ULTRA LOW POWER CONSUMING, THERMALLY STABLE SULPHIDE MATERIALS FOR RESISTIVE AND PHASE CHANGE MEMRISTIVE APPLICATION

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The use of conventional chalcogenide alloys in rewritable optical disks and the latest generation of electronic memories (phase change and nano-ionic memories) has provided clear commercial and technological advances for the field of data storage, by virtue of the many well-known attributes, in particular scaling, cycling endurance and speed, that these chalcogenide materials offer. While the switching power and current consumption of established germanium antimony telluride based phase change memory cells are a major factor in chip design in real world applications, the thermal stability and high on-state power consumption of these device can be a major obstacle in the path to full commercialization. In this work we describe our research in material discovery and prototype device fabrication and characterization, which through high throughput screening has demonstrated thermally stable, low current consuming chalcogenides for applications in PCRAM and oxygen doped chalcogenides for RRAM which significantly outperform the current contenders.

Our particular interest in the field of electronic data processing and storage is concerned with the discovery of new chalcogenide alloys to outperform the commonly used Ge:Sb:Te (GST) for PCRAM applications. There is a wide range of chalcogenide alloys, range from pure chalcogenides, to pnictogen-chalcogen, tetragen-chalcogen, metal chalcogenides to halogen-chalcogenides [1]. Many of these compounds are covered within high-level patent literature, within which a vast array of potential compounds suitable for phase change memory are proposed, yet with relatively few studied in detail [2]. Indeed, even among phase change memory cells fabricated with the most conventional GST compounds, the reasons why these compositions provide us with useful and attractive physical properties are still veiled [3]. It is therefore our belief that the field and material space is ripe for a thorough analysis of the compositional space to provide both a better understanding of the range of properties the numerous chalcogenide alloys offer and to optimize the compositions to meet the demands of practical solid state memory and information processing devices. Through high throughput synthesis and characterisation techniques, one can quickly reach the optimal composition for a family of alloys for use in different applications and find exciting new physical phenomena in an incredibly efficient manner (Figure 1).

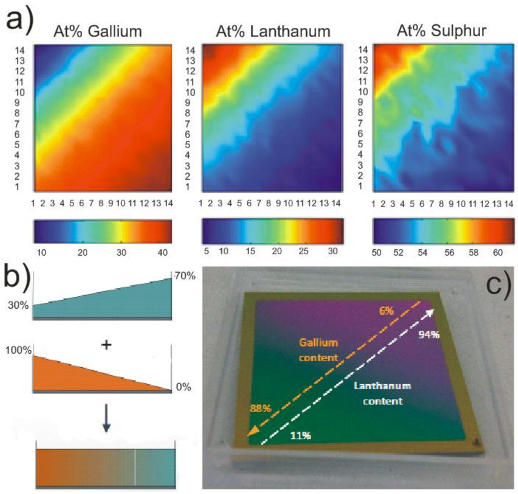

Figure 1: a) EDX results mapping the composition across the sample, b) thickness of individual elemental components across sample for a binary alloy, c) High throughput chip mapping the composition of GLS family of glasses.

High-throughput physical deposition screening techniques provide a unique route to the exploration of thin film media (4). They exploit the deposition of chalcogenide compositional gradients across areas of several square centimetres, and allow rapid analysis of

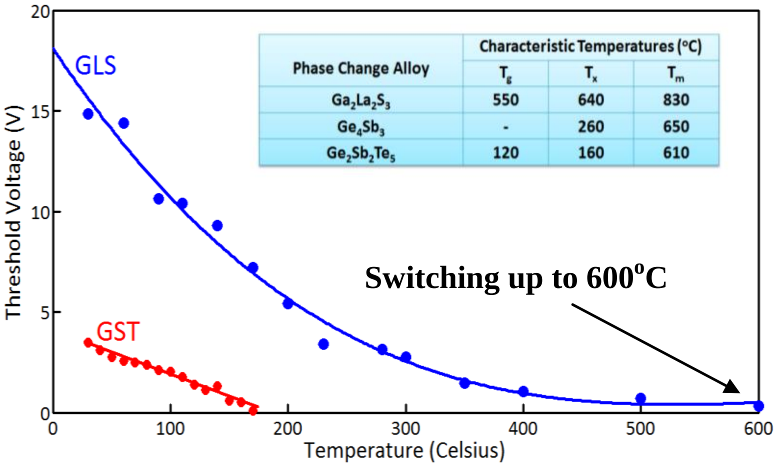

Figure 2: top) The temperature dependence of the threshold voltage of a Ga:La:S and Ge:Sb:Te based memory cells. bottom) The crystallisation temperatures (^{o}C) of GLS compared with other Sb and Te based alloys.

optical, electronic and thermal properties as a function of composition. As such, we show that compositionally optimised phase change media based on the gallium and lanthanum chalcogenides can perform well above the well-known benchmark performance of germanium antimony telluride devices.

The experimental work we have completed shows that these compounds offer set and reset currents over an order of magnitude lower, than an equivalent germanium antimony telluride device, while at the same time offering improved thermal stability and the potential for improved endurance. Our nano scale devices based on Ga:La:S continues to show the ability to display a measurable threshold up to 400^{o}C higher than equivalent germanium antimony telluride based memory cells Figure 2).

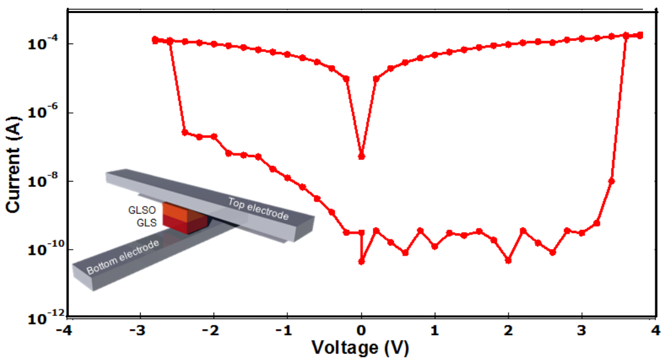

Figure 3: Current voltage characteristics of the device in the on and off states in both polarities.

Additionally, through the incorporation of oxygen rich GLS alongside the standard GLS used previously, bipolar resistive switching is observed in the characteristics of such devices. Typical read state current voltage characteristics is shown in Figure 3, with the corresponding resistance memory window of operation, showing a resistance ratio of up to 10^{6} Ohms.

Summary:

Through the combination of high throughput synthesis and nanofabrication techniques we reveal ultra-fast optimisation techniques for data storage, both PCRAM and RRAM applications. We reveal enhanced temperature stability in phase change alloys identified through high throughput screening of families of chalcogenide alloys. Through the incorporation of oxygen into optimised high stability phase change alloys bipolar resistive switching with very large resistance windows is observed. Work in progress is fully quantifying a range of chalcogenides to provide optimized materials for commercial memory based devices.

References

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