Thursday Morning, November 1, 2001

Photonics Materials Topical Conference
Room 120 - Session PH-ThM

Photonic Materials: Studies on the Nano Scale

Moderator: K. H. A. Bogart, Bell Laboratories, Lucent Technologies

8:20am **PH-ThM1 Chalcogenide Glasses as Nonlinear Optical Materials and Their Application in Optical Communication Systems**, ***H.Y. Hwang***, Bell Laboratories, Lucent Technologies **INVITED**

Chalcogenide glasses exhibit an enhanced Kerr nonlinear refractive index n2, which can be used in a number of applications such as optical switching, pulse shaping, etc. We have explored a range of bulk chalcogenide glasses for optimization at communications wavelengths (~1.55 ?m), motivating current experiments in thin film planar waveguides as well as fiber devices. Low-loss single mode waveguides have been fabricated in a number of ways, and their linear and nonlinear optical properties will be presented. Strong Bragg gratings have also been fabricated using replica molding from holographically generated templates. Finally, the use of chalcogenide films as lateral waveguide cladding of semiconductor optical devices will be described.

9:00am **PH-ThM3 Crystallization Kinetics in Chalcogenide Glasses**, ***S. Ziegler***, Aachen University Technology, Germany, Aachen

Chalcogenide alloys are frequently used for rewritable optical data storage where submicron sized regions of the film are switched between an amorphous and a crystalline state. Since the kinetics of this process are crucial for the success of the technology employ a combintion of different techniques to study the transformation. The activation energy for crystallization is determined by measurements of the electrical resistance upon heating. The structural changes upon heating is derived from x-ray diffraction while x-ray reflectometry is employed to measure the density change upon crystallization. For a number of different alloys density and thickness changes upon crystallization between 5 and 10% are observed. These density changes are accompanied by irreversible stress changes which could possibly limit the lifetime of the films. Nevertheless the measured stress change is much smaller than the stress change expected for a purely elastic deformation. This can be explained by a viscous flow of the amorphous pulse which can also account for the changes of film topography upon crystallization is observed by atomic force microscopy. Microscopic measurements of the crystallization kinetics reveal of correlation with the film stoichiometry, in particular the relative abundance of Ge-Te bonds in GeSbTe alloys. Concepts of combinatorial synthesis are employed to identify phase change materials with fast transformation kinetics.

9:20am **PH-ThM4 Single Quantum Dots as Tunable Artificial Atoms**, ***D. Hessman***, *M. Holm, J. Persson, M.-E. Pistol, C. Pryor, L. Samuelson,* Lund University, Sweden **INVITED**

We present micro-photoluminescence studies of self-assembled InP quantum dots (QDs) embedded in GaInP. The QDs are pyramid shaped and usually about 15 nm high, with a slightly elongated base of about 40 by 50 nm. There are however also smaller QDs with similar lateral extension but with a considerably smaller height. The change in size is, as expected, accompanied by a change in quantum confinement with a corresponding change in emission energy. In addition, there is a transition from a single sharp emission peak for the smallest dots to several 1 meV broad emission lines emitted over a 50 meV energy range for the largest dots. The reason for this behaviour is unintentional doping in the barrier material, resulting in electron accumulation in the QDs. This gives rise to emission in an energy range corresponding to the energy range occupied by these electrons. Larger QDs accumulate more electrons and thus emit over a larger energy range. For the largest dots, the number of electrons is large enough that Coulomb-induced dephasing sets in, resulting in a dramatic line-width broadening. By depositing a semi-transparent Schottky gate on top of the sample, photoluminescence spectra of single QDs can be obtained as a function of bias. Varying the bias, the number of electrons in a large QD is tuned in the range 0-15. For biases such that only a few electrons are present in the QD, the Coulomb-induced dephasing is reduced and the originally 1 meV broad lines split up into sharp lines. We conclude that InP/GaInP is a very interesting system, with QDs acting as tunable artificial atoms, controllable both by size and external bias.

10:20am **PH-ThM7 Dynamic Response of the Electro-optic Effect in Epitaxial Ferroelectric Thin Films**, ***B.W. Wessels***, Northwestern University **INVITED**

Ferroelectric thin films are of considerable promise for use as electro-optic, and non-linear optical materials. Electro-optic (EO) waveguide devices fabricated from thin films offer several advantages over bulk material including lower driving voltages, smaller size, higher modulation speeds and the potential for monolithic integration. Recently we reported ferroelectric thin film electro-optic modulators that operate at frequencies up to 20 GHz. We have also investigated the dynamic response of the electro-optic effect in thin film BaTiO@sub 3@ and KNbO@sub 3@ . The dynamic response has a temporal dependence given by the expression t@super -m@exp(-Bt)@super n@. Measurements of the film birefringence, polarization and dielectric transients show qualitative agreement over 11 orders of magnitude in time. The observed dependence is attributed to the dynamic response of ferroelectric domains.

11:00am **PH-ThM9 Two-stage Growth of Patterned Epitaxial Lithium Niobate for Photonic Application**, *V. Joshkin,* University of Wisconsin-Madison*; K. Dovidenko, S. Oktyabrsky,* NYS Center for Advanced Thin Film Technoogy*; D. Saulys, T.F. Kuech,* ***L. McCaughan***, University of Wisconsin-Madison

LiNbO3 is an ideal material for linear and nonlinear photonic crystals. Potential commercial applications have long been frustrated by the chemical stability of this material. We present a new two-stage growth method for fabricating patterned crystalline LiNbO3 structures for photonic applications. The method is based on physical and chemical properties of amorphous and polycrystal LiNbO3 films grown by high pressure chemical vapor deposition (CVD) from metal alkoxide precursors. In the first stage, the CVD technique is used to deposit amorphous or polycrystalline LiNbO3 films on a crystalline substrate at high deposition rates (~2micron/hr). Patterned structure can now be formed after this first stage using a rapid wet or dry etching of amorphous LiNbO3 (up to 6micron/min depending on etching regimes). In the second stage, a post-growth anneal at high temperature(900°C- 1100°C) converts the film to single crystal LiNbO3. Under the proper annealing conditions, the LiNbO3 bulk self-diffusivity dominates the surface mobility, allowing epitaxial films that maintain the shape of micron-size pattern. These patterned structures are characterized by AES, SEM, HRTEM and DXRD. The effect of substrate on film quality is investigated. Lift-off processing on films grown by two-stage growth technique is demonstrated. Comparison of high vacuum chemical beam epitaxy with high pressure CVD from alkoxides is performed.

Photonics Materials Topical Conference
Room 120 - Session PH-ThA

Photonic Materials: Applications and Processing

Moderator: K.H.A. Bogart, Bell Laboratories, Lucent Technologies

2:00pm **PH-ThA1 Recent Progress on Silica-based Planar Lightwave Circuits for Photonic Networks*, S. Mino,*** NTT, Japan **INVITED**

The increasing demand for Internet traffic is the motivation for a large-capacity and flexible network. Photonic networks utilizing wavelength division multiplexing (WDM) are expected to meet these requirements. Silica-glass-based planar lightwave circuit (PLC) technologies provide various optical devices for such photonic networks. This paper reviews silica-based PLC devices including arrayed-waveguide gratings (AWG), thermo-optic switches (TOSW), and hybrid-integrated PLC devices with optical semiconductor devices. A PLC is an optical integrated circuit that employs silica glass, which is a stable optical fiber material. Thus the PLC has characteristics that include low-loss, compactness, low-cost, suitability for mass-production, and good reliability. The AWG multiplexer is a key component in dense optical WDM networks, since it is capable of multi/demultiplexing N optical signals of different wavelengths. This is because the multiplexer employs the same system as a grating-based spectrometer. We recently reported a 400-ch AWG multiplexer, which is the largest number of channels yet achieved. An optical switch is required to eliminate the bottleneck in conventional electronic switching systems and the PLC-TOSW is a promising candidate because of its excellent characteristics and reliability. We have already reported 16x16 and 1 x 32 TOSW modules. We can construct a larger-scale photonic switching system with more than 100 ports using these modules. Furthermore we developed hybrid-integration technologies in which optical semiconductor devices can be assembled on a PLC substrate. Using hybrid integration, we can realize a high-speed wavelength channel selector and an optical transceiver for optical access systems.

2:40pm **PH-ThA3 Silica Deep Etching with Vertical and Smooth Sidewall and Reduced RIE Lag*, D.Y. Choi,*** *J.H. Lee, D.S. Kim, S.T. Jung,* Samsung Electronics, Korea

Silica waveguides are very important for use in Planar Lightwave Circuits(PLC) because of its low loss and inherent compatibility with silica optical fibers. Deep silica etching(>30um) is necessary when silica PLC is used as a platform to integrate with active devices(LD, PD, SOA, etc.). To lower propagation loss, polarization dependent loss(PDL), and reflectance at waveguide end facet(junction between waveguide and active device), vertical and smooth sidewalls are required. In this work the profile and sidewall roughness of etched waveguides were investigated. Vertical profile was obtained when etching mask was thickened and polymer deposition on sidewall was promoted. But sidewall roughness was increased as deposited polymer thickened. When the clamp in the plasma chamber was changed from alumina to silicon, vertical and smooth sidewall was obtained. RIE lag(Aspect ratio Dependent Etching) becomes important in deep silica etching. We investigated the extent of RIE lag as a function of aspect ratio of trench structures, etching depth, bias power, and pressure. RIE lag increased irrespective of etching depth as aspect ratio increased. When process pressure was high and Si clamp was used, nearly RIE lag-free trench was etched.

3:00pm **PH-ThA4 Development of Integrated Multifunctional Optical Sensors based on III-Nitrides Grown on Si*, D. Starikov,*** *J.-W. Um, C. Boney, A. Bensaoula,* University of Houston

An approach to integrating III-Nitrides-based optoelectronic diode structures into multifunctional optical sensors working in the absorption, scattering, or fluorescence mode is described. The proposed concept is evaluated using an optical sensor prototype assembled from discrete III-Nitrides- and Si-based components coupled to a sapphire window. Testing of this prototype proved the applicability of a wide-range silicon photodetector and UV/blue LEDs in multifunctional optical sensors, and the feasibility of the back-side illumination with a lateral setup of the components. Absorption of light was measured in aquatic polyethylene glycol solutions placed between the sapphire window and a mirror attached in front of it. Observable signals were measured for dilutions ranging from 1000-35000 ppm with a linear dependence for concentrations up to 5000 ppm. The internal reflection from the sapphire window, resulted in a low signal-to-noise ratio, since our prototype did not have any antireflection coating. Scattering measurements were performed using slurries of alumina powder in water at particle concentrations from 6x105 to 4x1012 cm-3. The highest sensitivity and dynamic range is achieved for particle sizes of 0.3-5 mm. The photoresponse dependence is linear for very small (0.05 mm) and very large (15 and 20 mm) particles. Fluorescence measurements of Fluoresceinâ„¢ dye and Chlorophyll in ethanol solutions ranging in concentration from 0.029 to 58 ppm show a more than 6 times wider dynamic range and 5000 times higher sensitivity to the concentration variation than either absorption or scattering measurements. In addition fluorescence shows sensitivity to the pH of the solution. The above results are currently utilized in device modeling, simulation and development of integrated GaN-InGaN multifunctional sensors on Si and sapphire. The talk will present the latest results on the growth, processing, and characterization of these sensors.

4:00pm **PH-ThA7 Application of Photosensitive Methylsilsesquiazane(MSZ) to Lithographic Fabrication of Three Dimensional Periodic Structures*, T. Matsuura,*** *A. Yamada, J. Murota,* Tohoku University, Japan

|> We have proposed a novel lithographic process for fabricating three dimensional periodic structures.@footnote 1@ The essence of the process is that multiple layers of photoresist are coated on the wafer with each layer being exposed with a different pattern without development, and finally after all the photoresist layers are exposed they are developed from upper ones. In this paper, we have applied photosensitive methylsilsesquiazane (MSZ) to enhance the potential of the process. MSZ was spin-coated on the Si wafer, pre-baked at 90°C, and exposed to UV light with a lines-&-spaces mask. Then, the wafer was kept in a moisture case. MSZ contains Si-N bonds, which are converted to alkaline-soluble Si-O bonds after UV-generated photoacid and hydrolysis. Without development of the MSZ at this time, 20nm-thick aluminum is vacuum-evaporated, and then the second photosensitive MSZ was coated. Here, the aluminum layer suppresses mixing of the MSZ layers during coating and penetration of the light to the first layer during exposing the second layer with a different pattern. After these coating and pre-patterning processes are repeated for desired times, the wafers were dipped in a standard developer (TMAH) for MSZ. The areas of the thin aluminum layers wetted by TMAH are also etched, and a periodically stacked structure is formed. When the wafer is cured at 400°C in O@sub 2@, the remaining MSZ is converted directly to methylsilsesquioxane (MSQ) containing stable Si-O-Si networks. As remarkable merits, the present process is simple, easy, and fast, and it possesses intentional-defect-introduction-ability and compatibility with microlithography technology. @FootnoteText@ @footnote 1@ Matsuura et.al, SSDM 2000, p.542.

4:20pm **PH-ThA8 Microphotonics: The Next Platform for the Information Age*, L.C. Kimerling,*** Massachusetts Institute of Technology **INVITED**

A rebuilding of the world's information infrastructure is taking place to give instantaneous availability of data, voice and video. This revolution of the Information Age is being gated more by the introduction of new materials and components, than by the design of systems, software and networks. The key frontier is the large scale integration and manufacturing of photonic components to enable the distribution of high bit rate optical streams to the individual information appliance. It is now one-half century since the advent of solid state electronics with the invention of the transistor. Through unparalleled gains in functionality at relatively constant cost, integrated circuits have enabled telecommunications, computation and manufacturing to move to the leading edge of societal change. This revolution has been conducted with "the turn of a single knob": the shrinking of device dimensions. During the last two decades a new "killer technology" has emerged in the telecommunications field. This photonic technology uses optical fibers for interconnection, and has delivered an exponential increase with time of information carrying capacity to the industry. A single optical fiber, with several hundred gigabits/second of capacity, is limited by electronic processing at each circuit node. To avoid this problem direct optical connections are required. To provide full functionality, optical components must be integrated at densities compatible with microelectronic integration. This microphotonics platform represents not only a solution to information access, but it can also solve key problems relating to reliability and complexity that threaten to end the advance of the silicon integrated circuit technology. The Information Age was ushered into existence by Microelectronics. The future will depend on the networking of communications and databases for universal accessibility. This new Age of Connectivity will require a mating of microelectronic and fiber optic technology through integrated of Microphotonic functionality.

Photonics Materials Topical Conference
Room 134/135 - Session PH-ThP

Poster Session

PH-ThP1 Photoconductivity Perculiarities of @gamma@- Irradiated Silicon, Doped with Sulfur in Spectral Region 10,6 MCM, ***A.V Karimov,*** *R.Sh. Avezov,* Academy of Sciences of Republic Uzbekistan, Uzbekistan*; V.T. Tulanov,* National University of Uzbekistan named after M.Uilugbek, Uzbekistan

@gamma@-irradiation influence on Si < s > photoconductivity in spectral region 10,6 mcm was investigated. It was found that while compensation degree was increased both dark and light resistivities increased by 3-4 orders. Photoconductivity of sulfur doped silicon in the region of 10,6 mcm was investigated very poor. We know only one work,@footnote 1@ fulfilled under photoreciever cooling up to 5 K. The purpose of this paper is to investigate @gamma@-irradiation influence on Si ~~-photoconductivity under cooling up to liquid nitrogen temperature. It is known that under @gamma@ -irradiation of silicon a number of donor and acceptor levels are created in the gap.@footnote 2@ As donor levels are placed in the lower half of the gap and sulfur creates a number of donor levels in the upper part of the gap, they don't reveal themselves in 10,6 mcm photoconductivity. Only acceptor levels have influence, decreasing the filling of donor levels created by sulfur and free electrons concentration in conductivity band. The samples were investigated with specific resistivity 80 @OMEGA@.cm., produced by sulfur diffusion into crucileless p type silicon with initial specific resistance 1600 @OMEGA@.cm. Samples were of parallelogram form with dimensions 10 x 8 x 1 mm@super 3@. Two nickel contacts were drifted electrochemically on one side of greater area at 7mm apart from one another. As irradiation source there was used impulsive CO@sub 2@ laser LGI 50, that gives impulse of 150 mcs duration and 13 mJ energy. Direct voltage 10 V was applied to the sample. Dark current value and photoresponse were measured by memorizing oscillograph S8 12. As @gamma@ irradiation source there was used @super 60@Co, that created flux 1,7 10@super 12@ quanta/cm@super 2@ s. Kinetic equation for one level model (but with several values of energetic levels) was solved and it was established that no less than two energetic levels in semiconductor's gap take part in 10,6 mcm photoconductivity. @FootnoteText@ @footnote 1@ N. Sclar. Infrared Physics. 1976, V.16, P.435 @footnote 2@ V.C. Vavilov, I.P. Kekelidze and L.S. Smirnov. Influence of radiations on the semiconductors. M. Nauka, 1988.~~

PH-ThP2 Using the Ultrasound Treatment for Grain Boundary Passivation and Improvement of Multi-Si Recombination Properties, *A.V Karimov,* Academy of Sciences of Republic Uzbekistan, Uzbekistan*; **Kh. Ismailov**, Sh.N. Bahronov,* Academy of Sciences of Republic Uzbekistan

The photoconverters (PC) has been produced on the base of n and p type multicrystalline silicon with the thickness of 250-300 µm. The technological route of PC included the chemical and mechanical treatments of the wafers (cutting, chemical and mechanical polishing, chemical cleaning and drying), p-n junction was formed by boron thermal diffusion (T~1000-1070 °C) or phosphorous (T~930-970 °C) those penetrated to 0.4-0.7 µm from the solid state reused target. The multi-layer system Ti-Ni-Cu has been used as a collector. The annealing of contacts was carried out at T~ 540-600 °C. The contact frontal topology has been chosen as one- and two-sided grid with the collector buss width of 1mm and contact grid - 0.2 mm. The distance between strips was 3mm. The silicon monoxide (d~ 1000 A) and dioxide SnO@sub 2@ layers were formed by CVD method. This layers were used as antireflection coatings. The total PC area was ~2 cm@super 2@. The samples have been used to study the influence of ultrasonic treatment. The samples have been put into bath with ethanol. On the bottom of the bath was placed the ultrasonic wave sensor (CTS-19). Generator G3-41 with controllable output power exited it. For our case 2.5 MHz frequency and 1 W/cm@super 2@ power were used. The exposure time was chosen experimentally, all measurement was carried out at room temperature. Study of the spectral characteristic of solar cells based on multicrystalline Si under the ultrasonic treatment shown the significant dependence on the exposure time. For example, the 40 minutes exposure leads to photosensitivity increasing. The following increasing of the exposure time up to 120 minutes caused reducing of the photosensitivity on 10-15 %. The spectral characteristics in short-wave spectral range are changed substantially compared to long-wave range. The voltage-current characteristics behave analogously, but they demonstrate the increasing of open circuit voltage (~5%). The dependence of short circuit current on the exposure time in the USW is qualitative agreed with the photocurrent spectral dependence. Totally the changing of the solar cell parameters can be connected with series resistance, and with changing of the material parameters.

Author Index

Bold page numbers indicate presenter