Tuesday Afternoon, October 3, 2000

Photonics
Room 310 - Session PH-TuA

Challenges in Photonics Materials and Device Processing

Moderator: V. Teal, Lucent Technologies

2:00pm **PH-TuA1 From Integrated Optics to MOEMS at LETI , the Key Role of Plasma Processes***, **J.M. Margail**, P.B.M. Brunet-Manquat, C.C. Chabrol, T.E. Enot, M.J. Jadot, P.N. Noel, G.G. Grand, E.O. Ollier, P.M. Mottier,* CEA/LETI, France **INVITED**

Integrated Optics on Silicon, so-called IOS, started to be studied in France in 1973. In the early eighties the Laboratoire d'Electronique, de Technologie et d'Instrumentation (LETI), mainly focused in optical sensor development and worked to set up a photonic technology based on plasma processing (deposition and etching) of silicon oxide and nitride. During this period, IOS technology grew in maturity, strongly pushed forward by the increasing demand for optical fiber-based telecommunications. Today, low price optical passive components are targeted using microelectronic based processes and mass production. However one of the key issues for low price devices is the connection to optical fibers (pigtailing). It is estimated that pigtailing represents 80 percent of the component price. To overcome this problem, LETI introduced so called U-grooves formation for passive fiber alignment. This was performed by the application of silicon micro machining, using isotropic plasma etching of silicon. This introduction, during the second part of the eighties of silicon micro machining in the Integrated Optics group at LETI, opened the route to Optical MEMS (Micro-Electro-Mechanical-Systems) development. Today the strong demand concerning Optical Telecommunication pushed strongly forward the development of Optical MEMS and particularly optical microswitches devices for "fully optical" information routing. This paper will focus on the use of plasma processes for photonic device processing, it will be presented and illustrated (key issues, performances) by some examples of fabricated photonic devices as WDM Phasar, passive alignment of 1 to 8 dividers,1 to 8 optical microswitches.

2:40pm **PH-TuA3 Optical Properties of Tantalum Oxide Films Produced by High Density Plasma Enhanced Chemical Vapor Deposition***, **J.B.O. Caughman**, D.B. Beach, G.E. Jellison, Jr.,* Oak Ridge National Laboratory

Tantalum oxide films are being studied for use as waveguides for optical interconnect applications. The films have been deposited using a plasma enhanced CVD process using a high density inductively coupled plasma source. The inductively coupled source operates at 13.56 MHz and couples power to the plasma via a flat spiral coil. An oxygen plasma is produced in the ionization region and a tantalum containing precursor is injected downstream. The plasma produces atomic oxygen that interacts with the precursor in the gas phase as well as at the surface of the growing film. The deposition rate varies as the plasma coupling makes the transition from predominantly capacitive coupling to inductive coupling, which is related to the amount of atomic oxygen being produced. Gas phase composition is being determined by in-situ mass spectroscopy, and the optical properties of the films are being determined by using spectroscopic ellipsometry. Typical films have a bandgap of 4.3 eV and a refractive index of 2.19. The relationship between atomic oxygen production and films properties will be presented.

3:00pm **PH-TuA4 Processing of (Pb,La)(Zr,Ti)O@sub 3@ Waveguide Devices on Nb-doped SrTiO@sub 3@ by Solid-phase Epitaxy***, **K. Nashimoto**, H. Moriyama, K. Haga, M. Watanabe, E. Osakabe, S. Nakamura, T. Morikawa,* Fuji Xerox Co., Ltd., Japan **INVITED**

It is very attractive to utilize (Pb,La)(Zr,Ti)O@sub 3@ (PLZT) ferroelectric materials for optical waveguide devices because of their excellent electro-optic properties. It is also of great interest to fabricate an electrode/ferroelectric waveguide/electrode structure since a narrow electrode gap resulting in a low-voltage drive will be achieved as compared with conventional LiNbO@sub 3@ waveguide devices which have coplanar electrodes. For realizing the structure, epitaxial PLZT thin films are able to be grown on Nb-doped SrTiO@sub 3@ (Nb:ST) semiconductor substrates. However, it has been difficult to prepare a low-loss PLZT waveguides by vapor phase growth techniques. While, we demonstrated the growth of a heterostructure waveguide consisted of a PZT waveguide layer and a PLZT buffer layer on a Nb:ST substrate by solid-phase epitaxy. The PLZT buffer layer was introduced to avoid absorption loss by the substrate. The solid-phase epitaxy is a simple and useful process in terms of stoichiometric composition control, uniform large-area fabrication, low-loss capability, and waveguide patterning. The substrates were spin-coated with methoxyethoxide precursor solutions, preannealed to form amorphous thin films, and annealed to promote the solid-phase epitaxial crystallization of the thin films. The propagation loss in the grown epitaxial PLZT heterostructure waveguides was less than 1 dB/cm. Effective electro-optic coefficients as large as 40 pm/V and polarization insensitive properties were confirmed. A simple wet-etching process followed by the solid-phase epitaxy was developed for making 5 µm-wide channels in the PLZT waveguides. Digital matrix switches fabricated by the wet-etching and the solid-phase epitaxy showed low propagation losses and low-voltage responses.

3:40pm **PH-TuA6 Comparison of Dry and Wet Etch Processes for SiO@sub 2@/TiO@sub 2@ Distributed Bragg Reflectors for Vertical Cavity Surface Emitting Lasers***, **G. Dang**, H. Cho, K.P. Lee, S.J. Pearton,* University of Florida*; S.N.G. Chu, J. Lapata, W.S. Hobson,* Bell Labs, Lucent Technologies*; F. Ren,* University of Florida

Vertical-Cavity Surface Emitting Lasers (VCSELs) have generated much interest in the photonic devices field. They show tremendous promise for commercial applications involving optical fiber wave-guiding and optoelectronic integrated circuits. The semiconductor-based distributed Bragg reflector (DBR) and dielectric mirror are commonly used in VCSELs. We demonstrated a dry etch process of fabricating SiO@sub 2@/TiO@sub 2@ distributed Bragg reflector for 850 and 980 nm vertical cavity surface emitting lasers. The etchings was conducted with an inductively coupled plasma system. Both SF@sub 6@/Ar and Cl@sub 2@/Ar based etching chemistries were investigated. Very slow etch rates were obtained for TiO@sub 2@ by using Cl@sub 2@/Ar chemistry due to the low volatility of etch products, TiCl@sub x@. Using SF@sub 6@/Ar based chemistry, similar etch rates of TiO@sub 2@ and SiO@sub 2@ were obtained which is desired for alternating SiO@sub 2@/TiO@sub 2@ layers etching. An average etch rate of 1200 Å/min was achieved at ICP and rf power of 500 and 245W, respectively. Wet chemical etch processing was also explored using buffered oxide etchant and diluted HF. Etch rates of 1200 and 2000 Å/min in dilute HF solution were obtained for TiO@sub 2@ and SiO@sub 2@, respectively. However, a significant etch-undercut of the structure and delamination at the SiO@sub 2@/TiO@sub 2@ interfaces were observed with the wet chemical etching due the internal stress between the SiO@sub 2@/TiO@sub 2@ layers.

4:00pm **PH-TuA7 Advances in Materials and Design of Optical Amplifiers***, **D.J. DiGiovanni**,* Bell Laboratories, Lucent Technologies **INVITED**

To meet the explosion in demand for capacity, communications systems are increasing bandwidth and performance. The performance of optical amplifiers, the enabling component of these systems, must be extended through fiber design and operation to support this explosion. Even greater capacity can be realized using other gain media, such as Raman amplifiers. This talk will discuss EDF design issues and progress in Raman amplification. An EDFA consists of a length of silica optical fiber whose core is doped with several hundred ppm Er. Population inversion achieved using diode laser pumping at either 1480 nm or 980 nm provides gain to an optical signal around 1530nm. Signals of many wavelengths can be amplified simultaneously allowing up to 160 wavelength channels to pass over a single fiber. This allows tremendous increases in capacity as channel counts increase. The C-band EDFA (1530-1565nm) is ubiquitous and is being augmented with L-band amps (1565 to 1610nm). One of the most critical amplifier characteristics is uniformity of gain and noise over the spectral window of the amplifier. Glass hosts such as fluorides and tellurites can provide more uniform gain but face many technical difficulties. The low loss window of silica extends from 1300 to 1600 nm, significantly broader than the gain region of EDFAs. Rare earth substitutes to erbium have had limited success, though Tm-doped amplifiers look promising. The most successful approach by far is the use of Raman amplification, in which pump powers of about one Watt generate gain over several kilometers of fiber through scattering from optical phonons. Raman amplifiers have been demonstrated at many wavelengths and offer great promise as discrete amps or in combination with EDFAs. Gain can also occur within the transmission fiber itself, reducing noise and increasing capacity and reach. Next generation systems must employ Raman amplification to continue to grow capacity.

4:40pm **PH-TuA9 A Roadmap for Integrated Microphotonics***, **L.C. Kimerling**,* MIT Microphotonics Center **INVITED**

Low cost, high reliability and high functionality are the driving forces for on-chip circuit integration. Photonics has created a breakthough technology for high capacity information delivery over long distances. However, this technology has been implemented in a discrete point-to-point architecture that is reminiscent of the electronic ancestors of today's microelectronic chips. The need for integrated microphotonics is driven from two sources: 1) interconnection bottleneck that limits integrated circuit speed, and 2) all optical networking for the global distribution of information to finer network tributaries. The key components of the emerging roadmap for microphotonic integration are as follows. What are the appropriate architectures that deliver the full advantages of optics rather than emulate the electronics heritage? What devices will become the standard microphotonic circuit components? What are the materials systems and fabrication processes on which the new integrated microphotonics industry infrastructure will be built? This talk will outline the current view of the emergence of microphotonics and the near term challenges to its implementation as a global smart interconnection paradigm.

Author Index

Bold page numbers indicate presenter