Gallium-lanthanum sulphide films for waveguide devices

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Gallium-lanthanum sulphide (Ga_2S_3-La_2S_3) (GLS) glasses have a range of novel optoelectronic applications. The material is transparent from ~0.65 μm to ~10 μm, covering the important near-infrared telecommunications and mid-infrared 'fingerprint' spectral regions. The lanthanum content ensures very high solubility for other rare-earth dopant ions such as Er^{3+}, Ho^{3+}, Pr^{3+}, Nd^{3+}, etc., which can be used as active laser or optical amplifier species. The low phonon energy of GLS glass gives rise to low nonradiative relaxation rates, which opens the possibility of operating lasers in this host material in the mid-infrared. Laser action to wavelengths approaching 5 μm may be feasible in high-quality films. An unusual property of the material is that the refractive index can be substantially and permanently modified by over 1% by exposure to illumination above the band gap, typically at 0.5145 μm wavelength or shorter.

We have constructed a novel laser ablation chamber dedicated to the production of GLS films. Sellmier equations and Urbach edge-absorption parameters have been deduced by detailed fitting to experimental data across the entire transparency range (0.6 μm to 10 μm) of the material. These parameters are required for device design and performance prediction. Extensive studies of the dependence of the film parameters on film-deposition conditions, target composition, and film post deposition annealing have been made. Film compositions are found to depend strongly on the target fluence used; near threshold (2.8 J/cm^2) fluences lead to films with near-normal sulphur stoichiometry (S/Ga + La) = 1.60), whilst the more usually employed high fluences (5 − 10 J/cm^2) result in sulphur deficient films (S/(Ga + La) = 0.8) and strong Urbach tail absorption.

In order to study the photorefractive effect a novel instrument that measures differential reflectivity between two closely adjacent spots has been constructed. Reflectivity differences below 10^{-5} are easily measured. This enables both the sign and magnitude of the index change to be readily measured at any wavelength. In GLS, in contrast to the more widely studied arsenic and germanium chalcogenide glasses, index changes are negative and the films photobleach rather than photodarken. We will report the effect of deposition conditions on film photosensitivity.

The thickness of GLS films required to provide single-mode propagation on a glass substrate is inconveniently thin owing to the very high refractive index difference. The properties of waveguides using ablated zinc sulphide underlayers to increase single-mode thicknesses and similar capping layers to protect the top surface are reported. The zinc sulphide underlayer also eliminates absorption in the mid-infrared by evanescent fields in the substrate.

Doped GLS targets are currently being fabricated to investigate the comparative properties of dopant ions such as Nd^{3+}, Er^{3+}, and Ho^{3+} in the films as compared to bulk glass. Kinetic and spectroscopic properties of the doped films are reported, with initial attempts at planar-waveguide-confined laser action.