore allowing an unambiguous assignment of h_{QD} and [P] to the observed PL transitions. For the samples under investigation, it was concluded that the electronic transitions can be best attributed to a 3 ML-thick wetting layer and 4 to 13 ML-thick QDs with a relatively constant [P] of 10 ± 1 %.

[1] N. Liu, et al., Phys. Rev. Lett. 84, 334 (2000).
[2] S. Raymond, et al., Semicond. Sci. Technol. 18, 385 (2003).

4:00pm **EM+NS-MoA7 Improved Long-Term Thermal Stability of InGaN/GaN Multiple Quantum Well Light-Emitting Diodes using TiB_2- and Ir-based p-Ohmic Contacts**, *L. Stafford, L.F. Voss, S.J. Pearton, H.T. Wang,* ***F. Ren***, University of Florida

InGaN/GaN multiple quantum well light-emitting diodes (MQW-LEDs) are commercially available in a broad range of wavelengths for use in applications such as full color displays, traffic signals, and exterior lighting. There is also interest in shorter wavelength LEDs with AlGaN active regions which can be used in conjunction with down conversion phosphors to produce white light, and hold significant promise for next generation lighting technology. Nevertheless, to compete with fluorescent and other high-efficiency lighting sources, it is essential to drive GaN-based LEDs at very high current densities to maximize light output. One drawback of the high current densities is self-heating of the heterostructure. This can produce either indiffusion of the Ohmic contact elements, leading to an electrical short of the pn junction, or intermixing of the contact scheme, producing very rough surface morphology. One possible way to prevent excessive Ohmic contact degradation is to use a high-melting-point diffusion barrier in the contact stack. TiB_2, with a melting temperature of ~3000°C, reasonable electrical resistivity (28 μΩ.cm) and thermal conductivity (26 $W.m^{-1}.K^{-1}$), and heat of formation comparable to those for silicides or nitrides, shows promise as a diffusion barrier. In this work, we report on the long-term annealing characteristics at 200-350°C of InGaN/GaN MQW-LEDs with TiB_2- and Ir-based p-Ohmic contacts. This high-temperature stress stimulates accelerated aging of GaN-based LEDs and gives an idea of the expected reliability of the Ohmic contacts. By comparison with companion devices with conventional Ni/Au Ohmic contacts fabricated on the same wafer, MQW-LEDs with TiB_2- and Ir-based Ohmic metallization schemes showed superior long-term thermal stability after 45 days at 200°C and 350°C, as judged by the change in turn-on voltage, leakage current, and output power. This is a promising result for applications where high-temperature operation is required.

4:20pm **EM+NS-MoA8 Effects of N Incorporation on the Electronic Properties of GaAsN Alloy Films and Heterostructures**, ***Y. Jin***, *M. Reason, H. Cheng, R.S. Goldman, C. Kurdak*, University of Michigan

(In)GaAsN alloys with a few percent nitrogen have potential applications in infrared laser diodes, high efficiency solar cells, and other electronic devices. However, as-grown materials often exhibit poor photoluminescence efficiencies and electron mobilities substantially lower than those of (In)GaAs. In this work, we investigate the effects of N incorporation on the electronic properties of GaAsN alloy films and heterostructures grown via molecular-beam epitaxy. The total N concentrations and substitutional N fractions were determined by nuclear reaction analysis and Rutherford backscattering spectrometry studies of the bulk-like GaAsN films. Four-terminal magnetoresistance and Hall measurements were performed from 1.6K to room temperature on both bulk and heterostructure films. In GaAsN bulk films, N-composition dependent free carrier concentrations were observed at room temperature, suggesting that N acts as an electron trap. In addition, a strong T dependence of sheet resistivity and electron mobility was observed. This suggests the localization of carriers due to N-induced potential fluctuations in the conduction band, which may be explained in the framework of Anderson localization. Using modulation-doped AlGaAs/GaAs(N) heterostructures, we determine the N-related scattering effects in the GaAs(N) channel, with minimal contributions from ionized impurity scattering from dopants. Low temperature magnetoresistance and Hall measurements of the heterostructures were performed while the carrier densities in channel layer were manipulated via front-gating and illumination. An increase in electron mobility with free carrier density was observed for all heterostructure samples. For control samples (GaAs channel), the mobility depends exponentially on carrier density, i.e., $\mu \sim n^a$, where α is typically 1~1.5, suggesting the dominant scattering mechanism is long-range ionized impurity scattering. For the nitride samples (GaAsN channel), α is 0.2~0.3, and the mobility saturates for $n > 1.5x10^{11} cm^{-2}$, suggesting that N atoms act as short-range neutral scattering centers. The effects of rapid thermal annealing on the substitutional and interstitial N concentrations and the resulting transport properties of GaAsN films will also be discussed.

4:40pm **EM+NS-MoA9 Interface- and Photo-Based Manipulation of Point Defects for Nanoelectronics**, ***Y. Kondratenko***, *R Vaidyanathan, C.T.Z. Kwok, E.G. Seebauer*, University of Illinois, Urbana - Champaign

As electronic devices scale deeper into the nanometer regime, key aspects of device performance become increasingly dominated by point defects within the semiconductor. An obvious example is current flow in silicon nanowire devices, which is heavily influenced by residual point defects. The present work discusses two new mechanisms for controllably manipulating point defect concentrations in semiconductors at the nanoscale, using silicon as a specific example. In the first mechanism, the ability of free surfaces or solid interfaces to annihilate point defects within the solid can be altered by several orders of magnitude through either chemical state modification or mild ion bombardment. The resulting dangling bonds at the surface or interface interact with the defects through direct bond-addition reactions and through electrostatic attraction or repulsion. In the second mechanism, low-level photostimulation to produce excess charge carriers changes the average charge state of certain varieties of point defects, which in turn affects their diffusion rates toward nearby interfaces. Depending on the temperature and time of exposure, diffusion rates can be either enhanced or inhibited. Experiments using arsenic and boron diffusion as markers for defect behavior in silicon are described that demonstrate both mechanisms. Rate-equation-based modeling accurately describes all qualitative and most quantitative aspects of the results.

5:00pm **EM+NS-MoA10 Programmable Memory Devices using Gold Nanoparticles Capped with Alkanethiol of Different Carbon Chain Lengths**, ***P.-Y. Lai***, *J.-S. Chen*, National Cheng Kung University, Taiwan

In recent years, organic nonvolatile memory devices have attracted much attention due to its high potential for fabricating high density, low cost and flexible electronic components. In this work, we have fabricated an organic memory consisting of gold nanoparticles and polystyrene sandwiched between aluminum (Al) electrodes. The gold nanoparticles capped with three different carbon chain lengths of the alkanethiol ligand are prepared by the two-phase arrested growth method. The pristine device, which is initially at a low-conductivity state, exhibits an abrupt increase of current when the device is scanned up to the certain voltage. The high-conductivity state can be returned to the low-conductivity state by applying a positive voltage. The length of the alkanethiol which encapsulates gold nanoparticles affects the distribution of threshold voltage to turn on the memory device. The carbon chain length of alkanethiol varies the electron tunneling ability due to the modification of energy barrier. The results correlate the length of the alkanethiol with switching speed, cyclic write-read-erase-read times, and retention time of memory devices will also be discussed.

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