Photonics
Room 310 - Session PH-TuM
Fundamental Properties and Applications of Photonic Materials

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

8:20am **PH-TuM1 Integrated Photonics for Optical Communications: A Materials Processing Challenge*, A.E. White,*** Bell Laboratories, Lucent Technologies **INVITED**

The drive to higher and higher lightwave transmission capacity has come in part through deregulation, but also from demand for internet access, telecommuting, and broadband services. Historically, in order to meet that demand, service providers used higher transmission rates, but now there is a clear trend toward wavelength division multiplexing (WDM), which has some significant advantages. When the switching is done in the optical layer, it will be possible to have true wavelength routing and a reconfigurable network. To implement this vision, a number of sophisticated optical components will be required. In the late 1980's, researchers started to explore whether the functionality of passive optical components, such as fibers and taps, could be combined, similar to the way that electrical components (resistors, capacitors, and transistors) are combined in an integrated circuit (IC). The primary goal was to reduce manufacturing costs, but the additional advantages of ICs, such as reduced size, increased performance (especially at high speeds), and greater reliability, are also be desirable in photonics. The silicon wafer can be used as a platform to attach lasers and detectors as well, hence the name "silicon optical bench" for this technology. Silicon optical bench technology leverages off the silicon IC industry for low cost, high quality flat substrates as well as processing developments and equipment. Initially, the focus was on passive waveguide structures and considerable effort went into designing a materials and processing technology that would be compatible with standard semiconductor manufacturing equipment and would also produce planar waveguides that were well-matched to standard single mode (SM) optical fiber. As the devices become more complex - from routers, to reconfigurable add/drop filters, to Er-doped planar waveguide amplifiers - new materials and processing challenges have arisen.

9:00am **PH-TuM3 Infrared Ellipsometry Characterization of Porous Silicon Bragg Reflectors***, S. Zangooie, M. Schubert, C. Trimble, D.W. Thompson,* ***J.A. Woollam,*** University of Nebraska, Lincoln

Porous silicon (PS) has been the subject of intensive investigation for applications of the material in disciplines such as silicon based electronics, gas- and biosensor technologies, as well as optics. Industrial applications of PS demand fast and non-destructive determination of the material properties in terms of, e.g., thickness, porosity and surface chemical characteristics. In this work variable angle of incidence infrared spectroscopic ellipsometry is employed to simultaneously determine the real and imaginary parts of the dielectric function of the solid phase of the porous silicon Bragg reflectors without the necessity for additional measurements on reference samples, employment of the Kramers-Kronig technique, or extrapolation of experimental data beyond the measurement range. In addition to the thickness, volume porosity, inhomogeneity and optical anisotropy, properties of the solid part of the porous material are investigated in terms of the optical dielectric function and surface chemistry. The high sensitivity of the technique is employed to detect and identify infrared resonant absorptions related to different Si-H as well as Si-O-Si vibrational modes. Resonances due to Si@sub 2@-Si-H@sub 2@, Si@sub 3@-Si-H, Si@sub 2@-Si-H@sub 2@, Si-O-Si stretching modes, as well as Si@sub 2@-Si-H@sub 2@ scissor and Si@sub 2@-Si-H@sub 2@ wagging mode are revealed and characterized. A relatively large resonance at 626 cm@super -1@ is attributed to the Si-Si bond stretching caused by the asymmetry in surface related bonds creating an IR-active net dipole moment. The material is found to have positive birefringence. The electrical resistivity of the solid part of the porous material is determined to be 0.03 @ohm@ cm, and larger than the corresponding bulk value of 0.019 @ohm@ cm. Furthermore, the carrier concentration in the investigated porous material shows a decrease from 6.2 * 10@super 18@ cm@super -3@ to 4 * 10@super 18@ cm@super -3@.

9:20am **PH-TuM4 IR Fiber Optics Development at the Naval Research Laboratory*, J.S. Sanghera,*** Naval Research Laboratory **INVITED**

IR transmitting chalcogenide glasses and fibers are being developed at the Naval Research Laboratory for numerous military, commercial and biomedical applications in the infrared region. Significant progress has been made in the areas of chemical and glass purification, glass fabrication and fiberization technology. Consequently, long lengths of optical fibers have been fabricated that possess low loss, high strength and high threshold to laser damage. The fibers are being developed for, and implemented in, infrared countermeasure systems, threat warning systems and fiber optic based chemical sensor systems for facility clean up and environmental monitoring as well as biomedical tissue diagnostics. The fibers have also been used in a scanning near field infrared microscope (SNIM) to demonstrate an optical resolution of 100 nm and topographic resolution of 20 nm. The ability to dope these materials with rare earth ions has led to bright sources in the IR beyond 2 um which are useful for characterizing missile seekers and focal plane array detectors. In addition, these low phonon energy glasses are excellent hosts for rare earth ions for making potential lasers and amplifiers. We will present our latest results regarding fabrication of the fibers, fiber properties and their applications.

10:00am **PH-TuM6 First-Principles Study of Oxygen-Deficient Defects in Silicate and Germanosilicate Glasses*, K. Raghavachari,*** Bell Laboratories, Lucent Technologies

The prominent 5-eV absorption band in silicate and germanosilicate glasses has been the subject of extensive investigations by many groups. Several defect models involving oxygen deficiency have been proposed to explain the experimental observations. In particular, careful analysis of the associated photoluminescence bands indicates the presence of more than one component to the absorption band. However, the microscopic defect models responsible for this absorption band are still under debate. In this work, we have investigated the structural and electronic properties of oxygen deficient defects in silicate and germanosilicate glasses by first-principles quantum chemical studies using a cluster approach. In particular, the photoabsorption and photoluminescence properties of several competing defect models have been evaluated. The performance of different quantum chemical methods for the accurate calculation of the optical properties of defects is assessed. The effect of Ge on the relative thermodynamic stabilities of the defects is examined. Careful comparisons are performed with the known experimental observations. New models are proposed to explain the different components of the 5-eV photoabsorption band in glasses.

10:20am **PH-TuM7 Dynamic Polymeric Photonic Components*, L. Eldada,*** Telephotonics, Inc. **INVITED**

A key advantage of polymeric materials over more conventional optical materials such as glass, is the considerably larger variation that their refractive index undergoes with temperature. The large magnitude of the thermo-optic coefficient dn/dT (about 25 times larger in most polymers than in glass) can be leveraged to produce power-efficient thermally actuated dynamic photonic components. We review the global advances in thermo-optic polymeric components which include switches, tunable filters, and variable optical attenuators (VOA's). NxN switches can be digital optical switches based on X junctions or Y junctions, or they can be interferometric switches based on directional couplers or Mach-Zehnder interferometers (MZI's), including generalized MZI's (GMZI's) which are compact devices that consist of a pair of cascaded NxN multimode interference (MMI) couplers with thermal phase shifters on the N connecting arms; tunable filters can be based on phasars, gratings, thin films, or microring resonators; and VOA's can be based on interferometry, mode confinement, or switching principles.

11:00am **PH-TuM9 The Understanding and Realization of Photonic Crystals*, C.A. White,*** Bell Laboratories, Lucent Technologies **INVITED**

Interest in photonic crystals has shown explosive growth in recent years. This interest spawns from the potential for new devices ranging from new optical crossconnects to novel lasers to microstructured optical fiber as well as the possibility of experiments in fundamental physics ranging from enhanced fluorescence lifetimes to atomic traps. All of these applications are made possible not because of the discovery of new physical phenomena, rather through a novel manner of looking at conventional optics. In this talk, I will discuss the theory of these new materials highlighting how relatively simple optical concepts give rise to the exciting properties photonic crystals. I will construct a simple intuitive notion of what defines a photonic crystal and specifically what gives rise to the photonic band gap. Building on this discussion of the physics, I will present our efforts on the realization of two and three dimensional photonic crystals at Bell Laboratories.

11:40am **PH-TuM11 Plasmonics: Electromagnetic Energy Transfer and Switching Below the Diffraction Limit in Nanoparticle Chain Arrays***, M.L.* ***Brongersma****,* California Institute of Technology, US*; S.A. Maier, H.A. Atwater,* California Institute of Technology

The integration density of integrated optics appears to face the fundamental limitation that structures for guiding and modulation of light must have dimensions comparable to the wavelength of light. Recently however, it was theoretically shown that this problem can be circumvented by "plasmonics", i.e., transport of electromagnetic energy along linear chains of closely spaced 10-50 nm diameter metal nanoparticles. This transport relies on the coupled near-field electrodynamic interaction between metal particles that sets up coupled plasmon modes. We have modeled the electromagnetic transport properties of corners, tees, and switches that consist of chains of metal nanoparticles. Both full electromagnetic field calculations using finite difference time domain methods and calculations in the point dipole approximation indicate strong guiding of electromagnetic radiation, and electromagnetic dispersion relations are obtained. It is shown that propagation is coherent and the group velocities can exceed saturated velocities of electrons in semiconductors (about 10^5 m/s). High efficiency transmission of energy around sharp corners is possible. The transmission is a strong function of the frequency and polarization direction of the plasmon mode. The factors dictating the choices for particle and host material will be described. To date, we have also performed experiments using nanophotonic analog structures that operate in the microwave frequency regime. We find that in analogs to optical plasmonic devices operating at 8 GHz, the transmitted intensities around both sharp corners and tees are high and closely agree with the results of microwave device simulations. Finally, the operation of a "plasmon switch" that acts as an all-optical inverter is modeled. Recent efforts to fabricate and test nanoscale plasmonic structures will be discussed; we note that such "plasmonic devices" potentially are among the smallest structures with optical functionality.

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