Nano-Scale Sulphide Phase Change Materials and Applications

Robert E Simpson[1], Chung-Che Huang[1], Chia-Jong Liu[2], Chao-Yi Tai[3], D W Hewak[1]

(1) Optoelectronics Research Centre, University of Southampton SO17 1BJ
(2) Institute of Physics, Academia Sinica, Nankang 11529, Taipei, Taiwan
(3) Department of Optics and Photonics, National Central University, Jhongli, Taiwan

Sulphur-based phase change materials have been investigated for potential nano-scale electrical phase change memories. These materials are stable in both there crystalline and amorphous phases. Switching is achieved by either melting the material to form an amorphous area or heating above its crystallisation temperature. This can be achieved through Joule heating by application of an energy pulse in the form of an electrical current or laser heating. In this work the switching speed of the films has been investigated using a dual laser system to write and read the marks created in the films. A 658nm diode laser focussed through a 0.65NA objective was used to deliver pulses with incident optical powers up to 130mW and pulse time ranging from 5ns to 1us. The change in reflectivity of the samples was measured using the same objective and a 635nm diode with an incident power of 20μW. This type of device is commonly known as a static tester [1,2].

Ga:La:Cu:S films, 350nm in depth, were sputtered onto quartz substrates. The static tester was used to generate a matrix of power, time and reflectivity. The map generated from these measurements is given in figure 1a. It shows materials are capable of crystallising in 150ns. This is comparable to the well researched, and consequently, optimised material Ge$_2$:Sb$_2$:Te$_5$[3], commonly referred to as GST, see figure 1b.

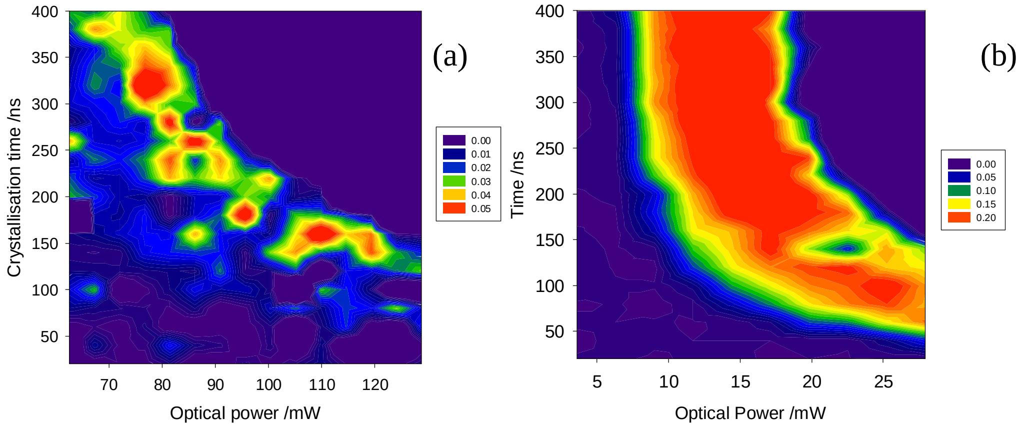

Figure 1: Optical Power, Time, Reflectivity maps for (a) Ga:La:Cu:S and (b) Ge:Sb:Te films, both 350nm in depth deposited on Quartz substrates

The GST material has been optimised for phase change optical disks with write lasers close to the wavelength of our 658nm write laser, hence the large change in reflectivity upon crystallisation. However this material is not optimised for phase change electrical storage. One of the foremost issues with this material is its low resistivity in its crystalline phase; 1e-6 Ω.m. Researches have tried doping this material with nitrogen which can have a positive affect, increasing the resistivity by a factor of 20 [4]. Increasing the resistance of the phase change cell, decreases the power requirements to reach the characteristic temperatures of the phase change material. In contrast to the low resistivities of GST, the GaLaS materials have proved to be to be in the range of 3e8 Ω.m to 6e8 Ω.m for the crystalline phase and 3e9 to 6e9 Ωm for the amorphous. Thus much lower currents are required to generate the necessary temperatures in the material.

In this work we will present, recent electrical, thermal and optical measurements of Sulphide based phase change materials. A 20nm by 100nm line-memory cell has been fabricated using e-beam lithography and dry etching. Such structures have proven to allow a wider choice of electrode materials. The majority of the surrounding materials can be chosen to have a low thermal conductivity and a line memory has good scalability potential [5]. Integration of the Sulphur based material into this structure has been modelled using multi-physics finite element analysis; this will also be presented.

[1] Yamada, J. et.al. Appt. Phys. 69 (5), 1991 PP2849-2856
[2] Mansuripur et.al, Applied Optics, Vol. 38, No. 34, 1999, pp7095-7104
[3] G. F. Zhou and B.A.J Jacobs Jpn.J.Appl.Phys. Vol.38(1999) Pt.1 1625-1628
[4] Horii et.al., ‘A Novel Cell Technology Using N-doped GeSbTe Films for Phase Change RAM’, 2003 Symposium on VLSl Technology Digest of .Technical Papers
[5] Lankhorts et.al., Nature Materials, VOL 4,APRIL 2005, pp347-352