Characterization of Luminescent Si-based Materials through X-ray and Electron Spectroscopies

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Even though silicon is a poor light emitting material due to its indirect bandgap, there is significant interest in the development of Si-based light sources for integrated photonics, which could draw on the existing infrastructure for large-scale fabrication and integration. Two promising methods of forming light-emitting Si-based materials are (i) the reduction in size down to the nanoscale, where quantum confinement leads to increased emission efficiencies and (ii) the incorporation of rare earth dopants to achieve emission characteristic of the atomic energy levels of the rare earth ions.

One common method of forming Si-nanostructures involves the deposition of a Si-rich thin film (oxide, nitride, or oxynitride) followed by an anneal process to induce a phase separation of the excess Si and the embedding dielectric. The details of light emission from both Si-ncs and rare earth doped thin films depend strongly on the local bonding structure and the presence of interface defect states in the host dielectric .

In this paper we discuss the characterization of luminescent Si-ncs embedded in undoped and rare earth-doped silicon oxide and nitride thin films grown using PECVD-based techniques. Post-deposition the films have been subjected to high temperature thermal annealing to induce nanocluster formation and optical activation of the rare earth ions. Photoluminescence experiments have been conducted using a HeCd laser source emitting at 325 nm.

Through the use of X-ray spectroscopies, including X-ray absorption spectroscopy (and the study of the X-ray absorption near-edge structure, XANES) and X-ray excited optical luminescence (XEOL), information on the bonding structure of the films has been obtained and luminescent states have been probed at site-specific energies related to the constituent bonding atoms within the film. Details of the luminescence and bonding structure of the films have been related to the composition and post-deposition treatment of the films. The results are compared with those obtained through the use of electron energy loss spectroscopy, energy filtered transmission electron microscopy (TEM), and high resolution TEM, which allow for the analysis of details of the bonding and atomic nanostructure of the films.

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