Phase Change Gallium and Germanium Chalcogenides for Optical, Electronic and Plasmonic Switching

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ABSTRACT

We show that the phase-change technology behind rewritable optical disks and the latest generation of electronic memories can also offer applications in active plasmonics and metamaterials. A range of chalcogenides have been fabricated and characterized for their optical, thermal and electrical properties. Experimental demonstrations show that excitation-induced refractive index changes in gallium lanthanum sulphide (Ga:La:S), a can provide high contrast switching functionality. We have fabricated a silver/GLS interface which can support surface plasmon-polaritons and also incorporated a Ga:La:S thin film with a metamaterials based on arrays of resonance cells. We demonstrate both plasmonic modulation and metamaterials switching through reversible refractive index changes in the chalcogenide.

Key words: chalcogenide, phase change, plasmonics, metamaterials, switching

1. INTRODUCTION

The phase-change technology behind rewritable optical disks and the latest generation of electronic memories has provided clear commercial and technological advances for the field of data storage, by virtue of the many key attributes chalcogenide materials offer. New generations of optoelectronic devices are being driven by the merging of optics and electronics, as photons and electrons begin to cooperate in a single material platform. As a part of this evolution, plasmonics and metamaterials brings with them the ability to focus and manipulate light on the nanoscale, far beyond the diffraction limit of conventional optics. With strongly established credentials in the `parent' fields of photonics and electronics, chalcogenides have much to offer in the plasmonic and metamaterial domains. Indeed, their chameleon nature: they can be crystalline or amorphous, metallic or semiconducting, and conductors of ions or electrons[1], makes chalcogenides an obvious platform technology for this evolution.

2. EXPERIMENTS AND RESULTS

In the past year, we have developed a range of chalcogenide glass families, in particular based on Ge:Sb, Ge:Sb:S, Ge:Sb:Te, Ga:La:S and Ga:La:Te, encompassing well known phase change materials as well as more novel compositions and demonstrated their functionality for optical and electronic applications. Germanium antimony based thin films with tunable compositions were fabricated by chemical vapour deposition[2] (CVD) and phase transitions demonstrated with the electrical characterization. Gallium sulphide (Ga:La:S) based films were deposited by RF-sputtering using targets prepared in-house by melt quenching to an amorphous state and both optical and electronic switching has been shown. Our earlier work with more conventional Ge:Sb:Te materials[4] made it clear that chalcogenide-based phase change materials lend themselves to compositional spread analysis and we have now extended this work, using high throughput thin film synthesis and characterization based on ultra high vacuum physical vapour deposition technology, to explore the full phase diagram of the Ga:La:Te glass family.

Our work with phase change materials has also evolved into the areas of plasmonics and metamaterials. High quality Ga:La:S/silver interfaces supporting SPP propagation have been formed and, furthermore, photo-induced refractive index changes in the chalcogenide have been used to actively control signals in such plasmonic waveguides. Nanoscale electro-optic switching has also been demonstrated via the exploitation of a frequency shift in the narrow-band Fano resonance of a plasmonic planar metamaterial hybridized with Ga:La:S: An electrically stimulated transition between amorphous and crystalline forms of the glass brings about a 150 nm shift in the near-infrared resonance of the structure providing transmission modulation with a contrast ratio of 4:1 in a device of sub wavelength thickness.

3. CONCLUSION

In summary, we show that chalcogenide based phase change functionality has the potential to be extended to wider applications, beyond the realm of optics and electronics and play a key role in the integration of electronic and photonic devices through active plasmonics and metamaterial switching.

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Biography

Professor D. Hewak is head of the Novel Glasses and Fibres Group at the ORC and an international expert and innovator in the synthesis and application of chalcogenide materials. He works on the purification and synthesis of chalcogenide materials, glass melting and the fabrication of optical fibres, thin films, microspheres and nanoparticles and collaborates with industrial partners and universities worldwide. He has been working in the area of phase change materials since 2001.