Amorphous silicon based thin films for photonic applications

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Silicon has long been the material of choice for microelectronic applications while photonics has yet to see one material become the clear choice for the development of integrated photonic circuits. Typically, while silicon has found use in waveguide and detector applications, it has been disregarded as a photonic material due to its indirect bandgap, making the development of silicon-based light emitters difficult. More recently luminescence has been observed in silicon when it is made porous or when silicon nanocrystals are formed in silicon rich silicon oxide based materials. In both cases the luminescence results from quantum confinement effects in the nanostructured silicon.

Here we present our work on amorphous silicon and silicon rich silicon oxide thin films that were deposited using electron cyclotron resonance plasma enhanced chemical vapor deposition. Following the deposition of these films they were subjected to thermal annealing in argon and nitrogen ambients at temperatures of 400 to 1200 °C for times up to 120 minutes.

Following their deposition and annealing treatments the composition of these films has been analyzed using Rutherford backscattering and elastic recoil detection experiments. Atomic bonding and structure have been determined through the use of Fourier transform infrared spectroscopy, x-ray diffraction and atomic force microscopy experiments. The optical properties of these films have been analyzed using spectroscopic ellipsometry operating from 600-1100 nm. Luminescence studies were done on these films using a HeCd photoluminescence setup. The results of these experiments will be discussed as a function of the initial compositions of these films and the annealing conditions.

In the case of the amorphous silicon films, high temperature annealing induces the formation of microcrystallinity, which in turn causes the formation of pits within the film. As the annealing temperature is increased these pits grow in size and cause the formation of a porous structure as shown in figure 1. Silicon rich silicon oxide films undergo phase separation upon annealing resulting in a Si phase located within an amorphous SiO_2 host matrix. The Si phase then nucleates and silicon nanocrystals form within these films. Figure 2 shows an AFM image for a film having 42% silicon, annealed for 60 minutes at 900 °C, causing nanoclusters of Si to form.

We will conclude by discussing the results from these experiments in terms of applications to nanophotonic circuits and devices and the suitability of silicon to play a dominant role in their development.

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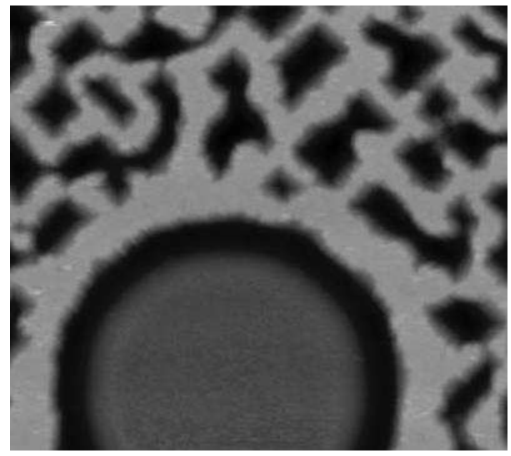

Figure 1: An AFM image of an amorphous Si film annealed at 1200 °C for 60 minutes.

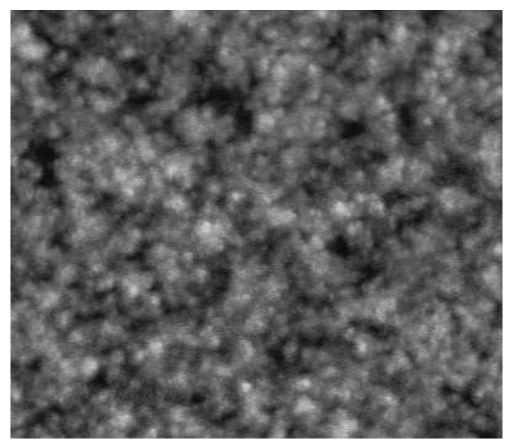

Figure 2: An AFM image of a silicon rich silicon oxide film having 42% silicon annealed at 900 °C for 60 minutes.