Advances in planar photonic integration with a novel ultrafast laser plasma fabrication process

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We report a novel method for the simultaneous implantation of multiple, atomically dissimilar ions into silica matrix using ultrafast laser processing for developing a variety of functional optoelectronic materials. High index contrast (>10%) waveguides (n=1.6) in silica with rare earth co-doping and sequential doping are realized with femtosecond plasma implantation, assisted by physicochemical reactions at the plasma-silica interface. Homogenous rare earth doped and undoped waveguides with no dopant segregation are fabricated, having the potential for devices like loss-less splitters, waveguide amplifiers and laser platforms. For an Er^{3+}-ion doped waveguide, the absorption and emission cross sections at 1534 nm are estimated as 3 $x10^{-22}$ cm^2 with a measured fluorescence lifetime of 12.9 ms. The 1 mm thick substrates with the planar waveguides on it were measured to have a high optical transparency of 95 % and the waveguide propagation losses of < 0.5 dB/cm at 1550 nm. Selective doping and un-doped regions are achieved with a masked implantation approach in the same substrate with a good control over the step index waveguide formation. Multi-rare earth ion doped channel waveguides are accomplished on this platform in a single step process, reported for the first time in ultrafast laser processing. This can support the mass manufacturing of photonic integrated circuits in a CMOS foundry line. Further, this method can be extended for engineering the optical devices and sensors with hybrid integration of silica, silicon, metal and polymer materials.

[250 word abstract]

[100 words summary]

Multi-ion doped silica planar waveguides are realized with a femtosecond pulsed laser fabrication process. Co-doping and sequential doping of rare-earth tellurite glasses ($79TeO_2$-10ZnO-$10Na_2O$-$1Er_2O_3$/$1Yb_2O_3$) on silica results in a step index waveguide with an effective index of 1.6. Channel waveguide amplifiers are realized in a single step process with direct masking technique, never reported previously in ultrafast laser processing of optical waveguides. The high homogeneity and excellent control of the plasma implanted rare earth doped and undoped waveguides that can be fabricated on fused silica offers the opportunity to engineer passive and active integrated optical circuits with power splitters, amplifiers and laser in a single processing step. Details of the step index wave guide engineering and process controls will be presented.