Thursday Afternoon, November 3, 2005

Electronic Materials and Processing
Room 310 - Session EM2-ThA

Dilute Nitrides and Small Bandgap Semiconductors
Moderator: R. Ahrenkiel, University of Denver

2:00pm **EM2-ThA1 Narrow Band Gap Group III-Nitrides***, W. Walukiewicz,* Lawrence Berkeley National Laboratory **INVITED**

Incorporation of small amounts of N into group III-V semiconductors leads to a dramatic reduction of the band gap of resulting IIIN@sub x@V@sub 1-x@ alloys. This effect can be well described by the Band Anticrossing (BAC) model that considers the interaction between localized states of N and the extended conduction band states. The interaction splits the conduction band into two nonparabolic bands, resulting in large changes in the electrical and optical properties of these materials. The BAC model provides a consistent and quantitative description of experimentally observed data including the large band gap bowing, splitting of the conduction band, and increase of the electron effective mass. Comprehensive studies of the electronic structure and electrical and optical properties of InN and In-rich In@sub 1-x@Ga@sub x@N alloys will also be discussed. In addition to having a narrow gap (0.7 eV), InN also has an extremely high electron affinity of 5.8 eV, placing the conduction band edge of this material 0.9 eV below the average energy of dangling bond defects (Fermi level stabilization energy, E@sub FS@). This unusual band alignment has profound consequences for the behavior of dopants and defects and explains the extreme proclivity of InN and In-rich group III-nitride alloys for n-type conduction. As grown, undoped InN is always n-type with electron concentrations ranging from mid 10@super 17@ cm@super -3@ to as high as 10@super 21@ cm@super -3@. We show that similar range of electron concentrations can be achieved by irradiation of thin InN films with 2 MeV He@super +@ ions.

3:00pm **EM2-ThA4 Electronic Properties of GaAsN Quantum Wells***, **S. Turcotte**, N. Shtinkov, J.-N. Beaudry,* École Polytechnique de Montréal, Canada*; G. Bentoumi,* Université de Montréal, Canada*; R.A. Masut,* École Polytechnique de Montréal, Canada*; R. Leonelli,* Université de Montréal, Canada*; P. Desjardins,* École Polytechnique de Montréal, Canada

Dilute semiconductor nitrides heterostructures are very promising for a variety of device applications including lasers and photovoltaic cells. The optimization of such devices relies on the understanding of the fundamental electronic properties of quantum well structures. Among these, optical transitions, quantum confinement, and band offsets need to be clarified. Using a combination of techniques including optical absorption and photoluminescence, we have studied GaAs@sub 1-x@N@sub x@ quantum wells in GaAs(001). Two series of samples grown by MOCVD were investigated. The first consists of 7-period, 10-nm-thick GaAs@sub 1-x@N@sub x@ multiple quantum wells (MQW) with x ranging from 0.001 to 0.02 as determined from high-resolution x-ray diffraction. A series of single quantum wells (SQW) was also fabricated to investigate the effect of well thickness, from 2.8 to 11.3 nm, for a nominal N content of x=0.01. The low-temperature (near 5K) PL spectra of the MQWs are characterized by a 10-20 meV wide emission peak at an energy decreasing from 1.5 eV to 1.3 eV with increasing N content. Annealing at 700°C for 2 min. resulted in more intense PL emission with negligible change in energy. Electronic structure calculations are carried out using a tight-binding model.@footnote 1,2@ We obtain an excellent agreement between experimental and numerical results for the case corresponding to perfectly aligned GaAs and GaAsN valence bands. The absorption edge measured at 6 K for the SQWs structures decreases from 1.45 to 1.35 eV with increasing thickness. By fitting these results to the tight-binding calculations, we deduce an electronic confinement of the order of 55 meV and 125 meV for the thickest and thinnest layers, respectively. @FootnoteText@ @footnote 1@ N. Shtinkov, P. Desjardins, and R. A. Masut, Phys. Rev. B 67, 081202(R) (2003)@footnote 2@ N. Shtinkov, S. Turcotte, J.-N. Beaudry, P. Desjardins, and R. A. Masut, J. Vac. Sci. Technol. A 22, 1606 (2004)

3:20pm **EM2-ThA5 High-Performance, Lattice-Mismatched GaInAs***, **M.W. Wanlass**,* National Renewable Energy Laboratory **INVITED**

GaInAs is a pseudobinary III-V compound semiconductor that has a direct bandgap, and full miscibility, over its entire composition range. The room-temperature bandgap varies significantly, from 0.36 eV (InAs) to 1.42 eV (GaAs), between the binary endpoints. The above characteristics make GainAs particularly well suited to photovoltaic (PV) energy converter applications that require infrared-responsive components. Arbitrary bandgaps within the available range are achieved by considering epitaxial, lattice-mismatched (LMM) heterostructures grown on commercially available crystalline substrates (e.g., Ge, GaAs, and InP). We discuss structural approaches involving compositional grading that yield LMM materials with excellent minority-carrier parameters. A variety of characterization techniques are used to elucidate the microstructural and electronic properties. Specific PV device applications and results are also presented.

4:00pm **EM2-ThA7 Comparison of a Dominant Electron Trap in n-Type and p-Type GaNAs Using Deep-Level Transient Spectroscopy***, **S.W. Johnston**, S.R. Kurtz,* National Renewable Energy Laboratory

Both p-type and n-type dilute-nitrogen GaNAs epitaxial layers grown by metal-organic chemical vapor deposition were characterized by deep-level transient spectroscopy (DLTS). For each case, the dominant DLTS signal corresponds to an electron trap having an activation energy of about 0.2 to 0.3 eV for p-type GaNAs and about 0.3 to 0.4 eV for n-type GaNAs. In p-type GaNAs, the electron traps fill slowly, as the DLTS signal reaches saturation using zero-bias filling pulses with widths on the order of 1 to 10 seconds. When applying a large range of filling-pulse widths, the activation energy tends to decrease from about 0.3 eV for short filling pulses to about 0.2 eV for longer filling pulses. In n-type GaNAs, the electron trap activation energy also tends to slightly decrease with increasing filling-pulse widths. For short pulse widths of microseconds to milliseconds, the activation energy is just below 0.4 eV, and for long pulse widths of seconds, the activation energy is just above 0.3 eV. The electron traps fill quickly in the n-type GaNAs, as the DLTS signal approaches saturation in microseconds. The capture cross-sections determined by the DLTS Arrhenius plots are typically about 10@super -13@ to 10@super -12@ cm@super 2@. The electron-trap densities range from 10@super 15@ to 10@super 16@ cm@super -3@ in mid-10@super 17@ cm@super -3@ n-type-doped GaNAs having a bandgap of 1.35 to 1.4 eV. These trap parameters give an estimated carrier lifetime of 1 ns or substantially shorter.

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