OPTICAL PROPERTIES OF Si-BASED MATERIALS FOR PHOTONIC APPLICATIONS

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As the microelectronics industry approaches fundamental limits in terms of processing speed, integrated photonics and optoelectronics are generally regarded as future candidates to increase speeds, primarily in the area of optical interconnects. Unfortunately, as of yet there exists no ideal material for monolithically integrated photonics. Silicon, the dominant material in microelectronics, has an indirect energy band gap and is an inefficient light emitter. Si would, however, be the material of choice for integrated photonics due to the large array of processing tools available for Si and the ability to avoid complex hybrid optoelectronic integration schemes. While bulk Si is not suitable for the development of a Si-based emitter, nanocrystalline Si (nc-Si) does not suffer the same limitations. When taken down to the nanoscale, quantum confinement effects begin to affect the recombination process. Under these circumstances luminescence can be obtained from Si based materials [1].

In this paper we present work related to the formation of nc-Si within silicon rich silicon oxide (SRSO) thin films deposited by electron cyclotron resonance (ECR) PECVD and inductively coupled plasma (ICP) CVD. Post-deposition, these films have been annealed at high temperatures. The anneal process causes the excess Si to precipitate within a SiO_2 amorphous host. At sufficiently high temperatures (T ~ 1000 °C) nanocrystals are able to form. The size and structure of these nanocrystals have been analyzed through x-ray diffraction and transmission electron microscopy and correlated to the initial film composition, while the bonding structure of the oxide has been analyzed using Fourier transform infrared spectroscopy.

Figure 1 shows the photoluminescence spectra for films having 36 and 39% Si and annealed at 1100 °C. The PL spectra were obtained using a HeCd laser, emitting at 325 nm. Quantum confinement enables luminescence to be observed, however, the observed PL emission wavelength is related to defect states associated with the oxide [2]. The refractive indices of SRSO films with compositions from SiO_2 to *a*-Si have been determined through the use of spectroscopic ellipsometry. Both the PL and refractive indices of these films have been analyzed as a function of film composition and anneal conditions, and the obtained results have been related to the structural modifications associated with nanocrystal formation within these films.

Based on these results the potential applications of Si-based films for integrated nanophotonics, specifically as light emitting devices and waveguides, are discussed and significant challenges associated with using these films for these applications are reviewed.

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References:

[1] L. Pavesi and D.J. Lockwood (eds.), Silicon Photonics, Springer, 2004.
[2] M.V. Wolkin *et al*. Phys. Rev. Lett. **82** (1999) 197.

Figures:

Figure 1: PL Spectra for films having 36 and 39% Si deposited by ECR-PECVD and ICP-CVD.