SYMPOSIUM P

Optical Microstructural Characterization of Semiconductors

November 29 – 30, 1999

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* Invited paper

SESSION P1: NEAR-FIELD TECHNIQUES I
Chairs: Javier Piqueras and M. Selim Unlu
Monday Morning, November 29, 1999
Salon C/D (M)

8:30 AM *P1.1
INTERNAL SPATIAL MODES AND LOCAL PROPAGATION PROPERTIES IN OPTICAL WAVEGUIDES MEASURED USING NEAR-FIELD SCANNING OPTICAL MICROSOPY. 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/silica buried waveguides. The period of the observed standing modes provides a direct measure of the effective index, 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 prevent accurate device modeling. The NSOM local probe measurements provide a means of detailed characterization, and defects in processing and their affects 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 the issue of perturbation of the NSOM probe on the measurement of the local field shows a weak but measurable perturbation, and the dependence on aperture and material parameters will be discussed. An additional area of great currrent interest is in Photonic Bandgap systems, and our results in Si and glass PBGs will be presented.

9:00 AM P1.2
PHOTOREFLECTANCE NEAR-FIELD SCANNING OPTICAL MICROSCOPY. Charles Paulson, University of Wisconsin, Dept. of Chemistry, Madison, WI; Jingxi 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 Electrical Engineering, Madison, WI; Thomas Kuech, University of Wisconsin, Dept. of Chemical Engineering, Madison, WI.

Photoreflectance (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 measurments 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 shear-force feedback with the surface and is then scanned over the surface while topography and optical signals are recorded as a function of sample position. By launching both the pump and probe light down the fiber, spatially resolved sub-micron scale measurments of the surface electric field have been made. Application of Photoreflectance 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 SeS_2 or $(NH_4)_2S$, are being used for the quantitative evaluation of the efficacy and uniformity of passivation at the sub-micron level.

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

A large number of diamond-shaped As_2O_3 microcrystals (1- 50 μm in size) on GaAs substrates can be produced by anodic etching of GaAs wafers in HCl. Polarization-dependent Raman spectroscopy has unambiguously identified the As_2O_3 microcrystals and accessed 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 As_2O_3. 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. Evoy and H.G. Craighead, School of Applied and Engineering Physics, Cornell University, Ithaca, NY; S. Keller, U.K. 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 (STL) offers an interesting alternative to standard cathodoluminescence (CL) as it injects minority carriers directly into the energy band without involving impact ionisation. The technique has yet to be employed for the imaging of defects in any material system. Its enhanced resolution would permit the analysis of defects on a scale unattainable 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 laser 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 STL. The luminescence of plain GaN is dominated by the band-edge lambda=356 nm range 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=30-55 nm. The low temperature STL of the MQW is dominated by the expected lambda=456 nm range. Carriers unable to reach the MQW are trapped by the neighboring surface states, leading to the inhibition emission from the cap and the dominance of MQW emission in the resulting spectrum. The corresponding STL 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 STL 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
Salon C/D (M)

10:15 AM *P2.1
LIGHT-EXCITED JUNCTION SPECTROSCOPY METHODS FOR CHARACTERIZATION OF ELECTRONIC DEFECTS IN NOVEL MATERIALS. Anna Cavallini, Antonio Castaldini, INFM-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 characterizing 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 levels, 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, afford 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 opto-electronic applications. This paper will report results obtained by P-DLTS, 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 PRESSURE HEAT TREATMENT. Tongjun Yu, Sendai Research Center, Telecommunications Advancement Organization of Japan, Sendai, JAPAN; Tetuji Matsuo, Ken Suto, Dept. of Materials Science, Tohoku Univ.,Sendai, JAPAN; Junichi Nishizawa, Semiconductor Research Institute, Sendai, JAPAN.

High quality GaP crystal with low defect density, has been required by many important applications of opto-electronic 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 (TDM-CVP), successively to GaP substrate annealing at growth temperature (1133K) under various 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 characterizing the LPE layers and revealing the 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 PHCAP 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 temprature, under the optimum phosphorous pressure, the defects in GaP substrate crystal reach an equilibrium state, so that their diffusion to growth layer decreases greatly.

11:00 AM P2.3
LOW TEMPERATURE PHOTOLUMINESCENCE AND PHOTOINDUCED CURRENT SPECTROSCOPY ON CdZnTe GROWN BY HIGH-PRESSURE BRIDGMAN TECHNIQUE. Aziz Zerrai, Laboratoire de Physique de la Matiere, INSA, Lyon, FRANCE; Sylvia Mergui, Florida International Univ, Dept of Electrical and Computer Engineering, Miami, FL; Karim Cherkaoui, Laboratoire de Physique de la Matiere, INSA, Lyon, FRANCE; Makram Hage-Ali, Laboratoire PHASE, Strasbourg, FRANCE; Ghanem Marrakchi, Georges Bremond, Laboratoire de Physique de la Matiere, INSA, Lyon, FRANCE.

CdTe and recently CdZnTe semi-insulating materials are very promising compounds for applications like radiation detectors, photorefractive 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), photoinduced current spectroscopy (PICTS), and thermo-electric effect spectroscopy (TEES) have been carried out on several CZT samples taken from the same ingot grown by the High Pressure Bridgman technique (HPB). The PL bandgap 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. Martin Bayerl, Martin S. Brandt, Martin Stutzmann, 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, reduced dimensionality, and advances in preparation 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, EDMR) provides new possibilities to investigate the microstructure of defects with strongly enhanced sensitivity. The aim of this talk is to briefly present the basic physics 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
PHOTOREFLECTANCE SPECTROSCOPY EVALUATION OF HIGH-QUALITY STRAINED PIEZOELECTRIC MOVPE InGaAs/GaAs QUANTUM WELL STRUCTURES GROWN ON (111)A GaAs SUBSTRATES. Soohaeng Cho, A. Sanz-Hervas, Jongseok Kim and A. Majerfeld, University of Colorado, Dept of Electrical and Computer Engineering, Boulder, CO; C. Villar, E.T.S.I. Telecomunicacion, Departamento de Tecnologia Electronica, Madrid, SPAIN; B.W. Kim, Electronics and Telecommunications Research Institute, Yusong, Taejon, KOREA.

Photoreflectance (PR) spectroscopy is a powerful technique for the optical evaluation of semiconductor 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 transition energies and to obtain 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/GaAs/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 use for various optoelectronic devices. Photoreflectance spectroscopy, in combination with a structural technique such as high-resolution X-ray diffractometry, enabled us to perform a comprehensive 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 $< 111 >$ electronic parameters. The linewidths of the PR transitions were used to assess the interfacial quality of a QW structure with a well width of 41 $\AA$. From a theoretical analysis of the linewidths based on the Bose-Einstein phonon-coupling model we determined an interfacial roughness of $\pm$ 1 monolayer for the first time for this materials system.

SESSION P3: LUMINESCENCE I
Chairs: Partha S. Dutta and Leonid Tsybeskov
Monday Afternoon, November 29, 1999
Salon C/D (M)

1:30 PM *P3.1
OPTICAL MICRO-CHARACTERIZATION 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 hetero-structures a systematic determination and a correlation of the structural, chemical, electronic, and optical properties on a micro- or nano-scale 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 nano-characterization of semiconductors. Our CL-system combines low temperatures (5K<T<300K), an overall spatial resolution of Δx<45nm, 35ps time resolution and high spectral resolution. However, the unique feature of our CL system is the imaging of complete CL spectra: While the focused e-beam is digitally scanned over typically 256x200 pixels a complete CL spectrum $I(\lambda)_{x,y}$ is recorded at each pixel (x,y) yielding a 3D data set $I(x,y,\lambda)$. All type of data cross sections through this $I(x.y.\lambda)$ tensor can be generated, e.g. sets of monochromatic CL images $I(x,y,\lambda_1)$, local CL spot spectra $I(x_1,y_1,\lambda)$, CL spectrum linescans $I(s,\lambda)$, as well as CL wavelength images $\lambda(x,y)$ mapping the local emission peak wavelength. Selective Area Growth and Epitaxial Lateral 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 large regions of low-dislocation-density GaN. Self-organized GaN pyramids as well as ELO GaN on stripe patterned SiO_2- and W-masks are comprehensively characterized by CL microscopy and micro-Raman-spectroscopy. Stripe orientations in $<1\bar{1}00>$ and $<11\bar{2}0>$ 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 1.7th power of the electron beam energy, operation with the low energy electron beam strongly 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; 3.7 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-tetrapot was recorded. The ratio of the ultraviolet emission to the visible luminescence at the center of tetrapot is different from those of the points along the arm. This suggests that the central position is much defective 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. Albrecht, Institut fúr Werkstoffwissenschaften, Mikrocharakterisierung, Universität Erlangen-Nürnberg, GERMANY; J.M. Ulloa, J. Piqueras, Dpto. Fisica de Materiales, Facultad de Ciencias Fisicas, Universidad Complutense de Madrid, SPAIN; H.P. Strunk, Institut für Werkstoffwissenschaften, Mikrocharakterisierung, Universität Erlangen-Nürnberg, GERMANY; D. Hanser, and R.F. Davis, Deparment of Materials Science and Engineering, North Carolina State University, Raleigh, NC.

The correlation of the defect 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 Indium content up to 14 per cent has been grown by MOVPE on SiC substrates.An AlN and GaN layer of total thickness μm was used as a buffer layer. The In concentration was measured by X-ray diffraction, taking into account the pseudomorphic growth of the layers as observed by TEM. Structural measurements were completed with AFM images of the samples showing a high density of pinholes of about 50 nm diameter. The density of pinholes increases with the In content in the layers, which can be explained by elastic relaxation at pinholes. No misfit dislocations are observed at the interface between the InGaN layer and the GaN buffer layer, which would indicate plastic relaxation of the misfitted InGaN/GaN system. Optical characterization was carried out by means of reflectance spectrometry, 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 films induced by the Indium incorporation in the layer. Cathodoluminescence images show the spatial distribution of the emission sites. For pinholes with a diameter in the μm range we observe enhanced band edge luminesecence arround the pinholes, but a reduced luminescence at the apex of the pinhole. Comparism with finite element calculations shows that the luminescence is directly correlated with the strain disribution in the layer: enhanced strain correlates with reduced luminescence, while strain relaxation may enhance the luminescence. We discuss the influence of strain with respect to In incorporation, the appearence of piezoelectric fields and effects due to strain induced band bending.

2:30 PM P3.4
SCANNING CATHODOLUMINESCENCE OF InGaN THIN FILMS. N. Missert, 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 ambient temperature scanning cathodo-luminescence (SCL) 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 up to a factor of four at the highest In content examined to date. Scanning electron microscopy and atomic force microscopy indicate a high density of submicron surface pits for the In containing layers. SCL images show that the luminescence intensity can vary by up to a factor of three over a 16 μm by 16 μm scanned region, where for the In containing films, the surface pit position corresponds 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 brightest 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 multiprogram 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 BAND-A EMISSION IN HOMOEPITAXIAL DIAMOND THIN FILMS. D. Takeuchi[a], H. Watanabe[a,b], S. Yamanaka[a], H. Okushi[a] and K. Kajimura[b], Electrotechnical Lab, Tsukuba, JAPAN; H. Sawada,[a] H. Ichinose,[a] Dept of Material Science, Univ of Tokyo, Tokyo, JAPAN; T. Sekiguchi,[a] Institute of Material Science in Tohoku Univ, Sendai, JAPAN; [a]Also at CREST, JST (Japan Science and Technology Cooperation), and [b]Institute of Materials Science, Univ of Tsukuba, Tsukuba, JAPAN.

Diamond films grown by chemical vapor deposition (CVD) usually show band-A emission (2.95 eV) at visible area and no excitonic emission at room temperature by cathodoluminescence (CL). Recent progress in our study on homoepitaxial diamond films was obtained through the low CH_4/H_2 conditions by microwave-plasma chemical vapor deposition. These showed atomically flat surfaces and excitonic emission (5.27 eV) at room temperature, while band-A emission (2.95 eV) disappeared. On the other hand, when the CH_4 concentration was increased, homoepitaxial diamond films included unepitaxial crystallites (UC). Scanning CL measurement showed that the band-A emission only appeared at UC sites, while other flat surface parts still showed excitonic emission. High-resolution transmission electron microscopy (HRTEM) revealed that (111) $\Sigma3$ CSL boundaries were dominant in UC sites, and some other kind of grain boundaries such as (112) $\Sigma3$ or (114) $\Sigma9$ boundaries existed. Besides, there were grain boundary dislocations between UC and epitaxial region in the film. Because (111) $\Sigma3$ is a coherent boundary which never causes dangling bonds, these results suggest that the band-A originate from grain boundaries such as (112) $\Sigma3$ or (114) $\Sigma9$ and/or grain boundary dislocations in diamond film. In the literatures, the origin of band-A emission was pointed out to be attributed with 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
SPECTRALLY RESOLVED CATHODOLUMINESCENCE DETERMINATION OF DOPANT DIFFUSION IN InP/InGaAsP BASED MULTI QUANTUM WELL FABRY-PEROT LASERS. Carlo Zanotti-Fregonara, Claudio Ferrari, Laura Lazzarini and Giancarlo Salviati, CNR-MASPEC Institute, Parma, ITALY; Marina Meliga, Daniele Bertone, Rongyin Fang, Giuliana Morello, Roberto Paoletti, CSELT Laboratory, Torino, ITALY.

Low temperature monochromatic cathodoluminescence (CL) spectral analyses and imaging were used to determine the widths of resistive 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 contained nine 1% compressive InGaAsP strained wells (9 nm thick) and eight -0.8 tensile InGaAsP strained barriers (9.6 nm thick) and was sandwiched between two quaternary confinement regions (100 nm thick). The MQW was grown on an InP:Sn 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:Zn and InGaAs:Zn+ conctact layers. Two sets of devices were studied: i) with the active stripe etched by standard RIE (Reactive Ion Etching) (batch #34) and ii) with the active stripe obtained by the ISE (In Situ Etching) technique by using chlorinated compounds inside the MOCVD reactor (batch #48) (D. Bertone et al., J. Cryst. Growth 195, 624 (1998)). The widths of the resistive 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 invstigations. Resistive regions on each side of the MQW were found to be larger (680 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 dopant 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 NANOWHISKERS (NANOWIRES) ON A Si{111} SURFACE. N. Ozaki, Y. Ohno and S. Takeda, Dept. of Phys., Graduate School of Sci., Osaka Univ., Machikane-yama, Toyonaka, Osaka, JAPAN.

Many and various efforts have so far been made to study optical properties of nanostructures of semiconductors, such as nanowires and nanodots. Nanostructure semiconductors are expected to show distinctive optical properties from bulk semiconductors due to quantum confinement effects. Especially, silicon nanostructures have been predicted to show visible luminescence and, in fact, the luminescence has been reported in some cases. We have investigated optical properties of Si nanowhiskers[1] (nanowires) grown on a Si{111} surface via the vapor-liquid-solid (VLS) growth mechanism. The minimum diameter of the wires reaches the critical value at which the effect of quantum confinement comes out. We have utilized cathodoluminescence (CL) spectroscopy in a transmission electron microscope (TEM),which enables us to obtain both luminescence spectra and high resolution TEM images of whiskers simultaneously. Several broad peaks appeared in the visible (green-red) region of the CL spectrum measured at room temperature. The visible light emission was not observed from bulk Si. And at low temperature (20K), these luminescence peaks became sharp and their intensities were enhanced. We present the detailed characterizations of the luminescence and discuss the origin of the luminescence. [1]N. Ozaki, Y. Ohno and S. Takeda, Appl.Phys.Lett. 73, 3700 (1998).

4:00 PM P3.8
LUMINESCENCE FROM SELF-ORGANIZED QUANTUM WELL STRUCTURES IN CuPt-ORDERED GaInP. Y. Ohno and S. Takeda, Dept of Phys, GSS, Osaka Univ, Osaka, JAPAN.

Various kinds of planar 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 GaInP/InP quantum well structures are self-organized in planar defects in CuPt-ordered GaInP 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 GaInP 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_g - 8 meV, E_g - 14 meV, E_g - 20 meV, and E_g - 30 meV, in which E_g represents the energy gap) from the APBs. From the results of polarized CL spectroscopy, we propose a new model that GaInP/InP quantum well structures are self-organized in the APBs on (001) and $(\bar{1}1\bar{1})$ and an 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 InGaAs/GaAs MULTI QUANTUM WELL BASED SOLAR CELLS BY CATHODOLUMINESCENCE INTENSITY PROFILES. Massimo Mazzer, CNR-IME Institute, Lecce, ITALY; Keith W.J. Barnham, Imperial College of Science, Technology and Medicine, Physics Department, Blackett Laboratory, London, UK; Giancarlo Salviati, CNR-MASPEC Institute, Parma, ITALY.

Low temperature cathodoluminescence (CL) spectroscopy was used to study the strain field distribution around misfit dislocations (MDs) in MQW based InGaAs/GaAs solar cells (P. Griffin 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 930 nm. Monochromatic CL micrographs at 930 nm showed luminescence emitted only by a narrow region around MDs, the effect of 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 across MDs were analysed after eliminating spurious effects due to the non uniform light collection efficiency along the scan line (M. Mazzer, PhD Thesis, Imperial College of Science Technology and Medicine, London, UK (1998)). This was achieved by normalising the profiles acquired at different wavelengths to a reference one. At 930 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 about 1 micrometer to the left of the original one (918.2 nm). Going beyond the MQW peak, at 916.2 nm, a roughly specular profile was obtained with a maximum at about 1 micrometer 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 odd symmetry with respect to the misfit line. So, at one side of the dislocation the emitting material band gap increases due to the deformation potential, while the opposite occurs on the other side.

4:30 PM P3.10
HOMOGENEITY OF THERMALLY ANNEALED SI-LIGHTLY Fe-DOPED InP. M. Avella, J. Jimenez, E. de la Puente, Dept Fisica de la Materia Condensada, Univ de Valladolid, Valladolid, SPAIN; R. Fornari, MASPEC-CNR Institute, Parma, ITALY.

Semiinsulating (SI) InP is an important material for fabrication of integrated optoelectronic circuits and high frequency devices. SI-InP substrates are currently obtained by adding pure iron to the starting charge in the LEC growth procedure. Iron is a deep acceptor and compensates the residual shallow donors of the undoped InP crystals. Relatively large amounts of iron ($>10^{16}$cm^{-3})are necessary in order to obtain the semiinsulating behaviour with consequent drawbacks (inhomogeneity, Fe outdiffusion to epilayers grown on those substrates). Therefore, there is a trend to pursue a reduction of the iron content in the SI-InP crystals while improving the electrical properties. Different approaches have been attempted, among them annealing lightly Fe doped n-type InP. In the present work, semiconducting InP samples with low iron content ($\sim$4-5$\times10^{15}$cm$_{-3}$) have been annealed at 900°C for 60 hours in a phosphorus ambient. These samples have been studied by Hall effect, Scanning Photocurrent (SPC) and Scanning Photoluminescence (SPL) measurements. The resistivity increased up to about $8\times10^7\Omega$cm after annealing while SPC maps showed an homogeneous distribution of the electrically active Fe concentration [Fe_{In}]. SPL measurements also showed an uniform distribution of the substitutional [Fe_{In}]. It is interesting to note that our mappings do not reveal the presence of the growth striations, typical of as-grown LEC InP:Fe crystals. This implies that the Fe striations are dissolved during the thermal process, as 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 semiinsulating state, probably connected with a significant loss of residual donor complexes, and a redistribution of the dopant, with beneficial effects in terms of wafer uniformity.

4:45 PM P3.11
STUDY OF THE RADIATIVE AND NON-RADIATIVE RECOMBINATION PROCESSES AT DISLOCATIONS IN SILICON BY PHOTOLUMINESCENCE AND LBIC MEASUREMENTS. Sergio Pizzini, Simona Binetti, Maurizio Acciarri, Marco Casati, Milano-Bicocca Univ, INFM and Dept of Materials Science, Milano, ITALY.

It is well known that the sharp, room temperature luminescence emission at 1.54 μm 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 it of reconstruction, interaction or passivation processes, possibly assisted by metallic or non-metallic impurities. As an example, in the case of Er-doped samples an almost continous transition occurs from the Er luminescence to the dislocation luminescence as soon as the samples are heated at 1100°C in a oxidising 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 cleanest conditions, taking the deformation temperature sufficiently low to avoid the interference of oxygen segregation. 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: Sukekatsu Ushioda
Tuesday Morning, 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. Xiong Zhang, Soo-Jin Chua, 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 vapor deposition. The InGaN/GaN MQWs samples were characterized at room temperature by photoluminescence (PL) spectroscopy. It was found that the InGaN/GaN MQWs grown on the composite intermediate layers with double multilayered buffers gave rise to much more intense (2.5 times larger in PL Intensity) and sharper (40% less in PL peak line-width) green- (2.53 eV) and blue-light (2.76 eV) excitonic transitions, and highly suppressed GaN band-edge-related transition, as compared with the identical InGaN/GaN MQWs grown over conventional GaN and AlN single buffer, or the composite intermediate layers with only one multilayered buffer under the same reactor configuration and growth conditions. This fact indicates that by using the proposed composite intermediate layers with double multilayered 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 δ-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. Jagadish, Department of Electronic Materials Engineering, Research School of Physical 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 $2x10^{18}/cm^3$ and $2x10^{20}/cm^3$ in 4 nm 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 recombination shows a strong dependence on excitation intensity and temperature. Our results indicate hat this new emission is related to the transition between spatially separated electrons and holes. The holes are located in p-type Zn δ-doped region, while the electrons are located in the undoped GaAs region. The magnetic field dependence of this new emission in PL spectrum indicates that the effective mass of the holes involved in the optical transition is about 0.2 m_0. 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 PHOTOLUMINESCENCE. V. Higgs, Bio-Rad Micromeasurements 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 μm). The excitation laser beam is modulated to confine the photogenerated carriers; defects are detected due to the reduction of the localised recombination lifetime.
Si p-type (10 Ohm.cm) wafers were intentionally contaminated with various levels of Ni and Fe ($1x10^9$-$5x10^{10}$ 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, ($1x10^9$-5 $x10^{10}$ atoms/cm^2) the PL intensity actually increased initially and reached a maximum value at $5x10^9$ atoms/cm^2. It is suggested that during contamination the Cu related defects have complexed with existing defects (that have stronger recombination 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 ($1x10^{10}$-$1x10^{11}$ 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 analysed, 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 SrS:Cu THIN FILMS BY PULSED LASER DEPOSITION. D.C. Morton, D. Ravichandran, S. Blomquist, K. Kirchner, M.H. Ervin and J.Y. Choe, Army Research Laboratory, Adelphi, MD.

SrS:Cu thin-films were fabricated on to a Si (100) orientation using laser ablation technique. A typical deposition was done with a base pressure of 6 mT Argon & H_2S gas (5:1 ratio). Laser power was typically 550mJ/pulse at 50 Hz. with deposition time of 2.5 hr. 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 4.1-4.5 μm. Grazing angle X-ray diffraction pattern shows polycrystalline SrS films with a cubic structure. SEM micrograph shows crystallized particles with a grain size of 120 nm. EDAX analyses on these crystallites show Sr and S throughout the films without any secondary metal ions. However, the resulting films did not show any PL emission. The films were further crystallized by post annealing at different temperatures up to 1150°C in air atmosphere. Photoluminescence measurements on these annealed films showed a bright green emission broad band at 495 nm with excitation peak at 270 nm. AFM images of these films showed well defined with a 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 POROUS SILICON AND SILICON OXYNITRIDE. Xingsheng Liu, Jesus Noel Calata, Guo-Quan Lu, Virginia Polytechnic Inst and State Univ, Dept of Materials Science and Engineering, Blacksburg, VA; Hoyu Liang, Wangzhou Shi, Xuanyin Lin, Shantou Univ, Science Research Institute, Shantou, CHINA; G.G. Qin, Peking Univ, 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 it has promising applications in color displays and optoelectronic devices. The photoluminescene (PL) mechanisms for porous silicon (PS) as well as 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 (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 photoexcitation processes: (1) photo-excitation occurs in nanometer Si particles (NSPs) and in the Si oxide layers covering NSPs, and (2) radiative recombination of electron-hole pairs takes 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 440nm and 360 nm band are ascribed to O and N related LCs, respectively. As such, the quantum confinement/luminescence center model appears to be a satisfactory model in explaining the experimental results.

SESSION P5: NEAR-FIELD TECHNIQUES II
Chair: Bennett B. Goldberg
Tuesday Morning, November 30, 1999
Salon C/D (M)

10:30 AM *P5.1
NEAR-FIELD PHOTOCURRENT STUDIES OF DISLOCATION ELECTRICAL ACTIVITIES IN RELAXED GeSi FILMS. Julia W.P. Hsu, Matthew H. Gray, Qin Xu, 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 (001) 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 photoresponse, making it possible to correlate electrical activities 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 quantitatively 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 anisotropic 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 NSOM. 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 imaging, but also, by simultaneously measuring 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 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 obtain time resolution 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 CHARACTERIZATION BY SCANNING NEAR FIELD OPTICAL MICROSCOPE. Xavier Borrise, Nuria Barniol, Francesc Perez-Murano, Gabriel Abadal, Xavier Aymerich, 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 10 nm and vertical resolution of 1 nm, and the optical field distribution have been obtained. Images obtained over rib waveguides show the guided mode intensity distribution, allowing to characterize the propagation of the light in the device for up to 1mm. 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 to study the behaviour of the light in such a small devices.

11:45 AM P5.4
STM-LIGHT EMISSION FROM METAL DEPOSITED SEMICONDUCTOR SURFACES. Naoki Yamamoto, Shigeru Kagami, Hiroki 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 monochrometer, and detected by a photomultiplier tube (PMT) and a CCD detector. An emission spectrum is measured by a CCD detector, and a photon map 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 multipole modes of the local plasmon excited in a gap region between the tip and the surface. A photon map taken at 80 K showed a uniform contrast for a flat terrace 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)7x7 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
MICRO-RAMAN CHARACTERIZATION OF ARSENIC-IMPLANTED SILICON: INTERPRETATION OF THE SPECTRA. James P. Lavine and David D. Tuschel, Eastman Kodak Company, Rochester, NY.

Ion implantation introduces disorder into semiconductors and the resulting Raman spectra are related to the crystalline semiconductor's 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 polarization/orientation (P/O) micro-Raman spectroscopy. The arsenic was implanted at 150 keV through a 0.06 nm-thick thermal oxide into (100) silicon and the dose varied from 2 x 10^{13} to 5 x $10^{15}/cm^2$. 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 $10^{14}/cm^2$, 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. Si-As vibrations are reported to occur at Raman shifts of 360 cm^{-1} or less. Attempts to understand the origins 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 520 cm^{-1} band that are much less than the data. In addition, the P/O 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
DEPTH-RESOLVED MICRO-SPECTROSCOPY OF POROUS SILICON MULTILAYERS. S. Manotas, F. Agulló-Rueda, Materials Science Institute of Madrid (CSIC), SPAIN; J.D. Moreno, R.J. Martín-Palma, R. Guerrero-Lemus, J. M. Martínez-Duart, Autonomous Univ of Madrid, Dept of Applied Physics, SPAIN.

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 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 asymmetrically towards the low energy side. The lineshape 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 480 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 use the change of frequency with depth to monitor the stress. 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 CATHODOLUMINESCENCE MICROANALYSIS OF POROUS GaP MEMBRANES. I.M. Tiginyanu, I.M. Tiginyanu, Technical Univ of Moldova, Chisinau, Moldova; M.A. Stevens Kalceff, Microstructural Analysis Unit, Univ of Technology, Sydney, AUSTRALIA; A. Sarua, G. Irmer, J. Monecke, Technical Univ, Freiberg, GERMANY; H.L. Hartnagel, Technical Univ, Darmstadt, GERMANY.

Free-standing porous GaP membranes were fabricated by anodic 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. Micro-Raman analysis of the interaction between the longitudinal optical phonons and plasmons in porous membranes performed by using a Jobin-Yvon triple spectrometer allowed us to obtain specific information about the electro-optical properties of microstructured GaP. In particular, apart from carrier exhausted areas 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. Cathodoluminescence (CL) microanalysis with spectral resolution of 5 nm was carried out at accelerating voltages 15-30 keV in the temperature interval from 80 to 300 K. Along with two overlapping 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 huge surface upon charge carrier behavior and emission characteristics of porous GaP is discussed.

2:15 PM P6.4

RAMAN SCATTERING STUDY ON InP/InGaAs/InP HEMTs. K. Radhakrishnan, T.H.K. Patrick, P.H. Zhang, 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 $6x10^{17}/cm^3$ to $2.5x10^{18}/cm^3$ in the donor layer of $In_xGa_{1-x}As/InP$ 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 $In_xGa_{1-x}As/InP$ HEMT samples, with the two LO modes (InAs-like LO and GaAs-like LO) located at 226 cm^{-1} and 268 cm^{-1}, respectively. At a frequency of $347cm^{-1}$ 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 assuming that the donors are fully ionized. 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 follows the theoretical prediction. As the InGaAs channel thickness was increased from 140Å to 260Å, the InAs-like LO mode peak shifted to a lower wavenumber from $235.4cm^{-1}$ to $228.5cm^{-1}$ while that of GaAs-like LO mode remained at a constant wavenumber of $268cm^{-1}$.

2:30 PM P6.5

RAMAN SPECTROSCOPY OF ULTRAHEAVILY DOPED POLYCRYSTALLINE SILICON FILMS. N.H. Nickel and P. Lengsfeld, 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 $\AA$ 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 (B_2H_6), 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 $\approx$1000 $\AA$ to $\approx$ 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 wavenumber 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 characteristic resonances are due to a resonant interaction 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: Nader M. Kalkhoran
Tuesday Afternoon, November 30, 1999
Salon C/D (M)

3:15 PM *P7.1

OPTICAL AND MICROSTRUCTURAL CHARACTERIZATION OF NANOCRYSTALLINE SILICON SUPERLATTICES. L. Tsybeskov, Department of Electrical and Computer Engineering, University of Rochester, Rochester, NY.

Nanocrystalline silicon superlattice (nc-Si SLs) is a stucture consisting of Si nanocrystal layers separated by nanometer-thick SiO_2. This work is focused on nanoscale Si structure metrology. Number of characterization techniques such as transmission electron microscopy (TEM) and atomic force microscopy (AFM), Auger elemental microanalysis, X-ray diffraction and X-ray small angle reflection have proved that the nc-Si SL exhibits very narrow nanocrystal size distribution (less than 5% in average) and very abrupt and flat nc-Si/SiO_2 interface with a roughness of $< 4\AA$. A long range order in the nc-Si SL is obtained along the direction of growth by periodically alternating layers of Si nanocrystals and SiO_2; the observation of folded acoustic phonon modes in Raman scaterring shows that the quality of the Si/SiO_2 interfaces and the layer periodicity are almost comparable with conventional superlattices grown by very precise (and expensive) techniques such as MBE or MO CVD.
Phonon-assisted tunneling is observed in a bipolar nc-Si based structure, which confirms that the nc-Si/a-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 nc-Si SL quantum device applications.

3:45 PM *P7.2

MICROSTRUCTURAL CHARACTERIZATION OF ANTIMONIDE BASED III-V COMPOUNDS AND THEIR EFFECT ON ELECTRO-OPTICAL PROPERTIES OF SUBSTRATE MATERIALS AND DEVICES. Partha S. Dutta, Ronald J. Gutmann, Rensselaer Polytechnic Institute, Electrical, Computer and Systems Engineering Department, Center for Integrated Electronics and Electronics Manufacturing, Troy, NY; Greg W. Charache, Lockheed Martin Inc., Schenectady, NY; C.A. Wang, MIT-Lincoln Laboratory, Lexington, MA.

Antimonide based III-V compounds (GaSb and related ternaries and quaternaries) are becoming increasingly popular for long wavelength lasers, photodetectors, and thermophotovoltaic 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-reflectance Spectroscopy. The optical properties obtained from these techniques are correlated with chemical and structural characteristics of materials studied through X-ray and Transmission Electron Microscopic techniques. Specific examples include: the role of iso-electronic and transition metal dopants on native defects, phase separation and alloy inhomogeneity in ternary, and quaternary compounds; the effect of microstructure and dopants on the carrier lifetime 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 PM P7.3

OPTICAL PROPERTIES OF PSEUDOMORPHIC Sn_xGe_{1-x} ALLOYS. Regina Ragan and Harry A. Atwater, Thomas J. Watson Laboratory of Applied Physics, California Institute of Technology Pasadena CA.

The Sn_xGe_{1-x} semiconductor alloy system exhibits a tunable energy bandgap which undergoes an indirect-to-direct energy gap transition with a corresponding high oscillator strength near x = 0.11, as determined by thickness-dependent infrared transmittance measurements. For strain-relieved films, the direct energy 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_xGe_{1-x} alloy suitable for optoelectronic applications in the 2-4 micron range. Recently we have grown homogeneous pseudomorphic, dislocation-free Sn_xGe_{1-x} /Ge by molecular beam epitaxy, with structural characterization by X-Ray reflectivity measurements coupled with Rutherford backscattering spectroscopy. Infrared transmittance and reflectivity measurements have been performed on pseudomorphic Sn_xGe_{1-x} alloy films coherent to a Ge(001) substrate indicate a similar indirect-to-direct gap transition with increasing Sn composition. Deformation potential theory analysis of strain-induced splitting of band critical points, as well as new developments in the optical properties and formation of Sn quantum dot structures via phase separation during thermal annealing of initially compositionally homogeneous Sn_xGe_{1-x} alloy films will be discussed.

4:30 PM P7.4

ZnO POWDER LASERS. E.W. Seelig, R.P.H. Chang, Northwestern University, Dept of Materials Science and Engineering, Evanston, IL; J.Y. Xu, H. Cao, Northwestern University, Dept of Physics and Astronomy, Evanston, IL.

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, and its lasing properties, measured with various photoluminescence techniques. [1] H. Cao, et al, Phys. Rev. Lett. v. 82, p. 2278 (1999).

4:45 PM P7.5

GRAIN STRUCTURES AND LASING PROPERTIES IN ZnO FILMS. Xiang Liu, Northwestern Univ, Dept of Materials Science and Engineering, Evanston, IL; Junying Xu, Hui Cao, Northwestern Univ, Dept of Physics and Astronomy, Evanston, IL; Robert P.H. Chang, Northwestern Univ, Dept of Materials Science and Engineering, Evanston, IL.

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 glass. By controlling the growth temperature and film growth rate, different grain sizes and crystallinity were obtained. SEM and AFM revealed that 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 50~100nm. 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 this width was greater than one degree, no lasing was observed up to very high pumping energy. However, the lasing threshold didn't increase monotonously 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.
Exhibition Hall D (H)

P8.1

OPTICAL ABSORPTION AND LUMINESCENCE STUDY OF THE EFFECT OF THERMAL TREATMENTS ON THE POROUS SILICON SURFACE. R. Plugaru, G. Craciun, Institute of Microtechnology, Bucharest, ROMANIA; M. Bercu, Faculty of Physics, University of Bucharest, ROMANIA; J. Rams, J. Piqueras, Departamento de Fisica de Materiales, Facultad de Fisicas, 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^{-1}cm. 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 PHOTOVOLTAIC DEVICES. B. Ünal, A.N. Parbukov and S.C. Bayliss, Solid State Research Centre, Faculty of Applied Sciences, De Montfort University, The Gateway, Leicester, UNITED KINGDOM; V.I. Beklemyshev, V.M. Gontar, I.I. Makhonin, State Research Institute for Problems in Physics after F.V. Lukin, Zelenograd, Moscow, RUSSIA. S.A. Gavrilov, Moscow 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 areas by standard photoresist methods, and the process can be applied at any suitable technological stage of microelectronic manufacture. The porous Si produced has a strongly 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 stain-etched PS surface has been 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 electroless 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, Licai Wang, Scott Summers and Hari Reehal, 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 PH_3 gas introduced into the growth chamber to make the films n-type. Estimates of film crystallinity and stress are made from the frequency and lineshape of the main Raman band of silicon, and from x-ray diffraction patterns. Crystallinity and stress are related to the PH_3 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. Ila, Center for Irradiation of Materials, Alabama A&M University, Normal, AL; D.B. Poker, D.K. Hensley, 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 occured. The Raman spectra reveal whether annealling has substantially removed the implantation damage.

Acknowledgements: This work is supported by the Center for

Irradiation of Materials at Alabama A&M University and NASA-LeRC Contract No. NAG3-2123. The work at ORNL was sponsored by the Division of Materials Science, US Department of Energy, under Contract DE-AC05-96OR22464 with Lockheed Martin Energy Research Corp.

P8.6
ANALYSIS OF THE CRYSTALLIZATION KINETICS AND MICROSTRUCTURE OF POLYCRYSTALLINE SiGe FILMS BY OPTICAL TECHNIQUES. J. Olivares[a], P. Martin[b], A. Rodriguez[a], J. Sangrador[a], J. Jimenez[b], T. Rodriguez[a]. [a]E.T.S.I.T.-U.P.M., Madrid, SPAIN. [b]Universidad de Valladolid, Valladolid, SPAIN.

Polycrystalline SiGe films are of interest for the fabrication of thin film transistors. In this work, X-ray diffractometry, Raman spectroscopy and ultraviolet reflectance 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 on oxidized Si wafers. The Ge fraction of the films was in the 0-0.4 range. The samples were crystallized at temperatures ranging from 550 to 600°C. Raman spectra were acquired using the 514.5 nm line of an Ar^+ laser. UV reflectance spectra were measured in the 200 to 400 nm wavelength range. The crystalline fraction of the films was determined as a function of the annealing time using: a) the 111 peak of the X-ray diffraction curves, b) the integrated intensity of the Si-Si Raman band of the crystallized phase, and c) the area under the characteristic peak around 280 nm of the reflectance spectra. The results from X ray diffractometry and Raman spectroscopy are representative of the whole film thickness. The absorption depth of the UV radiation is around 4 nm for the wavelengths of interest, and therefore only the top surface region is analyzed. The crystalline fraction vs. the annealing time data were fit using Avrami's model and the characteristic parameters of nucleation and growth were so extracted. For samples with Ge fractions below 0.3 the three experimental techniques yield the same Avrami's curves, pointing to an equivalent nucleation and growth mechanisms in the film volume and in the surface region. For Ge fractions above 0.3 and crystallization temperatures above 575°C, the Avrami's curves obtained from reflectance measurements were shifted toward longer times. The crystallinity, texture and residual stresses of the fully crystallized films were also determined from the measurements. A discussion of these results is presented.

P8.7
MICRO-RAMAN CHARACTERIZATION OF UNUSUAL DEFECT STRUCTURE IN ARSENIC-IMPLANTED SILICON. David D. Tuschel, James P. Lavine, 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, no longer restricted to phonons of zero crystal momentum, 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 arsenic implantation of silicon. Off-axis, macro-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 was found for orientational dependent lattice damage and an unusual defect structure. Polarization/Orientation micro-Raman spectra reveal a band between 505 and 510 cm^{-1} with a crystal orientation dependence similar to that of the silicon optical mode at 520 cm^{-1} but whose signal variation is 45° out of crystallographic phase with respect to the 520 cm^{-1} substrate Si band.

P8.8
RAMAN MICROPROBE ANALYSIS OF SELECTED SEMICONDUCTORS SUBJECT TO CONTACT LOADING. Vladislav Domnich, Yury 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. This kind of loading has a very significant nonhydrostatic 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 and fast tool for both in-situ and ex-situ monitoring of pressure-induced phase transformations in semiconductors. In the present work, study of high-pressure phase transformations and amorphization under indentation in selected semiconductors (diamond, SiC, 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
CONFOCAL MICRO-RAMAN CHARACTERIZATION OF SiC EPILAYERS. Ran Liu, Motorola, Embedded Systems Technology Laboratories, Mesa, AZ.

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 (~ 0.8 μm) and depth resolution (~ 2 μm). Both lateral and depth variation of the free electron concentration and scattering time were measured from n^- SiC epi layers on n^+ SiC substrates and from H^+ implanted SiC. A defect phase induced by oxidation process was also analyzed as function of the depth and the lateral positions.

P8.10
CHARACTERIZATION OF GALLIUM ARSENIDE CRYSTALS GROWN UNDER MICROGRAVITY CONDITION BY CATHODOLUMINESCENCE. Chengji Li, Yunyan Li, Lanying Lin, Xingru Zhong, Nuofu 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 attached great importance to the scientists. The samples were Te, Si heavily doped GaAs and undoped semi-insulating GaAs crystals that were grown from melt under microgrvity condition in the Chinese recoverable satellites. A home-made cathodoluminescence(CL) system attached to the JXA-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 quite uniform of distribution. A very clear region near the interface was grown in a good growth condition. The Marangoni 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-growth 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 was 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 confimed this result.

P8.11
STUDY OF SOLID PHASE RECRYSTALLIZED ZINC SELENIDE BY CATHODOLUMINESCENCE MICROSCOPPY. A. Urbieta, P. Fernández, J. Piqueras, Dept. Física de Materiales, Fac. Físicas, Univ. Complutense, Madrid, SPAIN; V. Muñoz, Dept. Física Aplicada-Ito. Ciencia de Materiales, Univ. Valencia, Valencia, SPAIN.

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, Se-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 (2.5-2.6eV region) as well as to the point defect structure (2.0-2.5eV region). In the near infrared range the recrystallized samples show several luminescence bands between 0.8eV and 1.5eV. 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 ranges. The presence of annealing twins, and possibly cubic regions, in the samples is revealed by a strong CL contrast.

P8.12
STUDY OF GaSb p-n JUNCTION DEVICES BY CATHODOLUMINESCENCE AND SCANNING TUNNELING SPECTROSCOPY. Pedro Hidalgo, Bianchi Méndez, Javier Piqueras, Facultad de Físicas, Universidad Complutense, Madrid, SPAIN; Partha S. Dutta, Dpt. Electrical, 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 by scanning tunneling spectroscopy. The junction depths, measured by SIMS, varied in the different samples from 0.4 μm to 1 μm. CL plan-view observations of the Zn diffused side enable to study the homogeneity of the diffusion treatment. 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 CITS (Current Imaging Tunneling Spectroscopy) in the n and p sides of the junction, clearly show the respective conductive behaviour and provide the values of the surface band gaps. Surface band gaps are lower than in undoped material and in some areas of the p-side a nearly metallic behaviour is observed in the conductance curves. The mentioned characterization techniques are used to control the quality of the junctions prepared by different diffusion methods.

P8.13

CATHODOLUMINESCENCE FROM $In_xGa_{1-x}As$ LAYER GROWN ON GaAs USING A TRANSMISSION ELECTRON MICROSCOPE.
Naoki Yamamoto, Tomohiro Mita, Dept of Physics, Tokyo Inst Technology, Tokyo, JAPAN; Stefan Heun, Alfonso Franciosi, Laboratorio TASC-INFM, Trieste, ITALY; Jean-Marc Bonard, Dept de Physique, EPFL, Lausanne, SWITZERLAND.

$In_xGa_{1-x}As$ epilayers grown on GaAs (100) were studied by cathodoluminescence (CL) spectroscopy with a 0.8 nm resolution, combined with a transmission electron microscope. The ternary layers were grown by molecular beam epitaxy at 490°C with nominal x=0.04 composition and 2 μm nominal thickness. The substrates were GaAs(001) wafers, on which 150nm-thick GaAs(001)2x4 buffer layers were grown at 600°C. In these conditions the ternary layers is expected to be largely relaxed, through the formation of a network of misfit dislocations oriented along perpendicular [110] and [1$\bar{1}$0] directions. The peak intensity of the CL emission from the $In_xGa_{1-x}As$ epilayer was observed at wavelength of 868 nm at 35 K. However, low-temperature monochromatic CL images showed well-defined inhomogeneities in the spectral emission giving rise to linear features along the [110] and [1$\bar{1}$0] directions. In particular, 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 peak 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 $In_xGa_{1-x}As$ layer, i.e., from In-rich region 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 inhomogenities.

P8.14

STUDIES OF PHOTOREFLECTANCE IN $Cd_{1-x}Mn_xTe$/ $Cd_{1-y}Mn_yTe$ SUPERLATTICES.
Chenjia Chen, Xuezhong Wang, Haitao Li, Xiaogan Liang, Guangyu Chai, Peking University, Department of Physics, Beijing, CHINA; Zheng Ning, Xun Wang, Fudan University, Surface Physics Laboratory, Shanghai, CHINA.

Studies of photoreflectance (PR) spectroscopy on a series of $Cd_{1-x}Mn_xTe/Cd_{1-y}Mn_yTe$ superlattices (SLs) have been investigated at liquid nitrogen and room temperature. A series of samples with different wells of $Cd_{1-x}Mn_xTe$ (x=0-0.01) and barriers of Cd$_{1-y}$MnyTe (y=0.3-0.8) were grown by molecular-beam epitaxy (MBE) technique on (001) GaAs substrates. A CdTe buffer of ~0.5 μ was grown on the substrate. Photoreflectance spectra obtained for typical samples exhibit derivative structures which correspond to the heavy- and light-hole interband excitonic transitions from the quantized conduction-band states. With a least-square fit of a line shape function, the transitions above E_o(GaAs) and E_o(CdTe) can clearly be identified as confined 11H, 11L, 22H, 33H 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 $Cd_{1-x}Mn_xTe/Cd_{1-y}Mn_yTe$ 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 extreme and split the degeneracy of the heavy and light-hole valence band edge. 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 calculations 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. 19874005)

P8.15

NONDESTRUCTIVE ANALYSIS OF CURRENT GAIN OF InP/InGaAs HETEROJUNCTION BIPOLAR TRANSISTOR STRUCTURES USING PHOTOREFLECTANCE SPECTROSCOPY.
Hiroki Sugiyama, Noriyuki Watanabe, Kazuo Watanabe, Takashi Kobayashi, NTT Photonics Laboratories, Atsugi-shi, Kanagawa, JAPAN; Kazumi Wada, MIT, Dept. of Material Science and Engineering, Cambridge, MA.

We have measured the photoreflectance (PR) spectra from InP/InGaAs heterojunction bipolar transistor (HBT) wafers 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/n-InP emitter layer/p^+-InGaAs base layer/undoped InGaAs collector layer/n^+-InGaAs subcollector layer and identical in all samples. The base layer quality was the most important factor in the determination of the current gain and was intentionally controlled by changing the growth temperatures. PR spectra clearly showed 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 fields calculated by the analysis of FKOs were almost the same value, the PR intensity of the maximum peak in the FKOs decreased from 1.5E-4 to 5E-5 as the current gain decreased from 330 to 72. The reduction of the PR intensity means that the density of the nonradiative recombination centers in the emitter region increases [1]. For a single n-InP layer without a junction with a p^+-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 layer 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. Nakanishi et al. Jpn. J. Appl. Phys. 32 (1993) 6206.

P8.16

PHOTORMODULATION SPECTROSCOPY AND IMAGING OF QUANTUM STRUCTURES USING NEAR-FIELD SCANNING OPTICAL MICROSCOPE.
Yong-Hoon Cho, Sang-Kee Eah, S.C. Hhong, 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 PR results. The PL and PLE measurements were carried out using a 488 nm line of a 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 illumination mode with lens collection and the hybrid mode of 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 (NFPR) measurements, the pump and probe beams were focused into one single mode fiber tip using a 2 $\times$ 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 NFPR experiments were carried out as a function of the excitation intensity, sample-tip distance, and sample position. As a result, the NFPR technique allows us to have the several advantages to overcome shortages of conventional near-field optical techniques; (i) a 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.

P8.17

MICROCHARACTERIZATION OF ELECTRON EMISSION PROPERTIES OF BORON DOPED POLYCRYSTALLINE DIAMOND BY THE CURRENT IMAGING TUNNELING SPECTROSCOPY (CITS) MEASUREMENT.
Yangdo Kim, Woon Choi, Fukuoka Industry Science & Technology Foundation, Fukuoka, JAPAN; Yoichi Iseri, Kyushu Mitsumi Ltd, Fukuoka, JAPAN; Toshihiro Ando, Core Research for Evolutional Science Technology, Tsukuba, JAPAN; Hideyoshi Wakimoto, Hajime Tomokage, Fukuoka Univ, Dept of Electronics Enigineering and Computer Science, Fukuoka, 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 filed. 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 of electron emission site 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 10nm were observed to be 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 showed stable and reproducible electron emission over several measurements. The current imaging tunneling spectroscopy (CITS) study showed that high electron emission at some crystalline phases while other phases showed relatively no measurable electron emission. The CITS study also revealed that the electron emission initiated at the grain boundaries rather than on top of the grains, 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. Landi, Universidad de Buenos Aires, Facultad de Ciencias Exactas y Naturales, Dpto de Fìsica, 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. This thermal noise limits the use of light modulation when very high spatial resolution is desired in fluorescence or nonlinear optics near field experiments, being an extreme case the measurement of the optical rectification with scanning tunneling microscopes. 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 direction. 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 to 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.

P8.19
QUANTUM CONFINEMENT OF E_1 AND E_2 TRANSITIONS IN GE QUANTUM DOTS EMBEDDED IN AN Al_2O_3 OR An AlN MATRIX. C.W. Teng, J.F. Muth, R.M. Kolbas, North Carolina State University, Dept of Electrical and Computer Engineering, Raleigh, NC; K.M. Hassan, A.K. Sharma, J.Narayan, North Carolina State University, Dept of Materials Science and Engineering, Raleigh, NC.

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 an Al_2O_3 or an AlN matrix were deposited on sapphire substrates by pulsed laser deposition. The average dot sizes (73 Å to 260 Å) 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 E_1 and the E_2 transitions in the absorption spectra at room temperature and 77 K shift toward higher energy (ΔE_1=1.19 eV; ΔE_2=0.57 eV) as Ge dot size decreases (73 Å). 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/GaAs QUANTUM DOTS. X.C. Wang, S.J. Chua, 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 Stranski-Krastanow growth mode are of great interest due to their fundamental physics and potential device applications. Among them, InAs/GaAs QD is a representative system, which 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 and around them, which strongly affect the electronic structure, 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 for the photoluminescence emission from the interband transitions and infrared absorption due to the intersubband transitions in the dots. Therefore, further developments in the use of QD structures for devices such as lasers and detectors depend on the achievement of tunability of dot shape and sizes in order to both 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/GaAs quantum dots due to interface 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 atom interdiffusion in the annealed samples. This work shows ability to tune the wavelength for applications like infrared detectors and lasers based on intrasubband transitions of self-assembled QDs.

P8.21
EXCITONS IN GaAs/AlAs HETEROSTRUCTURES WITH INTERFACE CORRELATION. M.V. Belousov, A. Yu. Chernyshov, I.E. Kozin, Inst of Physics, St. Petersburg State Univ, St. Petersburg, RUSSIA; C. Ell, H.M. Gibbs, G. Khitrova, Optical Sciences Center, Univ of Arizona, Tucson, AZ.

We have demonstrated interface correlation effect (the memory of previous surface form) for AlAs layers in grown heterostructures. This is the new way for improving AlAs interface under the growth conditions that are optimal for GaAs quantum wells (QW's). We use interface correlation effect to enlarge macroroughness of the GaAs QW bottom interface (AlAs surface) to the scale of the top one (GaAs surface). To do this each barrier of the QW has been formed by a short-period GaAs/AlAs superlattice (SL) grown with growth interruptions after GaAs. 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 GaAs QW thickness. But when the AlAs 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 narrowest exciton linewidth occurs when the AlAs layer thickness is an integer number of monolayers. Then each AlAs surface almost reproduces the large-island GaAs surface just below it, providing a better GaAs-on-AlAs interface on which to grow the QW.

P8.22
PHOTO-INDUCED CURRENT SPECTROSCOPY IN UNDOPED CVD DIAMOND FILMS. E. Borchi, M. Bruzzi, D. Menichelli, S. Pirollo, S. Sciortino, Dipartimento di Energetica, 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^{-3} torr vacuum condition. The traps have been 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 spectrum is generated by processing 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 observed by subsequently heating the samples with different constant heating rates. Both TSC and PICTS spectra have shown dominant peaks around 550 K. These signals have been simultaneously analyzed to carry out a signature of any deep levels consistent with the two different techniques. The coupled 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 bands, corresponding to a total defect concentration of the order of 10^{19} cm^{-3}.

P8.23
MICROVOIDS IN POLYCRYSTALLINE CVD DIAMOND.
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The microstructure of CVD diamond is influenced by the columnar nature 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 of both electrical and mechanical properties of the materials. While void structures on the order of 1-10 microns have been observed in diamond 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 bulk of the material. Two optical methods have been used. Small angle light scattering is used to obtain voids 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 a mechanical failure and will allow the modification of growth processes to reduce the presence of voids.

P8.24
PHOTOEMITTERS BASED ON GLASS-ITO STRUCTURES.
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The work contains results of investigations on the phenomena of the electron emission and photoemission in thin oxide layers (ITO) in which internal electric field has been generated. Basing on the Malters effect [1] the sample was a glass with conducting films evaporated on its both sides [2]. One film (In_2O_3:Sn) of the thickness 10÷20nm was the emitting surface. The other, of thickness 1μm, was polarized in order to create an internal field (field electrode). The internal electric field was created by applying a negative voltage U_{pol} to field electrode (-2000V÷OV). Evaporation was made by reactive ion sputtering. The investigations were performed in the vacuum of the order 10^{-6}Pa. As a result of applying U_{pol} 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 analyser. The amplitude spectra N(U) = f(U) (for various U_{pol}) were measuremed for unilluminated samples and illuminated by a quartz lamp type XBO 150. The N(U) = f(U) dependence can approximately described by a Gauss function [3]. This was done using a computer programme with the non-linear regression method which also allowed to determine the best fit parameters. At U_{pol} = -500V it is impossible to describe the spectrum by a single gaussian and at U_{pol}, = -2000V we have to use three gaussian curves. Electron emission yield dependence on the intensity of an internal field and illumination were measured. With increasing U_{pol} and after illumination the count frequency n of pulses grows monotonically. At low U_{pol}, ($\leq$ |-700V|) the increase is linear. At higher U_{pol}, this dependence is exponentional (n = k exp(aU_{pol}). This may be an evidence that the electric field initiates electron collisions which proceed according to impact ionization mechanizm. Energy analysis of emitted electrons was performed by the retarding field method. Measurements of electrons energy in field induced emission showed that about 80% o electrons have energy up to 10 eV but some electrons (a few percent) of energy about 50 eV are also detected.
[1] L. Malter, *Phys. Rev.*, 49, p.478, 1936.
[2] J. Olesik, B. Calusiński, *Thin Solid Films*, 238, p.271, 1994.
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P8.25
PHOTOINDUCED CURRENT SPRECTROSCOPY IN THE QUANTUM HALL REGIME.
Andreas Böhm, Barbaros Özyilmaz, Joachim Heil, Uwe Beyer and Peter Wyder, Hochfeld-Magnetlabor, 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 the carrier transport in a two-dimensional electron gas (2DEG). A laser-beam is coupled into an optical fiber, which can be scanned by a mechanical cryogenic micropositionning device. Due to the photoelectric effect carriers can be injected into the 2DEG at the point of illumination. To record a carrier 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 sensible and allows resolutions better than 4μm to visualize the potential profile of the 2DEG in a standard Hall bar device at low temperatures and in high magnetic fields. We see flux channels due to the edge confining potential. At higher magnetic fields B the potential profile is peaking near the edge with an HWFM of less than 10μm. The observed features 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 polarity of these oscillations depend on the mobility of the sample, on the position of the light spot, on the illumination power and on a 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 method is a useful tool to characterize the current transport in two-dimensional heterostructure devices especially at high magnetic fields.

P8.26
DETERMINATION OF OPTICAL PROPERTIES OF FLUOROCARBON POLYMER THIN FILMS BY A VARIABLE ANGLE SPECTROSCOPIC ELLIPSOMETRY.
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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 300-800 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/roughened FC/FC/Si). The regression analysis was performed using the three-phase model and a best-fit mean 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 0.531 (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 (B-EMA). We found that the best-fit MSE was reduced when surface roughness was included.

P8.27
OPTICALLY INDUCED CONDENSATION OF IMPURITIES EXCITATIONS IN TRANSPARENT SOLIDS.
Edward A. Manykin, Pavel P. Poluektov, RRC Kurchatov Inst; Michael I. Ojovan, SIA Radon, Applied Research Center, Moscow, RUSSIA;

The interaction of electromagnetic radiation with impurities in transparent solids is studied for the case when interaction between excitations become significant. It is shown, that intense optical radiation leads to condensation of impurities excitations. The condensed excited state, consisting of excited impurities, is an energetically favorable phase, which minimize the energy of the system. Nevertheless condensation, as a rule, causes mechanical stresses, in some cases followed by breaches of solids. The physical and mathematical foundations of condensation of excitations are considered. It is shown that condensation occurs when overlapping of excitations wave-functions become significant. Critical density of impurities excitations, when condensation occurs, it 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 a not purely electronic character. Condensed excited state's equation is 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 stresses arising in the impurity system are determined by zero isotherm of condensed excited state. It is shown that due to these stresses the impurities may be redistributed considerable in the material. Conditions for breaking pints are determined, when matrix are destructed by optically induced stresses. The possibility of formation of non-equilibrium defects in the crystal lattice of transparent material is discussed. Assessments of changes of both absorption and recombination spectrums 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 a transparent material due to condensation of impurities excitations. REFERENCE: J. Moscow Phys. Soc., vol. 8 (1998), p.19-22.

P8.28
HYBRIDAZATION IN ELECTRONIC STATES AND OPTICAL PROPERTIES OF COVALENT AMORPHOUS SEMI-CONDUCTORS.
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The electronic structure and optical properties of covalent amorphous semiconductors are theoretically studied with special attention to the s-p hybridization in electronic states and the spatial correlation of atoms. One-dimensional tight binding model is 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 interatom transfer energy of an electron 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 10 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 band 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 hybridazation. 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.

P8.29

VIEWPORT INFLUENCE ON PROCESS AND IN-SITU MEASUREMENTS IN MOCVD VERTICAL ROTATING DISC REACTORS. Anton Prokopenko, Alexander Gurary, 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.

P8.30

ENERGY BEHAVIOR OF NEGATIVELY CHARGED MAGNETO-EXCITONS IN QUANTUM WELLS AND HETEROJUNCTIONS. F.M. Munteanu[1,2], Yongmin Kim[1], C.H. Perry[1,2], D.G. Rickel[1], J.A. Simmons[3] and J.L. Reno[3]; [1]NHMFL-Los Alamos National Laboratory, Los Alamos, NM; [2]Northeastern University, Boston, MA; [3]Sandia 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 received increasing attention recently. Our experimental investigations performed on modulation and δ-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 (X_t) and singlet (X_s) 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 δ-doped QW with a well-width of 20 nm, the X_t and X_s 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 whole range of available fields. The appearance of the negatively charged X_t and X_s states are directly related to the formation of the non-localized neutral exciton (X^0). The experimental results confirm theoretical predictions that the higher Landau levels and higher energy subbands play an meaningful role in their energetic evolution.

P8.31

CHARACTERIZATION OF SILICA-BASED WAVEGUIDES USING CONFOCAL RAMAN MICROSCOPY. M.J. Matthews, A. Harris, A.J. Bruce 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 $(0.3\mu m)^2$ laterally and $1.3\mu m$ 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 phosphorus 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 (D_1 and D_2) found in the Raman spectra of vitreous SiO_2 at $\sim$490cm^{-1} and $\sim$600cm^{-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.