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Analysis of the Structure, Optical Properties, and Luminescence of Silicon Nanocrystals Formed in Silicon Oxide Based Thin Films

T. Roschuk, J. Wojcik, and P. Mascher
Centre for Electrophotonic Materials and Devices and Department of Engineering Physics,
McMaster University,
Hamilton, Ontario, L8S 4L7, Canada.

Nanostructured silicon shows promise as a potential material for future integrated photonic applications. Silicon is traditionally an inefficient emitter due to its indirect bandgap, however, when silicon is made porous or silicon nanocrystals are formed within an amorphous host matrix, quantum confinement effects begin to occur and luminescence becomes possible in these materials which may one day allow for silicon to be used for monolithically integrated photonic circuits.

In this paper we present our work on the formation of silicon nanocrystals in silicon rich silicon oxide materials, spanning the range of compositions from those close to SiO_2 to SiO, produced by post deposition annealing of thin films grown by electron cyclotron resonance plasma enhanced chemical vapor deposition. In addition we discuss the effects of annealing in materials that are highly silicon rich, spanning the range of SiO to near amorphous Si. Finally, we will discuss the relevance of these results in terms of applications for future nanophotonic devices.

Analysis of the composition and structure of these films through techniques such as Rutherford backscattering, elastic recoil detection, Fourier transform infrared spectroscopy, X-ray diffraction, and electron microscopy reveals the effects of annealing on the underlying material systems properties. Through the use of spectroscopic ellipsometry the variation of the optical constants of these films after annealing treatments has been determined. The luminescence of these materials is discussed in relation to the effects of annealing and the material characteristics as determined through the above mentioned techniques.

Annealing of these films causes a phase separation of the excess silicon producing Si and SiO_2 phases. As the anneal temperature is increased the Si phase begins to nucleate and form into nanocrystals within a SiO_2 host. Annealing of highly silicon rich materials still causes the formation of Si and SiO_2, however, in the case of compositions close to SiO neither the Si nor SiO_2 phase is present in sufficient quantity to act as a host material and both phases must coexist. For compositions close to amorphous silicon FTIR spectra revealed that annealing produces a SiO_2 phase, however, since the oxygen is not present in large quantities, the SiO_2 phase must be contained within an amorphous Si host.

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