SYMPOSIUM P

Optical Microstructural Characterization of Semiconductors

November 29 – 30, 1999

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*Invited paper
SESSION P1: NEAR-FIELD TECHNIQUES I
Chairs: Jiwon Fligner and M. Selm Ulu
Monday Morning, November 29, 1999
Sala C/D (M)

8:30 AM *P1.1
INTERNAL INITIAL MODES AND LOCAL PROPAGATION PROPERTIES IN OPTICAL WAVEGUIDES MEASURED USING NEAR-FIELD SCANNING OPTICAL MICROSCOPY.
Bennett B. Goldberg, Dept of Physics and Photonics Center, Boston University, Boston, MA.

Near-field scanning optical microscopy has been used to measure the internal spatial modes and local properties controlling optical wave propagation in glass/silicon buried waveguides. The period of the observed structures is determined by the numerical aperture of the excitation beam, which combined with the measured modal shape determines the values of all spatial components of the wave vector. Small fluctuations in the material properties of structures can present accuracy and resolution problems. The NSEOM allows for local probe measurements to provide a means of detailed characterization, and defects in processing and their effects on performance are readily identified. We have also developed a technique that can obtain detailed information about the locations of remote dielectric interfaces based upon the rate of change in the phase of the standing wave as a function of wavelength. Experimental results addressing this issue of perturbation of the NSEO probe on the measurement of the local field show a weak but measurable perturbation, and the dependence on aperture and material parameters will be discussed. An additional area of great current interest is in photonic bandgap systems, and our results in Si and glass PBGs will be presented.

9:00 AM **P1.2
PHOTOCURRENT MEASUREMENTS NEAR-FIELD SCANNING OPTICAL MICROSCOPY.
Charles Franchon, University of Wisconsin, Dept. of Chemistry, Madison, WI; Jiayuan Sun, University of Wisconsin, Dept. of Chemical Engineering, Madison, WI; Arthur B. Ellis, University of Wisconsin, Dept. of Chemistry, Madison, WI; Leon McCaughan, University of Wisconsin, Dept. of Engineering, Madison, WI; Thomas Kitech, University of Wisconsin, Dept. of Chemical Engineering, Madison, WI.

Photoconductivity (PR) spectroscopy is a useful technique for determining the surface electric field of direct gap semiconductors. PR employs pump and probe beams of light, each above the band gap of the semiconductor. The probe beam is scanned in wavelength while the pump remains fixed. The reflectivity of the semiconductor at the probe wavelength is modulated by the pump light. By monitoring the changes in the reflectivity of the probe, Franz-Keldysh oscillations can be observed in the reflected spectra of the probe light. These spectra can be used to calculate the surface electric field of direct gap semiconductors. In previous studies PR has been employed to determine the effect of passivating agents on the surface electric field of semiconductors. In this investigation we will report on spatially resolved measurements of the electric field from passivated samples using Near-field Scanning Optical Microscopy (NSOM) combined with PR. NSOM uses a tapered fiber optic probe to deliver light to sub-micron areas of a surface. The tip of the probe is brought into close-focus, and then scanned over the surface. The reflection of the optical signal is recorded as a function of a sample position. By launching both the pump and probe light down the fiber, spatially resolved sub-micron scale measurements of the surface electric field have been achieved. Application of Photoconductance Near-field Scanning Optical Microscopy (PRNSOM) to the passivation of GaAs surfaces for measuring the local surface electric field will be shown; supporting calculations of the field strength and resolution limitations will also be presented. GaAs samples that have been surface passivated in micron scale patterns, by either Se3S or [NH4]2S, are being used for the quantitative evaluation of the efficiency and uniformity of passivation at the sub-micron level.

9:15 AM *P1.3
ARSENIC OXIDE MICROCRYSTALS IN POROUS GaAs NETWORK: CHARACTERIZATION BY CATHODOLUMINESCENCE AND NSOM.
Xiaoying Li and Paul W. Bohn, Department of Chemistry, University of Illinois, Urbana, IL.

A large number of diamond-shaped As2O3 microcrystals [1-50 μm in size] can be produced by anodic etching of GaAs wafers in HC1. Polarization-dependent Raman spectroscopy has unambiguously identified the As2O3 microcrystals and located the damage to the GaAs surface by the electrochemical process. Photoluminescence (PL) spectroscopy of such samples shows a strong emission band centered around 540 nm. Spatially resolved studies using cathodoluminescence and near-field PL spectroscopy and microscopy indicate that the strong 540 nm emission band comes from a large number of weak emitters of As2O3. A small number of strong emitters in the visible range originated from amorphous impurity inclusions are also identified.

9:30 AM *P1.4
SCANNING TUNNELING MICROSCOPE-INDUCED LUMINESCENCE STUDIES OF DEFECTS IN GaN LAYERS AND HETEROSTRUCTURES.
S. Kim, School of Applied and Engineering Physics, Cornell University, Ithaca, NY; S. Keller, UK; Mishra, and S.P. DenBaars, Department of Materials, University of California, Santa Barbara, CA.

Electron beam-induced luminescence has been widely used for the spatially resolved characterization of optoelectronic materials. Scanning tunneling microscope-induced luminescence (STM) offers an interesting alternative to standard cathodoluminescence (CL) as it injects minority carriers directly into the energy band without involving impact ionization. The technique has yet to be employed for the investigation of defects in any material system. Its enhanced resolution would permit the analysis of defects on a scale unsuitable with CL. The GaN system is of high interest for optoelectronic applications in the blue and near-UV spectral regions. Material grown on sapphire has shown high dislocation densities that proved detrimental to device operation. In addition to high dislocation densities, InGaN/GaN QWs involve the presence of nanometer scale In-rich clusters. We report the nanometer scale analysis of non-radiative recombination at threading dislocations in plain GaN, and the observation of nanometer scale fluctuations of luminescence in a InGaN/GaN multi-quantum well (MQW) with STI. The luminescence of plain GaN is dominated by the band-edge lmbd=356 nm at low temperature. The corresponding images display non-luminescent areas at threading dislocation sites. Fitting the luminescence decay at these sites yields hole diffusion lengths of L=355 nm. The low temperature STI of the MQW is dominated by the expected lmbd=456 nm range. Carriers unable to reach the MQW are trapped by the neighboring surface states, leading to the inhibition emission from the gap and the dominance of MQW emission in the resulting spectrum. The corresponding STI map exhibits 30-100 nm wide fluctuations of luminescence. Possible origins include microstructural issues, In segregation, and fluctuations of carrier scattering. These results represent the first application of STI to defect studies. The technique could significantly contribute to the development of highly efficient optoelectronic materials.

SESSION P2: PHOTOELECTRICAL AND RESONANCE TECHNIQUES
Chair: Takashi Sekiguchi
Monday Morning, November 29, 1999
Sala C/D (M)

10:15 AM **P2.1
LIGHT-EXCITED JUNCTION SPECTROSCOPY METHODS FOR CHARACTERIZATION OF ELECTRONIC DEFECTS IN NOVEL MATERIALS. Anna Cavallini, Antonio Castaldi, INFN, Bologna Univ, Dept of Physics, Bologna, Italy.

A number of deep level transient spectroscopy (DLTS) has been developed over two decades from the pioneering paper of Miller et al. [1] due to the growing importance of characterization electronic defects in semiconductors. However, conventional DLTS cannot be used at all or is of limited use for two classes of materials: i) materials with free carrier concentration comparable or lower that that of defect associated level, and ii) wide band-gap materials such as GaN and SiC since the range of level energies in the gap accessible to DLTS is restricted to about 1 eV of either band edge. This paper will report on a few spectroscopy methods that utilize light injection to overcome the DLTS limitations by photo-ionization of the deep levels. Photo-DLTS, Photo-Induced Transient Spectroscopy (PITS) and Photo-Isothermal Transient Spectroscopy (Photo-ICTS), the last one using monochromatic below-gap excitation, offer the opportunity for the investigation of levels in compensated materials, such as CdZnTe, as well as mid-gap defects in wide-gap materials, such as SiC and GaN, which presently are of great interest because of their very promising electronic and optoelectronic applications. This paper will report results obtained by PDLTS, PITS and Photo-ICTS relevant to the above-cited materials. [1] GL Miller, DV Lang and LC Kimerling, Ann. Rev. Mater. Sci. 1977, 377

10:45 AM *P2.2
INVESTIGATION OF DEEP LEVELS IN GaP LIQUID PHASE EPITAXIAL LAYERS ON SUBSTRATES WITH VAPOR PHASE PRETREATMENT. E. Inoue, Japan National Research Center, Telecommunications Advancement Organization of Japan, Sendai, JAPAN; Tetuya Matsuo, Ken Sato, Dept. of Materials Science, Tohoku Univ. Sendai, JAPAN; Jumichi Nishizawa, Semiconductor Research Institute, Sendai, JAPAN.

A number of deep level transient spectroscopy (DLTS) has been developed over two decades from the pioneering paper of Miller et al. [1] due to the growing important of characterization electronic defects in semiconductors. However, conventional DLTS cannot be used at all or is of limited use for two classes of materials: i) materials with free carrier concentration comparable or lower than that of defect associated level, and ii) wide band-gap materials such as GaN and SiC. Since the range of level energies in the gap accessible to DLTS is restricted to about 1 eV of either band edge. This paper will report on a few spectroscopy methods that utilize light injection to overcome the limitations by photo-ionization of the deep levels. Photo-DLTS, Photo-Induced Transient Spectroscopy (PITS) and Photo-Isothermal Transient Spectroscopy (Photo-ICTS), the last one using monochromatic below-gap excitation, offer the opportunity for the investigation of levels in compensated materials, such as CdZnTe, as well as mid-gap defects in wide-gap materials, such as SiC and GaN, which presently are of great interest because of their very promising electronic and optoelectronic applications. This paper will report results obtained by PDLTS, PITS and Photo-ICTS relevant to the above-cited materials. [1] GL Miller, DV Lang and LC Kimerling, Ann. Rev. Mater. Sci. 1977, 377
High quality GaP crystal with low defect density has been required by many important applications of optoelectronic devices such as green light emitting diode and Raman laser. We fabricated GaP liquid phase epitaxial (LPE) layers with temperature difference method under controlled vapor pressure (TD-M-CVP), successively to GaP substrate single-stripe with temperature phosphorus vapor pressures around the optimum one (150 Torr) for stoichiometric crystallization of GaP. Very precise measurements of photocapacitance (PHCAP) and photoluminescence have been carried out for the TD-M-CVP grown and two LPE layers. By designing the optimum mechanism of defect formation. Comparing to the GaP layers usually grown on GaP substrates without being annealed, very obvious reduction of deep level densities in such epitaxial layers on annealed GaP substrates has been observed by HPHCAP measurements, and clear increases of photoluminescence intensities have been obtained both at 77K and room temperature. It is considered that during the process of heat treatment at growth temperature, under the optimum phosphorus pressure, the GaP substrate moves into the crystalline state, so that their diffusion to growth layer decreases greatly.

11:00 AM P2.3
LOW TEMPERATURE PHOTOLUMINESCENCE AND PHOTON-DUCTION CURRENT SPECTROSCOPY ON CdZnTe GROWN BY HIGH-PRESSURE BRIDGMAN TECHNIQUE. Aziz Zerru, Laboratoire de Physique de la Matière, INSa, Lyon, FRANCE; Sylvain Menguy, Florida International Univ. Dept of Electrical and Computer Engineering, Miami, FL; Karim Cherkaoui, Laboratoire de Physique de la Matière, INSa, Lyon, FRANCE; Mokram Hage Ali, Laboratoire PHASE, Strasbourg, FRANCE; Ghassan Meraydji, Laboratoire de Physique de la Matière, INSA, Lyon, FRANCE.

CdZnTe and recently CdZnTe semi-insulating materials are very promising compounds for applications like radiation detectors, photoconductive systems for optical telecommunications or substrates for infrared detectors. Therefore, the characterization of defect and impurity levels is of great importance to improve the electrical properties of these crystals. Low temperature photoluminescence (PL), photocurrent induced spectroscopy (PICTS), and thermoelectric effect spectroscopy (TEES) have been carried on several CdZnTe samples taken from the same ingot grown by the High Pressure Bridgman technique (HPB). The PL band-gap edge luminescence allowed us to study the quality of the material. We have also determined the Zinc segregation through the ingot. A broad luminescence band at lower temperature was observed and compared to the PICTS results. This comparison enabled us to understand the origin of this defect. The variation of the defects concentrations through the ingot was made possible through the PICTS results. Finally, these results will be used to implement the resistivity model.

11:15 AM *P2.4
SPIN-DEPENDENT RECOMBINATION IN SEMICONDUCTORS: RECENT RESULTS. Bernhard Brandt, Martin Stuttman, Walter Schottky Institut, Technische Universität München, Garching, GERMANY.

Magnetic resonance techniques have played a crucial role for our present knowledge about the microstructure of point defects in almost all semiconductors. Recently, however, standard spin resonance has become less relevant for modern semiconductor physics, because size reduction, reduction of dimensionality, and impurities in present-day techniques usually lead to defect concentrations too low for direct resonance detection. Here the combination of spin resonance with optical characterization methods such as photoluminescence (optically detected magnetic resonance, ODMR) or photoconductivity (electrically detected magnetic resonance, EDRM) provides new possibilities to investigate the microstructure of defects with strongly enhanced sensitivity. The aim of this talk is to briefly present the basic physical ideas of spin-dependent recombination and then to discuss recent examples of the application of this method to semiconductors and device structures of current interest.

11:45 AM P2.5
PHOTOELECTRICE SPECTROSCOPY EVALUATION OF HIGH QUALITY STRAINED PIEZOELECTRIC MOVPE InGAs/InGaAs QUANTUM WELL STRUCTURES GROWN ON [111]A GaAs SUBSTRATES. Soo-Hyung Cho, A. Simionenko, Jongseok Kim and A. Majerfeld, University of Colorado, Dept. of Electrical and Computer Engineering, Boulder, CO; C. Villar, E.T.S. Telecomunicacion, Departamento de Telefónica Electrónica, Madrid, SPAIN; B. W. Kim, Electronica y Telecomunicaciones Research Institute, Yusong, Taejon, KOREA.

Photoelectron spectroscopy (PES) is a powerful technique for the optical evaluation of semiconductors. In this work the quantum well (QW) heterostructures, particularly when a Piezoelectric (PE) field is present, as it provides a non-destructive, sensitive and efficient procedure to determine both the QW confined states by direct observation of the different optical transitions and optical band gap through the PE field from the Franz-Keldysh oscillations that develop in the presence of an electric field. In this work we have used room temperature PR to study a high quality strained InGaAs/InGaAs/AlGaAs double confinement single QW structure grown by MOVPE on a [111]A GaAs substrate. Heterostructures of InGaAs/GaAs/AlGaAs grown on <111> oriented GaAs are of interest due to their fundamental new properties, such as the presence of a strong piezoelectric field in the strained InGaAs layers and their potential applications as optoelectronic devices. Photoreflectance spectroscopy, in combination with a structural technique such as high-resolution X-ray diffraction, enabled us to carry out a detailed study of the optical transitions in the QW. The experimental transition energies were explained using a theoretical model that included the actual potential profile with a piezoelectric field of 131 kV/cm and a set of appropriate values for the <111> electronic parameters. The linewidths of the various transitions were found to be strongly dependent on the QW structure with a well width of 41 Å. From a theoretical analysis of the linewidths based on the Bose-Einstein photon-coupling model, we determined an interface roughness of ± 1 monolayer for the first materials system.

SESSION P3: LUMINESCENCE

Chair: Partha S. Dutta and Leonid Tsybeskov
Monday Afternoon, November 29, 1999
Salon C/D [M]

1:30 PM *P3.1
OPTICAL MICRO-COMPARISON OF SELECTIVE AREA GROWTH GALLIUM NITRIDE HETEROSTRUCTURES. J. Christen, Institute of Experimental Physics, Otto-von-Guericke University, Magdeburg, GERMANY.

For a detailed understanding of complex semiconductor heterostructures a systematic determination and a correlation of the structural, chemical, electronic, and optical properties on a micro- or nanoscale is essential. Combining luminescence spectroscopy with the high spatial resolution of a scanning electron microscope, as realized by the technique of cathodoluminescence (CL), provides a powerful tool for the nanocharacterization of semiconductor. Our CL-system combines low temperatures (5K<T<300K), an overall spatial resolution of Δx<56nm, 3 ps time resolution and high spatial resolution. However, the unique feature of our CL system is the imaging of complete CL spectra. While the focused electron-beam is digitally scanned over typically 256x204 pixels a complete CL spectrum I(λ)=I(y,x,λ) is recorded at each pixel (x,y) yielding 3D data set I(x,y,λ). All type of data across cross sections through this I(x,y,λ) tensor can be generated, e.g. sets of monochromatic CL images I(x,y,λ), local CL spot spectra I(x,y,λ), CL spectrum linescans I(x,λ), as well as CL wavelength images I(x,y,λ) mapping the local emission peak wavelength. Selective Area Growth and Epitaxial Layer Overgrowth (ELO) has recently proven to be an efficient way of locally reducing the density of threading dislocations in GaN. From a technological standpoint it is desirable to produce larger regions of low-dislocation-density GaN. Self-organized GaN pyramids as well as ELO GaN on strain-relaxed SiO2- and W-masks are comprehensively characterized by CL microscopy and micro-Raman-spectroscopy. Stripe orientations in <118> and <112>d direction result in significantly different overgrowth schemes. CL microscopy directly images the formation of different growth domains. Plan view CL images visualize the local areas of improved crystal perfection, which only involve a part of the total ELO regions. The CL microscopy is combined with PL and micro-PL and micro-Raman Spectroscopy and correlated with TEM and EDX.

2:00 PM P3.2
DEVELOPMENT OF LOW ENERGY CATHODOLUMINESCENCE SYSTEM AND ITS APPLICATION TO THE STUDY OF ZnO POWDERS. Takashi Sekiguchi, IMR, Tohoku Univ, Sendai, JAPAN.

We have developed a cathodoluminescence (CL) system with high spatial resolution using a thermal-field emission gun operating in low electron beam energies. Since the diameter of the electron-hole pair generation sphere is proportional to the 1/4 power of the electron beam energy, operation with the low-energy electron beam reduces the probe size of CL. High spatial resolution smaller than 100 nm is achieved when it is operated with an electron beam energy less than 3 kV. The optical system of CL was improved to detect weak luminescence from specimens. Parallel detection of CL spectra using CCD was also adopted. Luminescence property of ZnO powders in various shapes and size was studied with this system. In typical ZnO powders, both the ultraviolet emission (band edge, 3.4 eV) and the visible emission (deep level related, 2.2 eV) were observed, although
their intensities varied from powder to powder. The variation of CL spectra along one particle of ZnO micro-tetrapod was recorded. The ratio of the intensity emission to the visible region in the center of tetrapod is different from those of the points along the arm. This suggests that the central position is much deficient compared with the arm regions. We also observed a decrease of CL intensity during observation. Such degradation may be explained in terms of the damage of high density of generated minority carriers or surface contamination during operation.

2:15 PM P3.3
OPTICAL PROPERTIES AND DEFECT STRUCTURE OF MOVPE InGaN FILMS A. Cremades, Dpto. Fisica de Materiales, Facultad de Ciencias Fisicas, Universidad Complutense de Madrid, SPAIN; M. Aballe, Institut für Werkstoffwissenschaften, Mährisch-Akademie, Universität Erlangen-Nürnberg, GERMANY; J.-M. Ullut, J. Piqueras, Dpto. Fisica de Materiales, Facultad de Ciencias Fisicas, Universidad Complutense de Madrid, SPAIN; H.P. Struck, Institut für Werkstoffwissenschaften, Universität Erlangen-Nürnberg, GERMANY; D. Hauser and R.F. Davis, Department of Materials Science and Engineering, North Carolina State University, Raleigh, NC.

The correlation of the structure and optical properties of these samples is of interest due to the use of two-dimensional InGaN films as active layers of optoelectronic devices (e.g., blue-lasers). A series of 100 nm thick InGaN films with In content up to 14 per cent has been grown by MOVPE on Si substrate. An AlN and GaN layer of total thickness 1.5 µm was used as a buffer layer. The In concentration was measured by photoluminescence spectroscopy, and the layer thickness by ellipsometric measurements. The samples were characterized by photoluminescence spectra, X-ray diffraction, and TEM. The structural characteristics of the layers were studied by AFM and X-ray diffraction. The optical properties of the layers were studied by measuring the photoluminescence and cathodoluminescence. Results indicate a dependence of the optical properties on the In content in the samples, as well as on the residual stress in the layers induced by the In incorporation in the layer. Cathodoluminescence images show the spatial distribution of the emission sites. For pinholes with a diameter in the 10-15 nm range we observe enhanced band edge luminescence around the pinholes, but a reduced luminescence at the apex of the pinhole. Comparison with finite element calculations shows that the luminescence is directly correlated with the strain distribution in the layer, enhanced strain increases with reduced luminescence, while strain relaxation may enhance the luminescence. We discuss the influence of strain with respect to In incorporation, the appearance of piezoelectric fields and effects due to strain induced band bending.

2:30 PM P3.4
SCANNING CATHODOLUMINESCEENCE OF InGaN THIN FILMS N. Masser, J. Han, M. H. Crawford, and R. G. Copeland, Sandia National Laboratories, Albuquerque, NM.

Recent blue light-emitting diodes and laser diodes rely on the high brightness of InGaN layers. The luminescence efficiency of these layers is higher than that of GaN despite similar threading dislocation densities. We have used scanning cathodoluminescence (CCL) to examine the spatial distribution of the luminescence in 0.2 µm thick InGaN layers grown by MOCVD, where the In content is varied from 0.5 to 4 percent. The peak wavelength shifts monotonically from 363 nm for pure GaN up to 380 nm for the 4% InGaN layer. The peak intensity gradually increases over that of pure GaN by a factor of four at the highest In content examined to date. Scanning electron microscopy and atomic force microscopy indicate a high density of dislocated surface pits for the In containing layers. CCL images show that the luminescence intensity can vary by a factor of three over a 16 µm by 16 µm scanned region, where for the In containing films, the surface pit position correlates to a reduced CL intensity. Remarkably, for the highest In content films, the CL intensity in the vicinity of the pits is higher than the highest intensity regions of our planar, pure GaN films. The implications of these results for understanding the recombination mechanisms in InGaN relative to GaN will be discussed. Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company for the U.S. Dept. of Energy under contract DE-AC04-94AL85000.

2:45 PM P3.5
A STUDY OF THE ORIGIN OF BANDA-EMISSION IN HOMOEPIXTAL DIAMOND THIN FILMS D. Takeuchi, H. Watanabe, S. Yamazaki, H. Okada, K. Kajiyama, Electronic Materials Institute, JAPAN; H. Sawada, H. Ichihara, Dept. of Material Science, Univ of Tokyo, Tokyo, JAPAN.

Diamond films grown by chemical vapor deposition (CVD) usually show band A emission (5.27 eV) at visible area and no excited emission at room temperature by cathodoluminescence (CL). Recent progress in our study on homoeptital diamond films was obtained through the low CH4/H2 conditions by microwave-plasma chemical vapor deposition. These showed strongly excited band A emission (5.27 eV) at room temperature, while band A emission (2.95 eV) disappeared. On the other hand, when the CH4 concentration was increased, homoeptital diamond films included unperturbed crystalline areas (UC). Scanning CL images showed that the band A emission only appeared at UC sites, while other flat surface parts still showed exciited emission. High-resolution transmission electron microscopy (HRTEM) revealed that (111) 23 C3l boundaries were documented in UC sites, and grain boundary (GB) was observed as (112) 23 or (114) 29 boundaries existed. Besides, there were grain boundary dislocations between UC and epitaxial region in the film. Because (111) 23 is a coherent boundary which never causes dangling bonds, these results suggest that the band-A originate from grain boundaries such as (112) 23 or (114) 29 and for grain boundary dislocations in diamond film. In the literature, the origin of band A emission was pointed out to be attributed to dislocations, while not all of them showed the emission in the experiments. In our study, the emission area was localized only in UC sites, and combination of CL and HRTEM revealed the structure of emission center of the band A emission.

3:30 PM P3.6
SPECTRALYLY RESOLVED CATHODOLUMINESCENCE DIAPLOMATION OF DAP PIGMENTED INGaAsP BASED MULTI QUANTUM WELL FABRY-PEROT LASERS. Carlo Zonetti-Fregona, Claudio Ferrai, Laura Lanzarini and Giancarlo Salvioli, CNR-MASPEC Institute, Parma, ITALY; Marisa Melin, Daniele Bertone, Rossiny Pang, Giacometta Morello, Roberto Paoletti, CSELT Laboratory, Torino, ITALY.

Low temperature monochromatic cathodoluminescence (CL) spectral analyses are presented to study the width of reative regions (due to Fe diffusion) in multi-quantum-well (MQW) InP based laser devices. The active laser structure, a partially compensated MQW stack, was surrounded by a semi-insulating Fe-doped InP layer to realize high modulation bandwidth and low threshold devices. The MQW stack contains nine 15 nm compressive InGaAs strained wells (9 thick) and eight 0.8 tensile InGaAs strained barriers (9.6 nm thick) and was sandwiched between two quaternary confinement regions (100 nm thick). The MQW was grown on an InP:Zn buffer layer and was covered by an InP:Zn cladding layer. After the active stripe etching, a selective regrowth of thick InP:Fe and a thin InP:Sn layers was performed, followed by a conventional growth of InP:Sn and InP:Sn:Zn+ contact layers. Two sets of devices were produced, each with (i) with the active stripe etched by standard RIE (Reactive Ion Etching) (batch #34) and (ii) with the active stripe etched by the ISF (In Situ Etching) technique by using chlorine cutoms inside the MQW reactor (batch #48) (D. Bertone et al., J. Cryogenics 195, 624 (1998)). The width of the reative regions were estimated by comparing the 5 K CL emission width from the MQW and the actual width as obtained by XRD, TEM and SEM investigations. The widths region on each side of the MQW were found to be larger (880 nm wide, 50% of the well surface) in devices from batch #34 than in those (75 nm, 9% of the well surface) from batch #48, as expected on account of the different etching techniques used to define the ridge geometry. Monochromatic CL also confirmed the absence of the dopent confining InP:Sn stripes and the presence of substantial Sn diffusion (up to 3000 nanometers) into the substrate.

3:45 PM P3.7
OPTICAL PROPERTIES OF Si NANOWISKERS (NANOWIRES) ON A Si(111) SURFACE. S. Ozeki, Y. Ohno and S. Takeda, Dept. of Phys. Graduated School of Sci., Osaka Univ., Machikaneyama, Toyonaka, Osaka, JAPAN.

Many and various efforts have this far been made to study optical properties of nanostructures of semiconductors, such as nanowires and nanotubes. Nanostructure semiconductor have distinctive optical properties from bulk semiconductors due to quantum confinement effects. Especially, silicon nanowires have been investigated to show visible luminescence and photoluminescence has been reported in some cases. We have investigated optical properties of Si nanowiskers (nanowires) grown on a Si(111) surface via the vapor-solid-solid (VLS) growth mechanism. The diameter of the wires is about 100 nm. The effect of quantum confinement comes out. We have utilized cathodoluminescence (CL) spectroscopy in a transmission electron microscope.
4.00 PM P3.8 LUMINESCENCE FROM SELF-ORGANIZED QUANTUM WELL STRUCTURES IN CuPc-ORDERED GaPnY. Ohno and S. Takeda., Dept. of Phys., G55, Osaka Univ., Osaka, JAPAN.

Various kinds of plane defects are introduced in semiconducting materials during crystal growth and device processes. These defects are recently expected to show distinctive optical properties from the host materials. In this paper, we propose that GaPn/InP quantum well structures are self-organized in CuPc-ordered GaPnY and they show intense light emission. We found the self-organization of the structures for the first time by means of in-situ cathodoluminescence (CL) spectroscopy in a transmission electron microscope (TEM). The method is very useful for microscopic characterization of structural and electronic properties in materials. TEM data showed that the microstructure of the ordered GaPnY consisted of domains of ordered crystals bounded by anti-phase boundaries (APBs). By means of CL spectroscopy with the high-spatial resolution of 200 nm, we found new light emission (peaking at the photon energies of $E_p \approx 8\ eV$, $E_p \approx 18\ eV$, $E_p \approx 28\ eV$, and $E_p \approx 30\ eV$, in which $E_p$ represents the energy gap) from the APBs. From the results of polarized CL spectroscopy, we propose a new model that GaPn/InP quantum well structures are self-organized by the APBs and their electron-hole recombination in the wells results in the intense light emission of the satellite peaks.

4.15 PM P3.9 STUDY OF THE STRESS FIELD AROUND MISFIT DISLOCATIONS IN InGaN/GaN MULTILAYER QUANTUM WELLS BASED SOLAR CELLS BY CATHODOLUMINESCENCE INTENSITY PROFILING. M. Mugnai, C. Morini, E. Gori, L. Coccia, and A. Mazzu, Istituto Professore Giuseppe Mazzini, CNR-IMEM Institute, Lecce, ITALY. In this work, we report on the study of the stress field around the misfit dislocations of InGaN/GaN quantum wells used in the InGaN/GaN solar cell structure. The intensity profiles around the misfit dislocations were obtained by CL intensity mapping on cross-sectional TEM samples. The study was performed by means of a high-resolution electron microscope, equipped with an energy-dispersive X-ray spectrometer, to determine the presence of any possible precipitates or impurities inside the quantum wells. The results show that the stress field around the misfit dislocations is significantly reduced by the introduction of a thin GaN buffer layer between the InGaN/GaN quantum wells and the substrate.

Low temperature cathodoluminescence (CL) spectroscopy was used to study the strain field distribution around misfit dislocations (MDs) in MQW based InGaN/GaN solar cells (P. Grynszpektor et al., Proc. 14th EPSCE Conference, Barcelona, 1237 (1997)). The CL spectra presented a main peak at 917 nm [MQW] and a satellite one at 969 nm. Monochromatic CL micrographs at 969 nm showed luminescence emitted only from an area around the misfit dislocations, indicating non-radiative recombination being a weak dark contrast in the centre of the bright region. The localised emission was due to the impurity atmosphere surrounding the dislocation core. Monochromatic CL intensity profiles around the MDs were used to eliminate spurious effects due to the non uniform light collection efficiency along the scan line. (M. Mugnai, PhD Thesis, Imperial College of Science and Technology and Medicine, London, UK (1998)). This was achieved by normalising the profiles acquired at different wavelengths to a reference one. At 900 nm (maximum of the satellite peak) the profile was a gaussian centred at the dislocation core; everywhere else the CL emission was zero. Moving toward the MQW peak the background signal increased while the satellite peak decreased (921 nm) until a new maximum appeared at $\approx 1\ mu$m to the left of the original one (908.2 nm). Going beyond the MQW peak, at 916.2 nm, a roughly parallel profile was obtained with a maximum at about 1 $\mu$m to the right. This was explained by considering the calculated strain field distribution generated by the dislocation line. Since the MD Burgers vector has a component on the growth plane, the associated stress field has an out-of-plane component with respect to the misfit line. So, one side of the dislocation the emitting material band gap increases due to the deformation potential, while the opposite occur on the other side.

4.30 PM P3.10 HOMOGENEITY OF THERMALLY ANNEALED SLIGHTLY Fe-DOPED InP. M. Avella, J. Jimenez, E. de la Puente, Dept. Fisica de la Matem, Universidad de Valadolid, Valadolid, SPAIN; R. Fornari, MASPEC-CNRI Institute, Parma, ITALY.

Seminsulating (Si) InP is an important material for fabrication of integrated optoelectronic circuits and high frequency devices. Si-InP substrates are obtained by precipitation of iron during the LEC growth process. Iron is a deep acceptor and compensates the residual shallow donors of the undoped InP crystals. Relatively large amounts of iron ($>10^{19} \text{cm}^{-3}$) are necessary in order to obtain the seminsulating behavior with consequent drawbacks (inhomogeneous Fe outdiffusion to epilayers grown on these substrates). Therefore, there is a trend to reduce the iron content in the Si-InP crystals. The electronic properties of InP depend on the Fe concentration. In the present work we studied misfit InP samples with low iron content ($\approx 5 \times 10^{17} \text{cm}^{-3}$) and have annealed at 900°C for 60 hours in a phosphorus ambient.

These samples were studied by Hall effect, Scanning Photoluminescence (SPL) and Scanning Photoemission (SPE) measurements. The resistivity increased up to about $8 \times 10^{-5} \Omega \text{cm}$ after annealing while SPL maps showed a homogeneous distribution of the electrically active Fe concentration. The SPL measurements also showed an uniform distribution of the substitutional $\text{Fe}_{\text{In}}$. It is interesting to note that our mappings do not reveal the presence of the growth striations, typical of mis-grown LEC InP:Fe crystals. This implies that the Fe striations are dissolved during the thermal treatment and previously observed in heavily Fe-doped samples. The conclusion is that the thermal treatments produce two main effects: i) the conversion of lightly Fe-doped semiconducting InP to a seminsulating state, possibly connected with a significant loss of residual donor complexes, and ii) redistribution of the dopant, with beneficial effects in terms of wafer uniformity.

5:45 PM P3.11 STUDY OF THE RADIATIVE AND NON-RADIATIVE RECOMBINATION PROCESSES AT DISLOCATIONS IN SILICON BY PHOTOLUMINESCENCE AND LUMINOUS MEASUREMENTS. Silvia Pizzini, Silvano Benetti, Maurizio Acquaroli, Marco Costi, Milano-Bicocca Univ., INFN and Dept. of Materials Science, Milano, ITALY.

It is well known that the sharp, room temperature luminescence emission at 1.54 $\mu$m from dislocated silicon has set off a great interest for this material in view of its applications in the third window of optical telecommunications. For this reason the dislocation related luminescence in silicon, addressed recently a number of investigation aimed at understanding the mechanism of light emission and the nature of the centres responsible of it and, thereafter, at improving the luminescence yield. The problem is still unsolved as most of the experiments done gave contradictory answers to the main questions open, which concern the intrinsic or extrinsic nature of dislocation luminescence and the effect on its recombination, interaction or passivation processes, possibly assisted by metallic or non-metallic impurities. As an example, in some cases an almost continuous transition occurs from the Er luminescence to the dislocation luminescence as soon as the samples are heated at 1100°C in a coexisting atmosphere, but no clear indication about a possible role of the erbium on the dislocation luminescence was found, although from EXAFS measurements we could show that in dislocated samples the local configuration of Er is that of erbium in a erbium oxide phase. In order to go more insight on the problem, we started a systematic work on intentionally dislocated material, both p- and n-type, aimed at understanding the effect of metallic and non-metallic impurities on the dislocation luminescence. 60° dislocations were generated in the cleaved condition, taking the deformation temperature sufficiently low to avoid the interface degradation. The effect of oxygen, hydrogen and of dislocation interaction on radiative and non radiative recombination was investigated by using PL and lifetime and surface recombination rates measurements. A clear identification of the origin of the different dislocation PL bands has been obtained.

SESSION P4: LUMINESCENCE II
Chair: Sulekha Gokhade
Tuesday, November 30, 1999
Salon C/D (M)

8:30 AM P4.1 PHOTOLUMINESCENCE OF InGaN/GaN MULTIPLE QUANTUM WELLS GROWN ON A Si (001) SUBSTRATE. Xing Zheng, Suo-Jin Chu, Wei Liu, and Peng Li, National Univ. of Singapore, Dept. of Electrical Engineering, Singapore, REPUBLIC OF SINGAPORE.

InGaN/GaN multiple quantum wells (MQWs) have been grown on silicon (001) substrate using the specially designed composite intermediate layers with single or double GaN/AlGaN multilayered buffers by low-pressure metal-organic chemical vapour deposition. The InGaN/GaN MQW samples were characterized at room temperature by photoluminescence (PL) spectroscopy. It was found that the InGaN/GaN MQWs grown on the composite intermediate layer with double multilayered buffers show much more intense (2.5 times larger in PL Intensity) and sharper (40% less in PL peak lines-width) green (2.53 eV) and blue-light (2.76 eV) excitonic transitions, and highly suppressed GaN band-edge-related transitions, as compared...
with the identical InGaN/GaN MQWs grown over conventional GaN and AlN single buffer, or the composite intermediate layers with only one intermediate layer under the same configuration and growth conditions. This fact indicates that by using the proposed composite intermediate layers with double multi-termed buffers, the crystalline quality of the InGaN/GaN multiple quantum wells grown on a silicon substrate can be significantly improved.

8:45 AM P4.2
OPTICAL EMISSION RELATED TO HOLES CONFINED IN P-TYPE 4-DOPED LAYERS IN GaAs. Q. X. Zhao and M. Willander, Physical Electronics and Photonics, Department of Physics, Chalmers University of Technology and University of Göteborg, Göteborg, SWEDEN; P. O. Holtz, Department Physics, Linköping University, Linköping, Sweden; W. Lu, H. F. Dou, and S. C. Shen, National Laboratory for Infrared Physics, Shanghai Institute of Technical Physics, Chinese Academy of Sciences, Shanghai, CHINA; G. Li and C. Jagdish, Department of Electronic Materials Engineering Research, School of Materials Sciences and Engineering, The Australian National University, Canberra, AUSTRALIA.

Thin Zn-doped GaAs layers embedded in bulk GaAs, grown by metalorganic vapor phase epitaxy (MOVPE), are studied by means of optical spectroscopy. The concentration of Zn acceptors varies between $2 \times 10^{16}$ to 2$ \times 10^{17}$ cm$^{-2}$ in 4 mm doping regions. With increasing doping concentration, a new optical radiative transition appears in photoluminescence (PL) spectra below the energy position of the transition between the free electrons and holes bound to acceptors in bulk GaAs. The new recombinations show a strong dependence on excitation intensity and temperature. Our results indicate that this new emission is related to the transition between spatially separated electrons and holes. The holes are located in p-type Zn-doped region, while the electrons are located in the undoped GaAs region. The magnetic field dependence of this new emission in PL spectra indicates that the effective mass of the holes involved in the optical transition is about 0.2 m$^e$. To the best of our knowledge, this is the first time that such recombination in p-type delta-doped GaAs is confirmed from optical spectroscopy.

9:00 AM *P4.3
CHARACTERIZATION OF Si AND SOI STRUCTURES USING PHOTOLOMINESCENCE. V. Hugg, D. Ridgway, Semimet Inc., Ltd., Hemel Hempstead, UNITED KINGDOM.

A new Photoluminescence (PL) method has been developed to detect defects in the near surface region of Si wafers and Si-on-insulator (SOI) structures. Wafer maps (up to 300 mm) can be readily acquired and areas of interest can be scanned at high resolution (1 nm). The excitation laser beam is modulated to confine the generated carriers; defects are detected due to the reduction of the localised recombination lifetime. Si p-type (100 Ohm cm) wafers were intentionally contaminated with various levels of Ni and Fe ($1 \times 10^{17}$ to $1 \times 10^{18}$ atoms/cm$^2$) and annealed. The PL intensity was observed to decrease due to the metal related non-radiative defects. Whereas in contrast, for Cu ($1 \times 10^{17}$ to $1 \times 10^{18}$ atoms/cm$^2$) the PL intensity actually increased and reached a maximum value at $5 \times 10^{17}$ atoms/cm$^2$. It is suggested that during contamination the Cu related defects have complexed with existing defects (i.e. silicon nitride recombinant properties) and increased the PL. After increasing the Cu level further the PL intensity decreased. Another batch of wafers was contaminated with Ni and Cu ($1 \times 10^{17}$ to $1 \times 10^{18}$ atoms/cm$^2$) prior to CMOS thermal process simulation. On inspection of the device structures metal related defects could be observed (100-1000 defects/cm$^2$). These defects could be correlated with the oxide breakdown quality. PL maps of SOI bonded wafers revealed that the non-bonded areas, voids or gas bubbles could be detected. This was confirmed using defect etching and polishing, voids as small as 20 μm in diameter could be detected. SOI wafers fabricated using the separation by implanted oxygen (SIMOX) technique were also analyzed, variations in the recombination properties of the Si layer could be observed. Further inspection revealed that defects and non-uniformities of the buried oxide can be detected covering several microns. Defective areas were laser marked in situ, and then removed for defect confirmation using TEM analysis.

9:30 AM P4.4
FABRICATION OF Sr:Cu THIN FILMS BY PULSED LASER DEPOSITION. D.C. Morton, D. Rawchandran, S. Bolinger, K. Kirdnar, M.H. Edvins and J.Y. Choe, Army Research Laboratory, Adelphi, MD.

Sr:Cu thin-films were fabricated on to a Si (100) orientation using laser ablation technique. A typical deposition was done with a laser power of 6 mJ Argon & H$_2$ gas (5:1 ratio). Laser power was typically 550 mJ/cm$^2$ at 50 Hz, with an exposure time of 5 s. The substrate temperature was set to 550°C. The films appeared to be transparent with mirror like surface. The thickness of the films are found to be 4-1-5 μm. Grazing angle X-ray diffraction pattern shows polycrystalline structure. SEM shows crystallized particles with a grain size of 120 nm. EDAX analyses on these crystallites show Sr and Si throughout the films, without any secondary metal ions. However, the resulting films did not show any PL emission. The films were further crystallized at 1150°C at different temperatures up to 1150°C in air atmosphere in order to observe the effect of annealing at different temperatures. Photoluminescence measurements on these annealed films showed a bright green emission broad band at 450 nm with excitation peak at 370 nm. AFM images of these films showed well-defined columnar structure and a rough surface. The effect of post annealing on morphology, photo luminescence and cathodoluminescence will be presented.

9:45 AM P4.5
PHOTOLUMINESCENCE AND PHOTOLUMINESCENCE EXCITATION MECHANISMS FOR PHOTOINDUCED PLASMA AND SILICON OXYNITRIDE. Xianghong Liu, Jesus Noel Calabria, Guo-Quan Lu, Virginia Polytechnic Inst and State Univ Dept of Materials Science Engineering, Blacksburg, VA; Heyu Liang, Wengzhou Shi, Xueqin Lin, Shenxi University Research Institute, Shenxi, CHINA; G.Q. Qin, Peking University, Dept of Physics, Beijing, CHINA.

Progress in integrated optoelectronics technology requires the development of efficient and strongly light-emitting materials, especially silicon-based materials. Blue light-emitting semiconductors are of great interest as they promise applications in color displays and optoelectronic devices. The photoluminescence (PL) mechanisms for porous silicon (PS) and other light-emitting materials are still the subject of controversy. Through a comparative study of the light emission and light excitation property of PS and Si oxide, PL and photoluminescence excitation emission (PLE) mechanisms for blue light-emitting PS are analyzed in this paper. Silicon oxynitride films were prepared by plasma enhanced chemical vapor deposition (PECVD) method and the light emission and PL mechanisms were determined. An analysis of the PL and PLE spectra of PS and Si oxide indicated that for blue-light emission from PS, there are two types of photoluminescence processes: (1) photo-exciton occurs in nanometer Si particles (NSPs) and in the Si oxide layers covering NSPs, and (2) radiative recombination at the defects place in luminescence centers (LCs) inside the Si oxide layers. The experimental results strongly supported the quantum confinement/luminescence center model. Strong blue light (445 nm) and ultraviolet light (365 nm) emission from silicon oxynitride films at room temperature were observed. The 445nm and 365nm band are ascribed to O and N related defects, respectively. As such, the quantum confinement/luminescence center model appears to be a satisfactory model in explaining the experimental results.

SESSION 5: NEAR-FIELD TECHNIQUES II
Chair: Bennett B. Goldberg
Tuesday, November 30, 1999
Salon C/D (M)

10:30 AM *P5.1
NEAR-FIELD PHOTOCURRENT STUDIES OF DISLOCATIONS ELECTRICAL ACTIVITIES IN RELAXED GeSi FILMS. Julia W. P. Hsu, Matthew H. Gray, Qin Xi, Department of Physics, University of Virginia, Charlottesville, VA.

Using a near-field scanning optical microscope (NSOM), we perform photocurrent imaging to investigate dislocation electrical activity in compositionally-graded, strain-relaxed GeSi films grown on (100) Si substrates. The resolution of near-field photocurrent (NPC) imaging is ~ 100 nm, a ten fold improvement from far-field optical techniques. A topographic image is collected simultaneously with the spatially resolved photocurrent image. It is possible to resolve photocurrent from active local electrical activity with surface features. Threading dislocations are identified by signal reduction in the NPC images because they are carrier recombination centers. Two-dimensional numerical calculations of steady-state carrier distributions near defects are used to understand and quantify experimentally observed resolution and contrast. Another feature in the NPC images of these samples is associated with the non-periodic surface undulations, commonly known as crosshatch. Origin of crosshatch electrical activity is currently not understood. Using linearly polarized NSOM light for excitation, we find that the crosshatch contrast depends on polarization direction, indicating that it might arise from inhomogeneous electronic properties in the samples. We propose that strain fields associated with dislocations are responsible for the crosshatch contrast, and carry out calculations to estimate the magnitude of strain induced absorption changes. In addition, unexpected signal enhancement in areas surrounding the threading dislocations also show polarization dependence. To further
probe the nature of dislocation electrical activity, NPC experiments are performed on the same set of defects at various temperatures using a custom built variable temperature microscope (STM). The temperature dependence reveals that these dislocations probably contain low levels of metal contamination.

11:00 AM P5.2
OPTICAL CHARACTERIZATION OF INDIVIDUAL NANOSTRUCTURES BY STM LIGHT EMISSION. S. Ushioda, Research Institute of Electrical Communication, Tohoku University, Sendai, JAPAN, and CREST-Japan Science and Technology Corporation.

Visible light is emitted when electrons (holes) are injected into a sample from the tip of the scanning tunneling microscope (STM). The emission spectrum reflects the materials properties of the sample immediately below the tip. Thus by analyzing the spectra of the emitted light, one can not only determine the surface geometry by usual STM methods, but also, by simultaneous measurement of the emission spectrum, learn the electronic and optical properties of specific individual nanostructures. In this technique one first observes the STM image of the sample surface, and locates individual nanostructures of interest. Then the STM tip is fixed over the relevant structure, and the light emitted from the particular structure is collected and spectrally analyzed. One can thus obtain the emission spectra of extremely small surface objects with nearly atomic spatial resolution. Thus this novel spectroscopic technique is perfectly suited for characterization of surface nanostructures. Furthermore, by combining this technique with pulsed-laser induced light emission, one can observe time-resolved light emission in addition to the spatial resolution afforded by the STM. We will present various data obtained by STM light emission spectroscopy (STM-LES), including the results on individual quantum wells of AlGaAs/GaAs, metallic and semiconductor quantum dots, and the single crystal Au(110) surface. The usefulness, limitations, and future expectations of this novel technique will also be discussed.

11:30 AM P5.3
OPTICAL INTEGRATED WAVEGUIDES CHARACTERIZED BY SCANNING NEAR FIELD OPTICAL MICROSCOPE. Xavier Barrios, Nuria Barandiaran, Francisco Perez-Marino, Gabriel Alcolea Ximenez, David Jimenez, Universitat Autonoma de Barcelona, Barcelona, SPAIN.

This work deals with two main objectives: (i) the development of a scanning near-field optical microscope (SNOM) for the characterization of optical integrated devices compatible with a normal optical characterization set-up; (ii) the modification of standard rib waveguides in order to obtain smaller structures for design new optical devices. In the developed microscope, the experimental set-up allows a tapered uncoated optical fiber to scan with constant height the optical devices by means of a shear force control using a tuning fork, and to obtain the evanescent field coming out from the device. In this way, images showing simultaneously the topography with lateral resolution better than 1 nm and vertical resolution of 1 nm, and the optical field distribution have been obtained. Images allow to recognize the propagation of the light in the device for up to 1 mm. The identification of the guided mode propagation has been done by means of comparing the images with computer simulations. The measure of experimental decay lengths of the evanescent field obtained by the microscope, allows to determine the effective refractive index of the structure. Additionally to the designed instrument we have performed several modifications on the rib waveguides with atomic force microscope combined with standard microelectronics processes. In this way we have built small optical couplers, tapered waveguides and new structures to obtain monomode behavior from a multimode waveguide. The images showing the topography and light propagation obtained with the designed SNOM allows studying behavior of the light in such small devices.

11:45 AM P5.4
STM-LIGHT EMISION FROM METAL DEPOSITED SEMICONDUCTOR SURFACES. Naoki Yamamoto, Shigeru Kugami, Hiroyuki Minoda, Tokyo Inst Technology, Dept of Physics, Tokyo, JAPAN.

Light detection system for a UHV-STM has been developed to study semiconductor surfaces and metal deposited surfaces. Light emitted from a narrow region between a tip and a surface is collected by an ellipsoidal mirror in an STM chamber, passing through a monochromator, and detected by a photomultiplier tube (PMT) and a CCD detector. An emission spectrum is measured by a CCD detector, and a photon signal is obtained from a PMT signal. We applied this system to investigate light emission from a vacuum deposited silver layer on a Si(111) surface, and succeeded in detecting the light. When a silver layer is thick, multiple peaks appeared in the light emission spectra. Those peaks correspond to the multiple modes of the local phonon mode excited between the tip and surface. A photon map taken at 80 K showed a uniform contrast for a flat surface and a dark line contrast running along a single atom height step. Recently we could observe a photon map of a thin silver island on a Si(111) reconstructed surface, and have examined the dependence of the emission spectrum on island size and thickness. Change in optical property of a semiconductor surface by metal deposition has been examined.

SESSION P6: RAMAN SPECTROSCOPY
Chair: Martin Stutzmann
Tuesday Afternoon, November 30, 1999
Salon C/D [M]

1:30 PM P6.1

Ion implantation introduces disorder into semiconductors and the resulting Raman spectrum is very complicated due to the high density of states. Other features are often observed and they have been tied to the implanted ion or the disorder. Recent measurements of arsenic-implanted silicon were made in the backscattering mode with a confocal interferometric micro-Raman spectrometer. The arsenic was implanted at 1.5 keV through a 0.66 mm-thick thermal oxide into (100) silicon and the dose varied from 10^13 to 5 x 10^14/cm^2. A peak is observed between 505 and 510 cm^{-1} with 514.5 nm excitation. This peak is easily seen at a dose of 2 x 10^13/cm^2, grows in intensity with increased dose, and then decreases with additional arsenic. The peak's occurrence is more complex when the excitation wavelength is 488 nm, which hints at multiple causes for the peak. S-As vibrations are reported to occur at Raman shift 360 cm^{-1} or less. Attempts to understand the source of the peak start with the often used phonon confinement model. However, this model falters as the approximate arsenic atom spacing leads to predicted shifts of the silicon As bond that are much less than the data. In addition, the P/0 response of the peak differs from that of the 520 cm^{-1} band. Alternative explanations are explored. These include a disorder-induced first-order Raman scattering, resonant modes, and relaxed, partially-ordered regions of silicon.

1:45 PM P6.2

We have measured micro-photoluminescence (PL) and micro-Raman spectra on the cross section of porous silicon multilayers to sample different layer depths. We find noticeable differences in the spectra of layers with different porosity, as expected from the quantum confinement of electrons and phonons in porous silicon nanocrystals with different average sizes. The PL emission band gets stronger, blue shifts, and narrows at the high porosity layers. The average size can be estimated from the shift. The Raman phonon band at 520 cm^{-1} weakens and broadens symmetrically towards the low energy side. The line shape can be related quantitatively with the average size by the phonon confinement model. To get a good agreement with the model we add a band at around 880 cm^{-1}, which has been attributed to amorphous silicon. We also have to leave as free parameters the bulk silicon phonon frequency and its linewidth, which depend on temperature and stress. We reduced laser power to eliminate heating effects. Then we observe the change of frequency with depth to monitor thickness. At the interface with the substrate we find a compressive stress in excess of 10 kbar, which agrees with the reported lattice mismatch. Finally, average sizes are larger than those estimated from PL.

2:00 PM P6.3
MICRO-RAMAN STUDY OF CHARGE CARRIER DISTRIBUTION AND CATHODOLUMINESCECNE MICROANALYSIS OF FOROUS GaP MEMBRANES. J.M. Tjigymen, I.M. Tjigymen, Technische Universiteit van Mouldova, Clujnan, Moldova, M.A. Stevens Kuckell, Microstructural Analysis Unit, Univ of Technology, Sydney, AUSTRALIA; A. Sirun, G. Imers, J. Moreeke, Technical Univ, Freeberg, GERMANY; H.L. Hartung, Technical Univ, Darmstadt, GERMANY.

Free-standing porous GaP membranes were fabricated byodic etching of (111)-oriented crystalline substrates in a sulphuric acid solution. The formation of network-shaped porous structures with
average dimension of pores and GaP skeleton varying from 50 to 100 nm was evidenced by images obtained with a scanning electron microscope. Microanalysis of the interaction between the longitudinal optical phonons and phonons in porous membranes performed using a Jobin-Yvon triple spectrometer allowed us to obtain specific information about the electro-optical properties of nanocrystalline materials. In particular, from carrier extraction area surrounding the pores, the existence of conductive regions was demonstrated. It was found that the relative volume of conductive areas in porous membranes can be effectively controlled by changing the degree of porosity and the thickness of the depleted surface layer.

Cathodo-luminescence (CL) microanalysis with spectral resolution of 5 nm was carried out at accelerating voltages 15-30 kV in the temperature range from 80 to 300 K following two on-chip mapping. CL peaks at 1.5 and 1.6 eV related to the recombination of non-equilibrium carriers via donor-acceptor pairs, a broad emission band in the visible region was observed in the porous membranes. Data concerning spatial distribution of CL are presented and the impact of the large surface upon charge carrier behavior and emission characteristics of porous GaP is discussed.

2:15 P M P 6.4
RAMAN SCATTERING STUDY ON InP/InGaAs/InP HETRETS. K. Raharishkumar, T.H.K. Patrick, P.H. Zheng, H.Q. Zheng, and S.F. Yoon, Nanyang Technical University, School of Electrical and Electronic Engineering, Singapore, SINGAPORE.

Raman scattering was used to systematically study the effect of varying In mole fraction, x from 0.53 to 0.81 in the channel layer, and doping concentration from 6·10^{17} cm^{-3} to 2·10^{19} cm^{-3} in the donor layer of In_{x}Ga_{1-x}As/InP heterostructures. The effect of varying the channel thickness from 140 Å to 260 Å was also studied using Raman scattering. A two-mode Raman response was clearly observed for all the In_{x}Ga_{1-x}As/InP samples, with two LO modes (InAs-like LO and GaAs-like LO) located at 226 cm^{-1} and 268 cm^{-1}, respectively. At a frequency of 347 cm^{-1} a small peak was observed due to InP LO mode. As the In mole fraction was increased from 0.53 to 0.81, the InAs-like LO mode peak intensity increased while that of GaAs-like LO mode decreased. The peak intensity ratio of InAs-like LO mode and GaAs-like LO mode increased from 0.78 to 1.10. By increasing the doping concentration in the donor layer, there was an increase in the carrier concentration in the InGaAs channel making the donor LO mode dominant. The coupled mode between the InGaAs longitudinal optical phonons and electrons in the InGaAs channel shifted continuously to a lower wave number with the increase in ND in the InP donor layer. The experimental data of the carrier concentration in the barrier layer and the associated Raman peak followed the theoretical prediction. As the InGaAs longitudinal optical phonons were increased from 141 Å to 260 Å, the InAs-like LO mode peak shifted to a lower wave number from 215.4 cm^{-1} to 228.6 cm^{-1} while that of GaAs-like LO mode remained at a constant wave number of 398 cm^{-1}.

2:30 P M P 6.5
RAMAN SPECTROSCOPY OF ULTRAHEAVILY DOPED POLYCRYSTALLINE SILICON FILMS. N.H. Nickel and P. Lengfeld, Hahn-Meitner-Institut Berlin, Berlin, GERMANY.

Ultraheavily phosphorus and boron doped polycrystalline silicon (poly-Si) films are obtained through the following procedure. First, amorphous silicon films (a-Si:H) with a thickness of 1200 Å were prepared by rf glow-discharge decomposition. Phosphorus and boron doping was achieved by premixing silane (SiH_{4}) with various volume parts (up to 1%) of phosphine (PH_{3}) and diborane (BH_{3}), respectively. Subsequently, the a-Si:H films were crystallized with an excimer laser at various laser energy densities. The average grain size was determined from atomic force microscopy (AFM) micrographs and increased from ≤1000 Å to ≥2 µm as the laser energy density increased from 400 to 520 mJ/cm^{2}.
The poly-Si films were characterized using Raman spectroscopy in the backscattering geometry. All samples were completely crystallized; e.g., Raman measurements did not indicate the presence of a phonon band at 480 cm^{-1}. In contrast to single crystal silicon the LO phonon line of undoped poly-Si is shifted to smaller wave numbers and appears at 516 cm^{-1}. With increasing B or P concentration the LO phonon line shifts to 513 and 511 cm^{-1}, respectively. While in B doped poly-Si this shift is monotone in P doped material a decrease of the LO wave number is observed only for samples doped with more than 0.1% phosphine in the gas phase. For a given sample the position of the LO phonon is independent of the laser energy density. A shift or damping of the 2TA and 2TO modes was not observed. However, for high gas phase concentrations >0.1% Fano resonances are observed. These changes are due to free carriers and interband transitions between optical phonons and direct inter-valence-band transitions of electrons or holes. As the Fermi energy moves from the conduction to the valence band the Fano asymmetry parameter q changes its sign.

SESSION P7: OPTICAL PROPERTIES
Chair: Under M Kulkarni
Tuesday Afternoon, November 30, 1999
Salon C/D (M)

3:15 P M P 7.1
OPTICAL AND MICROSTRUCTURAL CHARACTERIZATION OF NANOCRYSTALLINE SILICON SUPERLATTICES. I. Tasybekov, Department of Electrical and Computer Engineering, University of Rochester, Rochester, NY.

Nanocrystalline silicon superlattice (n-Si SL) is a structure consisting of Si nanocrystal layers separated by nanometer-thick SiO_{2}. This work is focused on nanoscale Si structure metrology. Several characterization techniques such as transmission electron microscopy (TEM) and atomic force microscopy (AFM). Angular-dependent microanalysis, X-ray diffraction and X-ray small-angle reflection have proved that the n-Si SL exhibits very narrow nanocrystal size distribution (less than 5% in average) and very abrupt and linear SiO_{2}/Si interface with a root mean square of c. A long-range order in the n-Si SL is obtained along the direction of growth by periodically alternating layers of Si nanocrystals and SiO_{2}; the observation of four acoustic phonon modes in InP supercells shown the quality of the SiO_{2}/Si interfaces and the layer periodicity are almost comparable with conventional superlattices grown by very precise (and expensive) techniques such as MBE or MOVCD.

Phonon-assisted tunneling is observed in a bipolar n-Si based structure, which confirms that the n-Si/SiO_{2} junction is not only abrupt but also nearly defect-free. Using tunnel conductance spectroscopy, we observed a rich structure attributed to discrete energy levels in Si nanocrystals. The results hold promise for n-Si quantum device applications.

3:45 P M P 7.2
MICROSTRUCTURAL CHARACTERIZATION OF ANTIMONIDE BASED III-V COMPOUNDS AND THEIR EFFECT ON OPTICAL ELECTROPROPERTIES OF SUBSTRATE MATERIALS AND DEVICES. Partsa S. Dutta, Ronald J. Gutman, Rensselaer Polytechnic Institute, Electronic Computer and Systems Engineering Department, Center for Integrated Electronics and Engineering, Troy, NY; Greg W. Charriere, Lockheed Martin Inc., Schenectady, NY; C.A. Wieg, MIT-Lincoln Laboratory, Lexington, MA.

Antimode based III-V compounds (GaSb and related ternaries and quantum wells) are becoming increasingly popular for long wavelength lasers, photodetectors, and thermoelectric applications. In-depth understanding of the materials growth, processing, and intrinsic properties has become extremely essential, to fully exploit these systems for high performance devices. Key features of antimonide based materials and suitable characterization tools for evaluating the properties of substrates, epitaxial grown films and final device structures are highlighted. Topics include: Low Temperature Photoluminescence, Spatially Resolved Cathodo-luminescence, Scanning Tunneling Spectroscopy, and Photo-reflection Spectroscopy. The optical properties obtained from these techniques are correlated with chemical and structural characteristics of materials studied through X-ray and Transmission Electron Microscopy techniques. Specific examples include the role of structural and defect-migration metal dopants on native defects, phase separation and alloy inhomogeneity in ternary, and quaternary compounds; the effect of microstructure and defects on the carrier life time and recombination mechanisms; and the influence of point and extended defects on device characteristics, like leakage currents and quantum efficiency. A perspective on the use of optical microstructural characterization in improving materials growth technology, selecting suitable processing windows, and selecting device fabrication strategies are presented.

4:15 P M P 7.3
OPTICAL PROPERTIES OF PSEUDOMORPHIC Sn_{x}Ge_{1-x} ALLOYS. Regina Ragan and Harry A. Atwater, Thomas J. Watson Laboratory of Applied Physics, California Institute of Technology Pasadena CA

The Sn_{x}Ge_{1-x} alloy system exhibits a tunable energy bandgap which undergoes an indirect-to-direct energy gap transition with a corresponding high strength threshold. The transition energy density at 11 eV is determined by thickness-dependent indirect transition measurements. For strain-relaxed films, the energy gap bandgap has been found to decrease from 0.8 to 0.25 eV as the Sn composition increases from 0 ≤ x ≤ 0.15 making the Sn_{x}Ge_{1-x} alloy suitable for II-VI electronic applications in the 3-4 µm range. Recently we have grown homogenous pseudomorphic, strain-free Sn_{x}Ge_{1-x} alloys by molecular beam epitaxy, with structural characterization by X-ray reflectometry measurements coupled with Rutherford backscattering spectroscopy. Infrared transmission and reflectivity measurements have been performed on pseudomorphic Sn_{x}Ge_{1-x} alloy films.
coherent to a Ge(001) substrate indicates a similar indirect-to-direct gap transition with increasing Sn composition. Deformation potential theory analysis of the indirect-to-direct transition is also consistent with the results of past studies on InSb and other II-VI semiconductors.

4:30 P.M. P7.4

Traditionally, solid-state lasers have required high-purity, highly-ordered, epitaxial materials. This allowed the production of an optical cavity in which light was amplified with very little loss due to scattering. The problem is that in order to grow such materials, expensive high-vacuum systems are needed, and the choice of materials is very limited. We recently reported, however, that it is possible to achieve laser action with coherent feedback in highly-disordered, commercial ZnO powder [1]. We believe the laser action results from localization of photons within the medium. Essentially, because the powder consists of microcrystals less than 100 nm in size, the scattering mean free path is on the order of the wavelength, and the recurrent light scattering forms closed loop paths for light which behave as ring cavities for lasers; the laser cavities are “self-formed” in the highly-disordered medium. In our current work, we attempt to provide a more detailed characterization of the lasing behavior in ZnO powder which we have synthesized ourselves. The powder consists of spherical particles ranging from 0.3 to 3.0 µm in diameter, depending on the processing conditions. Each particle is comprised of many nanocrystallites less than 50 nm in size, but the size of these crystallites can be increased by post-synthetic annealing. Powders can easily be dispersed on substrates in any form ranging from a film several microns thick, to a sparse dispersion of particles on a surface. We examine the relationships between the structure of the powder, its lasing properties, measured with various photoluminescence techniques. [1] H. Cao, et al., Phys. Rev. Lett. 82, p. 2278 (1999).

4:45 P.M. P7.5

Optically pumped lasing has been realized in ZnO polycrystalline thin films as well as in powders. In order to understand the lasing mechanism, ZnO thin films were grown by MOCVD on different substrates, including c-plane sapphire and ITO glasses. By controlling the growth temperature and film growth rate, different grain sizes and crystallinity were obtained. SEM and AFM revealed that the grain sizes of ZnO thin films varied between ~30nm and ~300nm. The lowest optically pumped lasing threshold was obtained for films with grain sizes between 500-1000nm. According to x-ray diffraction results, ZnO thin films grown on c-plane sapphire had highly preferred c-axis orientation. The out-of-plane alignment was characterized by the rocking curve full width at half maximum (FWHM) of the ZnO [0002] reflection. If the linewidth was greater than one degree, no lasing was observed up to very high pumping energy. However, the lasing threshold didn’t increase monotonically with decreasing FWHM. The optimal FWHM value was approximately 0.5 degrees. These results indicate that the out-of-plane orientation of grains strongly affects the lasing threshold.

SESSION P8: POSTER SESSION: OPTICAL MICROSTRUCTURAL CHARACTERIZATION OF SEMICONDUCTORS
Chair: Anna Cavallini
Tuesday Evening, November 30, 1999
8:00 P.M. - 10:00 P.M.
Exhibition Hall D (H)

P8.1
OPTICAL ABSORPTION AND LUMINESCENCE STUDY OF THE EFFECT OF THERMAL TREATMENTS ON THE POROUS SILICON SURFACE. R. Plagnol, G. Cricchio, Institute of Microtechnology, Bucharest, ROMANIA, M. Bercu, Faculty of Physics, University of Bucharest, ROMANIA; J. Rama, J. Piqueras, University of Salamanca, Facultad de Física, Universidad Complutense, Madrid, SPAIN.

Infrared optical absorption and cathodoluminescence (CL) in the scanning electron microscope have been used to investigate the effect of oxidizing and inert thermal treatments on the surface structure of porous silicon. The samples annealed at 450°C show CL bands at 420-480 nm and broad bands at 540 nm and 640 nm. Further oxidation at 1000°C causes the reduction of the latter bands and a relative increase of the emission in the blue range. Samples subjected directly to the high temperature annealing show only the 420-480 nm emission. Infrared spectra of the treated samples show that the nature of the oxygen bonds is influenced by the first annealing also in the case of the two steps oxidizing treatment. A signature of the direct oxidation at the high temperature is given by an absorption band at 883±2 cm⁻¹. The results are discussed in the frame of existing models of emission of porous silicon related to the presence of surface states.

P8.2
A NOVEL STAIN ETCH FOR THE PRODUCTION OF POROUS SILICON PHOTOLUMINESCENT DEVICES. I. Unal, A.N. Parfunkov and I. Bogulaj, Solid State Research Center, Faculty of Applied Sciences, Dr. Monros University, The Grodno, UNITED KINGDOM; V.M. Beklemishev, V.M. Gontar, I.I. Mikhonkin, State Research Institute for Problems in Physics after F.V. Lukin, Zelenograd, Moscow, RUSSIA; S.A. Garnik, State Institute of Electronic Engineering, Technical University, Moscow, RUSSIA.

A novel stain (chemical) etching solution is described which results in the production of uniform and stable nano-dimensional porous silicon (PS). The etching solution allows formation of PS regions of controllable geometry and area by standard photoresist methods, and the process can be applied at any suitable technological stage of microelectronic manufacture. The porous Si produced has a sharply hydrogen-passivated surface, which makes the PS layer more conductive, and very suitable for PS-based device applications. Sandwich structure devices in which semi-transparent continuous gold electrodes are deposited on the nanostructured PS surface are observed to show high efficiency in photocurrent under visible light exposure. Additionally, platinum and palladium metallisation of the nanoporous silicon have been performed using a new technique of electronless metal deposition. These sandwich devices also show photovoltaic effects. The metal-coated PS has great potential for application in solar cells and photodetectors, since efficient, stable and widely-responsive devices can be produced. The process is also more cost-effective than current technologies since there is no necessity for antireflection coatings, and there is a reduction of device fabrication steps. Keywords: Stain etching, porous silicon and photovoltaics.

P8.3
CHARACTERISATION OF PLASMA-ASSISTED CVD-GROWN POLYCRYSTALLINE Si ON GLASS SUBSTRATES. Stephen Webb, Luci Wang, Scott Summers and Hari Reeshal, School of Electrical, Electronic and Information Engineering, South Bank University, London, UNITED KINGDOM

Thin films of polycrystalline silicon grown on glass substrates have potential applications as low cost solar cells. Ideally, the films should be crystalline, with as little amorphous material as possible, and this requires optimisation of the growth conditions for plasma-assisted CVD (chemical vapour deposition). In this study, the effects of varying the growth conditions are investigated using Raman and x-ray spectroscopy, and scanning electron microscopy. Both undoped and n-type films are grown, with PH₃ gas introduced into the growth chamber to make the films n-type. Estimates of film crystallinity and stress are made from the frequency and linewidth of the main Raman band of silicon, and from x-ray diffraction patterns. Crystallinity and stress are related to the PH₃ partial pressure, and the effects of the overall gas pressure and film thickness are also studied. Some films undergo laser annealing, which can increase the crystalline content of a film and form a surface on which further CVD deposition can occur. The effects of various laser fluences on crystallinity and stress are discussed.

P8.4
Abstract Withdrawn.

P8.5
OPTICAL CHARACTERIZATION OF ION IMPLANTED SiC. E.K. Williams, D. Ib, Center for Irradiation of Materials, Alabama A&M University, Normal, AL; D.B. Paker, D.K. Hessley, Solid State Division, Oak Ridge National Laboratory, Oak Ridge, TN; David J. Larkin, NASA Lewis Research Center, Cleveland, OH.

SiC samples implanted with Au, Ag, Pd at room and elevated temperatures have been characterized by optical absorption spectrophotometry and micro-Raman spectroscopy. The absorption spectra indicate whether nanocluster formation occurred. The Raman spectra reveal whether annealing has substantially removed the implantation damage. Acknowledgements: This work is supported by the Center for...

P8.6 ANALYSIS OF THE CRYSTALLIZATION KINETICS AND MICROSTRUCTURE OF POLYCRYSTALLINE SiGe FILMS BY OPTICAL TECHNIQUES. J. Olivares, P. Martin, A. Rodriguez, J. Sanguino, and F. Tietjens. CIT-UP, Madrid, SPAIN. Universidad de Valladolid, Valladolid, SPAIN.

Poly-crystalline SiGe films are of interest for the fabrication of thin film transistors (TFTs). X-ray diffraction, Raman spectroscopy and ultraviolet reflectometry have been used to characterize the solid phase crystallization kinetics and microstructure of these films. Amorphous SiGe layers were deposited by LPCVD at 450°C and annealed at 750°C. The Raman fraction of the film was measured in the 0.1-0.4 range. The samples were crystallized at temperatures ranging from 550 to 600°C. Raman spectra were recorded using the 514.5 nm line of an Ar+ laser. UV reflectance spectra were measured in the 200 to 1000 nm wavelength range. The crystalline fraction of the films was determined as a function of the annealing time. The peak of the X-ray diffraction curves, the integrated intensity of the Si-Si bond of the crystallized phase, and the area under the characteristic peak around 280 nm of the reflectance spectra. The results from X-ray diffraction and Raman spectroscopy are representative of the whole film thickness. The abscissa depth of the UV radiation is around 4 nm for the wavelengths of interest, and therefore only the top region surface is analyzed. The crystalline fraction vs. the annealing time data were fitting Arrhenius model and the characteristic parameters of nucleation and growth were extracted. For samples with Ge fractions below 0.3, the three experimental techniques yield the same results, suggesting an equivalent mechanism of crystallization. The integral of the reflectance spectrum was found to be consistent with the amount of crystallization. A discussion of these results is presented.

P8.7 MICRO-RAMAN CHARACTERIZATION OF UNIQUES DEFECT STRUCTURE IN ARSENIC-IMPLANTED SILICON. David D. Tscholak, James P. Lawine, Eastman Kodak Co, Rochester, NY.

Raman spectroscopy has often been used to study the damage to semiconductors induced by ion implantation. The Raman selection rules, which for crystalline materials restrict spectroscopic activity to the Brillouin zone center, break down as lattice order is broken. The Raman spectrum of ion-implanted crystals increasingly mirrors a phonon density of states spectrum characteristic of the Si matrix, in contrast to phonon spectra of amorphous microcrystal, as the lattice is disrupted by implantation. We have studied and characterized by macro- and micro-Raman spectroscopy the type of lattice damage induced by heavy ion implantation of Si and Ge. Micro-Raman spectra reveal extensive damage to the silicon lattice, consistent with many literature reports. However, when the same samples were analyzed in the backscattering mode by micro-Raman spectroscopy, evidence for crystalline defects was detected. These defects are not present in the bulk of the film but are concentrated in the surface region of the implanted films.

P8.8 RAMAN MICROPROBE ANALYSIS OF SELECTED SEMICONDUCTORS SUBJECT TO CONTACT LOADING. Vladimir Demchuk, Yuri Gogotsi, Univ of Illinois, Dept of Mechanical Engineering, Chicago, IL.

Contact loading is probably the most common kind of mechanical loading that all materials experience during processing or work. Examples are cutting and polishing, indentation testing, wear, friction and erosion. The study of loading has received significant attention over the last 20-30 years. It is now clear that mechanical stresses are a significant component of stress that leads to dramatic changes in the materials structure such as amorphization and phase transformations. The combination of indentation tests with Raman microspectroscopy provides a powerful tool for both isothermal and isostress monitoring of pressure-induced phase transformations in semiconductors. In the present work, study of high-pressure phase transformations and amorphization under indentation in selected semiconductor (diamond, Si, Ge, GaAs, InSb, and others) has been performed. High deviatoric stresses under the indenter and the possibility to vary the loading conditions supplied important information on the stress distribution around the indentations and allowed for an accurate determination of transformation conditions.

P8.9 COFocal MICRO-RAMAN CHARACTERIZATION OF SiC epilayers. Ran Li, Motorola, Embedded Systems Technology Laboratories, Menlo Park, CA.

The large visible optical penetration depth makes it difficult to isolate the Raman signals of SiC epilayers from those of the substrates such as SiC, sapphire and Si when visible laser lines are used. In this work, confocal micro-Raman was used to characterize 3C, 4H and 6H SiC layers on different substrates with enhanced lateral resolution (~0.08 μm) and depth resolution (~2 μm). Both lateral and depth variation of the free electron concentration and scattering time were measured from n+ SiC epilayers on n+ SiC substrates and from p+ implanted SiC. A defect phase induced by oxidation process was also analyzed as function of the depth and the lateral position.

P8.10 CHARACTERIZATION OF GALLIUM ARSENIDE CIRES GROWN UNDER MICROGRAVITY CONDITION BY CATHODOLUMINESCENCE. Chengli Li, Yunyan Li, Lanying Lin, Xingru Zhang, Nuoji Chen, Institute of Semiconductors, Chinese Academy of Sciences, Beijing, CHINA.

The high quality semiconductor crystals can be grown up in space due to both the elimination of thermal convection and avoidance of container contamination. It has been attracted great interest to the researchers. The samples were doped and undoped semi-insulating GaAs crystals that were grown from melt under microgravity condition in the Chinese recoverable satellites. A home-built cathodoluminescence(C/L) system attached to the JKA-3A Electron Probe was used for characterization of the GaAs samples. The crystal defects feature of on-earth-grown and in-space-grown GaAs have been revealed by CL images. The crystals grown on the earth processes both high density dislocations and pronounced impurity striations due to growth velocity fluctuations caused by thermal convection in the melt. For space growth GaAs, the striations were disappear and the dislocation density was much lower and in a quiet uniform distribution. A very clear region near the interface was grown in a good growth condition. The striation striations caused by surface tension near the surface have been observed in the first time in the Te-doped GaAs crystal. The cellular structure with dislocation loops on its wall has been found in the space-grown semi-insulating GaAs. The carrier concentration and its distribution of heavily doped GaAs have been measured by the peak energy and half width of CL spectra. There is an abrupt decrease of concentration about one order of magnitude at the earth-space growth interface due to the impurity segregation during recrystallization in space. The electron probe X-ray microanalysis also confirmed this result.


ZnSe samples obtained by a Solid Phase Recrystallization method have been studied by means of spatially and spectrally resolved cathodoluminescence. The samples were recrystallized in different atmospheres, SO2 rich and Ar, to investigate the influence of the thermal treatment conditions on the resulting defect structure. Cathodoluminescence images show clearly that after recrystallization, the samples are plastically deformed showing slip lines patterns. The spectra reveal important changes associated to the dislocation related emission (2.5-2.6 eV region) as well as to the point defect structure (2.0-2.5 eV region). In the near infrared range the recrystallized samples show several luminescence bands between 0.6 and 1.5 eV. The influence of the thermal treatments on the luminescence is discussed. In particular copper impurities appear to play an important role in some of the recrystallization induced spectral changes in the visible and infrared range. The presence of riming twins, and possibly cubic regions, in the samples is revealed by a strong CL contrast.

P8.12 STUDY OF GaSb-MN JUNCTION DEVICES BY CATHODOLUMINESCENCE AND SCANNING TUNNELING SPECTROSCOPY. Pedro Hidalgó, Bishni Méndez, Javier Piqueras, Facultad de Físicas, Universidad Complutense, Madrid, SPAIN. Partha Sarkar, Dyr Electronics, Computer and Systems Engineering, Rensselaer Polytechnic Institute, Troy, NY.
GaSb p-n junctions formed by Zn diffusion in Te-doped GaSb substrates have been characterized by cathodoluminescence microscopy and tunneling electron microscopy. The PL measurements, performed by SIMS, varied in the different samples from 0.4 µm to 1 µm. CL plane-view observations of the Zn-diffused side enable to study the homogeneity of the diffusion process. The presence of Zn is revealed in the CL spectra of samples with higher junction depths by an emission band peaked at about 760 meV. Spectra recorded by CIT (Current Imaging Tunneling Spectroscopy) in the n and p samples of the junction, clearly show the respective conductive behaviour and give values of the surface band gap. These results suggest that the p-side is more n-type and that its metallic character is observed in the conductance curves. The mentioned characterization techniques are used to control the quality of the junctions prepared by different diffusion methods.

**PS.13**
CATHODOLUMINESCENCE FROM In0.5Ga0.5As LAYER GROWN ON GaAs USING A TRANSMISSION ELECTRON MICROSCOPE. Nobuki Yamanato, Yutaka Onishi, Tetsuro Ishida, Dept. of Physics, Tokyo Inst. Technology, Tokyo; Stefan Hein, Alfonso Fracessino, Laboratori TASCIFEM, Trieste, ITALY; Jean-Marie Bourse, Dept. de Physique, EPFL, Lausanne, SWITZERLAND.

In0.5Ga0.5As epilayers grown on GaAs [100] were studied by cathodoluminescence (CL) spectroscopy with a 0.8 nm resolution, combined with a transmission electron microscope. The layers were grown by molecular beam epitaxy at 490°C with nominal x = 0.04 composition and 2 µm nominal thickness. The thicknesses were GaAs(0.01)-In0.5Ga0.5As(0.01)-In0.5Ga0.5As(0.01)-In0.5Ga0.5As(0.01)-In0.5Ga0.5As(0.01) layers grown at 600°C. In these conditions the ternary layers are expected to be largely relaxed, through the formation of a network of misfit dislocations oriented along perpendicular [110] and [110] directions. The emission from the In0.5Ga0.5As epilayer was observed at wavelength of 888 nm at 35 K. However, low-temperature monochromatic CL images showed well-defined inhomogeneities in the spectral emission giving rise to line features along the [110] and [110] directions. In particular, a dark-line contrast was observed in the CL images taken at the peak wavelength and at the shorter wavelengths, while bright-line contrast was observed for wavelengths longer than the peak wavelength. This implies that the gain wavelength shifts toward longer wavelengths along the observed features. After locally removing the GaAs substrate through ion milling, we observed CL images of the linear features with the same contrast obtained from regions which still included the substrate. This clearly indicates that the line contrast does not derive directly from the misfit dislocation network.

We conclude that the contrast originates instead from compositional inhomogeneities within the In0.5Ga0.5As layer, i.e., from In-rich regions which exist along the linear features. High-resolution TEM observations of plan-view and cross-sectional samples together with simultaneous observation of CL images are presently under way to clarify the spatial extent and symmetry of the compositional inhomogeneities.

**PS.14**
STUDIES OF PHOTOREFLECTANCE IN Cd1-xMnxTe/Cd1-xMnxTe SUPERLATTICES. Chien-Chia Chen, Xuezhong Wang, Huitao Li, Xinong Liang, GuangYi Gu, Peking University, Department of Physics, Beijing, CHINA; Zheng Ning, Xin Wang, Pudong University, Surface Physics Laboratory, Shanghai, CHINA.

Studies of photoreflectance (PR) spectroscopy on a series of Cd1-xMnxTe/Cd1-xMnxTe superlattices (SLs) have been investigated at liquid nitrogen and room temperature. A series of samples with different well widths of Cd1-xMnxTe (x=0.0, 0.05) and barriers of Cd1-xMnxTe (x=0.05) were grown by molecular-beam epitaxy (MBE) technique on (001) GaAs substrates. A CdTe buffer of >0.5 μm was grown on the substrate. Photoreflectance spectra obtained for typical samples showed peaks which correspond to the heavy- and light-hole interband excitonic transitions from the quantized conduction-band states. With a least-squares fit of a line shape function, the transitions above Eg (GaAs) and Eg (CdTe) can be clearly be identified as confined 1LH, 2LH, 2HH, 3HH in SLs.

Strain-induced effects play an important role in SLs since there is a large lattice mismatch between the well and barrier layers in Cd1-xMnxTe/Cd1-xMnxTe SLs, large strains present in the SLs structure, which strongly modify the potential profile along the growth axis (z axis). The strain effects, which include a hydrostatic and a shear component of the stress, produce shifts of the conduction and valence-band edges and split heavy and light-hole valence band edges. The excitonic transition energies of heavy- and light-hole can be determined after taking into consideration the strain-induced and quantum confinement effects. The theoretical considerations are in good agreement with the experimental results. The results of our experiments showed that the PR technique is a very powerful probe for the study of quantized state structures in the system of SLs.

This work was supported by the National Natural Science Foundation of China (No. 18774005).

**PS.15**
NONDESTRUCTIVE ANALYSIS OF CURRENT GAIN OF InP/GaAs HETEROSTRUCTURE BIPOLAR TRANSISTOR STRUCTURES USING PHOTOREFLECTANCE SPECTROSCOPY. Hiroki Sugiyama, Noriyuki Watanabe, Kanno Watanabe, Takashi Kobayashi, NTT Photonics Laboratories, Atsugi-shi, Kanagawa, JAPAN; Kotani Watanabe, Dept. of Material Science and Engineering, Cambridge, MA.

We have measured the photoreflectance (PR) spectra from InP/GaAs heterojunction bipolar transistors (HBT) grown by MOVPE on InP (001) substrates and found a correlation between the dc current gain and the peak intensity of PR spectra from the emitter region for the first time. The PR method has potential as a nondestructive method for determining the current gain of HBT-wafers. The layer structure was a n+-InGaAs cap layer/1µm-InP emitter layer/p+-InGaAs base layer/undeposited InGaAs collector layer/n+-InGaAs substrate. The emitter and base currents were identical for all samples. The base layer provided the most important factor in the determination of the current gain and was intentionally controlled by changing the growth temperatures. PR spectra showed strong Franz-Keldysh oscillations (FKOs) around the bandgap of InP, which were related to the built-in electric field in the emitter region. Though the electric field was calculated by analysis of (FKOs) at almost the same value, the peak intensity of the maximum peak in the FKO decreased from 1.55 to 4.55 as the current gain decreased from 330 to 72. The reduction of the PR intensity was especially prominent for the nonradiative recombination centers in the emitter region increases.

A single n+-InP layer without a junction with n+-InGaAs base layer, the PR intensity did not decrease with changing growth temperature.

Therefore, it is considered that the density of the recombination centers in the emitter region is strongly affected by the quality of the base layer and that the defects that act as the centers may diffuse from the base layer to the emitter layer during the growth. As a result, the intensity of the PR signal from the emitter region reflects the current gain of the samples. [1] H. Nakatani et al. Jpn. J. Appl. Phys. 32 (1993) 6296.

**PS.16**
PHOTOROMODULATION SPECTROSCOPY AND IMAGING OF QUANTUM STRUCTURES USING NEAR-FIELD SCANNING OPTICAL MICROSCOPE. Yong-Choon Cho, Sung-Kee Esh, S.C. Hyoung, D.S. Kim, W. Jhe, Seoul National University, Center for Near-field Atom-photon Technology and Dept of Physics, Seoul, KOREA.

We present the results of photoreflectance (PR) spectroscopic studies of GaAs/AlGaAs quantum structures using near-field scanning optical microscope (NSOM). Photoluminescence (PL) and PL excitation (PLE) were also measured using NSOM and compared with the results. The PL and PLE measurements were carried out using a 488 nm laser of an Ar+ laser and the tunable cw Ti:Sapphire laser, respectively, while for the PR measurements, the Ar+ laser and the tunable cw Ti:Sapphire laser were simultaneously used for pump and probe sources, respectively. All the spectra were obtained using both the reflection and transmission mode with lens collection and illumination and collection through the same fiber tip. The collected light through the lens or the fiber tip was dispersed by a double-grating monochromator for the PL and PLE measurements. For the near-field PR (NPFR) measurements, the pump and probe beams were focused into one single mode fiber tip using a 2 x 2 fiber coupler and the reflected light was collected by both a lens (illumination mode) and the same fiber tip (illumination collection mode) and then focused into a photodiode. The NPFR experiments were carried out as a function of the excitation intensity, sample tip distance, and sample position. As a result, the NPFR technique allows us to have the several advantages compared to the conventional near-field optical techniques; (i) higher signal-to-noise ratio, (ii) a better spatial resolution, (iii) a better spectral resolution, and (iv) a lower temperature sensitivity of the signal intensity.

**PS.17**
MICROCHARGEATIZATION OF ELECTRON EMISSION PROPERTIES OF BORON DOPED POLYCRYSTALLINE DIAMOND BY THE CURRENT IMAGING TUNNELING SPECTROSCOPY (CITS) MEASUREMENT. Yinguo Kim, Weon Choi, Fukoku Industry Science & Technology Foundation, Fukoku, JAPAN; Yoichi lseri, Kyushu Mitsumi Ltd, Fukoku, JAPAN; Toshio Ando, Core Research for Evolutional Science Technology, Tokyo, JAPAN; Hidetoshi Tomizuka, Fukoku University, Dept of Electronics Engineering and Computer Science, Fukoku, JAPAN.
Recently, diamond has been widely investigated for field emission display (FED) applications due to its high and stable electron emission under relatively low electric field. However, the electron emission mechanisms are not clearly understood yet, especially in polycrystalline phases because of the complex microstructures. In this presentation, the direct observation and repeatability of electron emitters and microstructure dependence of its electron emission properties of boron-doped polycrystalline CVD diamond thin films will be described. Small secondary grains with average size less than 1 um were observed on top of the isolated crystal surfaces. The electron emission generally increased with increasing doping concentration as well as the surface roughness of each isolated crystal. All samples were observed to be located in the top surfaces rather than in the bulk of the sample, but not all grain boundaries were active for electron emission. This observation suggests that the electrons transport through the grain boundary conductive channels and preferentially emit at the low electron affinity phases.

P8.18 QUENCHING THE THERMAL CONTRIBUTION IN LASER ASSISTED STM. Oscar E. Martinez, Sandra M. Lendi, Universidad de Buenos Aires, Facultad de Ciencias Exactas y Naturales, Dpto de Fisica, Buenos Aires, ARGENTINA.

When irradiating the sample with a modulated light intensity, light absorption results in tip and sample heating and expansion at the modulation frequency, obscuring other possible laser induced mechanisms. In this work we describe a method in which the thermal expansion at the modulation frequency can be reduced by orders of magnitude. The method is based on the irradiation of the sample with two interfering laser beams at different frequencies and incidence directions. When two light waves with different directions are superimposed, the interference pattern gives rise to spatially periodic temperature variations. If the frequency of one of the beams is slightly shifted from that of the other beam, the phase of the interference pattern will move, giving light fringes travelling in the illuminated zone. In this manner the total thermal load on the sample is kept constant, while each point is subjected to a modulated intensity at the difference between the two frequencies. With this travelling fringe scheme, we have measured the quenching of the thermal expansion on a silicon samples. Photothermal induced currents were reduced to levels below our detection while the signal due to photo-carrier injections remained constant.


A number of research efforts have been focused on self-assembled quantum dots based on germanium in which indirect optical transition takes place across the band gap. However, many questions regarding the confined electronic state transitions of Ge quantum dots still remain unanswered. In the present report, ten alternating layers of crystalline Ge quantum dots embedded in a Al2O3 or an AlN matrix were deposited on sapphire substrates by pulsed laser deposition. The quantum dots (QDs) were controlled by the laser energy density and the deposition time and characterized by high resolution transmission electron microscopy. The spectral positions of both the E1 and the E2 transitions in the absorption spectra at room temperature and at 77 K shift toward higher energy (ΔE=1.19 eV, ΔE=0.57 eV) as Ge dot size decreases (73 A). The deposition of the samples and the interpretation of optical absorption measurements in terms of quantum confinement of carriers in both transitions will be presented.

P8.20 EFFECTS OF RAPID THERMAL ANNEALING ON THE INTERSUBBAND ENERGY SPACING OF SELF-ASSEMBLED InAs/InGaAs QUANTUM DOTS. C.S. Wang, S.J. Chiu, S.J. Xu, Z.H. Zhang, National University of Singapore, Department of Electrical Engineering, SINGAPORE.

Self-assembled quantum dots directly obtained via the so-called Straniski-Krstovanic growth mode are of great interest due to their fundamental physics and potential device applications. Among them, InAs/InGaAs QD is a research topic that has been extensively investigated both experimentally and theoretically. However, the electronic structure of InAs dots still remains an open problem.

Indeed, the shape and size of the QDs as well as the strain distribution in materials around them, which strongly affect the photoelectric property of the QDs, are very difficult to be accurately determined. Although the defect-free dots can be formed in lattice mismatched heterostructures by the SK growth mode, inevitable size distribution in the dots results in inhomogeneous broadening. Both both for the photoabsorption from the interband transitions and infrared absorption due to the interband transitions in the dots. Therefore, further developments in the nanoscale devices such as lasers and detectors depend on the achievement of tunability of dot shape and size in order to control the wavelength and reduce the linewidth of the luminescence. In this paper, we showed the significant reduction of the energy spacing between ground state and excited state emissions from InAs/InGaAs quantum dots due to interfacial interdiffusion induced by thermal treatment. In addition, the strong narrowing of the luminescence linewidth of the ground state and excited state emissions from the InAs dot layers for the annealed samples indicates an improvement of the size-distribution of the QDs. Large blue-shift of the energy positions of both emissions was also observed. High resolution X-ray diffraction experiments give strong evidence of the interface recombination in the annealed samples. This work shows ability to tune the wavelength for applications like infrared detectors and lasers based on intraband transitions of self-assembled QDs.

P8.21 EXCITONS IN GaN/AlAs HETEROSTRUCTURES WITH INTERFACE CORRELATION. M.V. Belevskaya, Yu. Chernyshev, I.E. Kozin, Inst of Physics, St. Petersburg State Univ, St. Petersburg, RUSSIA, C Eil, H M Golub, Optical Sciences Center, Univ of Arizona, Tucson, AZ.

We have demonstrated interface correlation effect (the memory of previous surface form) in GaAs layers grown heterostructures. This is the new way for improving AlAs interface under the growth conditions that are optimal for GaAs quantum wells (QWs). We use interface correlation effect to enhance macroroughness of the GaN QW/GAAs interface (AlAs surface) to the scale of the typical (GaN QW surface). To do this each barrier of the QW has been formed by a short-period GaN/AlAs superlattice (SL) grown with growth interruptions after GaN. To test the interface correlation we investigated the exciton reflection spectra as a function of the AlAs SL layer thicknesses. Without interface correlation, the exciton spectra depend only on the GaN QW thickness. But when the AlAs layer surface repeats the previous GaAs surface, the distance between the two GaAs surfaces is an important parameter as well. It has been shown that interface correlation is preserved on the AlAs interface even after growth interruption. The maximum exciton linewidth occurs when the AlAs layer thickness is an integer number of monolayers. Then each AlAs surface which has been formed on a large-island GaN surface just below it, provides a better GaAs-on-AlAs interface on which to grow the QW.

P8.22 PHOTO-INDUCED CURRENT SPECTROSCOPY IN UNDOPED CVD DIAMOND FILMS. E. Bocchi, M. Bruni, D. Monichelli, S. Pirallo, St. Siricito, Dipartimento di Energia, Via S.Marta, Firenze ITALY.

Thermally Stimulated Currents [TSC] and Photo-Induced Current Transient Spectroscopy [PICTS] have been carried out on undoped CVD diamond films, in order to determine the characteristic parameters of the traps affecting the electrical transport processes. Measurements have been performed in the temperature range from 300 K to 700 K under 10⁻⁷ torr vacuum condition. The traps are excited by means of a pulsed Xenon lamp, operated at a frequency of 75 Hz and coupled to the vacuum system by means of an optical fiber, delivering an energy at the sample of the order of tens mJ per pulse. The PICTS spectra is generated by probing the current transients arising from photo-induced trapping and thermal release of the carriers during a heating scan. The trap priming before TSC experiments has been performed at room temperature, and thermal emission has been subsequently measured by subsequently heating the samples with different constant heating rates. Both TSC and PICTS spectra have showed a dominant peak around 550 K. This signal has been simultaneously analyzed to carry out a signature of any deep level consistent with the two different techniques. The integral equations relating deep levels distributions to measured emissions have been solved by means of a numerical procedure developed to this purpose. A distribution of deep levels has been found in the energy range 0.6-1.4 eV away from band, corresponding to a total defect concentration of the order of 10¹⁵ cm⁻³.3.
PS. 23  
MICROVOIDS IN POLYCRYSTALLINE CVD DIAMOND.  
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Worcester Polytechnic Institute, Worcester, MA.  

The microstructure of CVD diamond is influenced by the columnar  
structure of the growth process. As a result of this growth process,  
micron-scale voids are often incorporated into the film. These voids  
have an impact on both electrical and mechanical properties of  
the material. While void structures on the order of 1-10 microns have  
been observed in CVD films using SEM, it is difficult to characterize  
the void structure on a large scale. Here, we have taken advantage of  
the transparency of diamond in the visible to obtain quantitative  
information on voids in the material. Two optical methods have been used.  
Small angle light scattering is used to obtain void sizes and shape, while optical imaging is used to  
estimate the density of voids in the material. This information can be  
used to predict problems such as a mechanical failure and will allow the  
modification of growth processes to reduce the presence of voids.

PS. 24  
PHOTONIC BANDS BASED ON GLASSFIBER STRUCTURES.  
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Częstochowa, Częstochowa, POLAND.  

The work contains results of investigations on the phenomena of the  
electron emission and photoemission in thin oxide layers (ITO) on  
in which internal electric field has been generated. Based on the  
Møller effect [1] the sample was a glass with conducting films evaporated on  
its both sides [2]. One film (ITO Sr,SiO) of the thickness 10-50 nm was  
connected to a metal plate; on other side, of the same thickness, was a  
polarizing electrode in order to create an internal field (field electrode). The internal electric  
field was created by applying a negative voltage Vpol to field electrode  
(1000V/cm). Evaporation was made by reactive ion sputtering. The investigations were performed in the current range 0-100 mA.  
As a result of applying Vp= and illumination, photoelectrons are released and enter electron multiplier. The electrons create voltage pulses in  
the multiplier which are recorded in the multichannel pulse amplitude  
analysers. The spectrum N(E)= (E) for various Vp= were measured for unilluminated samples and illuminated by a quartz lamp type XBO 150. The N(E)= (E) dependence can approximately  
be described by a Gaussian function [3]. This was done using a computer  
programme with the non-linear regression method which allowed to  
determine the best fit parameters. At Vp= = 500V it is impossible  
to describe the spectrum by a single gaussian and at Vp= = 2000V we  
have to use three Gaussian curves. Electron emission yield was  
dependence on the intensity of internal field and illumination were  
measured. With increasing Vp= and after illumination the count frequency of pulses grows monotonically. At low Vp= (< -1000V) the  
intensity is linear. At higher Vp=, this dependence is  
exponential (n ~ exp(Vp=)). This may be an evidence that the  
electric field initiates electron collisions which proceed according to  
impact ionization mechanism. Energy analysis of emitted electrons was performed by the following field method measurements:  
electrons energy in field induced emission showed that about 80% of  
electrons have energy until 10 eV but some electrons (a few percent)  
of energy about 50 eV are also detected.  


PS. 25  
PHOTON-INDUCED CURRENT SPECTROSCOPY IN THE  
QUANTUM HALL REGIME.  
Andrew Bämm, Barbara Ozylmar,  
Joachim Heil, Uwe Heyer and Peter Wyder, Hochschule Magnetshöhe,  
Max-Planck-Institut für Festkörperforschung and Centre National de la  
Recherche Scientifique, Grenoble, FRANCE.  

We report experiments using a Hall photovoltage imaging technique  
to investigate transport properties in carbon-based electron gas  
(2DEG). A laser beam is coupled into an optical fiber, which can be  
scanned by a mechanical cryogenic micropositioning device. Due to  
the photoelectric effect carriers can be injected into the 2DEG at  
the point of illumination. To record a current flux image the fiber  
is scanned across the Hall bar and the lateral photovoltage between two  
contacts is recorded as a function of the fiber position. This  
technique is very sensitive and allows resolutions better than 5μm to  
visualize the potential. The carrier density in 2DEG is low  
temperatures and in high magnetic fields. We see flux channels due  
to the edge confining potential. At higher magnetic fields the potential  
profile is peaked near the edge with an HWFM of less than 10μm.  
The observed lines can be well described by the theoretical Hall  
voltage profile. The deduced current distribution indicates that  
75% of the total current moves within a narrow channel near the edge. The  
potential distribution near the edge and in vicinity of a small orifice  
was nicely imaged. Landau quantization of the electron states and  
the occurrence of back-scattering are the origin of so-called light-induced  
Shubnikov-de Haas oscillations periodic in 1/B. The shape and the  
periodicity of these oscillations depend on the mobility of the sample,  
on the position of the light spot, the illumination power and possibly  
applied external current. Strong changes in the features can  
be observed close to the edge. To our knowledge this kind of  
light-induced oscillations have been observed for the first time.  

Together with the imaging technique this rather new tool is a  
useful way to characterize the current transport in two-dimensional  
substrate heterostructures especially at high magnetic fields.

PS. 26  
DETECTION OF OPTICAL PROPERTIES OF  
FLUOROCARBON POLYMER THIN FILMS BY A VARIABLE  
ANGLE SPECTROSCOPIC ELIPSTOMETRY.  
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Materials Engineering, Ansan, KOREA; Hyung-Jin Shin, Samsung Electronics  
Co. Ltd, Core Technology Research Center, Suwon, KOREA.  

Optical properties of vapor phase [VP] deposited and spun-coated  
fluorocarbon (FC) thin films on silicon substrates, such as refractive  
index, extinction coefficient and film thickness were characterized by a  
variable angle spectroscopic ellipsometry [VASE] in the range of  
380-800 nm. A Lorentz model and a Cauchy model were used to fit  
the measured spectra in the above analysis. The Lorentz model allows  
us to simulate the optical constants of the FC films with a minimum  
number of parameters while maintaining Kramers-Kronig (KK)  
consistency between the real and imaginary parts of the optical  
constants. FC films are nearly transparent over the visible spectrum,  
so it is possible to assume k (extinction coefficient) = 0 over part of  
the visible spectrum in the Cauchy model. To accurately simulate the  
obtained ellipsometric spectra, we performed a regression analysis in  
two steps assuming a three-phase model [ambient/FC/Si] and a four-phase  
model [ambient/froth-fuged FC/FC/Si]. The regression analysis was performed through the Lorentz model and the best-fit  
mesh error squared error [MSE] value of 1.717 (VP deposited FC film  
Lorentz model) was obtained. However, the four-phase model was  
used to improve the best-fit result of 0.331 (VP deposited FC film,  
Lorentz model). The surface roughness layer was assumed to be a  
mixture of FC films and voids under the Bruggeman effective medium  
approximation (BEMA). We found that the best-fit MSE was reduced  
when surface roughness was included.

PS. 27  
OPTICALLY-INDUCED CONDENSATION OF IMPURITIES  
EXCITATIONS IN TRANSPARENT SOLIDS.  
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IA Rixon, Applied Research Center, Moscow, RUSSIA.  

The interaction of electromagnetic radiation with impurities in  
transparent solids is studied for the case when interaction between  
excitations becomes strong. It is shown, that intense optical  
radiation leads to condensation of impurities excitations. The  
condensed excited state, consisting of excited impurities, is an  
en ergothermally favorable phase, which minimizes the energy of  
the system. Nevertheless condensation is accompanied by  
strains, in some cases followed by breakage of solids. The physical  
and mathematical foundations of condensation of excitations are  
considered. It is shown that current density occurring during  
excitation of excitations wave-functions become significant. Critical density  
of impurities excitations, when condensation occurs, is found. It is  
shown that in comparison with the well known metal-insulator  
transition in the electron-hole system of semiconductors, the  
non-equilibrium condensation of impurities excitations has not  
only pure electronic character. Condensed excited state’s excitation  
was obtained on the basis of application of pseudo-potential theory and  
density functional method. Energetic and mechanical parameters of  
condensed excited state are studied. Numerical estimates show that  
condensed excited state is a quite stable formation with enough long  
life time. The stress raising in the impurity system is determined by  
the model of conceptual condensed state. It is shown that these stresses  
the impurities may be redistributed considerable in the material.  
Conditions for breaking pints are determined, when matrix is  
destroyed by optically induced stresses. The possibility of  
formation of defects in the optical transparent material is discussed.  
Assessments of changes of both absorption and recombination  
spectra are given in relation with direct registration of the  
condensation of impurities excitations. It is demonstrated that  
intense optical radiation can significantly change properties of  
transparent material due to condensation of impurities excitations.  

PS. 28  
HYBRIDIZATION IN ELECTRONIC STATES AND OPTICAL  
PROPERTIES OF COVALENT AMORPHOUS SEMICONDUCTORS.  
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Systems Engineering, Waseda, JAPAN.  

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The electronic structure and optical properties of covalent amorphous semiconductors are theoretically studied with special attention to the sp hybridization in electronic states and the spatial correlation of atoms. One-dimensional tight binding models are used in which the base of electronic states is a set of s and p-orbitals of an atom which is randomly located in space. The electron transfer energy between a pair of nearest neighbour atoms is assumed to depend linearly on their interatomic distance. All the electronic states are numerically calculated for a 150-atom system and the ensemble average is taken over 11 samples. Following results have been obtained. As the degree of randomness increases, the degree of hybridization decreases for so-called weak bonds and rearrangements in the covalent bonds take place. The bond gap width decreases but lasts rather long compared to a case if we neglect the spatial correlation. The optical absorption spectrum shows characteristic peaks, which reflect the peaks in the partial (s or p) density of states in the valence and conduction bands and then reflect the degree of hybridization. Self-consistent calculations for the distribution of the interatomic distance and the local covalent bond have been also performed to explain a universal value for the steepness parameter of the Urbach tails in various materials.

PS.20
VIEWPORT INFLUENCE ON PROCESS AND IN-SITU MEASUREMENTS IN MOCVD VERTICAL ROTATING DISC REACTORS. Anton Prakopenko, Alexander Guray, Matthew Schurman, Jeffrey Ramer, EMCORE Corporation, Somerset, NJ.

Optical access to the wafer for the in-situ process monitoring and control is a requirement for the advanced MOCVD equipment. Depending on their location and design, viewports can affect the reactor flow dynamics and temperature distribution inside the growth chamber thus ultimately affecting the deposition process. Furthermore, deposition on the viewport can influence the accuracy of in-situ measurements. We have investigated viewport influence on the MOCVD vertical rotating disc reactors manufactured by EMCORE Corporation. Computational fluid dynamics and finite-element modeling allowed predictions of the conditions that eliminate viewport influence on deposition results. The validity of model predictions was verified by examining the results of actual deposition runs on the reactor. We have also demonstrated that under normal operating conditions, slight deposition on the viewport has minimal effect on the accuracy of in-situ pyrometric temperature measurements.

PS.30
ENERGY BEHAVIOR OF NEGATIVELY CHARGED MAGNETO-EXCITONS IN QUANTUM WELLS AND HETEROJUNCTIONS. F. M. Montagno Jr., Yongmin Kim, D.H. Perry, D.G. Rikus, J.A. Simmons, and J.L. Reno, Los Alamos National Laboratory, Los Alamos, NM; 2Northeastern University, Boston, MA; 3Sandia National Laboratory, Albuquerque, NM.

The formation and behavior with magnetic field of the negatively charged magneto-excitons (X⁻) in modulation doped quantum wells (QWs) and single heterojunctions (SHJs) have been receiving increasing attention recently. Our experimental investigations performed on modulation doped GaAs/AlGaAs QWs and SHJs in high magnetic fields (up to 60T) and low temperatures (0.3-1.5K) showed that Coulomb interaction plays an important part in the exciton formation. We find that the triplet (X₃) and singlet (X₁) states of X⁻ behave in a different manner due to the reduction of the cyclotron radius with increasing field and the proximity between the electron and hole layers. In the case of a β-doped QW with a well-width of 20 nm, the X₃ and X₁ states cross at a magnetic field of about 40T, whereas a modulation-doped SHJ shows no crossing and the two states move in an almost parallel configuration over the available fields. The appearance of the negatively charged X₃ and X₁ states are directly related to the formation of the non-local neutral exciton (X⁰). The experimental results confirm theoretical predictions that the higher Landau levels and higher energy subbands play an meaningful role in their energetic evolution.

PS.31
CHARACTERIZATION OF SILICA-BASED WAVEGUIDES USING CONFOCAL RAMAN MICROSCOPY. M.J. Matthews, A. Harris, A.J. Brooks and M.J. Cardillo, Bell Laboratories, Lucent Technologies, Murray Hill, NJ.

Confocal Raman microscopy was used to investigate both chemical and structural defect profiles of various silica-based waveguides with 3D spatial resolution of (0.3 µm)² Internally and 1.3 µm axially. Compositional variations across fiber and planar waveguides produced by either CVD or FHD techniques were probed by evaluating the intensities of chemically relevant vibrational bands in the Raman spectra. In particular, the concentration of boron and phosphorous across cladding and core layers was quantitatively profiled using the intensities of the Si-O-B and P=O vibrational bands respectively, showing the depletion of dopants near layer boundaries. Two prominent defect bands (D₁ and D₂) found in the Raman spectra of vitreous SiO₂ at ~490 cm⁻¹ and ~600 cm⁻¹ respectively, were also used as sensitive monitors of the structural variation across both optical fibers and planar waveguides. The effect of inhomogeneous structural and chemical defect densities on device performance is discussed.