Abstract

Rare-earth activated transparent glasses and glass-ceramics have great potential for applications in the integrated optics. Glasses, in general, are amorphous in nature; whereas glass-ceramics are two-phase composite materials having nanocrystals embedded in the amorphous glass matrix leading to the advantage of crystalline environment in the glass matrix. In this thesis, we study optically active materials (e.g. Eu, ZnO, graphene oxide (GO)) incorporated glasses and hybrid nanocrystals embedded low-loss glass-ceramic waveguides based active photonics devices for integrated optic applications. Eu-doped transparent ZnO films have been fabricated by sol-gel method and effect of controlled heat-treatment temperatures on structural and optical properties of Eu-doped ZnO films have been studied. Extended X-ray absorption fine structure analysis has been performed to understand the local environments of Eu-ions within the crystalline ZnO environments. The Förster energy transfer process from ZnO to Eu^{3+} is studied by photoluminescence (PL) and PL excitation spectra. Moreover, Eu-doped 70 SiO_2 – (30-x) HfO_2 – x ZnO (x = 0, 2, 5, 7 and 10 mol%) ternary glass-ceramic waveguides have been studied extensively to obtain ZnO incorporated low-loss ((0.3 to 0.6)$\pm$0.2 dB/cm) glass-ceramic waveguides. Interestingly, controlled growth of hybrid nanocrystals are observed with an average size of 3 nm–25 nm, composed of ZnO encapsulated by a thin layer of nanocrystalline HfO_2, with an increase of ZnO concentration from x = 2 mol% to 10 mol% in the ternary matrix. PL spectra show the signature of mixed valence state of Eu-ions (both Eu^{2+} and Eu^{3+}) in the ternary matrices. The effect of ZnO concentrations on the local environment of Eu-ions are investigated by analysis of the time-resolved PL spectra and the PL emission lifetimes of Eu^{2+} and Eu^{3+} ions. Furthermore, 70 SiO_2 – 23 HfO_2 – 7 ZnO (mol%) waveguide, the optimal waveguide containing ZnO with low propagation loss (0.5$\pm$0.2 dB/cm), has been studied to demonstrate the structural evolution of ZnO/HfO_2 nanocrystals and its effect on Eu^{2+}/Eu^{3+} emission as a function of heat-treatments. It is observed that HfO_2 evolves as both spherical and rod-like nanocrystals whereas ZnO evolves as spherical nanocrystals. The highly crystalline environment in the ternary matrix leads to the reduction process of Eu^{3+} to Eu^{2+} and hence enhances the blue emitting characteristic of ternary waveguide.

Finally, SiO_2–HfO_2 waveguides are fabricated by UV-photolithography method followed by wet chemical etching. GO integrated SiO_2–HfO_2 channel waveguide has been demonstrated as an on-chip TE-pass waveguide polarizer. The controlled intensity tuning of the selective state of polarization of this on-chip waveguide polarizer has been demonstrated by chemical modification of GO flakes by laser irradiation technique.

Keywords: *Glass-ceramics, Waveguides, Rare-earth, Hybrid nanocrystals, Blue emission, Waveguide polarizer, Integrated optics.*