Electron Beam Direct Write of Chalcogenide Glass Integrated Optics

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Chalcogenide glasses are amorphous, glassy, semiconducting materials containing S, Se, or Te as the primary components, with network modifiers such as Ge, As, Sb, Bi, Ga, and Sn. They are of interest in photonics because of their low-loss transmission in the infrared, their large third order susceptibility, low two photon absorption at telecommunications wavelengths, and variety of bond rearrangement effects such as photoexpansion, photodarkening, electron beam induced deformation, and electron beam induced second harmonic generation. The large Kerr nonlinearities and relatively large refractive indices enable compact integrated optical circuits capable of all-optical switching.

In this work, electron beam induced deformations are explored for realizing optical waveguides in $Ge_{0.2}Se_{0.8}$ chalcogenide glass thin films. The approach is an etch-less technique that potentially allows realizing waveguides whose surface roughness is limited only by the roughness of the as-deposited film. Consequently, surface roughness scattering loss is reduced. The low-loss potential benefits resonant waveguide structures and waveguiding in general. The 20 weight percent Ge concentration is of interest due to the large photosoftening observed compared to other concentrations when the glass is exposed to near bandgap light.

We have observed that electron beam induced reliefs induced in $Ge_{0.2}Se_{0.8}$ thin films are mound-shaped and similar to rib waveguides. The height of the deformations produced by focused electron beam exposure, defined as the vertical distance between the deformation side trough and the peak, is chosen as a primary figure of merit for the response of the material to electron beam irradiation. Atomic force microscopy (AFM) is used to ascertain the topography of the material response. As shown in Fig. 1, the height of the deformations tends to increase with film thickness and number of exposures, where the number of exposures is defined as the number of passes over the same pattern. Strategies are developed to smooth the mound deformations and make them uniform transversely and longitudinally. The AFM image in Fig. 2 shows an example ring resonator device structure, written completely with this direct write electron beam technique. Directional couplers and waveguide tapers have also been written.

Strategies are also developed to simultaneously exploit the flexibility of direct electron beam writing and the speed of photolithography. Bus waveguides are first defined via photolithography and then electron beam induced structures are written on top of them. The scanning electron micrograph (SEM) in Fig. 3 shows an example this strategy. Periodic gratings are written using electron beams onto a shallow rib waveguide defined by photolithography.

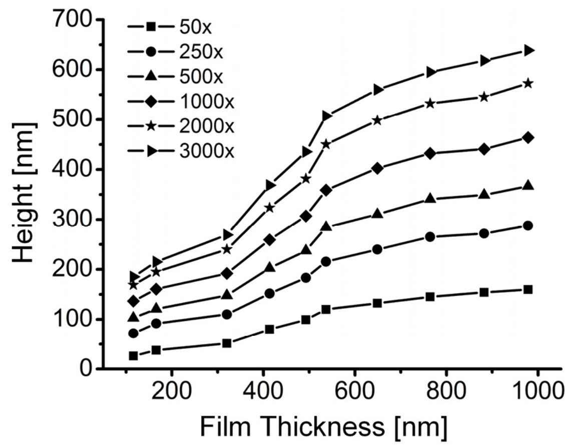

Figure 1. Height of the film reliefs versus film thickness for different electron beam exposure counts.

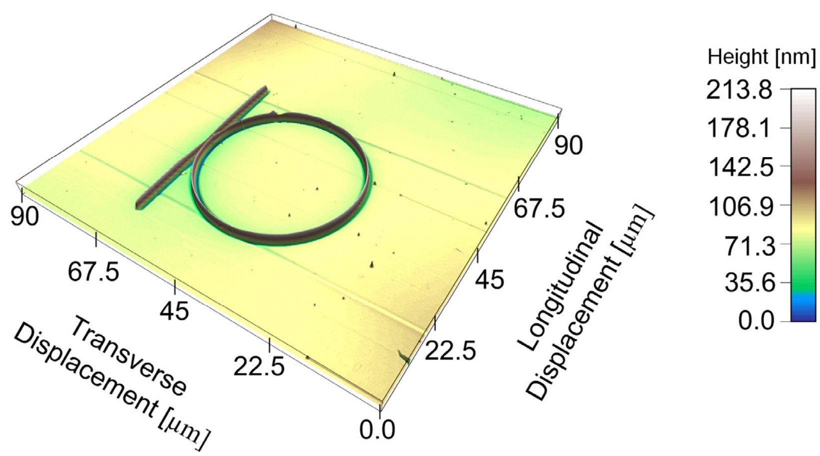

Figure 2. AFM image of a ring resonator device structure directly written by electron beams into a chalcogenide glass thin film.

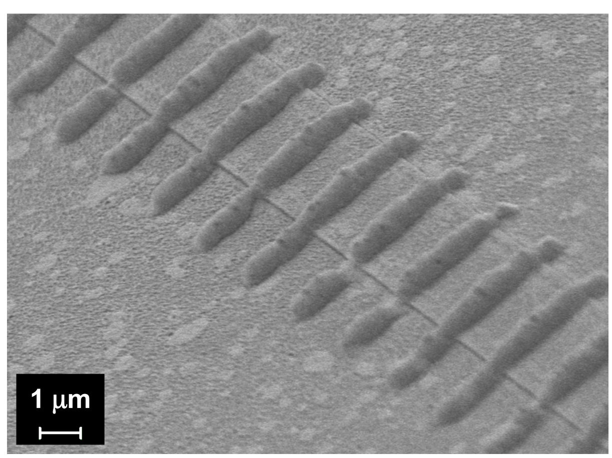

Figure 3. SEM image of the direct write of gratings using electron beams onto planar rib waveguides defined via photolithography.