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E-MRS Spring Meeting 2002
June 18 - 21, 2002

SYMPOSIUM E

Advanced Characterisation of Semiconductor Materials and Devices

Symposium Organizers:

Vito Raineri, CNR - IMETEM, Catania, Italy

Yossi Rosenwaks, Tel-Aviv University, Israel

Wilfried Vandervorst, IMEC, Leuven, Belgium

Papers will be published in Materials Science & Engineering B

E-MRS 2002 SPRING MEETING

SYMPOSIUM E

Tuesday, June 18, 2002 — Morning
Mardi 18 juin 2002 — Matin

Session I: Novel Methods
Session Chair: Reinhart Job

09:00 **E-I.1**

LIFETIME MEASUREMENTS USING SCANNING POSITRON MICROSCOPE
W. Triftshauser, Universitat der Bundeswehr Munchen, Germany

09:40 **E-I.2**

POSITRON BEAM ANALYSIS OF STRUCTURALLY ORDERED POROSITY IN MESOPOROUS SILICA THIN FILMS
A. van Veen, R. Escobar Galindo, H. Schut, S.W.H. Eijt, C.V. Falub, Interfaculty Reactor Institute, Delft University of Technology, Mekelweg 15, 2629 JB Delft, The Netherlands and A.R. Balkenende, F.K. de Theije, Philips Research Laboratories, Prof. Holstlaan 4, 5656 AA, Eindhoven, The Netherlands
Candidate materials for replacing conventional (dense) SiO2 as a dielectric in ICs include organic polymers and nanoporous silica. For inorganic materials, a high porosity is necessary to lower the dielectric constant towards the dielectric constant of air (k~1). We have applied Positron Beam Analysis (PBA) techniques to study ordered arrays of pores by a combination of depth selective positron annihilation Doppler Broadening and 2D-ACAR (two-dimensional angular correlation of annihilation radiation. We report that para-positronium (p-Ps) formation and the ortho-Ps (o-Ps) fraction are very sensitive probes to determine pore sizes and type of porosity (open or closed) in thin film materials. A percolation threshold for open porosity can be estimated non-destructively. Two different types of low-k SiO2 films were studied. The first type consists of cylindrical cavities (diameter 5.9 nm) stacked in a 2D hexagonal order. The other one consists of a 3D arrangement of spherical cavities with a diameter of 1.5 nm. Both films had a porosity of approximately 50%. In the first case a high, depth-dependent o-Ps fraction was measured, suggesting the presence of open porosity inside the sample. This was demonstrated by the observation of p-Ps escaping from the sample into the vacuum through a network of ordered and interconnected pores. The absence of p-Ps flying off in the second case indicates the absence of open porosity in that type of samples.

10:00 **E-I.3**

ANALYSIS OF MICROSTRUCTURES USING THE ION-ACOUSTIC EFFECT
Ch. Akhmadaliev and L. Bischoff, Research Center Rossendorf Inc., Institute of Ion Beam Physics and Materials Research, POBox 510119, 01314 Dresden, Germany
Acoustic waves generated in solids by pulsed ion beams can be used for imaging of microstructures or the investigation of near subsurface features of a sample. The main mechanism of the elastic wave emission is the periodical heating of the target material in a small region around the impact point.
Basic measurements were carried out on the IMSA-100 focused ion beam (FIB) system with a modulated beam at frequencies up to 4 MHz. The ion current was up to 10 nA (for Au+) at energies of 30-35 key, The FIB spot size was about a few micron, For the registration of the acoustic waves a piezoelectric sensor with integrated preamplifier was developed. To obtain a maximum output signal all measurements were made at the resonance frequency of the sensor followed by a lock-in technique processing and displaying on a PC, Further investigations of the ion-acoustic effect (IAE) at higher energies were made on the 3MeV-Tandetron accelerator.
A promising application is the acoustic analysis of surface and buried structures in a scanning ion acoustic microscope in micron and sub-micron ranges, combining the IAE and the advantages of a FIB. The lateral resolution is a function of the modulation frequency and the target parameters and so about 5 µm on a Si and 2µm on a glass sample could be obtained at the frequency of 4 MHz. At 20-30 MHz the predicted resolution should cross [he sub-micron barrier but this range could not be reached with our FIB system.

10:20 **E-I.4** SURFACE STATES AND BAND-TO-BAND NON-RADIATIVE TRANSITIONS IN SILICON SINGLE CRYSTAL INVESTIGATED BY PIEZOELECTRIC PHOTOTHERMAL SPECTROSCOPY

Aftab A. Memon(a), Atsuhiko Fukuyama(b), Syoichiro Sato(a) and Tetsuo Ikari(a), (a)Department of Electrical and Electronic Engineering, (b)Department of Applied Physics, Miyazaki University, 1-1 Gakuen Kibanadai-nishi, Miyazaki 889-2192, Japan

Piezoelectric photothermal spectroscopy (PPTS) measurements were conducted on p- and n-type silicon samples. The band-to-band electron transitions with phonon absorption and emission were detected. A signal bearing a lower energy edge around 1.048 eV at room temperature was due to band-to-band transitions absorbing a TO phonon. The signal with an edge above 1.19eV at temperatures less than 200K was due to band-to-band transitions emitting a TO phonon. The two signals were observed in both p- and n-type samples. A broad peak around 1.19±0.01eV at room temperature was also observed for both types of samples. We proposed that the signal was due to excitation of surface states` electrons. According to the model the surface states capture electrons (holes) in case of n-type (p-type) samples creating a surface potential. The surface potential elevates the energy of surface electrons above conduction band. Thermal energy at room temperature further enhances the electron energy making it hot enough for scattering. Optically excited surface electrons are scattered by hot electrons to the neighboring bulk layers where they recombine through non-radiative pathways. In many p-type samples the 1.19±0.01eV peak signal was intensified when exposed to light radiation. The signal disappeared when the sample was annealed at 350K in vacuum. We proposed that the surface states were either annealed or de-activated at 350K resulting in disappearance of 1.19±0.01eV peak signal.

10:40 **BREAK**

Session Chair: R.K. Ahrenkiel

11:00 **E-I.5** LOCK-IN IR-THERMOGRAPHY: A TOOL FOR MATERIAL AND DEVICE CHARACTERIZATION

S. Huth, O. Breitenstein, MPI für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany

In this contribution we present the measurement principle and the technical realization of higly sensitive Lock-in IR-Thermography. This technique allows the detection of surface temperature variations down to 10 µK at a lateral resolution down to 5 µm. Lock-in IR-Thermography can be used for the detection of weak leakage currents in electronic devices and MOS structures. Leakage currents of about 1 mA can be localized within seconds and some µA may be detected after less than 1 h measurement.

Lock-in IR-Thermography is already a well-established tool for the characterization of shunts in solar cells and has also been used for the functional testing of other electronic devices like integrated circuits.

In addition to these applications we have used this technique also for the localization of gate oxide integrity defects (GOI defects) in CZ-grown silicon MOS structures. We have developed a procedure to determine the density and the lateral distribution of GOI defects across whole wafers.

11:40 **E-I.6** INVESTIGATION OF DEEP EL6 LEVELS IN SEMI-INSULATING GaAs BY MEANS OF A TEMPERATURE VARIATION OF PIEZOELECTRIC PHOTO-THERMAL SIGNALS

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Piezoelectric photo-thermal (PPT) spectroscopy is a sensitive technique for investigating the thermal and electronic properties of semiconductors and gives information on non-radiative recombination. We have previously measured the temperature variation of the PPT signal intensity from 20 to 160 K for bulk SI-GaAs, and observed four peaks. We have carried out theoretical analysis based on the rate equations of electrons in conduction band and corresponding deep levels and obtained electronic parameters for these levels. In the present paper, the temperature dependence of PPT signal intensity is measured at higher temperature region (from 160 K to room temperature) than that before. One additional peak was observed. We carried out the curve fitting for the experimental result by the similar theoretical analysis. However, the temperature dependence of quasi-Fermi level in SI-GaAs that we did not consider in the last model was taking into account. The observed peak is then considered to be due to the nonradiative electron transitions through EL6. We also carry out the curve fitting for the previous experimental results again with advanced model proposed here. We got more good agreement between the experimental result and calculation than before for the lower temperature peaks. We report on the usefulness of the new methodology for deep level spectroscopy by measuring the temperature dependence of the PPT signal intensity especially for the high resistive semiconductor wafers.

12:00 **E-I.7** X-RAY DIFFUSE SCATTERING THIN FILMS INVESTIGATION

S. Logothetidis, Y. Panayiotatos, C. Gravalidis, P. Patsalas, A. Zoy Department of Physics, Aristotle University of Thessaloniki, 54006 Thessaloniki, Greece

X-Ray Diffuse Scattering (XDS) technique, complementary of X-Ray Diffraction or Reflectivity (XRD-XRR), determines the roughness, morphology and nanoparticle distribution of thin films. We demonstrate here the ability of XDS to investigate the films' nanoscale structure and the to determine additional geometrical features such as correlation length and fractal characteristics. XDS has the advantage against XRD and electron diffraction that it can be used to study amorphous and nanostructure materials. We also show that XDS can be used for phase identification of amorphous materials and combined with XRR for quantitative analysis of composite films using the Distorted Wave Born Approximation with the concept that the film surface behaves like a Self-Affined medium. As model systems we study amorphous Boron Nitride (a-BN) and a-Carbon films. It was found that XDS spectra of a-BN films containing both cubic and hexagonal phases exhibit two set of Yoneda peaks, located at angles characteristic of the corresponding BN densities, while a-BN films containing only hexagonal phase exhibit one set, characteristic of the hexagonal BN. This indicates that the two BN phases are not atomically mixed. The opposite, strong atomical mixture of sp2 and sp3 components, was found in a-C films by XDS. Additionally the growth mechanism for a-C films deposited with or without ion bombardment assistance is predicted and discussed.

12:20 **E-I.8** GLOBAL EVALUATION OF STRIPPING EFFICIENCY BY TD-GCMS

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Both for production monitoring and advanced process engineering, the contamination on silicon wafers must be characterized in a fast, sensitive, reliable, and non-invasive way after each critical production step. Constraints appearing with the use of sub 0.1µm technologies and new materials, drive to important developments of new cleaning processes, especially resist stripping.

Today, process evaluation and production monitoring are well performed by image engineering, such as visual inspection, SEM, and bright field inspection tool. Nevertheless, the need for a simple and low cost method, highly sensitive to the residual contamination laying on devices structures is still very important. Indeed, despite very high resolution and capabilities for organic and inorganic defects, SEM is a local technique. Accordingly, defect detection is limited to high surface concentration, typically > 106/cm2 for sub-micronic defects such as stripping residues. On the other hand, bright field inspection tool is a global method based on pattern recognition and comparison, but it shows a poor sensitivity to the fluoro-carbonated contamination induced by etching processes.

In this work, we demonstrate the capability of GCMS applied to the whole wafer inspection using specific thermodesorption protocol. This method usually applied to the analysis of organic contamination in the ultra-trace range, is here used for a global and very sensitive evaluation of stripping efficiency.

12:40 **LUNCH**

Tuesday, June 18, 2002 Afternoon
Mardi 18 juin 2002 Après-midi

Session II: Carrier Profiling
Session Chair: W. Vandervost

14:30 **E-II.1**

CARRIER ILLUMINATION FOR MONITORING OF CMOS ULTRA-SHALLOW JUNCTIONS
T. Clarysse(a), W. Vandervorst(a,b), R. Lindsay(a), P. Borden(c), E. Budiarto(c), (a)IMEC, Kapeldreef 75, 3001 Leuven, Belgium, (b)KU Leuven, INSYS, Kard. Mercierlaan 92, 3001 Leuven, Belgium, (c)Boxer Cross Inc.,125 Constitution Drive, Menlo Park, CA 94025, USA
Carrier Illumination (CI) is an optical technique for the non-destructive in-line monitoring of ultra-shallow (sub-70 nm) junctions used in advanced CMOS devices, with a throughput that enables mapping of large-diameter wafers. In this work, the state-of-the-art of understanding of CI and its advanced capabilities will be discussed. CI is based on the measurement of the interference between laser reflections from the wafer surface and an optically-generated excess carrier profile pinned to the edge of the doped region. For ideal box-like CVD profiles, the CI-signal versus junction depth response demonstrates better than 2 A depth resolution. For less abrupt profiles, the CI signal is a function of both depth and abruptness. Detailed studies have been made to quantify the CI response over a wide range of junction abruptness, with a range of dopants (B, BF2, As, Sb implants and B-doped CVD Si), a variety of RTA anneal and PAI conditions, with junction depths from 10 to >100 nm. They suggest that CI may be optimized to correlate to SIMS junction depth at selected concentrations ranging from 2e18 to 4e19/cm3. The CI response also shows a shift between B and BF2, possibly arising from surface discharging by F ions, an effect that can be corrected using proper calibration. This fundamental characterization enables non-destructive, non-contact, in-line measurement of extension properties in a channel with doping typical of modern CMOS FETs.

14:50 **E-II.2**

COMPUTATIONAL ANALYIS OF ETCHING PROFILE EVOLUTION FOR THE DERIVATION OF 2D DENSITY MAPS IN Si
G. D'Arrigo(a), G. Garozzo(b,c), A. La Magna(a) and C. Spinella(a), (a)Istituto per la Microelettronica e i Microsistemi, CNR-IMM, Stradale Primosole 50, 95121 Catania, Italy, (b)STMicroelectronics, Stradale Primosole 50, 95121 Catania, Italy, (c)Dipartimento di Fisica dell'Universita di Catania, Corso Italia 50, 95100 Catania, Italy
The numerical simulation of the etched surface evolution is applied to the selective (chemical and electrochemical) etching dopant delineation technique. The analysis of the etched sample section, obtained by means of Transmission Electron Microscopy, is performed using a 3D simulation code based on the Level set method for evolving surfaces. The correlation between the etched profile and the total dopant distribution is inferred, assuming that a functional relationship F=F{d(P)} occurs between the local dopant density d(P) and the local etch rate F(P). The reliability of the etch rate expression, derived by the theory of the charge transport in the solution-semiconductor interface, has been demonstrated also using the direct electrical simulation of the current flow during the etching process. The calibration of the technique consists in the fit of the parameters in the F=F{d(P)} relation depending only on the external conditions (bias potential, chemical moisture). The fitting has been performed, using reference profiles, at fixed optimal conditions in the case of n-doped, p-doped samples and in presence of p-n junctions. The measurement of the 2D dopant density map is based on the cross graphical comparisons, performed automatically by the computational tool, between TEM images of the eroded zone and the simulations of the etched surface, obtained using trial dopant distributions.

15:10 **E-II.3**

CARRIER CONCENTRATION AND MOBILITY IN B DOPED Si[1-x]Ge[x]
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Hall effect measurements in the 4-300 K temperature range have been used to investigate the electrical properties of B doped Si[1-x]Ge[x] layers (with $0<x<0.4$) grown by MBE on Si(100). The Hall concentration and mobility of strained Si[1-x]Ge[x] layers have been converted into carrier concentration and drift mobility using the appropriate Hall scattering factor. The comparison between the chemical B concentration profile (measured by Secondary Ion Mass Spectrometry) and the Hall carrier concentration allowed to determine the Hall scattering factor of partially and fully relaxed Si[1-x]Ge[x]. The mobility of either relaxed and strained layers was equal to that of Si and independent of the Ge concentration for $x<0.2$ and B concentration >1e18 at/cm3. Therefore in this range the ionized impurity scattering resulted the main factor limiting the carrier mobility. The mobility of partially relaxed Si[1-x]Ge[x]alloys was lower than that of totally relaxed layers. This indicates that annealing of point defects, present in the as-grown layer at concentration above the equilibrium, occurs during the relaxation process. The determined mobility values were used to convert the Spreading Resistance into carrier concentration profile and the agreement between the Hall and SRP was excellent. The effect of the band deformation due to Ge into the alloy was evident at low temperature, where m~T^a, and a large reduction of a with increasing Ge concentration was observed.

15:30 **BREAK**

16:00-18:00 **POSTER SESSION**

E/P01 DEGRADATION STUDY IN SCH-SQW GaAs/AlGaAs LASERS

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SCH-SQW GaAs/AlGaAs laser diode structures grown by MBE were investigated. The structures had wavegiude and cladding bulk layers replaced with GaAs/AlGaAs SLs. Accelerated aging tests were applied to the laser diodes. The devices were divided into two groups dependently on the results obtained in the lifetests. Some lasers showed stable operation during 3000h, others demonstrated fast degradation as observed by measuring the output optical power. The degradation of lasers was studied by I-V curve analysis. The presence of defects was studied by means of DLTS. DX and other defects have been revealed by the DLTS spectra. In lasers which showed rapid degradation a deep trap at EC-0.63eV was observed in much higher concentration comparing with the concentration of the trap in the reference samples. On the basis of its emission characteristics the trap is interpreted as a complex involving point defect and oxygen. Its enhanced concentration can be due to trapping of oxygen at the "inverted interface". For comparison, the trap concentration in GRIN-SCH-SQW GaAs/AlGaAs lasers studied was lower an order of magnitude. In the latter case the SLs were not embedded in the layers and lasers did not exhibit the rapid degradation. In spite that the mechanism for degradation is not clear, a marked correlation between an increase in the concentration of the deep level at EC-0.63 eV and degradation of lasers suggests that this level can limit the performance of the optoelectronic devices.

E/P02 COMPARISON OF ELECTRIC FIELD EMISSION FROM DIAMOND-LIKE CARBON COATED DIFFERENT SI SURFACES

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Field emission of electrons from diamond-like carbon (DLC) coated different Si surfaces is compared. Thin films of DLC were coated on smooth and rough surfaces of Si and Si micro-tips using pulsed ArF laser deposition. All DLC coated surfaces exhibited electron emission in the field of 10-15 V/micron ranges, which was lower than uncoated Si tips. The data were analyzed using the Fowler-Nordheim (F-N) theory and the effective work function of electron emission is interpreted as due to the contact tunneling of electrons from the Fermi level of sp2 clusters to the conduction band of sp3 clusters. Analysis also shows that the low work function (several hundred meV) of DLC coated flat Si surfaces deduced from the F-N analysis is ambiguous.

E/P03 PREPARATION AND INVESTIGATION OF HETEROSTRUCTURES BASED ON THE I-IIInVIm TERNARY COMPOUNDS

I.V. Bodnar, T.L. Kushner, Yu.V. Rud, V.Yu. Rud, Belarusian State University of Informatics and Radioelectronics, P.Brovki 6, 220027 Minsk, Belarus

The given work presents the result of Schottki barriers photosensitivity study based on the ternary compounds of CuIn3Se5, CuGa3Se5 and CuGa5Se8. The pointed compounds are crystallized in defective chalcopyrite structure and they can be used for the creation of photo converters. The monocrystals were grown with Bridgeman method. The photosensitive structures were obtained with the vacuum precipitation of the thin layers of indium on the crystals surface. The ohmic contacts were created with the soldering of contact conductors with an alloy based on gallium. It is obtained that indium contact with the ternary compound crystals' plate surface possesses detection at the negative polarity of the external bias on the semiconductor. On lighting such barrier the photovoltaic effect is observed where the sign of photo voltage does not depend on the photo registration geometry. The maximum value of the voltaic photo sensitivuty is reached when the structures are lit from metallic layer side. It is revealed that structures' photosenitivity spectra based on CuIn3Se5, CuGa3Se5 and CuGa5Se8 display broadband characteristic that witnesses good quality of the first Schottki barriers on the new substances. Full width of the photosensitivity spectra is 900 meV on the half height for the barriers based on CuIn3Se5. It is shown that the obtained structures can be used as broadband photo converters of the natural radiation.

E/P04 INVESTIGATION OF DEEP LEVELS IN Ni-DOPED Si BY A TEMPERATURE DEPENDENCE OF PIEZOELECTRIC PHOTOTHERMAL SIGNALS

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Since the performance of silicon (Si) semiconductor devices is greatly influenced by the quality of the substrate, it is very important to know the role of deep lying defect levels. We have recently reported that the activation energies, the concentrations and the electron capture cross sections deep defect levels in semi-insulating GaAs were well investigated by the temperature variation of the piezoelectric photothermal (PPT) signals [1]. The great advantage of this technique is that it is a direct monitor of the nonradiative recombination processes that is a major process for the deep levels. In this paper, we report on the results for applying our new technique to Si wafers that has a deep levels induced by nickel (Ni) atoms. The Ni level is already well characterized by a usual DLTS technique [2].

The temperature variation of PPT signal intensity of Ni-doped and non-doped Si samples from 77 to 298 K was measured. The theoretical model was performed for the temperature variation of the PPT signals by using a rate equation in the conduction band and Ni deep level. Curve fitting to the experimental results made us to estimate characteristic parameters for the Ni deep acceptor. Since those observed parameters agree with that reported, we found our proposed experimental methodology is a useful optical characterization technique for deep levels in semiconductors.

[1] A. Fukuyama, et al, J. Appl. Phys, 89 (2001) 1751
[2] S. Tanaka, et al, Jpn. J. Appl. Phys, 35 (1996) 4624

E/P05 THE RESIST CHALLENGE FOR 157nm PHOTOLITHOGRAPHY

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Fluorine laser lithography at 157nm is the next generation optical lithography in the international roadmap towards the 70nm node. Following illumination at 157nm (7.8 eV) the parent molecule disintegrates to small fragments, which could impose serious problems on the projection system. We have used as test materials silicon and carbon based polymers with aromatic or aliphatic molecular structure and the basic photochemical mechanisms of the photodissociation dynamics at 157nm was investigated. Our experimental results suggest that [1]: 1) At 157nm there is photochemical bond breaking; 2) The density of the dissociative electronic states of the small diatomic or triatomic radicals which are correlated with the excited electronic states of the monomer of the different polymeric materials at 7.8 eV is high suggesting photodissociation probability at this wavelength is close to one; 3) The molecular photofragments are flying apart with supersonic speed and therefore the presence of more or less steep dissociative excited electronic states is inherent to the molecular structure; 4) Probability of cleavage of side chains is higher than of the main chain; 5) Out-gassing depends on material's purity. [1] Research on Optical Polymeric and Molecular Materials assisted by VUV Light at the NHRF. E. Sarantopoulou, Z. Kollia and A. C. Cefalas. Lamda Physik Highlights 58, May 2001.

E/P06 STRUCTURAL,OPTICAL AND CATHODOLUMINESCENCE CHARACTERISTICS OF UNDOPED AND TIN DOPED ZnO THIN FILMS PREPARED BY SPRAY PYROLYSIS

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Cathodoluminescence spectroscopy and imaging have been studied of undoped and tin doped ZnO films fabricated by spray pyrolysis of zinc chloride and tin chloride. The luminescence films had a polycrystalline hexagonal wurtzite type structure. The composition and the stoichiometrie of these films were examined by electron probe microanalysis. Both undoped and doped films had a good optical transmission. Intrinsic films present the well-know blue green emission characteristic of ZnO films. Tin doped films exhibit the emission at 378, 463 and 672 nm. We have found that the predominant peak corresponding to these emissions varies with excitation voltage.

E/P07 EFFECT OF SUBSTRATE TEMPERATURE ON CATHODOLUMINESCENCE OF ITO THIN FILMS PREPARED BY SPRAY PYROLYSIS

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Highly conducting and transparent tin-doped indium oxide (ITO) thin films were deposited on glass substrates by spray pyrolysis. The characterisation of ITO thin films prepared under different deposition parameters is investigated. The transmission, resistivity and luminescence of the films were found to be strongly dependent on these parameters. The films prepared at the optimum conditions exhibit low resistivity and optical transmission larger than 90% in the visible region. ITO cathodoluminescence films prepared at 450°C and 500°C has been studied. These samples exhibit a strong luminescence peaks in visible region at 460nm and 650nm.

E/P08 TRANSISTOR-LIKE PROPERTIES OF SUPERCONDUCTING FLUX FLOW TRANSISTOR FABRICATED BY THE ICP PROCESS

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Superconducting Flux Flow Transistors with micron channel (3 ㎛) have been fabricated based on the flux flow using high temperature superconducting thin films by the ICP etching technique.

The characteristic of the fabricated devices was investigated using liquid nitrogen by examining the current-voltage (I-V) characteristics of YBCO channel under the various applied current. The induced voltages increased with an increase of the body current, Ibdy and the control current, Ictl.

The critical current of SFFT was altered by varying the external applied current Ictl. As Ictl increased from 0 to 12 mA, the critical current decreased from 28 to 22 mA.

The obtained rm values are under 0.1Ω at an Ibdy of 40 mA. The current gain of the device can be obtained from △Ic/△Ictl and then the current gain was about 0.5. Output resistance was below 0.2 Ω.

The three terminal characteristics of the device were successfully obtained using ICP etching method.

E/P09 CAPACITANCE STUDY OF DEFECTS INDUCED IN HEAVILY DAMAGED REGION FORMED IN HYDROGEN IMPLANTED Si

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Recently, there has been an increasing interest in attempts to extend the scope of electrical techniques, especially those involving depleted layer spectroscopy to study the electrical activity of defects induced by ion-implantation in the case of high damage. In this work C-T and C-V(T) characteristics have been measured to study defects created in p-type Cz-Si implanted with 130keV H-ions at a high dose of 4xE16cm-2. The post-implantation annealing was carried out at 450C/10h, i.e., at the temperature of thermal donor creating in Si. We report on forming a thin p-type layer at the surface of an n-type Si. This is interpreted as a result of the presence of acceptor-like deep-level defects created during implantation. The defects manifest themselves through several unusual features. A flat region, vertical rise in capacitance, and hysteresis effects in the C-V dependence have been observed during voltage sweep. Our experiments with filling and emptying deep traps with carriers also reveal unusual hysteresis effects in the C-T curve. The results obtained can be readily understood if we assume that defects themselves control their occupancy in the depletion region, that are present in very high concentration and defect distribution is inhomogeneous as usual created in implanted samples. Our results compliment results recently obtained in the case of high damage caused by Ar-ion implantation. However, the sudden jumps in capacitance are unusual and reported for the first time.

E/P10 CATHODOLUMINESCENCE STUDIES OF III-NITRIDE STRUCTURES IN THE TRANSMISSION ELECTRON MICROSCOPE

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Modern optoelectronic devices like light emitting diodes or laser diodes are based on low dimensional heterostructures (i.e. thin layers or nanoscopic islands) of a semiconductor A embedded in a semiconductor B. Charge carriers in these nanoscopic heterostructures have quantised energy levels that sensitively depend on structure size and chemical composition. For both, the understanding of fundamental physical processes in such devices and for optimising the growth conditions the knowledge of structure, chemistry and strain distribution down to an atomic level and their influence on optical properties is essential.

In this contribution we will show that cathodoluminescence performed in the transmission electron microscopy (TEM) combined with electron energy loss spectroscopy and high resolution electron microscopy can sustantialy contribute to gain this knowledge based on structural and spectroscopic information (optical as well as chemical) directly correlated with high spatial resolution.

We will present three examples for this approach from our current work related to group-III nitrides: (i) the influence of compositional fluctuations on optical properties of InGaN quantum wells, (ii) analysis of electrical, optical and structural properties of extended defects in GaN, and (iii) defect luminescence in Mg-doped GaN.

E/P11 RECOMBINATION LIFETIME IN n- VERSUS p-TYPE InP

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In spite of the numerous applications of InP, little has been done regarding study of its bulk lifetime and carrier recombination mechanisms. In general, the minority carrier (holes) lifetimes are long in n-InP (in the range of 100ns~1ms), depending on doping, crystal quality and growth methods. On the other hand, the minority carrier (electron) lifetime in p-InP was found to be very short due to a high concentration of deep, nonradiative recombination centers and the dominance of nonradiative recombination.

The different recombination mechanisms may be understood by measuring the temperature dependence of the different lifetimes. In this work we report the results of an extensive and systematic study of the excess carrier lifetime in undoped, S and Sn doped n-type and Zn doped p-type InP as a function of temperature. The measurements are based on photoluminescence (PL) and time-resolved photoluminescence (TRPL) measurements at a wide temperature range (4-300K).

It is found that two main processes govern the electron lifetime in p-InP: non-radiative recombination at Zn-induced neutral acceptor centers, and trapping at shallow unintentional donor impurity centers. In n-InP, on the other hand, the lifetime is goverened by radiative processes. This is due to the fact that in n-InP the non-radiative lifetime is much greater, thus the minority carrier lifetime is dominated by radiative band-to-band and donor-valence band transitions.

E/P12 OPTICAL PROPERTIES (CuInSe2)1-x(2ZnSe)x SOLID SOLUTIONS

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Solid Solutions (CuInSe2)1-x(2ZnSe)x and a ternary compound CuInSe2 are prospective materials for the creation of the efficient photo converters of the solar energy. The present work shows results of the transmission and reflection spectra studies of the solid solutions of (CuInSe)1-x(2ZnSe)x in the region of the own absorption edge.

The given research was carried out on the crystals that were grown with Bridgeman-Stockbarger method (x=0.0-0.4)or the method of the chemical transport reactions (x=0.5-1.0) employing iodium as a carrier. The samples to be measured were prepared by mean of their grinding and polishing from one or both sides (depending on the method of the crystals growth). Spectra were registerd with "Beckman-5240" and "Specord UV-VIS" spectrophotometers at 80 and 293K in the wavelengths region of 0.4-2.0 mkm.

The optical absorption coefficient was calculated according to the generally accepted formula that takes into account multiple reflection in the plane-parallel sample. The band gap width (Eg)were determined.It was established that Eg with composition x for the solid solutions (CuInSe2)1-x(2ZnSe)x at 80 and 293K changes non-linearly and can be described with the functions hereunder.

Eg(x)=1.032 + 0.864x + 0.864x2 for 80K;

Eg(x)=0.990 + 0.443x + 1.238x2 for 293K.

E/P13 3D TEM SILICON DEVICE ANALYSIS BY COMBINING PLAN-VIEW AND FIB SAMPLE PREPARATION

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Cross-sectional TEM analysis has become routinely used in semiconductor industry to support failure and yield analysis. Plan-view TEM analysis however is much less performed. In this presentation it will be illustrated that plan-view TEM analysis can add valuable information in yield analysis studies especially when lattice defects are involved.

Generally, in plan-view TEM analysis the top 0.1-1 µm of the Si substrate is studied. Therefore, all or most metal and dielectric layers are to be removed prior to further specimen preparation. The most general approach is to float off all layers by the dissolution of the firstly grown or deposited oxide layer in diluted HF. It will be discussed that this approach has some disadvantages and that in specific cases, like e.g. silicon-on-insulator devices, mechanical de-processing using planar lapping has to be applied.

3-dimensional information can be obtained by combining cross-sectional TEM analysis with a plan-view analysis. If the available material is limited it can become a difficult choice whether to go for a cross-sectional or a plan-view analysis. Therefore it was explored if a cross-sectional specimen could still be made out of a plan-view specimen, using the plan-view analysis to locate precisely the failure site. This has recently been successfully done using the in-situ plucker tool in the focused-ion-beam machine. The problems to be solved in order to make this technique generally applicable will also be addressed.

E/P14 DEPOSITION KINETIC OF AIRBORNE ORGANIC CONTAMINATION ON WAFERS AS MEASURED BY TD-GCMS

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Since organic contamination is today widely recognized as detrimental for advanced microelectronic devices, the control of airborne contaminants in clean rooms is a main challenge in future fabs. Particularly, measurement of the sticking coefficients of organic contaminants present in clean room air is important. This knowledge will allow to define the acceptable exposure times of wafers in production environments (clean room air, storage box…) to avoid critical surface contamination levels, as established by the ITRS Roadmaps. To reach this purpose, airborne concentration of individual contaminants and corresponding amounts adsorbed on wafers must be determined simultaneously.

Thanks to its powerful identification and quantification capabilities down to trace levels of contaminants both for air and surface analysis, Thermo Desorption-Gas Chromatography-Mass Spectrometry (TD-GC-MS) is the method of choice for the determination of sticking coefficients. In this paper, the selective adsorption of airborne contamination from clean room air on silicon wafers was studied with 2 types of surfaces: SiO2 and bare Si (HF last). A description of the analytical set-up will be given, with the description of an home-made thermodesorption chamber of substrates up to 300 mm scale, giving a sensitivity down to 10e12 at.C.cm-2. Typical adsorption kinetic of main organic contaminants will be given and compared to the global surface contamination kinetic as measured by other methods.

E/P15 THE INFLUENCE OF DOPANT OUT-DIFFUSION ON THE THERMAL STABILITY OF SI/SI1-XGEX/SI HETEROSTRUCTURES GROWN BY CVD

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The thermal stability and dopant out-diffusion of npn- or pnp-doped Si/Si0.8Ge0.2/Si structures grown by reduced pressure CVD have been studied by using high resolution X-ray diffraction and secondary ion mass spectroscopy. The influences of in- or out-diffusion of dopants e.g. boron, phosphorous,arsenic or carbon with concentrations in range of 1x1018-1x1019 cm-3, in SiGe or adjacent layers on the thermal stability of the structure are discussed. Firstly, by doping the strained Si0.8Ge0.2 layer and having the adjacent layers undoped, the thermal stability of the structures is shown to be dramatically increased compared to a totally intrinsic grown structure. This is attributed to the lower activation energy for dopant diffusion compared to misfit dislocation formation. Secondly, when the dopants are present only in the Si buffer and cap layers no enhancement in the thermal stability of the Si0.8Ge0.2 was observed. Finally, when pnp or npn structures are grown, a poor thermal stability is obtained indicating the interaction of dopant out-diffusion eases the SiGe relaxation. A solution to this problem is employing a thin intrinsic spacer on both sides of SiGe layer in order to avoid the direct impact of the dopants. These results contribute an important vision for designing high thermal stabile heterojunction bipolar transistors.

E/P16 ULTRATHIN OXIDES FOR THE SCM ANALYSIS OF SUB-MICRON DOPING PROFILES

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The Scanning Capacitance Microscopy (SCM) technique has been used to study B and P doped Si test structures epitaxially grown on (100) Si substrates. Each sample has a unipolar or bipolar, staircase-like 1D doping profile composed of sub-micron uniformly doped steps, as obtained by Secondary Ion Mass Spectroscopy profiling. The quality and the thickness of the ultrathin oxides grown with the standard low-temperature UV-ozone method on polished and cleaved (110) sections have been investigated with the help of Attenuated Total Reflection and Spectroscopic Ellipsometry on different (110) Si substrates. Cross-sectional SCM results obtained on samples covered by this oxide are presented, discussed and compared to results obtained on cleaved samples oxidized by simple air exposure. The results show that the native oxide covering a (110) cleaved section may yield SCM images of sufficient quality, with low charging level and no contrast reversal on a wide range of doping levels, as well as observed on sections prepared with the standard UV-ozone technique. However, the long-term (day-to-day) stability of the SCM signal on native oxides is poor and the effects of the UV-ozone oxidation on that stability are discussed.

E/P17 MODIFICATION AND CHARACTERIZATION OF THIN SILICON GATE OXIDES USING CONDUCTING ATOMIC-FORCE MICROSCOPY

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Due to the ongoing trend towards miniaturization in semiconductor industries the formation of structures in the nanometer regime becomes a great matter of interest. Here, we investigate the growth of oxide structures on silicon gate oxides using Conducting Atomic-Force Microscopy (C-AFM). The experiments shall contribute to the understanding of electrically induced oxide formation.

By applying voltage pulses between a highly boron doped diamond coated AFM tip and silicon gate oxide samples under ambient conditions, surface modifications with lateral dimensions of about 100 nm are achieved due to local oxidation. The process of structure formation is studied in dependence of the applied voltage, the pulse duration, and the voltage polarity. The threshold electric field (Eth) necessary for protrusion growth shows an almost constant value for different thermal oxide thickness (dox) when positive sample voltages are applied. However, an exponential decrease of Eth is observed with increasing dox for negative sample bias. Further, the quality of the initial gate oxides and the produced oxide structures are compared by applying a voltage ramp to the sample and measuring the tunnelling current. From a Fowler-Nordheim fit we can draw conclusions about the oxide quality before and after the electrically induced oxidation process.

E/P18 INFRARED PHOTOREFLECTANCE SPECTROSCOPY OF GaInAsSb-, GaAlAsSb-BASED QUANTUM WELL

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Infrared photoreflectance (IRPR) has been used for the first time to characterisation GaInAsSb-, GaAlAsSb-based quantum well (QW) structures. The contactless and nondestructive characterisation enables detection confined states (ground state and excited states) in the QW, and electric fields in the structure. These QW’s have been measured in the 10-300 K temperature range. Clear and well-resolved resonances, which could be attributed to the infrared optical transitions originating in both the GaSb buffer and the quantum wells, were observed. Observed energies agree with these calculated by means of the envelope-function model adopting the accepted values for materials parameters and making allowance for the typical composition and thickness uncertainties. Obtained results showed that the infrared photoreflectance technique is powerfull tool, which give many information about these structures and is convenient, easy to use, and inexpensive.

E/P19 STRUCTURAL AND MORPHOLOGICAL CHARACTERIZATION OF HETEROEPITAXIAL CEO2 FILMS GROWN ON YSZ (100) AND TIO2 (001) BY MOCVD

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Cerium dioxide (CeO2) thin films are extensively studied for applications in microelectronic devices, as catalytic agent and, if suitably <100> oriented, as buffer layers for the deposition of high critical temperature (HTc) superconducting films. In particular, it is an interesting buffer for the growth of HTc films on rutile (TiO2) substrates, which represent promising substrates for the fabrication of HTc passive filters. In this context, we report on the metal-organic chemical vapor deposition (MOCVD) of CeO2 (100) films from the Ce(III) hexafluoroacetylacetonate diglyme adduct on TiO2 (001)and YSZ (100) substrates.

The significant lattice mismatch between <100> oriented CeO2 films and TiO2 (001) substrates (about 17%), points to a more critical epitaxial growth than in the case of depositions on YSZ (100) substrates.

The heteroepitaxial growth of the <100> oriented CeO2 films was tailored by varying deposition parameters and comparing results with those obtained on YSZ (100) substrates. A complete structural characterization indicate that all CeO2 samples grown in the 450-750°C deposition temperature range, are <100> oriented. The FWHM values of the rocking curves of the (200) reflection indicate that the alignment of CeO2 grains, with respect to the c-axis, improves on increasing deposition temperatures.

The (111) pole figure was recorded on both substrates and point to good in-plane crystalline texture. Morphological characterization was performed as well.

E/P20 EVALUATION OF A PLASMA ENHANCED CHEMICAL VAPOR DEPOSITION SILICON NITRIDE THIN FILM FOR GaAs DEVICE MANUFACTURING

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Silicon nitride thin films are widely used in GaAs MMIC device fabrication. The layers serve as dielectric films in capacitors, surface passivation, diffusion barrier and mechanical protection. The most commonly used technique by which silicon nitride is deposited is plasma enhanced chemical vapor deposition (PECVD) using a gaseous mixture of SiH4/NH3/N2. The process parameters, such as substrate temperature, gas flows, total chamber pressure and RF generator power may vary, causing significant changes to the layer physical properties and chemical composition. The device definition includes both deposition of the dielectric layer and its patterning, which is done by etching the exposed SiN via a photoresist mask. The etching process has to be very accurate to define patterns with only few microns width of openings or gaps. The current study examines the influence of deposition and etching process conditions on the layer characteristics and the devices critical dimension (CD) control.

Empirical formulas that correlate process parameters (temperature, gas flow ratio, pressure and RF power) with layer properties have been found and with very high precision yield the deposition rate, wet and dry etching rates and refractive index of the layer. Better understanding of etching processes and the way they relate to layer characteristics led to significant improvement in (CD) control of the device.

E/P21 INFRARED ANALYSIS OF THIN LAYERS BY ATTENUATED TOTAL REFLECTION SPECTROSCOPY

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Interest in infrared spectroscopy (IRS) have been stimulated by the increasing need for non destructive surface characterization providing structural and chemical information about the new materials used in microelectronic devices. Standard infrared spectroscopy of thin layers is limited because of its lack of sensitivity. The use of optical configurations such as the Attenuated Total Reflection (ATR) allows to characterize nanometric layers. This paper will present the results of a study conducted for a better understanding of the capabilities and limitations of this technique.

A theoretical analysis based on a perturbation method is used to elucidate the results of ATR measurements performed on silicon oxide layers of different thickness on silicon substrates. This analysis shows that the absorbance ATR spectrum in p polarization is the image of the layer energy loss function, under specific conditions. It is highlighted that the ATR enhanced sensitivity is controlled by the air gap thickness, the optical properties of the media involved, and the probing light polarization. The exact ATR spectrum simulation using a matrix formalism showed that the straightforward interpretation in terms of the layer dielectric function is limited to a very narrow layer thickness range. The fitting process of the ATR spectrum is considered for layers with a thickness out of this range and it is evaluated for the interpretation of experimental spectra obtained for the silicon oxide layers.

E/P22 RAMAN MEASUREMENT OF STRESS DISTRIBUTION IN MULTICRYSTALINE SILICON SAMPLES

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The problem of stress is a crucial issue for the mechanical stability of multicrystalline Si (mc -Si) and may cause yield problems during manufacturing of solar cells due to breakage.

We present investigation of mc-Si exploiting the sensitivity to mechanical stress of the Raman frequency peak position. Micro-Raman spectroscopy with high spatial resolution was applied to analyse the stress distribution in the vicinity of grain boundaries in solar grade silicon.

Two types of mc-Si, block cast and ribbon grown Si samples, were scanned in our experiments. Changes in the Raman peak position of about 0.1 reverse cm over a scale of several micrometers were detected at the grain boundaries. The Raman peak shift was used to estimate the stress. The results on block cast Si show, that the stress distributes over a 4 m line inside the grain. Approaching the boundary, the stress is initially compressive and increases up to 35 MPa, than it transfers in tensile stress down to -35 MPa just on and immediately after the grain boundary and away from it there is no detectable stress.

The factors, influencing the accuracy of the local stress measurement were analysed. Three major restrictions of the technique have to be considered: (i) local heating, (ii) the signal-to-noise ratio and (iii) surface topology.

The samples were polished to increase the sensitivity to weak stresses. Micrographs of the samples were taken by optical microscopy to locate the region of interest.

E/P23 TEMPERATURE BEHAVIOR OF EXTENDED DEFECTS IN SOLAR GRADE SILICON INVESTIGATED BY PHOTOLUMINESCENCE AND EBIC

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Dislocations and grain boundaries show a detrimental influence on solar cell performance due to their recombination activity. The contamination of the defects by impurities strongly affects their recombination strength. It has been shown, that temperature dependency of EBIC recombination activity gives a quantitative access to the contamination level at the dislocations. A comparison of band-to-band and defect (D1) photoluminescence (PL) with EBIC temperature behaviour on multicrystalline Si revealed, that intensive D1 band luminescence and a remarkable reduction of the band-to-band PL intensity are observed at the defect sites. It was found that wafer regions with pronounced D1 band correspond to dislocations with a weak contamination level down to a few tens impurity atoms per µm of the dislocation length.

In the present work we show the temperature dependence of defect and band-band luminescence as measured between 80 K and room temperature for defects of different contamination level. In the discussion we try to answer whether the PL temperature behaviour contains similar information about the defect contamination level as the EBIC c(T) behaviour.

E/P24 RAMAN AND PHOTOLUMINESCENCE STUDIES OF CdS AND CdTe THIN FILMS GROWN BY RF-PLANAR MAGNETRON SPUTTERING IN LARGE AREA SUBSTRATES

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A systematic study on CdS and CdTe thin films grown by RF-Planar Magnetron Sputtering was performed by means of Raman and Photoluminescence spectroscopies in the temperature range from 10 to 300 K. The semiconducting CdS and CdTe films were grown in soda-lime and conducting glass (SnO2:F)large area subtrates (450 cm2). The influence of the substrate, substrate temperature and deposition time on the properties of both kind of films were analized, in order to optimize the growth conditions.

E/P25 ANALYSIS OF THE 1.55 eV PHOTOLUMINISCENCE BAND OF CdTe POLYCRYSTALLINE FILMS

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Photoluminiscence (PL) spectra of CdTe at low tempeartures usually show a narrow band at 1.55 eV, sometimes together with phonon replicas. It has been shown that this band is associated with a transition involving an acceptor level due to a cadmiun vacancy, however there is discrepancy about the high energy electronic level which originates this transition. It is assumed that this high energy level comes from the bottom of the conduction band or arise from a non-excited level due to a superficial donor. In order to clarify the origin of this level we have carried out Photoluminescence Excitation Spectroscopy (PLE) studies at 10 K and also analyzed the temperature dependece of the photoluminescence in CdTe polycrystalline samples. Our results allowed us to stablished that the high energy level for the 1.55 eV PL transition originates from a non-excited level due to a superficial donor.

E/P26 SOME PHYSICAL PROPERTIES OF CHALCOPYRITE AND ORTHORHOMBIC AgInS2 THIN FILMS PREPARED BY SPRAY PYROLYSIS

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The chalcopyrite semiconductors of the I-III-VI2 group have shown considerable technological interest in diverse areas of solid–state devices. AgInS2 is a semiconductor compound of the I-III-VI2 family which crystallizes in tetragonal (chalcopyrite–type) or orthorhombic ordered phases. We have prepared AgInS2 thin films by the spray pyrolysis technique. The effects of the chemical composition of the spray solution upon the structural, the optical and the electrical properties of the films have been studied. It was found that films prepared from Ag–rich and equimolar solutions crystallize in the chalcopyrite structure of AgInS2, otherwise deposited films crystallize in the orthorhombic modification of AgInS2. All prepared films showed an n-type conductivity in the range between 10-3 – 10-4 S/cm and an absorption coefficient of the order of 105 cm-1 for photon energies near the fundamental edge. Optical bandgap energies of chalcopyrite and orthorhombic AgInS2 were 1.83 and 1.94 eV, respectively, which are in good agreement with those reported by other authors. Additionally, the low temperature photoluminscence (PL) spectra of chalcopyrite and orthorhombic films display deep PL peaks which might be associated to electron–hole recombination between deep - donor and deep - acceptor defects.

E/P27 ANNEALING EFFECT ON THE STRUCTURAL AND OPTICAL PROPERTIES OF ZnO THIN FILM ON InP

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II-VI semiconducting ZnO thin films have been fabricated by pulsed laser deposition (PLD) process on InP (100) substrates. Thin films were annealed at various temperatures in order to study the annealing temperature dependence of the structural and optical properties of ZnO thin film grown on InP substrate. The structural and optical properties were characterized with X-ray diffraction (XRD) and photoluminescence (PL), respectively. In our study, we have found some defect levels from the PL spectra and derived the defect centerís activation energy. According to XRD data, it could be thought that the films had some strains but relaxed by annealing processes.

E/P28 PROPERTIES OF ITO FILMS ON nc-Si THIN FILMS ON P-TYPE Si SUBSTRATE FABRICATED BY PULSED LASER DEPOSITION

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Transparent conducting ITO (indium tin oxide) on nc-Si(Nanocrystalline Si) thin films on p-type Si substrate has been fabricated by pulsed laser deposition using a Nd:YAG laser in the laser fluence range of 1~3 J/㎠ with wavelength of 355 nm. Primary pressure was maintained at 1 ◊10-5 Torr. ITO thin films were grown at various substrate temperatures(RT~300℃) and at different pressures of oxygen(0~50 mTorr). The optimized oxygen pressure, substrate temperature and laser energy density to fabricate ITO anode for the maximum device efficiency will be reported. EL(electroluminescence) properties from the structure of ITO/nc-Si/p-type Si wafer were observed to investigate the possibility of ITO electrode for Si light emitting devices.

E/P29 STRUCTURAL AND ELECTRICAL CHARACTERIZATION OF EPITAXIAL 4H-SiC LAYERS FOR POWER ELECTRONIC DEVICE APPLICATIONS

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Although the high potentiality of Silicon carbide (SiC), its technology shows at the moment some limitations, due to the defects present in the crystalline structure. We have focused our analysis on commercial 4H-SiC epitaxial layers. A preliminary investigation has been performed by Optical and Scanning Electron Microscopies with the aim to evidence the defect morphology on a large scale. An insight on the defect structure has been obtained by Atomic Force Microscopy, Profilometer technique, Micro-Raman and Micro-Photoluminescence spectroscopies. Different types of defects such as comets, super dislocations, etch pits and so on, have been characterized finding interesting peculiarities such as different polytypes inclusions. Moreover, the influence of such defects on the SiC electrical performance has been deeply analysed through the realization of Schottky barriers onto SiC regions including specific kinds of defects, then performing electrical characterization such as Electron Beam Induced Current (EBIC), Deep Level Transient Spectroscopy (DLTS) and Double-DLTS techniques. By the EBIC analyses of the defect contrast, also at different bias conditions, the correlation among the defect morphology and their recombination activity has been obtained. DLTS and Double-DLTS has allowed to specify energy position in the gap, concentration and capture cross section of the defects specifically selected.

E/P30 EFFECTS OF POST-ANNEALING TREATMENT ON THE PROPERTIES OF ZnO THIN FILMS ON SAPPHIRE

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ZnO thin films on (001) sapphire substrates have been deposited by pulsed laser deposition. In order to investigate the effect of post-annealing treatment in oxygen on the optical property of ZnO thin films, films have been annealed at various substrate temperatures after deposition. After post-annealing treatment in the oxygen ambient, the optical properties of ZnO thin films were characterized by PL(Photoluminescence). The structural properties of ZnO thin films were characterized by XRD. As the post-annealing temperature increases, intensity of UV(380 nm) peak is decreased while the intensity of visible(about 490 nm~530 nm) peak is increased. Crystallinity of ZnO film is enhanced at annealing temperature above 700℃. Structural and optical properties of ZnO films have been investigated for the application of light emission device.

E/P31 ROLE OF ZnO BUFFER LAYER ON THE PROPERTIES OF ZnO THIN FILMS

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We studied the effects of the ZnO buffer layers in the growth of epitaxial ZnO films. Buffer layer and ZnO thin films have been deposited by pulsed laser deposition technique at the substrate temperatures of 200℃ and 400℃, respectively. Samples of ZnO films on sapphire (Al2O3) substrate with different thicknesses of ZnO buffer layers were investigated by characterizing structural, electrical and optical properties. To investigate the stress between the film and the substrate, X-ray diffraction and scanning electron microscopy were used. The buffer layers could relax stresses induced by the lattice mismatch and different thermal expansion coefficients between ZnO epilayer and sapphire substrate. The ZnO films grown on ZnO buffer layer with optimized thickness have shown good ultra-violet(UV) emission properties. It was found that the use of ZnO buffer layer plays an important role in improving the quality of the ZnO film which could be a good candidate for light emitting devices.

E/P32 EFFECT OF Si DOPING ON THE ELECTRICAL PROPERTY OF ZnO THIN FILM

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Thin films of ZnO/Si/ZnO structure were deposited on (001) sapphire substrates by pulsed laser deposition using Nd:YAG laser. After deposition, ZnO thin films were annealed at various conditions for Si-doping. Based on the SEM and XRD data of annealed films exhibiting only (002) ZnO peak without any Si peak, it was found that all films were c-axis oriented and Si in intermediate layer was fully diffused into ZnO layers. The electrical property of Si-doped ZnO thin films was investigated by Hall measurement. All Si-doped films showed n-type characteristics and the electron mobility of ZnO thin films was improved by Si doping.

E/P33 LASER WAVELENGTH AND PARTIAL PRESSURE EFFECTS ON THE FORMATION OF NANOCRYSTALLINE Si

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Si thin films on p-type (100) Si substrate have been fabricated by pulsed laser deposition technique using a Nd:YAG laser. Different laser wavelengths (l=1064 nm, 532 nm and 355 nm) are used to deposit Si nanocrystallites (nc Si). The pressure of the environmental gas during deposition was varied from 1 to 3 Torr. After deposition, Si nanocrystallites have been annealed in various ambient gas and temperature. Si nanocrystallite have shown strong blue PL band. Green and orange band also have been observed from Si nanocrystallites. Si nanocrystallites grown by PLD showed visible PL strongly depending on the growth conditions such as laser wavelength, background gas pressure. Electroluminescence (EL) properties of formed nanocrystalline Si will be discussed using indium-tin-oxide (ITO)/nc-Si/p-type Si/SiO2/Ti/Pt structure.

E/P34 TRANSMISSION ELECTRON MICROSCOPY AND EDS ANALYSIS OF SCREEN-PRINTED CONTACTS FORMATION ON MULTICRYSTALLINE SILICON SOLAR CELLS

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In photovoltaic industry, contacts fabrication is an important step of solar cell efficiency. In order to reduce the cost of the device, the metallisations are realized by screen-printing a paste. In this work, we have analysed large area industrial solar cells with pn junction, SiO2 passivation layer and TiO2 antireflection coating (ARC) on front side. During the process, front contacts are screen-printed after TiO2 ARC deposition. The metallisation paste is composed of a glass powder, an active metal (Ag for front paste and Ag/Al for rear paste) and a binding agent. Its deposition is followed by a rapid firing step at high temperature (firing-through the oxide layers) and an annealing at lower temperature under reducing ambient. The aim of this study is to understand chemical and metallurgical mechanisms that occur in front and back side metallisations during heat treatments necessary for contacts formation. Observations are realized with a 200 kV Field Effect Gun-TEM associated to an EDS analysis. A software allows to pilot the beam scanning along a surface or a line to obtain respectively a X-ray cartography or concentration profiles by elements. Cross sections samples are realized by the tripod method. The main result of this analysis is that front contact ohmicity is not realized by the silver active metal of the paste but by metallic species like Pb and Zn coming from sintered powder. The influence of the titanium from ARC is also discussed.

E/P35 SCREEN PRINTED AL AND AG CONTACTS FORMATION BY RAPID THERMAL ANNEALING IN MULTICRYSTALLINE SILICON SOLAR CELLS

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The aim of the present work is to optimized the annealing parameter in both front and back screen printed contacts realization on p-type multicrystalline silicon phosphorus diffused. The RTA treatments were carried out at various temperatures from 450 to 800℃ and annealing time ranging from 30 to 75s in air, O2 and N2 ambiance. The contacts parameters are obtained according to Transmission Line Model measurements. A good RTA cycle is obtained with a temperature plateau of 650℃-700℃ and annealing ambiance of air. The cooling down rate on the contact resistance is more important in the case of rear contact. The best annealing condition of temperature plateau, time, ambiance, cooling rate was obtained for contact resistance.

E/P36 STRUCTURAL CHARACTERIZATION OF GaAsBi SEMICONDUCTOR ALLOY BY RUTHERFORD BACKSCATTERING SPECTROSCOPY COMBINED WITH CHANNELING TECHNIQUE

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GaAsBi alloy layer, which has been successfully grown by low-pressure MOVPE growth, shows an interesting optical characteristic that the temperature variation of the band-gap energy is as small as 0.1 meV / K. Therefore Bi-containing semiconductor alloy is a good candidate for temperature-insensitive wavelength semiconductor lasers, which are very important devices for next generation Wavelength Division Multiplexing optical fiber communication systems.

In this report, structural characteristics of the GaAsBi alloy layer grown by MOVPE growth method have been studied by Rutherford backscattering spectroscopy (RBS) combined with channeling technique. Although the alloy layer was grown at fairly low temperature as low as 365 C, the structural perfection of the alloy was fairly good. RBS was used to investigate the position of Bi atom in the GaAsBi zinc-blende lattice. Fluorescence extended X-ray absorption fine structure (EXAFS) analysis was also applied to investigate the local structures around Bi in GaAs1-xBix. It is confirmed that more than 99 % Bi atoms position on the As site in GaAsBi zincblende structure by RBS channeling technique.

The result in this research that the crystal structural perfection of the metastable GaAsBi alloy is fairly good encourages the application of the newly coming metastable alloy to optoelectronic devices.

E/P37 PHYSICAL AND ELECTRICAL DEGRADATION OF ZrO2 THIN FILMS UPON VARIOUS GATE ELECTRODES MATERIALS

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As the channel lengths of CMOS evices are scaled down to a sub-100nm, an equivalent oxide thickness of sub-15Å will be required. However, the decrease of the thickness of SiO2 shows the significant leakage current. Therefore, dielectric materials with a high dielectric constant, possibly large band-gap, and good thermal stability have drawn a lot of attention as alternative gate dielectrics. Also, process compatibility and thermal stability with conventional poly-Si or alternative electrodes must be considered. Recently, ZrO2 has been considered as promising alternative materials due to high dielectric constant and good thermal stability with Si substrates. We investigated the electrical properties and thermal stability on sputtered ZrO2 films with various electrodes. ZrO2 thin films as a gate dielectric were deposited by reactive dc magnetron sputtering, followed by thermal annealing in N2 ambient using furnace. And then various metals such as Al, Pt, TiN and TiN/Al were deposited by sputtering as a gate electrode. Also, conventional poly-Si or poly-SiGe as a gate electrode were deposited by CVD. By HRTEM, XPS/AES and SIMS analyses, we evaluated compatibility and thermal stability between the ZrO2 films and electrodes. In comparison with Pt electrode, ZrO2 films with Al electrode formed Al-O amorphous interlayer. At the higher annealing temperature, a reaction of ZrO2 film with poly-Si was observed. And we compared electrical characteristics upon various electrodes.

E/P38 THE ANALYSIS OF BRIDGE TYPE SUPERCONDUCTING FAULT CURRENT LIMITER APPLYING MAGNETIC SHIELDING MODEL USING HIGH-TC SUPERCONDUCTING TUBE TO DC REACTOR OPERATION

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In this paper, To reduce the difficulty for the fabrication of High-Tc Superconducting wire consisting of bridge type superconducting fault current limiter, we suggested the modified bridge type superconducting fault current limiter applying magnetic shielding model using High-Tc superconducting tube to DC reactor operation.

Through the circuit analysis for operational characteristics, we analyzed the fault current limiting characteristics from the comparison of design parameters for the proposed model and showed that the suggested model can perform the same limiting operation in occurence of fault as conventional one required for High-Tc superconducting wire.

E/P39 CHARACTERIZATION OF Si(111) CRYSTALS IMPLANTED WITH SB+ IONS AND ANNEALED BY RAPID THERMAL PROCESSING

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Monocrystalline silicon, Si(111), targets are implanted (at room temperature) with antimony ions at 60 keV energy to 5_1014 or 5_1015 Sb+cm-2 dose. The samples are heat treated by means of rapid thermal processing (RTP) at 1000°C during 60 s, under nitrogen atmosphere. In this work, we report the measured evolution of the silicon surface damage, the radiation damage restoration and the behavior of antimony ions in relation to antimony dose and RTP processing. The investigation is carried out by He+ Rutherford backscattering spectrometry (RBS) (operating at 1.57 MeV energy in both random and channeling modes), X-ray diffraction (XRD) and atomic force microscopy (AFM) techniques.

For non annealed samples, it is shown that the thickness of the amorphous silicon layer, which is localized on the surface samples and enhanced by ion implantation, increases with the rise of antimony dose. Moreover, for the case of 5_1015 Sb+cm-2 dose, tensile stresses are put into evidence in the silicon lattice. After rapid thermal processing, a good surface damage restoration is obtained for all samples. However, a significant loss of antimony has occurred, especially for the specimens which are implanted with 5_1015 Sb+cm-2 dose, suggesting an antimony out-diffusion. Finally, a good morphological characterization of the specimens is provided by AFM technique.

E/P40 HIGH QUALITY HfO2 GATE DIELETRICS DEPOSITED BY REACTIVE SPUTTERING WITH Tox < 10≈

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The gate dielectric needs to be scaled down to 1nm for 100nm-node CMOS technology and beyond. However, the resulting gate leakage currents make such thin oxides impractical in many device applications; thus, an alternative material is required for the gate dielectric.

We evaluated the HfO2 films deposited by the conventional reactive sputtering and compared the results with the other films deposited by the modified reactive sputtering method. During hafnium sputtering, O2 was modulated to control the interface quality and to suppress the additional growth of the interfacial layer. Samples were then thermally annealed. According to the annealing methods, films showed different phase transition, which demonstrated that several polymorphs appeared in HfO2 films. TEM showed ~15Å thick bottom interfacial layer and it reduced down to ~5Å when Hf metal is covered before going through the reactive sputtering step, proving that it acts as an oxygen barrier. We obtained the equivalent oxide thickness of <10Å using modified reactive sputtering method and the leakage current level was quite low. As the films suffered heat treatment, leakage current characteristics were improved whereas the accumulation capacitances were degraded due to the growth of the interfacial layer. The flatband voltage shifted negatively which correlated with the positive fixed charges and post annealing in O2 was seen to decrease the net amount of positive charges.

E/P41 SYSTEMATIC POSITRON STUDY OF HYDROPHILICITY OF THE INTERNAL PORE SURFACE IN ORDERED LOW-K SILICA THIN FILMS

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We report the results of a systematic study on well-ordered mesoporous silica thin films with hydrophobic or hydrophilic character, using the non-destructive Doppler Broadening (DB) and Positronium fraction (f-Ps) positron beam analysis (PBA) techniques. The DB results, characterized by the S-parameter, are related to the open volume and chemical environment present at the positron annihilation site. The f-Ps technique is a very sensitive probe to determine the type of porosity (open or closed) in thin film materials. The samples studied present different pore size (2.5, 5 and 8 nm), pore fraction (from 4% to 57%) and changes in hydrophilicity. In the hydrophilic samples with small pore size the S-parameter increases with the porosity while the Ps-fraction remains almost unchanged. Increasing the pore size leads to smaller changes in S with porosity but shows an abrupt change in the Ps-fraction for samples with porosity higher than 45%, indicating a percolation threshold. Annealing experiments on the latter samples marked the sensitivity of PBA to the presence of water molecules covering the pore surfaces. On the other hand, for hydrophobic samples with high porosity (57%) the highest S parameter and Ps-fraction were obtained for the three pore sizes studied. The relationship between these observations and open porosity will be discussed in terms of branching of the positron annihilation channels inside the mesoporous films.

E/P42 CHARACTERISATION OF (CeO2)1-X-(SnO2)X THIN FILMS PREPARED BY PYROLYTIC SPRAY TECHNIQUE

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Mixed oxide thin films of (CeO2)1-x-(SnO2)x with x between 0 and 0,4 were prepared by spray pyrolysis technique. The composition of these films was determined by electron probe microanalysis (EPMA) and the crystalline structure by X-ray diffraction (XRD). Cyclic voltammetry (CV) was performed in an electrolyte of propylene carbonate with 1M LiClO4. These films were found to be able to insert/extract large charge densities of Li+ ions. The good performance was obtained by films with 10 % SnO2 (The charge capacity of these films was about 4 mC/cm2). They also remained transparent during Li+ intercalation.

E/P43 TRANSIENT SPECTROSCOPY OF EXCITED FREE-CARRIER-ABSORTPION AND THE MEASUREMENT OF BAND-GAP EDGES OF INDIRECT SEMICONDUCTORS

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A direct optical measurement of the fundamental band-gap absorption in Si and 4H-SiC is achieved by a novel type excitation spectroscopy using the time- and spatial-resolved free-carrier absorption transients. The initial part of the absorption transient after the nanosecond excitation pulse is recorded and analysed employing relationship between the band-band absorption coefficient, abb, and the instant carrier density profile and its value at the excited surface. The absorption components related with assisted phonons are well reflected in the abb(hv) spectra over an entire band edge of the low-doped Si and 4H-SiC epitaxial layers. With proposed method it is possible to examine in detail the influence of temperature, doping and injection on the fundamental absorption coefficient near the absorption edge. The appearances of band-gap narrowing to the value as low as a few meV are very well reflected.
Simple extensions of the technique allow carrier lifetime, surface recombination and carrier transport characterisation.

E/P44 BEHAVIOUR OF DEUTERIUM IMPLANTED INTO HEXAGONAL SILICON CARBIDE: OPTICAL ABSORPTION, POSITRON ANNIHILATION AND THERMAL DESORPTION SPECTROMETRY

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Wafers of 4H and 6H SiC were implanted with 30 keV D ions with fluences from 10E15 to 10E17 cm-2 at RT. For both polytypes deuterium desorption spectra are similar and show two weak low-T peaks (750 and 950K at ramp rate 3K/s, E~2.5eV) and a large high-T peak at 1600K (E~4.5eV). At ramp rate 1K/s the high-T peak consists of two or even three closely situated peaks. Low-T peaks might be attributed to deuterium trapped in vacancy-type defects; high-T peak could correspond to rupture of C-D or Si-D bonds and/or desorption from platelets. Positron annihilation spectrometry showed similar behaviour of S-W(E) for both polytypes. Samples have thin surface layer, damaged layer with complete positron trapping (Sdef/Sbulk=1.065) and bulk. We made in-situ 15min annealings with steps of 200K from 490K to 1490K. No clear difference in annealing of virgin 6H SiC and sample implanted to 10E15 D/cm2 can be noticed. Starting from 690K annealing surface S-value increases sharply. Surface S-W values does not permit to clearly distinguish if it was a C- or Si-like surface. Three weeks of exposure in air of annealed sample reduced surface SW dramatically. Damaged layer did not changed much due to annealing. Remarkably, increase in surface SW values with thermal annealing is much more pronounced and starts at lower temperatures in samples implanted with 420keV Xe ions. In addition we will discuss results of optical (UV-Vis-IR) characterization of samples.

E/P45 AN INVESTIGATION OF SiON/Si STRUCTURES FOR APPLICATIONS ON MOS DEVICES

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In recent years, oxynitride films are being examined as potential materials in replacing SiO2 in Metal-Oxide-Semiconductor (MOS) devices. Their main advantages are the low density of surface states, the high dielectric permittivity and the fact that the band energy of SiON can be adjusted between 5eV and 9eV depending on the [O]/[N] ratio, which give rise to potential application for heterostructures. In the present work, we examine thin films of SiON grown on Si substrates by CVD. Films with different [O]/[N] ratios were used, with O kept at 4-5%. Subsequent metalization lead to the creation of MOS devices and electrical characterisation took place in order to identify their electrical properties as a function of the nitrogen concentration. In addition, Rutherford Backscattering Spectroscopy (RBS) was used to verify the exact composition of the films. Electrical measurements allowed determination of the interface state density, the bulk charges and the dielectric constant of the films. The interface states density was found to lie between 1.74x1012 eV-1cm-2 for the samples with 64% of nitrogen, and 1.72x1011 eV-1cm-2 for those with 36%. The corresponding dielectric constant was found between 35 and 8 and the bulk trapped charges between 7.62 μCbcm-2 and 113 μCbcm-2.

E/P46 VOLUME AND GRAIN BOUNDARY DIFFUSIVITY OF BORON IN POLYCRISTALLINE SILICON DURING RAPID THERMAL ANNEALING

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The diffusion of Boron and Arsenic from polycristalline silicon into single cristal silicon during rapid thermal annealing (RTA) at temperatures between 1000 and 1150°C for 20 s has been investigated. Samples were caracterized by secondary ion mass spectrometry (SIMS). The volume and intergranular diffusion coefficient has been deduced from the Boron profiles. Depth profiles are analysed using the Suzuoka model. It is established that the grain boundary diffusivities are 2-3 larger than the volume diffusivities.

E/P47 STUDY OF MECHANICAL PROPERTIES OF PHOSPHORUS OR BORON DOPED a-Si:H FILMS

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The mechanical properties of the doped thin a-Si:H films play crucial role for their technological application and their determination is of great importance. One of the most suitable method for mehanical characterisation of thin films is the indentation technique.

The method enables to determine besides the film hardness also other important material properties such as the film elastic modulus, the fracture toughness of the film and the film-substrate interface and the internal stress etc.

The main objective of the recent work is to study the mechanical properties of series of boron- and phosphorous-doped a-Si:H films by means of indentation techniques and to compare the obtained values with the density of states carried out from combination of CPM, PDS and OT measurements. The aim is to find the relationship between the mechanical and optoelectronical properties of the doped a-Si:H films.

E/P48 CHARACTERIZATION OF CARRIER LIFETIME AND DIFFUSIVITY IN 4H-SiC USING TIME-RESOLVED IMAGING SPECTROSCOPY OF ELECTROLUMINESCENCE

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We report on time- and spectrally resolved studies of recombination radiation in 4H-SiC by combining imaging spectroscopy and gated optical emission microscopy techniques. An insight into the basic characteristics of 3D carrier dynamics was attained by combining data of electroluminescence imaged from the backside and from the cross-sectional plane of a forward biased PiN structure. We demonstrate the potential and efficiency of this method in mapping minority carrier lifetime and diffusivity parameters and also in locating and analysis of the structural defects in the active area. Finally, a detrimental impact of the intrinsic growth-related and long-term operation-induced defects on the carrier transport properties was directly revealed and quantified.

E/P49 INTERFACIAL TUNNELING OXIDE: IMPACT ON ELECTRICAL CHARACTERIZATION OF UNIPOLAR Si/Si BONDED JUNCTIONS

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The effect of interfacial tunneling oxide on the electrical characterization of unipolar Si/Si bonded junctions according to previously proposed procedures (V.A. Stuchinsky and G.N. Kamaev, Material Science and Semiconductor Technology 4 (2001), pp. 177 - 179) is numerically analyzed. The oxide additionally restricts the electric current across the junction thus giving rise to different occupation probabilities of interface states at the two Si/SiO_2 interfaces in a biased junction. As a result, different energy intervals at the two interfaces turn out to be probed simultaneously. In two limiting cases, depending on the transmission factor of the interfacial oxide layer and on the range of bias voltages, either interface states at both interfaces or only at the "windward" Si/SiO_2 interface are being probed. The CV measurements reproduce the doping level in the vicinity of the junction rather adequately. The action of the oxide layer induces no prominent features in the direct current-to-h.f. conductivity ratio vs voltage curve similar to those brought about by interfacial quasi-ohmic punctures.

E/P50 NANOMETER SCALE PHOTOVOLTAGE SPECTROSCOPY

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Surface photovoltage (SPV) is a well-established technique for the characterization of semiconductors, which is based on analyzing illumination-induced changes in the semiconductor surface potential. To date, all the SPV related techniques have a common significant drawback: they do not have high spatial resolution.

In this work we present a high resolution SPV system. The system is based on an illumination system combined with a Kelvin probe force microscope (KPFM), which measures the contact potential difference (CPD) between a sample surface and the tip of an atomic force microscope (AFM). By measuring the CPD as a function of wavelength, the whole surface photovoltage spectrum of a semiconductor sample is obtained with sub-micrometer spatial resolution. The illumination system is based on an imaging monochromator coupled to an optical fiber brought to a very small distance from the AFM cantilever. We present a series of high-resolution SPV and surface photovoltage spectroscopy measurements on epitaxial GaP layers, and show that the method is capable of measuring sub-bandgap electronic transitions. The lateral resolution of the technique is obtained by measuring surface photovoltage spectra on cleaved pn junctions, at different distances from the junction edges.

E/P51 MICROSTRUCTURAL STUDY OF ANNEALED Cr/Si SYSTEM USING CROSS-SECTIONAL TEM COMBINED WITH NANO-ANALYSIS

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Among the various characterisation methods generally used in the study of silicidation mechanisms, particularly interfaces structure, the Cross-Sectional Transmission Electron Microscopy (XTEM) combined with Nano-analysis were not much used. This work dealt on the study, by mean of this method, of interfacial atomic diffusion phenomena in thin Cr/Si system in dependence on heat treatment conditions. The chromium film of 800 Å thickness was electron gun deposited onto (111) oriented phosphorus implanted Si substrate. The XTEM observations of samples annealed at 475°C during 60 and 120 min showed that the chromium was partially consumed in opposite to the case where the Si substrate was not implanted. The thickness of formed chromium silicide was practically the same for 60 and 120 min. Nano-analysis revealed the presence of Si atoms at the surface and Cr atoms into the substrate leading to the formation of a crystalline Cr-Si alloy. However, after 500°C during 5 min the obtained results showed that no reaction occurred between Si and Cr and Si atoms were present in the Cr film. This indicated that Si diffused towards to the surface before silicidation.

E/P52 INFRARED STUDIES OF OXYGEN-RELATED DEFECT FORMATION IN IRRADIETED WITH NEUTRONS CZ - SILICON AFTER ANNEALING AT T= 450°C –650°C UNDER HYDROSTATIC PRESSURE

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Fourier-Transform Infrared Absorption Spectroscopy (FTIR) was used to study the creation/annihilation of the defects in an irradiated with neutron silicon grown by Czochralski method with the oxygen concentration ~ $9*10^{17}$ at/cm^3. The samples were irradiated with fast neutrons of energy E=5 MeV, at a fluence of 5x10^16 n/cm^2 at temperature t=40°C – 50°C and than subjected to the annealing (HT) at T=450°C or 650°C under hydrostatic pressure (HP) at 1.1GPa.

It has been stated that HP treatment at 450°C retards the TDD creation in an irradiated with neutron silicon. Beside of this it has been found out that HP treatment at 450°C influences significantly the acceptor-like defects concentration in the irradiated material. After HP-HT treatment at 650°C an increasing in the carrier concentration and an additional absorption band in spectral range 1000cm^{-1} –1200cm^{-1} was observed. The origin of this band is discussed.

E/P53 IMPROVED REPRODUCIBILITY OF SCANNING CAPACITANCE MICROSCOPY MEASUREMENTS FOR QUANTITATIVE 2D CARRIER PROFILING ON SILICON

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To play an important role as two dimensional (2D) electrical characterization technique, the calibration curves extracted from scanning capacitance microscopy (SCM) data to obtain a correct dopant profile, must be as reliable and reproducible as possible. In this context, the sample preparation process is a crucial step to ensure good quality, repeatable SCM measurements and avoid the called "contrast reversal" effect i.e. a decreased SCM signal for lower concentration levels. Thus, using for the calibration samples, n and p type epitaxial doping-staircase layers grown on uniformly doped Si substrate, we have focused our work on optimization of the preparation and overcome this critical problem for both types. It is shown that a final polishing of the surface by a 0.05 µm colloidal silica solution is needed to avoid it probably reducing the roughness surface and consequently the surface states in the SiO2/Si interface. Moreover, different oxides, thermal, wet-chemical and from ozone are investigated to obtain in practice a calibration curve as reproducible as possible from day to day. In this aim, the oxidation conditions are optimized to obtain an high SCM signal and oxide thickness from 3 to 6 nm. At last, we have obtained a good agreement between our experimental calibration curve and the called direct inversion model used for the 2D dopant profile.

E/P54 AN ELECTRICAL TECHNIQUE FOR THE MEASUREMENT OF THE INTERFACE RECOMBINATION VELOCITY BASED ON A THREE TERMINAL TEST STRUCTURE

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In this work a novel test structure to measure the surface or interface recombination velocity is presented, that can be used to measure the effect of different surface treatments made on an exposed surface after the test device has been fabricated. The test device is made by a vertical P+NN+ injecting diode, and by a floating N+ region that acts as a sense terminal on the top surface. It can be shown that the voltage measured between the top floating terminal and the bottom N+ one, when the diode is forward biased, depends from the recombination velocity at the surface region between the P+ and the sense regions. If this surface is exposed to a subsequent processing (as RIE etching, polisilicon or oxide deposition) after the device is realised, the recombining properties of that transition can be analysed. Two-dimensional simulations of the test structure operations was performed. A variation of two orders of magnitude of the sense voltage are induced by varying S in the typical range of interest between 1e2 and 1e7 cm/s, demonstrating the high sensitivity of the proposed method. The effectiveness of the method has been experimentally checked. In the full paper we will report on different passivation processes on the exposed surface (oxide, nitride and polisilicon layer deposition) as well as the effects of different cleaning treatments, like RIE and plasma etching.

E/P55 POLYTYPE DETERMINATION AT SiC/OXIDE INTERFACE BY INTERNAL ELECTRON PHOTOEMISSION SCATTERING SPECTROSCOPY

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Though the thermal oxide on SiC appears to be of equal quality as the oxide grown on Si, the mobility in the SiC MOS transistors is severely degraded in comparison to the SiC bulk value indicative of the presence of a high density of defects. One of the additional sources, as compared to Si/SiO2, of SiC/SiO2 interface states might be formation of a SiC polytype transitional layer with smaller bandgap.We attempted to determine the SiC polytype at the interface with thermal oxide using internal photoemission of electrons (IPE) from the SiC into the oxide. The IPE yield spectral curves for 4H-, 6H-, and 15R-SiC crystals oxidized in dry O2 were found to exhibit a drop in the energy range just above the bulk bandgap width of the corresponding polytype. The difference between the peak in the yield reduction and the bandgap is always close to the energy of optical phonons in SiC (about 100 meV) suggesting a relationship of the observed feature to additional energy loss by photoelectron excited in SiC via the Auger process. Therefore, taking into account the small (in the nm range) escape depth of photoelectrons, we conclude that the dry oxidation does not cause a polytypic transition at the SiC surface. However, upon SiC oxidation in H2O, no distinct energy loss peak can be observed anymore in the IPE spectra of 4H-SiC, possibly suggesting a polytypic transition.

E/P56 STRUCTURAL CHARACTERIZATION OF ALCVD ZrO2/Al2O3 NANO-LAMINATE DEPOSITS WITH HIGH TEMPERATURE GRAZING INCIDENCE XRD and TEM

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The structure of ZrO2/Al2O3 nano-laminate deposits prepared with ALCVD was studied using high-temperature grazing incidence x-ray diffraction and high resolution TEM. In the room temperature XRD spectra, a sharp and intense peak due to the constructive interference of x-ray beams reflected from correlative interfaces of laminae was observed. From the position and intensity of the peak, information relative to the thickness, deposition rate and interface roughness was obtained. The in-situ structure change during thermal anneals was studied as well with high temperature XRD measurement. It is found that the laminate structure has a trend to mix at high temperatures before crystallisation. All the results have been confirmed by high-resolution TEM.

E/P57 INFLUENCE OF N2 - H2 PLASMA TREATMENT ON CHEMICAL VAPOR DEPOSITED TiN MULTILAYER STRUCTURES FOR ADVANCED CMOS TECHNOLOGIES

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In deep submicron technologies (below 0.25 µm) poor conformity in vias with high aspect ratios or over extreme topographical structures of sputtered TiN have stimulated efforts to deposit TiN by chemical vapor deposition (CVD).
We show that closed TiN multilayers (5 to 10 nm) with excellent conformity can be produced by CVD from Ti[N(CH3)2]4 (so-called TDMAT) on heated substrate with an additional N2-H2 plasma treatment after deposition. They are well suited for deep submicron vias with aspect ratios of more than 3. We applied ToF-SIMS, TEM, AES, and XPS for a detailed characterization of morphology, structure and composition of the multilayers and demonstrate that low energy primary beams and sample rotation applied during ion sputtering analysis significantly improve the depth resolution in elemental depth profiles. This allows to characterize the effect of plasma treatments. The N2-H2 plasma treatment introduces a strongly anisotropic layer modification including etching, densification, crystallization and compositional changes. The plasma is effective in removing process induced contamination of the TiN layers (O, H, C, and related species) up to a depth of 3 nm. The concentration is reduced by more than one order of magnitude. A minor influence is detected up to a depth of 10 nm, obviously mainly due to outdiffusion. The obtained results are important for establishing a solid analytical support for deep submicron (0.18-0.13 µm) CMOS technologies.

E/P58 HELIUM IMPLANTATION IN SILICON: THE EFFECTS OF IMPLANTATION TEMPERATURE ON DESORPTION MEASUREMENTS

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Thermal helium desorption spectrometry was used to study the effects of implantation temperature in helium implanted silicon at 5x1016cm-2 – 50 keV, from RT to 800°C. Both isochronal and partial annealing schemes have been used and have allowed to raise important process and behaviour. Helium release from voids/bubbles in silicon is well described by the permeation from cavities to the surface. Entropy effects play a major role on the helium desorption from bubbles. Partial desorption results show that the release of helium by permeation from bubbles/voids to the surface has an activation energy 1.8 eV whatever the implantation temperature may be, but also whatever the implantation energy may be. These results are discussed in highlight of the Transmission Electron Microscopy observations. As for example, a implantation temperature of 600°C is needed to create cavities empty of gases. However, with increasing temperature more and more extended defects are formed. Finally at 800°C, no cavities or bubbles are created but only extended defects. In addition, positron annihilation experiments has been done to study the positron trapping at such interstitial defects.

E/P59 THERMODYNAMIC FUNCTIONS OF QUANTUM AND QUASICLASSICAL ELECTRON GAS IN SEMICONDUCTORS WITH WEAK BOND

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The thermodynamic potential, entropy, and other thermodynamic functions were calculated for layered crystals (LC) with weak chemical bond in one direction. For quantum case the results were carried out using the contour integration and for quasi classical gas using the reversible conversion of Laplass.

We compared the results, we got for different models of one-particle energy depending on quasi impulse. We also compared the results with isotropic crystal. The results we got are very different in the case of quasi classical gas and quantum gas. They show the espetially importance of using non parabolic energy dependance on impulses for quantum gasses.

E/P60 MEASUREMENT OF NITROGEN IN CZOCHRALSKI SILICON BY MEANS OF INFRARED SPECTROSCOPY

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A novel method for the quantitative measurement of nitrogen in Czochralski silicon by means of low temperature Fourier Transform Infra Red spectroscopy is presented, based on measurement in the far-infrared range. Its main advantage is the high sensitivity to nitrogen, 5×10^{12} at/cm^3, at least one order of magnitude better than the other published methods[1,2]. The method consists in measuring the sample at a temperature less than 15°K, in the spectral range of 200 to 300 cm^{-1}, where the absorption bands related to the electronic transition of the N-O species are present. The samples are prepared by means of a thermal treatment at a suitable temperature (e.g. 650°C) for a long enough time in order to reach the saturation of the N-O concentration and therefore assure that an equilibrium situation is obtained. An overview of the most common measurement methods for nitrogen in silicon is also reported, as well as a brief review of the literature on nitrogen and nitrogen-oxygen complexes in silicon.

[1] Y. Yamanaka et al. , Solid State Phenomena ,vols. 82-84 (2002), 63-68
[2] R. S. Hockett et al. Electrochemical Soc. Proc. Vol. 2000-17, 584

E/P61 MAGNETIC SUSCEPTIBILITY OF P+N JUNCTIONS IN CORRELATION WITH THE NATURE OF SILICON SUBSTRATE: CRYSTALLINE OR PRE-AMORPHIZED

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Increased requirements for reduction of electronic system dimensions, particularly in automotive and avionics systems, are the cause of new serious dysfunction problems and failure. These dysfunctions are often caused, by magnetic perturbations generated by neighbouring electrical modules. A deep study of magnetic susceptibility of electronic components and circuits is then necessary to find ways that enable to increase their immunity since conception. The tests are realized on two types of silicon P$^+$N junctions fabricated by new technologies using low energy B$^+$ implantation into n-type silicon. In the first type, the substrate is crystalline. In the second, the substrate is pre-amorphized by high-energy germanium implantation. The effect of pre-amorphization of the substrate on magnetic susceptibility of the junction is highlighted by electrical characterizations. The different measurements were performed under a controllable magnetic field magnitude ranging between 0 and 1 Tesla, with sample temperature varying between 77K and 300K using an Oxford Teslatron system.

E/P62 RAMAN SCATTERING FROM MAGNESIUM DOPED GaN AS-GROWN, HYDROGEN IMPLANTED AND ANNEALED (II)

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Often, a post growth treatment (such as implantation) of Mg –doped GaN is required to lower the resistance of the GaN, which may depend on structural changes via conduction electron-phonon interaction. We implanted Mg-doped GaN, grown by MOVPE, with 26KeV hydrogen ions at doses from 10^{12} up to 10^{15}cm^{-2}. Raman spectra were recorded after each implantation and annealing step. From reference sample, besides the well-known first order modes we observe several second - order broad bands centered at about 1156, 1270, 1317, 1390 and 1469 cm^{-1}. Implantation induces at least five new modes at 320, 380, 428 (shoulder of the A_{1g}-sapphire peak), 645, and 671 cm^{-1}. All these above bands are very well resolved, particularly at the highest dose of implantation. The second order Raman spectra are not affected by implantation. In the region 4000-4900cm^{-1}, several luminescence bands at 4272, 4469, 4618 and 4650cm^{-1} are present in the as grown sample. Implantation shifts all the bands towards higher energy and reduces their intensities. In the region 4900-5100cm^{-1}, of the reference sample we monitored two sharp emission lines at (694.4 nm- 1.7855eV: R1) and (693nm-1.7891eV: R2) with the intensity ratio: I(R2)/I(R1)< 1. The bands are due to transitions from the ($4\ A_2$) ground state of Cr^{3+} to the excited ($4\ T_2$) and ($4\ T_1$) levels observed also by PL (part I). Implantation at 10^{13} and 10^{15}cm^{-2} changes the intensities to I(R2)/I(R1)=1 and I(R2)/I(R1)>1, respectively. No recovery has been found after low temperature annealing. We have investigated the group-theoretical assignments of the second and third order Raman modes in wurtzite structure, shifts of modes due to stresses caused by Mg and hydrogen in GaN, as well as the influence of implantation on the LO phonon- plasmon coupled modes.

E/P63 MICROREFLECTIVITY STUDIES OF WAVELENGTH CONTROL IN OXIDISED ALGAAS MICROCAVITIES

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Wet oxidation of GaAs/AlGaAs structures is an important technique in the processing of advanced devices such as vertical cavity surface emitting lasers (VCSELs). For VCSELs, the low-index and electrically-insulating Al_xO_y layers have been used to obtain high-reflectivity and broad bandwidth distributed Bragg reflector mirrors (DBRs). A further recent development has shown that combined lateral-vertical oxidation of intracavity AlGaAs layers can tune the resonant wavelength of a semiconductor microcavity. The slow oxidation rate limits the lateral scale of practical wet oxidation to patterned and etched mesa devices to 50-100 μm in width, therefore post-processing assessment of spectral changes requires microreflectivity measurement capability.

Here, we describe developments in wavelength-control of 1300nm region microcavity structures, assessed and optimised by a specially developed simple microreflectivity set-up. This consists of microscope-objective focussing of broadband light, combined with optics to relay the data to a spectrograph, and a CCD camera for alignment. With this system, we can measure calibrated reflectivity of features down to a few 10's of μm over the spectral range 600-1800nm. We present microreflectivity measurements of wide-bandwidth oxidised DBRs, and most significantly, for the first time to our knowledge, of oxidation control of the resonant wavelength of a microcavity in the 1300nm range.

E/P64 CALCULATION OF OUTPUT CURRENT-VOLTAGE CHARACTERISTICS OF SOI MOSFET`s

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The current-voltage characteristics of SOI MOS-transistors created in thick (0,5 μm) silicon films by recrystallized laser beam is calculated. An equivalent circuit for computation of drain current includes _-MOS-transistor and horizontal ___-bipolar transistor, which form simultaneously in technological process. The peculiarity of formed bipolar transistor is that its base isolated by layers of undergate and insulating oxides. For calculation of the current of the bipolar transistor the potential of "floating substrate" (the under-channel region in which the holes accumulated under drain voltage), which causes of sharp increasing of drain current in the range of small drain voltage, is obtained.

The characteristics obtained have abrupt current drain region, known as "kink-effect", which can be described as summed influence of both transistors and at the same time the avalanche formation of charge carriers caused by ionization under influence of strong electric field does not play essential role.

Experimental current-voltage characteristics satisfactorily describe by the given model.

E/P65 NONELASTIC HEAVY-HOLE-PHONON INTERACTION IN MERCURY TELLURIDE

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The solution of Boltzmann equation is considered here in the case when the magnetic field directed along Z-axes and electric field has X- and Y- components . The solution is found in the form of series expansion of nonequilibrium distribution function with respect to carrier energy.

After the substitution of the solution into Boltzmann equation and double integration over the quasimomentum one can obtain the system of the algebraic equations relatively to the values Cα nb (n=0,1,2,3...; b=1,2 - respectively for electrons and heavy holes; α=1,2,3). For calculations the nonparabolic Kane model for the conduction band electrons and parabolic model for the valence band heavy holes were used, the bottom of the conduction band was taken as the zero energy. The next charge carrier mechanisms were taken into the consideration during the calculation: intraband scattering on the polar optical phonons, interaband scattering on the polar optical phonons, intraband scattering on the nonpolar optical phonons, interaband scattering on the nonpolar optical phonons, acoustic and piezoacoustic scattering, ionized and neutral impuriy scattering. The calculation was limited by the case of n = 5, which differed from the case n = 4 less than 1%. The temperature dependances of Hall coefficient and conductivity in the temperature range 4.2 –300 K are calculated. The contributions of the different scattering mechanism into the heavy-hole mobility in the temperature range 4.2 – 300 K are estimated.

E/P66 METHOD FOR INVESTIGATION OF SURFACE GENERATION VELOCITY IN MOS STRUCTURES

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Sensitive method for investigation of surface generation velocity of minority carriers S_g in MOS structures has been developed. Method is based on application of dynamic unsteady-state current-voltage characteristics (DUCVC) of MOS structures. Application of the DUCVC method provides direct determination of surface potentials and accurate separation of different generation mechanisms during inversion layer formation at semiconductor surface. Special technique for elimination of surface state charging current from the total generation current in DUCVC analyses has been proposed. The latter is necessary for correct S_g determination in irradiated samples with high surface state density. Surface generation velocity in Si-SiO_2 structures induced by low-energy electron beam irradiation has been studied. The influence of surface potential fluctuations on S_g values in MOS structures was discussed. The results of S_g investigation in small selected areas of Si-SiO_2 structures (10^{-6} cm^2) were presented

E/P67 ANNEALING EFFECT ON THE NONRADIATIVE CARRIER RECOMBINATION IN AlGaAs/GaAs INVESTIGATED BY A PIEZOELECTRIC PHOTOTHERMAL SPECTROSCOPY

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AlGaAs is widely used for quantum electronic devices such as LED and HBT. Intrinsic deep defect levels are known to cause a degradation of such devices. Annealing process followed by an ion-implantation is a most important process in the device fabrication. Since this annealing process affects a formation and destruction of deep levels, it is very important to understand an annealing effect on the carrier generation and recombination properties through deep levels. The recombination process of carrier through deep level is mainly nonradiative recombination. Piezoelectric photothermal (PPT) spectroscopy gives us useful information for the nonradiative transition through deep levels, the measurements were carried out for AlGaAs/GaAs heterostructure sample for investigating electron transitions especially at the interface. The PPT signal above the band-gap energy of GaAs substrate drastically decreased when the Si doped n-AlGaAs/GaAs was annealed at 815 degrees C for 30 min. In the frequency dependence measurements, we observed that the signal is almost frequency independent below a critical frequency around 250 Hz. The signal, then, decreased with 1/f above the critical frequency. We also found that this critical frequency shifted to the lower frequency region by the annealing. Our experimental results are explained by assuming that the annealing generates a deep level in AlGaAs thin film region and this level effectively traps the photoexcited carriers.

E/P68 THE AUTOCATALYTIC ANALYSIS OF THE THERMAL RECOVERY OF DEEP DEFECT EL2 IN SEMI-INSULATING GaAs

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Despite the technological importance and hence the extensive research, no general consensus has yet been reached on the exact microscopic structure of the deep level EL2 in GaAs. Much of the work has focused on its photoquenching property, i.e., the transformation from its normal (EL2n) to a metastable state (EL2*) when irradiated with photons of about 1.1eV below 130K, because it is a key phenomenon to obtain a clearer understanding of the microscopic structure of EL2. Here we describe our detailed PPT (piezoelectric photo-thermal) observations on the time-evolution of the thermal recovery from EL2* to EL2n. With decreasing temperature, the time-evolution changed from a Langmuir-type to a sigmoid-function-type with an incubation time. The whole variations, however, are well described with a single rate equation for the autocatalytic reaction. This success implies that the thermal recovery of EL2 contains a pair of modes: the slow recovery mode during the incubation time and the rapid recovery mode, which is accelerated by EL2n itself. The activation energy for the slow recovery mode was 0.31eV for the entire temperature range investigated, while the one for the rapid recovery mode was 0.27eV for T<120K and 0.13eV for T>120K. This indicates that there exist at least two elementary processes in the rapid recovery mode, in consistent with the model that EL2 is an As antisite-related complex defect accompanied with a deep hole trap.

E/P69 EVALUATION OF THE DENSITY OF STATES PARAMETERS OF a-Si:H BY AC PHOTOCONDUCTIVITY MEASUREMENTS AND NUMERICAL SIMULATION

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In this study, we discuss the measurements of AC-photoconductivity (AC-PC) and AC-Constant Photocurrent Method (AC-CPM) on thin films of intrinsic a-Si:H performed with chopped monochromatic light at different frequencies, and the results of a numerical model for AC photoconductivity.

High quality intrinsic a-Si:H samples, deposited in a conventional PECVD reactor, were illuminated with a monochromatic light in the photon energy region between 1.0 eV and 1.7 eV. The light was chopped with frequencies ranging from 10 Hz to 600 Hz, and incident photon flux could be varied between $1x10^{13}$-$3x10^{15}$ ph/cm^2/sec. Within these ranges, the magnitude of the photoconductivity and its phase difference with respect to the chopped pump light were measured as a function of the photon energy, the chopper frequency and the photon flux using a lock-in amplifier.

The numerical model has been developed[1] starting from Simmons-Taylor statistics[2]; both types of photocarriers have been taken into account. Typical already reported values for the density of states parameters have been selected at the beginning and a wide exploration has been performed. By means of simulation, we studied the influence of several external parameters, such as the excitation chopper frequency, the photon flux and the photon energy. The choice of the parameters strongly influences the energy and frequency dependence of the phase shift, as well as its absolute value. The most important parameters that affect the absolute value of the phase are charged to neutral capture cross section ratio, r. Application of the simulation model to the considered set of samples allows us to determine both the order of magnitude of the capture cross-section and the ratio of the capture cross section of the charged and neutral states.

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[2] J.G. Simmons, G.V. Taylor, Phys.Rev. B4 (1976) 502.

E/P70 CHARACTERIZATION OF IRON IMPURITY PRECIPITATES IN SILICON DEVICES

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The aim of this paper is to describe the techniques used to characterize and identify the nature of impurity precipitates in silicon substrate that were identified as device degradation root cause. Due to precipitates small width and rare occurrence, we had to combine a precise localization of emission spots with site specific TEM techniques (EDX and nanoprobe microdiffraction) to perform the analysis of the crystal defects suspected to be at the origin of the device failure. Thanks to these different techniques, the topology, the crystallography and the chemical composition of the precipitates have been determined.

E/P71 TRANSMISSION ELECTRON MICROSCOPY INVESTIGATION OF OXYGEN PRECIPITATION IN CZOCHRALSKI SILICON ANNEALED UNDER HIGH PRESSURE

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Czochralski-grown silicon (CZ-Si), with the concentration of interstitial oxygen atoms (O_i) up to about 10^{18}/cm^3, is the most widely used semiconductor material. Oxygen as the main impurity has the multiple influence on silicon crystals. Oxygen can improve the mechanical strength of silicon crystal by inhibiting the glide of dislocations that may unintentionally be introduced during wafer processing. And oxygen precipitates can act as “ intrinsic gettering” centers for metallic impurities so as to get a high quality denuded zone. So, it is important to investigate the growth mechanism of oxygen precipitates under different conditions.

In device fabrication processes, wafers are treated in different temperature ranges. In fact, the generation of oxygen precipitates depends on initial oxygen concentrations, annealing temperatures and its duration. It is also reported that the stress can also influence the formation of oxygen precipitates. The characteristics and mechanism of the growth of oxygen precipitates treated under atmosphere has been extensively studied. But few results related to oxygen precipitates generated under high pressures at different temperatures were reported. It is the main purpose of this article.

Systematic experiments were performed to investigate the oxygen precipitates generated under the high pressure (1GPa) by Transmission Electron Microscopy (TEM). The specimens were treated at 450_ for 10 hours, 957_ and 1130_ for 5 hours under the high pressure, respectively. In the specimen treated at 450_ for 10 hours, a new kind of sphere-like oxygen precipitates with the diameter of about 10 nm were observed by TEM. When the specimens were annealed at 957_ for 5 hours, TEM observation reveals that many punch-out dislocations formed. The experiments also points out that the polyhedron oxygen precipitates with the size of about 50 nm generated in the specimens treated at 1130_ for 5 hours under the high pressure.

It suggests that the high pressure can stabilize the oxygen precipitates with small sizes. By analyzing the influence of the high pressure on the equilibrium concentration of point defects, it can be concluded that the decrease of self-interstitials and the increase of vacancy is the main reason for the stability of the oxygen precipitates.

E/P72 PHOTOLUMINESCENCE STUDIES OF MAGNESIUM DOPED GaN AS GROWN, HYDROGEN IMPLANTED AND ANNEALED

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In the growth process of Mg- doped GaN a post growth treatment is necessary in order to convert the highly resistive, as grown GaN, to lower resistance p-type GaN. Our Mg-doped samples grown by MOVPE were implanted with 26 KeV hydrogen ions at doses ranging from 10^12 up to 10^15 cm^ (-2). After implantation the samples were annealed at 200 to 900°C. Low temperature luminescence (PL) spectra were recorded after each implantation and annealing step. From the as grown sample we observe a weakly resolved exciton-bound to neutral donor (BX) band at 3.47 eV as well as several bands at 3.28, 3.24, 3.20, 3.08, 3.00, 2.90, 2.84,and 2.76 eV. The second, third and fourth bands are associated with electron-Mg acceptor transitions. Particularly, the transition at 3.2eV originates from the conduction band - Mg acceptor level at 150 meV above the valence band. All the other transitions are phonon - replicas of the A1-LO mode (1LO,..,6LO). Implantation at low dose enhances the BX band and induces a new (rather weakly resolved) band at 3.35 eV. The enhancement of the BX band is due to the larger population of the donor (hydrogen)-bound exciton complexes related to the implantation. Implantation at higher doses increase the number of “electron-Mg-complexes”. Annealing at 200 up to 500°C causes an essential intensity drop of the BX and new 3.34eV hydrogen-related band. Further annealing to 700°C induces a broad structured band centered at (2.1—2.3)eV which could be the well known YL band. After annealing at 900°C the YL dominates spectra of all treated samples. However,the remaining “electron-Mg” transitions are also present with several well re solved phonon replicas. With the help of our Raman’s results (part II) we have investigated: i) Exciton-phonon (LA and LO) interactions, ii) Gaussian fits, and iii) Stresses (tensile or compressive) due to Mg and H in the GaN.

E/P73 NON-CONTACT AFM NANO-STRUCTURE IMAGING OF THIN Si POROUS LAYER FORMED ON THE (111)-Si PYRAMID

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The mechanisms of the complex microstructural changes in near surface areas of the silicon crystal occurring during porous silicon (PS) layer formation are not yet fully understood. It is generally accepted that pore initiation occurs at surface active defects or irregularities. Structural and morphological studies are currently the subject of many investigations, but they concern mainly PS layer formation on the platelet silicon surface. Results concerning the inhomogeneity and microstructure of thin PS layers formed on n^+- and p^+- type doped (111)-Si pyramids have been presented. The investigations have been focused on visualisation techniques, because the optical, electrical and physical properties of the PS layer depends strongly on its microstructure. Information about pore size and shape are not easy to obtain, and therefore different experimental techniques such as SEM, TEM and AFM have been used. The difference in morphology of the PS layer obtained in both cases (n^+- and p^+- type doped) is evident. Moreover, microstructure and morphology of PS layers depend strongly on the area of pyramid walls where the pores were formed. For p^+-type doped (111)-Si pyramids the pore sizes vary in a large range from 20 to 250 nm. For n^+-type doped (111)-Si pyramids the situation is more complicated. Generally, pore dimensions are smaller than the SEM resolution and they could only be observed by means of TEM and AFM.

E/P74 ATOMIC FORCE MICROSCOPY IMAGEING AND DIELECTRIC CHARACTERISTICS OF $Bi_2Ti_2O_7$ THIN FILMS

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$Bi_2Ti_2O_7$ thin films have been prepared by using low-pressure metal-organic chemical vapor deposition (LPMOCVD) for the first time. The triphenyl bismuth and titanium isopropoxied were used as precursors. Smooth films with strong (111) orientation were successfully prepared on p-Si (111) substrates at a substrate temperature of 560_ for an hour. The surface morphology and structure of the $Bi_2Ti_2O_7$ thin films were studied by atomic force microscope (AFM). We have obviously observed the anisotropy of $Bi_2Ti_2O_7$ film in AFM image for the first time, which show that the micro-crystal grains of $Bi_2Ti_2O_7$ film are rectangle shape after rapid thermal annealing (RTA). Dielectric characteristics of $Bi_2Ti_2O_7$ thin films were researched in terms of the relative dielectric constant (_r) and dissipation factor (tan_)on metal-isolator-metal (MIM) capacitors at frequency ranging from 0.5Hz to 1MHz. As a high-K thin film, $Bi_2Ti_2O_7$ thin film has its widely uses in storage capacitors or CMOS integrated device.

E/P75 RELAXATION PROCESS OF ION IRRADIATION DEFECTS IN IV-SEMICONDUCTORS

Y. Murakami, M. Miyata, A. Kenjo, T. Sadoh and M. Miyao, Dept. of Electronics, Kyushu Univ., 6-10-1 Hakozaki, Fukuoka 812-8581, Japan

Clarification of the relaxation process of point defects induced by ion irradiation is important to control their behavior. In the present study, IV-semiconductors (Si, heavily P-doped ($\sim 10^{20} cm^{-3}$) Si, Ge) were irradiated with Ar^+ ions at 25 keV (dose: $lx10^{13}$,$lx10^{16}$ cm^{-2}, dose rate: $3x10^{11}$-$6x10^{12}$ $cm^{-2}s^{-l}$, temperature: 30-250°C), and relaxation process of point defects was comparatively investigated by using spectroscopic ellipsometry.

At temperatures around 100°C, amorphization significantly depended on dose rate. We evaluated the critical dose rate, i.e., at which the defect generation rate and annihilation rate were balanced, by extrapolating the amorphicity vs. dose rate plot to amorphicity=0. The critical dose rate was independent of dose and depended on temperature. The Arrhenius plot of the critical dose rate showed that activation energies for defects relaxation process were 0.43 and 0.88 eV for Si and Ge, respectively. The activation energy reduced to 0.18eV for heavily P-doped Si. These results suggest that defect relaxation process is govemed by migration of V^0 in Si and Ge, while the process is govemed by migration of V^- in heavily P-doped Si. The defect relaxation in $Si_{1-x}Ge_x$ will be also discussed.

E/P76 INVESTIGATION OF MINORITY CARRIER DIFFUSION LENGTH IN SHALLOW JUNCTIONS BY ANGLE-RESOLVED ILLUMINATION TECHNIQUE

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In this paper we discuss a new approach to minority carrier diffusion length (Ld) investigation, following which a single monochromatic light beam, of appropriate wavelength (l), is incident on the device surface at different angles (Q). To be applied, the presented method requires the use of devices with a flat top surface, as the direction of propagation of the light in the bulk material has to be precisely known. In a typical experimental configuration carried out on a thick Silicon homojunction, the light source is a laser in the NIR range, the beam is focused on the optically active area of the device, between two adjacent fingers of grid shape metal top contact, and inclined with the incident plane kept parallel to the grid to avoid shadowing effect. In these experimental conditions, the short-circuit current of the device, Isc(Q,l,Ld), can be expressed as a function of the internal spectral response, SRint(Q,l,Ld) and device reflectance, R(Q,l). The incident photon flux is kept constant with incident angle Q. The diffusion length can be derived by fitting the experimental ratio SRint(O∞)/SRint(Q), plotted as function of the incident angle, with a theoretical curve derived by a model based on the “effective” absorption coefficient a'(l,Q)=a(l)/cos(Qr), where Qr is the refractive angle. By reducing the wavelength of the incident light the method can be applied to the investigation of shallow junction and amorphous crystalline heterojunction device.

Wednesday, June 19, 2002 Afternoon
Mercredi 18 juin 2002 Après-midi

Session III: Transmission Electron Microscopy
Session Chair: W. Triftshauser

13:00 **E-III.1** CHARACTERIZATION OF SEMICONDUCTORS BY ADVANCED TEM METHODS

A. Cullis, Dept of Electronic and Electrical Engineering, University of Sheffield, Mappin Street, Sheffield S1 3JD, UK

The transmission electron microscope (TEM) provides a number of methods of analytical electron microscopy which can give elemental analysis on scales approaching that of the atom. To realize optimum performance, it is necessary to use the high brightness source of the field emission gun TEM (FEGTEM). In the work to be described here, such an instrument has been employed in combination with three principal methods, namely energy dispersive X-ray microanalysis, energy-filtered imaging and high angle annular dark-field imaging. It will be demonstrated that these methods can give very high resolution microanalysis in a number of important areas of semiconductor nanotechnology, including determination of the nonuniform internal compositions of quantum dots and of quantum wells, together with observation of the near-surface distributions of dopants produced by low energy ion implantation. In each case, the impact of the FEGTEM measurements upon exploitation of the nanoscale structures for device applications will be emphasized.

13:40 **E-III.2** LOCAL COMPOSITION ANALYSIS OF SiC MICROSTRUCTURES FORMED BY ION PROJECTION IN SILICON USING ENERGY FILTERED TEM IN COMBINATION WITH FIB SPECIMEN PREPARATION

J.K.N. Lindner, Universität Augsburg, Institut für Physik, 86135 Augsburg, Germany; S. Kubsky, Ruhr-Universität Bochum, Experimentalphysik III, 44780 Bochum, Germany, and Laboratoire de Chimie Physique-Matière et Rayonnement, Université Pierre et Marie Curie, 75231 Paris Cedex 05, France; A. Schertel, FEI Company Deutschland, 85622 Feldkirchen, Germany

Well-defined buried epitaxial 3C-SiC layers can be formed in silicon by ion beam synthesis (IBS) in a narrow window of process parameters. Due to the excellent electrical, optical, mechanical and chemical properties of SiC, the IBS of such layers using keV C^+ ions has recently been studied to a large extend. Three-dimensional microstructures of SiC might be directly "written" into Si wafers using ion projection at MeV energies, if it is possible to adopt the keV IBS process parameters to the ion projection regime with MeV energies and substantionally higher beam current densities. This requires the local structural and compositional analysis of microstructures with nanometer resolution in both vertical and lateral direction, a task that presently can only be accomplished using energy filtered transmission electron microscopy (EFTEM).

Buried SiC microstructures with lateral dimensions in the µm range were formed by high dose projection of 1.5 MeV C^{2+} ions in Si(100) at different doses and temperatures and subsequent annealing for 10 h at 1250°C. Sections of individual SiC microstructures were prepared for cross-sectional TEM analysis using a focused ion beam (FIB) of Ga^+ ions. Besides the possibility to select an individual microstructure, the FIB technique has the advantage of producing specimen foils of uniform thickness. Therefore it was possible to map the carbon concentration of microstructures by EFTEM using the C_K absorption edge without the need of any sample thickness correction. Local overstoichiometric (>50%) carbon concentrations are shown to be correlated to the formation of an amorphous phase in the SiC and to significant swelling visible at the Si wafer surface 2 µm above.

14:00 **E-III.3** MICROCAVITY GETTERING IN SILICON

S.E. Donnelly(a), V.M. Vishnyakov(a), G. Carter(a), R.C. Birtcher(b), J. Terry(c) and L. Haworth(c), (a)Joule Physics Laboratory, Institute for Materials Research, University of Salford, UK, (b)Materials Science Division, Argonne National Laboratory, USA, (c)Scottish Microelectronics Centre, University of Edinburgh, Scotland, UK

Cavities of the order of a few nanometres in diameter have been under investigation for a number of years as a possible means of gettering transition metal impurities in silicon microelectronic devices. For the last three years a collaborative project has been underway at the Universities of Salford and Edinburgh in which materials researchers and device technologists have worked together both to study the fundamental aspects of cavity formation and the practicalities of incorporating this technology into actual devices. On the fundamental side, this paper will report on findings concerning the mechanisms of cavity growth and the optimum cavity morphologies for gettering. As far as the device work is concerned, the effectiveness of cavity gettering incorporated into a variety of microelectronic devices will be discussed. In particular, the results of tests of cavity gettering in MOS transistors with gate lengths from 1.5µm down to 0.35 µm will be presented.

14:20 **E-III.4** THE EVOLUTION OF CAVITIES IN Si CO-IMPLANTED WITH Si AND He IONS

Changlong Liu, E. Ntsoenzok, R. Delamare, CERI-CNRS, 3A, Rue de la Férollerie, 45071 Orléans, Cedex 2, France, D. Alquier, Laboratory LMP, 16 Rue Pierre et Marie Curie, B.P. 7155, 37071 Tours Cedex, France, G. Regula, Laboratoire TECSEN, UMR 6122, Université d'Aix-Marseille III, 13397 Marseille, France

CZ p-type Si(100) samples were first implanted with 80keV Si ions in the dose range from 1?1014 to 5?1015 /cm2, and then subjected to 1MeV 3He ion implantation to a dose of 5?1016 /cm2. The projected ranges for Si and He implants are calculated to be 0.12?m and 3.4?m, respectively. After co-implantation, some samples were subjected to thermal annealing at different temperature for 30min under a flow of N2 gas. Cross-section transmission electron microscopy (XTEM) was used to study the evolution of cavities. Meanwhile, RBS/c measurements were adopted to check the defects induced by Si ion implants. RBS/c measurements show that Si implant induce heavily damaged zone close to the surface at the low dose, and an amorphous layer extended from the surface to a depth of about 100nm at the highest dose. TEM observations indicate that the near surface defects produced by Si ion implantation can influence the evolution of He cavities, although the Si ion-induced defect region is a little far from the cavity band. This influence can be attributed to the diffusion of the interstitials from near surface into the cavity region. The He desorption from He cavities in the co-implanted samples has been also studied, and compared with the reference.

14:40 **BREAK**

Session IV: Measurements on Dielectrics
Session Chair: Y. Shapira

15:10 **E-IV.1** AN ADVANCED CHARACTERIZATION OF DEFECTS IN TUNNEL OXIDES

Domenico Caputo, Fernanda Irrera, Fabrizio Palma, Dept. of Electronics Engineering, University "La Sapienza", Via Eudossiana 18, 00184 Roma, Italy

Degradation of tunnel oxides during electrical stress constitutes the main cause of loss of reliability in non-volatile memories. Recently, we have introduced a new technique based on frequency resolved capacitance measurement under substrate accumulation (C-f), as alternative and complementary tool for investigation of defect distribution in oxides.
In this paper, we offer a comprehensive picture of oxide degradation. Within this frame, an analytical kinetics model describes the time evolution of defects through a rate equation ascribing the creation of new traps to weak-bond breaking due to energy released in electron scattering events (Scattering-Induced Degradation model, SID model). The calculated defect density is the input parameter of a Trap-Assisted-Tunnel model and a differential capacitance model to reproduce the experimental data of SILC and C-f measurements.
Capacitors featuring 7 nm-thick thermal oxides fabricated with production quality CMOS technology by ST Microelectronics (Agrate, Italy) were stressed under accumulation at different conditions. In particular, we varied the electric field through the oxide, the injected charge and the temperature. The stress conditions are used as input parameters of the SID model. The agreement between model results and experiment is excellent for both the SILC and C-f data. This demonstrates the correctness of the kinetics model and gives an overall comprehension of stress induced changes in thermal oxides.

15:30 **E-IV.2** STUDY OF TRAP CENTRES IN SILICON NANOCRYSTAL MEMORIES

A. Souifi, P. Brounkov, S. Bernardini, C. Busseret, L. Militaru, P. Masson, T. Baron and G. Guillot, LPM-INSA de Lyon, UMR CNRS 5511, 69621 Villeurbanne Cedex, France

After the first proposal of a memory transistor using silicon nanocrystals (nc-Si) as floating gates, other works have confirmed that non volatile memories using PMOS or NMOS transistors can be achieved. In spite of the fact that non volatile memories with Si-nanocrystals have been demonstrated, it remains necessary to understand the trapping phenomena in nc-Si and the influence of other parasitic traps. For future applications like NanoFlash memories, it is also necessary to improve higly sensitive electrical measurements in. For such studies, the use of Charge Pumping and Random Telegraphic Signal technics are shown to be usefull for single or few trap analysis. Our work is focussed on the determination of trap densities in NMOS transistor nanocrystal memories. Temperature dependent I-V and C-V static measurements have been used together with time domain measurements such as DLTS and Charge Pumping. The aim of the study is first to study the influence of fast traps at the SiO2/Si interface. Then, slow states related to oxyde traps are measured and the maximum number of trapped electrons per dot is extracted. A comparison between reference samples and Si-dot-samples is used to distinguish between trapping phenomena in the nano-floatting gates or in parasitic oxyde states.

15:50 **E-IV.3** PROBING CRYSTALLINITY AT Si/INSULATOR INTERFACES USING INTERNAL ELECTRON PHOTOEMISSION

V.V. Afanas'ev and A. Stesmans, Laboratory of Semiconductor Physics, University of Leuven, Belgium

High crystalline quality of the base semiconductor is prerequisite for high performance of surface-channel metal-oxide-semiconductor transistors. As the modern multistep technological processing may degrade the crystallinity, there is interest in the development of adequate monitoring methods. For this purpose we propose the internal photoemission of electrons (IPE) from Si into an insulator: Generally, the IPE quantum yield is found to deviate from a monotone increase in the vicinity of the spectral feature E2 at photon energy close to 4.3 eV, corresponding to optical excitation of direct transitions between high-symmetry points in the Brillouin zone of silicon. The amplitude of this deviation appears to be sensitive to various treatments such as Si oxidation and annealing, and implantation of the doping impurity, thus exposing the disordering introduced in the processed Si surfaces. Such application of the IPE yield spectroscopy will also be demonstrated for novel insulating layers on Si based on high-permittivity metal oxides (Al2O3, ZrO2, HfO2).

16:10 **E-IV.4**

HIGH RESOLUTION STUDY OF THE KINETICS OF INTERFACIAL FORMATION DURING DEPOSITION AND POSTANNEALING OF HIGH K DIELECTRICS ON SILICON

N. Bassim, V. Craciun, C. Essary, K. Seibein, J.M. Howard and R.K. Singh, Department of Materials Science and Engineering, University of Florida, Gainesville FL, USA

Current silicon transistor technologies are nearing the physical limits of miniaturization using SiO2 as the gate dielectric. Alternative high-k dielectric materials such as ZrO2 and Y2O3 are being considered as possible replacements. However, during deposition and post-deposition annealing, an interfacial layer is formed that has detrimental effects on the overall capacitance of the films. This presentation explores the kinetics of formation of this interfacial layer. Both ZrO2 and Y2O3 films were deposited using a pulsed laser deposition technique and were post-annealed under various atmospheres, temperatures and times. Using several characterization techniques such as high-resolution transmission electron microscopy with an EELS attachment, angle-resolved x-ray photoelectron spectroscopy and x-ray reflectivity, the thickness and chemical bonding of the interfacial layer were determined. These results were used to model the kinetics of the interface formation and to determined whether these kinetics follow similar, simpler models developed for the oxidation of silicon. Further comparisons were made with samples that contained a nitride pretreatment to study the nitride effectiveness in slowing the interfacial layer growth.

16:30 **E-IV.5**

ADVANCED CHARACTERIZATION OF Si / $Si_{1-y}C_y$ HETEROSTRUCTURES FOR nMOS DEVICES

F. Laugier, P. Holliger, J.M. Hartmann, T. Ernst, V. Loup, G. Rolland and D. Lafond, CEA-DRT, LETI / DTS, CEA / GRE, 17, Avenue des Martyrs 38054 Grenoble Cedex 9, France.

We have grown by Reduced Pressure Chemical Vapor Deposition Si / $Si_{1-y}C_y$ / Si heterostructures for ultra-short gate length (50 nm) nMOS devices. Indeed, tensile strained $Si_{1-y}C_y$ layers behave as channels for the electrons. Low energy Secondary Ion Mass Spectrometry, High Resolution X-Ray Diffraction, Atomic Force Microscopy and Transmission Electron Microcopy were jointly used to build a coherent picture of the growth process (layer thickness typically of a few nm). SIMS and XRD measurements indicate that high carbon concentration samples (substitutional C = 1.12 at.%) also contain many interstitial carbon atoms (interstitial C = 0.45 at.%). We have demonstrated in XRD and AFM that such Si / $Si_{1-y}C_y$ / Si stacks are stable versus standard thermal anneals and that their growth occurs satisfactorily on patterned wafers (although the growth is not selective versus SiO_2). We have thus integrated them into a conventional nMOS process. Cross-sectional TEM imaging shows that the resulting heterostructures are of high crystalline quality, with well defined interfaces. Finally, an in-depth SIMS analysis using either Cs^+ or O_2^+ primary ions of the C, O and B concentration profiles inside such transistors reveals that (i) some C segregation occurs during the growth of the Si cap, generating the presence of C inside the SiO_2 gate (ii) C atoms induce a strong reduction of the B diffusion from the anti-punch-through layer beneath, generating highly retrograde doping profiles. All those measurements will help understanding the electrical properties of such ultimate devices.

17:00-18:00 **PANEL DISCUSSION**

"Future trend in advanced characterization"

Chairs: V. Raineri, E.D. Simoen

Thursday, June 20, 2002 Morning
Jeudi 20 juin 2002 Matin

Session V: Scanning Probe Microscopy
Session Chair: Y. Rosenwaks

09:00 **E-V.1**

NANOSCALE POTENTIAL MEASUREMENTS USING KPFM
R. Shikler and Y. Rosenwaks, Tel-Aviv University, Israel
Kelvin probe force microscopy (KPFM) has become in recent years a valuable tool for characterizing and analyzing semiconductor surface electronic properties with nanometer resolution. The Kelvin probe force microscope measures the semiconductor work function by nullifying the electrostatic force between a vibrating tip and the semiconductor sample. It is accepted that the finite tip size in scanning probe microscopy can have a profound effect on the obtained topographic image. This phenomenon is enhanced in KPFM measurements because the electrostatic force is long range. Hence, the measured work function difference is not the real one but rather an average value of all the neighboring points.
In order to reconstruct the real contact potential difference (CPD) the tip-sample-interaction must be accurately modeled. The exact force that acts on the tip is calculated from the solution the Poisson equation of the tip-sample system. The Poisson equation is solved for a varying tip-sample voltage difference. The voltage that minimizes the electrostatic force is the measured CPD voltage. We shows that by knowing the tip shape and the tip-sample distance, the parameters of the sample can be fitted to get the measured image. Additional information about the position of the Fermi level at the semiconductor surface can be extracted from the entire force vs. voltage curve.

09:40 **E-V.2**

PROGRESS TOWARDS A PHYSICAL CONTACT MODEL FOR SCANNING SPREADING RESISTANCE MICROSCOPY
Pierre Eyben, Samuel Denis, Trudo Clarysse and Wilfried Vandervorst, IMEC vzw, Kapeldreef 75, 3001 Leuven, Belgium
As emphasized in the ITRS roadmap, two-dimensional carrier profiling is one of the key elements in support of technology development. On CMOS silicon devices, Scanning Spreading Resistance Microscopy (SSRM) has been demonstrated to have an attractive image resolution and concentration sensitivity. Through the automated construction of calibration curves, it allows for the fast semi-quantitative transformation of 1D & 2D resistance profiles/images to resistivity/carrier profiles/images. In order to arrive, however, at a reliable, fully quantitative analysis, recently a new physical contact model, involving a Schottky-like contact with tunneling and surface states has been proposed based on a qualitative agreement with experimental data. The first aim of this work is to refine this contact model in order to achieve a quantitative agreement between device simulations (with ISE/DESSIS) and experimental 1D profiles on well-calibrated, junction isolated (carrier spilling affected), sub-micron CMOS structures (both on cross-sections and bevelled structures). Among others, SSRS (Scanning Spreading Resistance Spectroscopy) collecting a full I-V curve at each data point will be used. Furthermore, the impact of this new contact model on the deconvolution procedure from the measured resistance profiles/images towards resistivity/carrier profiles/images through an improved correction factor database will be discussed.

10:00 **E-V.3**

KELVIN PROBE FORCE MICROSCOPY ON III-V SEMICONDUCTORS: THE EFFECT OF SURFACE DEFECTS ON THE LOCAL WORK FUNCTION
Th. Glatzel(a), S. Sadewasser(a), R. Shikler(b), Y. Rosenwaks(b), M.Ch. Lux-Steiner(a), (a)Hahn-Meitner Institut, Glienicker Str. 100, 14109 Berlin, Germany, (b)Tel-Aviv University, Tel-Aviv 69978, Israel
The application of Kelvin probe force microscopy (KPFM) in ultra high vacuum (UHV) allows to determine the absolute work function of surfaces with a very high energetic (< 5 meV) and lateral (< 20 nm) resolution [1]. Due to the long range nature of the electrostatic forces the geometry of the tip, cantilever and sample plays an important role in KPFM. We present measurements on different UHV cleaved III-V semiconductors. The (110)-surface shows work function variations due to defect states at step edges. From comparison to simulations we determine the effect of the tip geometry on the electrostatic signal. We observed band bending on the (100)-surface of GaP from surface photovoltage measurements. Even on the (110)-surface we found similar behavior, indicating the existence of surface states. Finally, we discuss the influence of the previous effects on KPFM measurement of a UHV cleaved GaP pn-homojunction.
[1] Ch. Sommerhalter et al., Appl. Phys. Lett. 75 (1999), 286

10:20 **E-V.4**

CHARACTERIZATION OF VERTICAL RESURF DIODES USING SCANNING PROBE MICROSCOPY
N. Duhayon(a), M. Xu(a), D. Alvarez(a), P. Eyben(a), W. Vandervorst(a), L. Hellemans(b), C. Rochefort(c), R. Van Dalen(c), (a)IMEC, Kapeldreef 75, 3001 Leuven, Belgium, (b)K.U.Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium, (c)Philips Research Leuven, Kapeldreef 75, 3001 Leuven, Belgium
In earlier work a new technique to manufacture vertical Resurf diodes was presented [1]. By using trench etching and subsequent Vapor Phase Doping (VPD) the alternating p-n junctions in the drift region are formed. In this paper the characterization of these structures is studied in more detail using Scanning Probe Microscopy (SPM). In a first part Scanning Capacitance Microscopy (SCM) is used to image the two-dimensional carrier profile of the device. Different trenches (with different depths and widths) are compared. All measurements show uniform Boron profiles along the trench sidewalls. Also the strong outdiffusion from p-body and substrate can be analyzed in detail. These results are in agreement with analogue measurements done with Scanning Spreading Resistance Microscopy (SSRM). Although SCM is commonly used on passive devices, it is also possible to measure active devices. By applying voltages to the Resurf diode, we can image what happens within the drift region in function of the applied bias. Also another SPM-based technique named Nanopotentiometry, which measures the local potential, is used for imaging the active working of the device. With higher applied bias we can see the drift region getting smaller. A comparison between both techniques (SCM and NP) will be presented.
[1] C. Rochefort, R. Van Dalen, N. Duhayon, W. Vandervorst, "Manufacturing of high aspect-ratio p-n junctions using Vapor Phase Doping for application in multi-Resurf diodes.", ISPSD 2002

10:40 **E-V.5**

TWO DIMENSIONAL INTERSTITIAL DIFFUSION IN SI MONITORED BY SCANNING CAPACITANCE MICROSCOPY

F. Giannazzo(a), V. Raineri(b), S. Mirabella1, S. Scalese(b), A. Terrasi(a), E. Napolitani(c), A. Carnera(c), D. de Salvador(c) and F. Priolo(a), (a)INFM and Department of Physics of the University of Catania, Corso Italia, 57, 95127, Catania, Italy, (b)CNR-IMETEM Stradale Primosole,50, 95121, Catania, Italy, (c)INFM and Dipartimento di Fisica dell'Universita di Padova, Via Marzolo 8, 35131, Padova, Italy

Scanning capacitance microscopy is applied to monitor the 2D interstitial diffusion in Si from a spatially confined source of excess interstitials produced near the surface by Si+ ion implantation. Three MBE-grown B spikes at fixed depths under the surface and with identical peak concentrations are used as marker layers to study the interstitial diffusion. On the as grown wafer, we fabricated a SiO2 mask structure, represented by a set of windows with different openings. After Si+ implantation, the sample was annealed at 800 °C for 5 minutes in nitrogen ambient. On the patterned region of the sample we performed SCM measurements. The sample was beveled to obtain a 10 times amplification in depth direction. We performed a conversion of the measured SCM profiles in carrier concentration profiles, by using the direct inversion technique. The comparison between SIMS and converted SCM profiles performed on unpatterned sample regions exhibits a good agreement both in the sensitivity and the depth resolution between the two techniques. The results show that after implantation and annealing the TED of the three B spikes is present. The converted SCM profiles in the patterned region allow to calculate the 2D path of the interstitials coming from the implanted region. The supersaturation of Si interstitials at fixed depths inside the wafer was monitored by the broadening and the consequent peak concentration lowering for the boron spikes located at those depths.

11:00 **BREAK**

Session Chair: A. Cullis

11:30 **E-V.6**

LATERAL SCANNING OF Si BASED SYSTEMS BY MEASUREMENTS OF THE MICROWAVE PHOTOCONDUCTANCE

M. Kunst and D. Jokisch, Hahn Meitner Institut, Bereich SE5, Glienickerstrasse 100, 14109 Berlin, Germany

Often, a post growth treatment (such as implantation) of Mg –doped GaN is required to lower the resistance of the GaN, which may depend on structural changes via conduction electron-phonon interaction. We implanted Mg-doped GaN, grown by MOVPE, with 26KeV hydrogen ions at doses from 10^{12} up to $10^{15}cm^{-2}$. Raman spectra were recorded after each implantation and annealing step. From reference sample, besides the well-known first order modes we observe several second - order broad bands centered at about 1156, 1270, 1317, 1390 and 1469 cm^{-1}. Implantation induces at least five new modes at 320, 380, 428 (shoulder of the A_{1g}-sapphire peak), 645, and 671 cm^{-1}. All these above bands are very well resolved, particularly at the highest dose of implantation. The second order Raman spectra are not affected by implantation. In the region 4000-4900cm^{-1}, several luminescence bands at 4272, 4469, 4618 and 4650cm^{-1} are present in the as grown sample. Implantation shifts all the bands towards higher energy and reduces their intensities. In the region 4900-5100cm^{-1}, of the reference sample we monitored two sharp emission lines at (694.4 nm-1.7855eV: R1) and (693nm-1.7891eV: R2) with the intensity ratio: I(R2)/I(R1)< 1. The bands are due to transitions from the ($4\ A_2$) ground state of Cr^{3+} to the excited ($4\ T_2$) and ($4\ T_1$) levels observed also by PL (part I). Implantation at 10^{13} and $10^{15}cm^{-2}$ changes the intensities to I(R2)/I(R1)=1 and I(R2)/I(R1)>1, respectively. No recovery has been found after low temperature annealing. We have investigated the group-theoretical assignments of the second and third order Raman modes in wurtzite structure, shifts of modes due to stresses caused by Mg and hydrogen in GaN, as well as the influence of implantation on the LO phonon- plasmon coupled modes.

11:50 **E-V.7**

NON INVASIVE ELECTRICAL CARACTERIZATION OF SEMICONDUCTOR INTERFACE

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The semiconductor-insulator interface is very critical for various devices. The Spectroscopic Ellipsometry and Time Resolved Microwave Conductivity (TRMC) are efficient tools for in-situ non invasive characterizations during growth of semiconductors and interfaces. From ellipsometry, one estimates the optical absorption, structural composition of the material in the bulk and near interface. The TRMC measures the transient microwave reflectivity induced by carriers photogenerated by a laser. The analysis of this signal (amplitude and shape) as a function of wavelength (visible or UV) and carrier density enable to separate between bulk and interface recombination, to estimate surface state density and surface recombination velocity. This is correlated with capacitance measurement. This analysis is achieved for interface such as cSi/SiO_2, cSi/Si_3N_4, $\mu cSi/\ Si_3N_4$.

12:10 **E-V.8** MEASUREMENT OF THE MICROWAVE HALL EFFECT FOR THE CHARACTERISATION OF SEMICONDUCTORS

M. Schrape(a), H. Tributsch(a), M.P. Klein(b) and M. Kunst(a), (a)Hahn Meitner Institut, Bereich SE5, Glienickerstrasse 100, 14109 Berlin, Germany, (b)Chemical Biodynamics Division, Lawrence Berkeley Laboratory, University of California, Berkeley CA 92740, USA

Charge carrier transport is an essential process for most applications of semiconductors. So the determination of the charge carrier mobility, one of the most important transport parameters, seems of great interest for the characterisation of semiconductors. In this work the use of the microwave Hall effect in a bimodal cavity for a contactless and non-destructive characterisation of semiconductors is investigated.

An analysis of a bimodal cavity in terms of the scattering matrix is given. It is shown that an absolute value of the mobility is determined from the measurement signal. Besides, a perturbation analysis is outlined which enables the correction for non-ideal behaviour of the cavity.

Experimental results on silicon and pyrite (FeS_2) are presented. A satisfactory agreement with results on the same samples obtained by conventional, i.e. DC, Hall measurements is observed.

The accuracy of microwave Hall measurements and so the mobility range measurable are considered. The application of a bimodal cavity for the characterisation of semiconductors in the microwave frequency range is discussed.

12:30 **LUNCH**

Thursday, June 20, 2002 Afternoon
Jeudi 20 juin 2002 Après-Midi

Session VI: Carrier Lifetime Based Methods
Session Chair: S. Martinuzzi

14:00 **E-VI.1** ADVANCED METHODS FOR MEASUREMENTS OF MINORITY CARRIER LIFETIMES AND DIFFUSION LENGTH
R.K. Ahrenkiel, NREL, USA

14:40 **E-VI.2** MAPPING OF MINORITY CARRIER LIFETIME AND MOBILITIES IN IMPERFECT SILICON WAFERS
O. Palais, L. Clerc, A. Arcari, S. Martinuzzi, UMR TECSEN, Universite of Marseille, France
Microwave phase-shift (µW-PS) technique was used to determine the bulk lifetime (b) of minority carriers. In such a contactless technique the phase-shift between a microwave beam (1GHz) and a sine modulated infrared excitation is related to b and surface recombination velocity S. Surfaces are passivated by an aqueous iodine solution, or by short phosphorus diffusion (850°C).
By varying the excitation modulation frequency S can be deduced. The technique works at a quasi constant excitation level, with a large excitation beam or with a focused beam (50µm) to get a lifetime scan map. The phosphorus diffused samples are transformed in N+P diodes and light beam induced current (LBIC) maps lead to a mapping of minority carrier diffusion length (L). From the  and L maps we can get a map of minority carrier diffusion coefficient (or mobility). Comparison of the measured values of  in surfaces passivated samples leads to an evaluation of S, that is in agreement with that got directly by changing the excitation frequency.
The proposed technique works in Si wafers containing oxygen precipitates and in multicrystalline Si wafers. Features of extended defect recombination strength, at the defects and far of them, as well as the local variation of S can be deduced.
In conclusion the association of mappings of lifetime by the µW-PS and of diffusion length by LBIC techniques lead to an enhanced knowledge of minority carrier properties in silicon wafers.

15:00 **E-VI.3** EXTRACTION OF THE CARRIER GENERATION AND RECOMBINATION LIFETIME FROM THE FORWARD CHARACTERISTICS OF ADVANCED DIODES
A. Poyai*, E. Simoen and C. Claeys*, IMEC, Kapeldreef 75, 3001 Leuven, Belgium, *also E.E. Dept. at KU Leuven, Leuven, Belgium, E. Gaubas, Vilnius University, Institute of Material Research and Applied Sciences, Sauletkio av. 10, 2040 Vilnius, Lithuania, A. Huber and D. Gräf, Wacker Siltronic A.G., P.O. Box 1140, 84479 Burghausen, Germany
Several techniques have been developed to measure both the carrier generation and recombination lifetime in the bulk of a silicon wafer.
The generation and recombination lifetime can for example be derived from the reverse and forward diode characteristics, respectively. Straightforward calculation can yield lifetimes differing several orders of magnitude from the values measured with other techniques. For modern, scaled junctions, this discrepancy is related to the high electric field and the shallow-junction effect in the reverse and forward characteristics, respectively. Therefore, this paper proposes to extract the generation and recombination lifetime from the recombination current in forward operation. The method will be applied to n+-p-well junctions fabricated in advanced processing schemes and on silicon wafers with different grown-in defect concentrations. It is shown that the obtained generation lifetime agrees well with the one found from the reverse current after correction for the electric field. The value of the recombination lifetime is confirmed by the data obtained from the cross-sectional microwave absorption technique and is close to the one calculated from the forward characteristics after taking the shallow junction effect into account. In conclusion, the proposed method gives reasonable values for the generation and recombination lifetime in advanced silicon p-n junctions.

15:20 **E-VI.4** TRIBICC (TIME RESOLVED ION BEAM INDUCED CHARGE COLLECTION) MEASUREMENT OF MINORITY CARRIER LIFETIME IN SEMICONDUCTOR POWER DEVICES BY USING GUNN'S THEOREM
C. Manfredotti, F. Fizzotti, A. Lo Giudice, C. Paolini, P. Olivero and E. Vittone, Experimental Physics Department, University of Torino, Torino, Italy, National Institute for Matter Physics, UdR Torino University, Torino, Italy
Ion microbeam techniques like IBIC (Ion Beam Induced Charge) are powerful methods in order to map the transport properties in semiconductors proposed for nuclear detection [1]. TRIBICC is a further improvement, since it can give also the time behaviour of charge collection. For long collection times, this means to gather informations also on lifetimes of carriers in the diffusion regions, which are always present in undepleted devices like electronic ones and in particular power devices and which are of paramount importance as inputs for simulation codes.By TRIBICC,in fact some difficulties could be avoided in analysis of data collected in cases when lifetimes and shaping times of electronic chain are similar, and the sensitivity of the method is worse. In order to suitably analyse TRIBICC data, a suitable theoretical model should be available : in general, Ramo's theorem is used, but its validity in cases when space charge is present is questionable, even if an extension has been proposed for totally depleted devices. A more powerful method is presented and discussed, which is based on Gunn's theorem [2] and on a particular generation function to be inserted in the adjoint of time-dependent continuity equation, together with a successful application of this method to a semiconductor power device is presented and discussed.
[1] C. Manfredotti et al, NIM B136-138(1998)1333
[2] J. B. Gunn, Solid State Electronics 1964, Vol. 8, 739

15:40 **BREAK**

Session VII: Impurity in Silicon
Session Chair: P. Wellmann

16:10 **E-VII.1** CHARACTERIZATION OF OXYGEN AND OXYGEN-RELATED DEFECTS IN HIGH AND LOWLY DOPED SILICON
E.D. Simoen, IMEC, Leuven, Belgium

16:50 **E-VII.2** RECENT ADVANCE APPLICATION OF AAS AND ICPMS IN SEMICONDUCTOR INDUSTRY
Mohammad B. Shabani, Y. Shiina, F.G. Kirscht and Y. Shimanuki, Mitsubishi Materials Silicon Co, Wafer Development Department, 314 Kaneuchi, Chiba 278-0015, Japan
In semiconductor industry, graphite furnace atomic absorption spectrometry (GF-AAS) and inductively coupled plasma mass spectrometry ICP-MS are used daily on a routine basis for wide range of quantitative metal impurities determination in chemicals, wafer surface and bulk and controlling through all customary device fabrication steps, such as wafering, polishing, cleaning, oxidation, epitaxy, ion implantation gettering evaluation and etc.
Analysis of silicon wafer surface
The advantageous and disadvantageous of vapor phase decomposition method (VPD) and drop etching method (DE) for recovery of metal impurities from the surface of the wafers will be discussed.
Analysis of bulk silicon near surface by depth profiling
Both VPD and DE method can collect only metal impurities on the top surface wafer that limits their application to the etching of bulk silicon near surface by depth profiling. In this case one-drop sandwich etching method (DSE) for etching of silicon for depth profiling studies will be discussed.
Analysis of bulk silicon
Bulk decomposition method (BD) and Room temperature acid vapor phase decomposition method (RT-AVPD) for recovery of metal impurities from the bulk of the silicon wafers will be discussed.
Analysis of chemicals
Analysis of chemical reagents for cleaning of silicon wafer in different steps of wafer manufacturing will be discussed

17:10 **E-VII.3** ABSORPTION COEFFICIENT OF OXIDE PRECIPITATES IN SILICON WAFERS AFTER DIFFERENT THREE-STEP ANNEALING
A. Sassella and A. Borghesi, INFM and Università di Milano Bicocca, Dipartimento di Scienza dei Materiali, via Cozzi 53, 20125 Milano, Italy, P. Geranzani and M. Olmo, MEMC Electronic Materials, viale Gherzi 31, 28100 Novara, Italy, M. Porrini, MEMC Electronic Materials, via Naizonale 59, 39012 Merano (BZ), Italy
While for commercial silicon wafers the procedure for the measurement of interstitial oxygen (O_i) from the 1107 cm^{-1} infrared (IR) absorption band is well consolidated, this is not true for wafers subjected to thermal treatments. In this case, indeed, the IR response related to the presence of oxide precipitates formed during the annealing strongly influences the measure of the O_i concentration, preventing also any quantitative evaluation of precipitated oxygen (usually obtained as the difference between O_i concentration before and after the wafer annealing).
Systematic measurements of the contribution of precipitates to the IR absorption of silicon are presented here, carried out on wafers subjected to three-step treatments. All the samples had the same initial O_i concentration of about 7_10^{17} cm^{-3} and were annealed following standard treatments for precipitate nucleation and growth, but varying the duration of each step. To precisely determine the intensity of the precipitate-related bands, the measurements were performed at liquid He temperature and the three-phonon contribution at 1118 cm^{-1} was subtracted. The results clearly show that a threshold time for the growth annealing exists, below which any precipitate-related response is not detectable, and that the threshold value is strongly dependent on the time of the nucleation annealing performed before.

17:30 **E-VII.4** OPTIMIZATION OF THE VPD TECHNIQUE FOR THE DETECTION OF METALLIC CONTAMINATION ON SILICON WAFERS
A. Danel, T. Lardin, C. Giroud, F. Tardif, CEA / LETI, Department of Silicon Technology, 17 rue des Martyrs, 38054 Grenoble cedex 9, France, R. Barrett, ESRF, BP 220, 38043 Grenoble cedex 9, France
The detection of ultra low impurity concentrations is one of the key challenges of wafer characterization. The shrinkage of critical dimensions in advanced microelectronic devices is possible only with accurate control of contamination. Thus, improvement of analytical methods tracking contamination, especially metals on wafers, is needed. Whilst the sensitivity of the detection methods (ICPMS, AAS, TXRF) is of great importance, it is worth noting that the wafer pre-analysis preparation and especially metal collection, can be critical in determining both the lower limits of detection (LLD) and, via the efficiency of the contamination recovery, the measurement accuracy.
In this paper, the Vapor Phase Decomposition (VPD) method used to collect metals from wafer surfaces prior to ICPMS, AAS, or TXRF analysis is studied in detail.
From a LLD point of view, the VPD protocol was analyzed to study the possible parasitic contamination introduced by each elementary step. The critical steps were identified and optimized in order to minimize detrimental impact on LLD. Finally, an order of magnitude improvement was gained by modifying the VPD reactor conditioning and generating in-situ high purity chemicals.
To study the contamination recovery, Synchrotron Radiation–TXRF was used to measure accurately the VPD efficiency for several metals. Specific VPD recipes were developed to target particular metals such as Cu or W, or specific surface type and materials such as SiC.

17:50 **E-VII.5**

OPTIMISATION OF A COMBINED TRANSIENT-ION-DRIFT / RAPID THERMAL ANNEALING PROCESS FOR COPPER DETECTION IN SILICON

Assia Belayachi(a), Thomas Heiser(a), E. Pihan(a), S.Bourdais(b), A.Kempf(c), (a)Laboratoire PHASE-CNRS, BP20, 67037 Strasbourg Cedex 2, France, (b)J.I.P.ELEC, 11 chemin du Vieux Chêne, 38240 Meylan Cedex, France, (c)Wacker Siltronic AG, B-RD-YP, PO-Box 1140, 84479 Burghausen, Germany

It has been shown that the Transient Ion Drift (TID) technique can detect Cu in silicon with a detection limit of the order of 1011 cm-3. Yet, copper needs to be interstitially dissolved in the bulk in order to be measured by TID. This is achieved through a high temperature treatment which either allows Cu atoms to indiffuse from the contaminated surface, or bulk Cu precipitates to be dissolved. A final quench is required to avoid significant precipitation or outdiffusion.

In this work, we show that a cooling rate of the order of 100°C/s, achieved in a modified Rapid Thermal Annealing (RTA) furnace on full wafers, is sufficient to keep the copper atoms interstitially dissolved. A mercury probe is used to allow TID measurements to be done immediately after the quench. The process is further optimized by keeping the annealing temperature and time as low as possible. One minute annealing at 600°C is shown to be sufficient to transfer most copper atoms from the surface into the bulk.

In a second set of experiments, dissolution kinetics of copper complexes, formed during a low temperature anneal, are investigated. Monitoring the interstitial Cu concentration as a function of a final high temperature annealing allows us to define the experimental conditions which lead to a complete recovery of the initially introduced copper impurities. In the light of these results, a general discussion on Cu precipitation in the bulk and out-diffusion to the surface is given.

Friday, June 21, 2002 Morning
Vendredi 21 juin 2002 Matin

Session VIII: Methods for Wide Bandgap Semiconductors
Session Chair: G. Guillot

09:00 **E-VIII.1** DETERMINATION OF DOPING LEVELS AND THEIR DISTRIBUTION IN SiC BY OPTICAL TECHNIQUES

P.J. Wellmann and R. Weingaertner, Materials Department 6, University of Erlangen, Martensstr.7, 91058 Erlangen, Germany

The wide bandgap semiconductor SiC has gained much interest for high-power, high-frequency and high-temperature device applications as well as substrate for GaN based (opto-)electronic devices. In this presentation a quantitative absorption measurement based tool for the determination of doping levels and their distribution in SiC will be reviewed which serves all the advantages of optical methods like being non-contact, non-destructive and quick. SiC exhibits unique optical absorption bands in the visible which exhibit a strong, linear dependence on the charge carrier concentration in both, n- and p-type SiC. Using spectrally resolved absorption measurements we were able to determine doping type and doping level for the technological relevant polytypes 4H- and 6H-SiC in the range of n=2*10^17cm-3...1*10^19cm-3 (nitrogen doping) and p=1*10^16cm-3...1*10^18cm-3 (aluminum doping) with an accuracy of about 15%…20%. Performing absorption mappings at specific optical transitions enabled us to reveal the spatial doping level distribution of SiC wafers within an error of 1%. The presentation will include (i) a review of the underlying physical effects, (ii) a description of the measurement setup, (iii) calibration plots and (vi) several examples of SiC wafer doping level mappings. Finally, the comparison to photoluminescence measurements and the transfer of the method to other semiconductor materials like GaAs will be discussed.

09:40 **E-VIII.2** THERMAL RECOVERY OF AMORPHOUS ZONES IN 6H-SiC AND 3C-SiC INDUCED BY LOW FLUENCE 420 keV Xe IRRADIATION

T. Bus, A. van Veen, A. Shiryaev, A.V. Fedorov and H. Schut, Interfaculty Reactor Institute, Delft University of Technology, Mekelweg 15, 2629 JB Delft, The Netherlands

Recovery of implantation defects is of paramount importance for applications of SiC in semiconductor devices. Up on implantation heavy ions produce along their tracks amorphous zones, which when overlapping at high fluences (>1014 cm-2) form a continuous amorphous band. Crystallization of this band requires temperatures higher than 8000C, while crystallized material might consist of many polytypes of SiC with different properties, hampering economic production. It is known that crystalline SiC can be prevented from turning amorphous by choosing implantation temperatures above 6000C. Therefore, it is likely that single cascade damage will recover at about this temperature. In order to perform a detailed study on the recovery of amorphous zones created by individual ions, defects created by very low fluences of Xe ions have been monitored by PBA. Positrons are very sensitive to defects, so that at fluences as low as 4´108 420 keV Xe cm-2 positron trapping has been observed. The fraction of positrons trapped in defects corresponds to results of a model where diffusion limited trapping was assumed in disordered zones predicted on the basis of SRIM calculations. The fraction increased linearly with fluence and saturation effects appeared at fluences >5´1012 cm-2. Similar implantations in Si and diamond, which are no compound materials, induced much less damage. Thermal recovery and recovery kinetics of the amorphized zones in 6H-SiC and in epitaxial 3C-SiC on Si are discussed.

10:00 **E-VIII.3** UV SCANNING PHOTOLUMINESCENCE SPECTROSCOPY APPLIED TO SILICON CARBIDE CHARACTERIZATION

J.M. Bluet, L. Masarotto, I. El Harouni and G. Guillot, Laboratoire de Physique de la Matière, CNRS (UMR5511), INSA de Lyon, Domaine Scientifique de la Doua, Bât. Blaise Pascal, 7 avenue Jean Capelle, 69621 Villeurbanne Cedex, France

In spite of great progress in SiC growth the rise of high performance reliable devices is still limited by the material quality. For wafers, while the micropipe density is reduced to 10 cm-2, the dislocation density is still about 104 cm-2. For epitaxial layers, the main problem is doping inhomogeneities (> 10%) on a two inches wafer. The presence of polytypes inclusions is also a recurrent problem in SiC. In order to analyse these defects, to understand their origin and their impact on devices performance, non destructive and few time consuming characterization tools are strongly needed. For such a tight quality control of the wafers, we have developed a scanning photoluminescence (SPL) apparatus working with an UV excitation. The PL mapping is obtained by scanning the sample, under a doubled Ar+ laser beam (244 nm) focused by a microscope objective. The PL signal can be either directly detected, giving integrated PL intensity, either dispersed, giving spectrally resolved PL. The optical signature of different defects will be presented. We will show that dislocation and micropipes density can be found without using chemical etching. Some examples of polytypes mixtures on epitaxial layers (3C inclusions) and bulk samples (4H and 6H) will be presented. Moreover, a method to obtain the minority carrier lifetime mapping from the integrated PL will be described .This is of prime interest both for the material quality control and for the development of bipolar devices.

10:20 **BREAK**

Session Chair: T. Van Veen

11:00 **E-VIII.4**

SCANNING SPREADING RESISTANCE MICROSCOPY OF Al DOPED 4H-SiC

J. Österman, L. Abtin, U. Zimmermann, S. Anand and A. Hallén, Royal Institute of Technology, Kista, Sweden

Silicon carbide is presently the most advanced wide bandgap semiconductor material. Four inch wafers are today available and a few devices, for instance Schottky diodes, have already reached the market. There are, however, still many technological problems to solve. One issue concerns the formation of p+n-junctions by ion implantation. This technology is prefered since it offers better control of the lateral dopant distribution than epitaxial growth, while thermal diffusion of dopants requires very high temperatures. The major disadvantage of ion implantation is the difficulty to reduce the implantation induced damage that, among other things, leads to poor activation of especially high dose implants, low charge carrier lifetimes and high reverse leakage currents. Several methods have been utilised to evaluate the active doping after ion implantation of SiC, for instance Hall measurements, CV and standard spreading resistance, but none of these have been able to monitor the strong gradient in doping concentration in this extremely hard wide bandgap material. Here we report on the successful usage of scanning spreading resistance microscopy (SSRM) of Al-implanted 4H SiC structures. The SSRM results are compared with scanning capacitance microscopy and sheet resistivity measurements and also with measurements of epitaxially grown Al doped samples.

11:20 **E-VIII.5**

PHOTOELECTRON SPECTRA OF Al DOPANTS IN 4H-SiC

D. Schmeißer(a), K. Irmscher(b) and H. Wagner(b), (a)Angewandte Physik-Sensorik, BTU Cottbus, Postfach 10 13 44, 03013 Cottbus, Germany, (b)Institut für Kristallzüchtung, Max Born Strasse 2, 12489 Berlin, Germany

Al-doped 4H-SiC epitaxial layers were grown in a hot-wall chemical vapor deposition (CVD) system on commercial 4H-SiC substrates (CREE). The incorporation of Aluminum has been studied in the concentration range from $2 \cdot 10^{14} cm^{-3}$ up to $3 \cdot 10^{20} cm^{-3}$. Epitaxial layers with doping concentration $N_A - N_D > 10^{19} cm^{-3}$ were studied by HV-TEM and synchrotron radiation investigations. In the concentration range from $1 \cdot 10^{19} cm^{-3}$ to $3 \cdot 10^{20} cm^{-3}$, measured by SIMS and Hall investigations, no Aluminum precipitation were detected in the grown layers.

For SiC samples with an Al concentration of $10^{20} cm^{-3}$ we have been able to detect the Al2p photoemission signal. The Al2p signal is recorded through the oxide layer (thickness of about 0.4nm), it has a main contribution at a binding energy of 73eV which corresponds to the energy typical for elemental Al^0. In spectra excited with higher photon energies the sampled photoelectrons originate from deeper layers. In these data we notice an additional shoulder in the Al2p signal at around 71eV. The evidence of two contributions is attributed to the fact that Al is incorporated at different lattice sites. As the latter data represent more bulk like properties we argue that Al in the bulk SiC occupies both, substitutional lattice sites and interstitial sites while in the surface near regions Al is found only at substitutional lattice sites.

11:40 **E-VIII.6**

DAMAGE FORMATION AND RECOVERY IN HIGH TEMPERATURE HELIUM IMPLANTED 4H-SiC

J.F. Barbot, E. Oliviero, M.L. David, M.F. Beaufort, S. Camelio, T. Girardeau, C. Tromas, C. Blanchard and A. Declémy, Laboratoire de Métallurgie Physique UMR6630, Université de Poitiers, SP2MI, Bd M. et P. Curie, BP30179, 86960 Futuroscope-Chasseneuil Cedex, France

Damage created by elevated temperature (750°C) 1x1017 He/cm2- 50 keV helium implantation into n-type 4H-SiC have been studied using different techniques (Transmission Electron Microscopy, X-ray diffraction, Atomic Force Microscopy, Spectroscopy Ellipsometry, Infrared Reflectivity). The microstructural changes of the buried layer have been studied along different annealing temperatures up to 1500°C. Tiny bubbles are readely formed after the 750°C implantation. When the annealing temperature exceeds 1200°C, the evolution of the damage shows great changes. After the 1500°C anneal, the damaged structure is relaxed but, the optical properties of the implanted SiC are not restored and the swelling of the implanted region is found to increase. In the same time the cavity formation is expected. Some aspects of helium induced damage at 750°C and its annealing behavior will be presented and discussed.