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Phase change properties of ternary $AgSbSe_2$ chalcogenide films

K. WANG[*a], C. STEIMER, M. WUTTIG
I. Physikalisches Institut der RWTH Aachen, 52056 Aachen, Germany
[a]*Present address: School of Physics and Astronomy, University of Southampton, SO17 1BJ, UK.*

Despite a low transition temperature the ternary $AgSbSe_2$ alloy possesses phase change properties including larger resistance change, a single crystalline structure and smaller volume change upon crystallization. Basic functionality of a reversible switching by a pulsed laser has been demonstrated.

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Keywords: $AgSbSe_2$ film, Phase change material, Chalcogenide, Reversible switching

1. Introduction

Amorphous chalcogenide films are the most attractive materials for the wide application of micro-optical, micro-mechanical and optical/electronic memories *etc* [1-6]. Among them, tellurium-based alloys are regarded as a class of suitable materials for memory applications [7-8]. Recently, remarkable high electrical resistance change upon transition was found in binary selenium-based alloys such as In-Se or Sb-Se systems [9-11]. Here, we report the electrical and structural properties as well as a reversible switching test in ternary $AgSbSe_2$ films. The results show this ternary selenium-based compound possesses a desired performance and might act as a novel class of alternative for the application in the optical/electronic memory.

2. Experimental

Thin films of $AgSbSe_2$ were fabricated on glass or Si substrates by evaporating single element sources in an MBE chamber [12]. Transition temperatures were determined by temperature dependent sheet resistance measurements in a protecting Ar-atmosphere. All X-ray-measurements were performed at room temperature (Philips X´Pert MRD System). Density and thickness changes upon crystallization were obtained from XRR. Local switching trial in the $AgSbSe_2$ films was performed using a static tester (λ = 830 nm) with an objective lens of high numerical aperture (N.A. = 0.8). Reflectance change of the created mark was monitored and the topography of the irradiated region was subsequently identified using an atomic force microscope (Dimension 3100, DI).

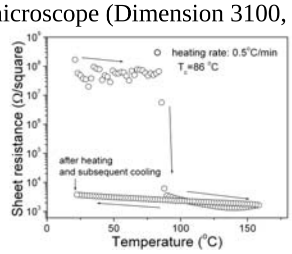

Fig. 1. Temperature-dependent sheet resistance measurement of a 72 nm $AgSbSe_2$ film on a glass substrate.

Fig. 1 shows the temperature-dependent sheet resistance of a 72 nm $AgSbSe_2$ film on a glass substrate taken at a heating rate of 0.5 °C/min. A sharp drop of the sheet resistance of more than four orders of magnitude is observed at 86 °C, which is later identified as an amorphous-to-crystalline transition by X-ray diffraction (XRD). The considerable noise at low temperature in the curve comes from the extremely high resistance value of the amorphous film, which is beyond the limit (~10^8 Ω/square) of the setup.

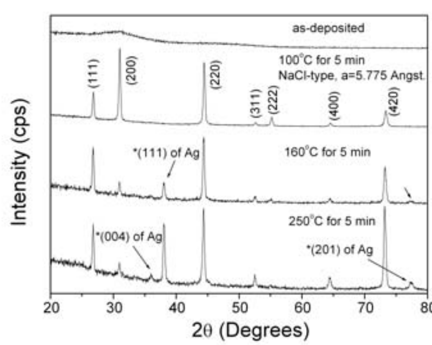

Fig. 2. XRD-scans of a 100 nm $AgSbSe_2$ film on a glass substrate in the as-deposited state and after annealing at different temperatures.

Fig. 2 depicts the XRD-scans of a 100 nm $AgSbSe_2$ film on a glass substrate in the as-deposited state and after annealing at different temperatures. The as-deposited films are confirmed to be in the amorphous state while a single crystalline phase with a NaCl-type structure is formed after annealing at 100 °C. The lattice parameter of the NaCl-type structure is determined to be a = 5.775 ± 0.005 Å, which agrees nicely with the values of 5.786 Å previously reported for single-crystalline $AgSbSe_2$ [13]. The XRD-data also confirm that the sharp drop at 86 °C in Fig. 1 corresponds to the amorphous-to-crystalline transition. Further annealing at temperatures higher than 160 °C will cause phase separation, which was identified to be a segregation of crystalline silver out from the NaCl-typed matrix.

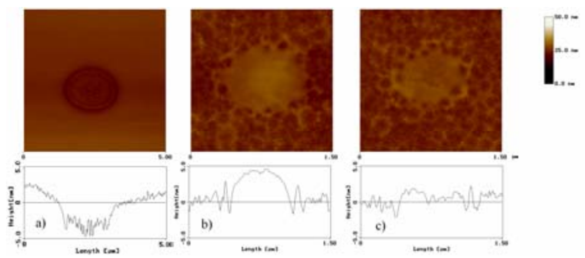

Fig. 3. a) An AFM image of a crystalline bit in an 87 nm as-deposited $AgSbSe_2$ film produced by laser of 15 mW and 80 μs, and its typical cross section. b) Amorphous bit written with a laser pulse of 20 mW and 150 ns into a crystalline surrounding. c) Perfect erasure by a subsequent laser pulse of 4 mW and 80 ns.

3. Phase change recording

A reversible recording/erasing trial is performed by a pulsed laser and AFM, as described elsewhere [14-17]. Fig. 3a shows an AFM image and a typical cross section of a crystalline mark. The crystalline bit is produced by a laser pulse of 15 mW and 80 μs. Crystallization does not only lead to a reflectivity increase but also an increase in film density [18]. Therefore the crystallized region corresponds to a depression in the amorphous surrounding. The modified area in Fig. 3a has a circular shape with a diameter of around 1.7 μm. The saturation depth of the bit is 4.2 ± 0.5 nm and the thickness of the as-deposited amorphous film is 87 ± 3 nm. This leads to a change in thickness of 4.8 ± 0.8%, which is in good agreement with the density change of 3.8% determined by XRR [12]. Fig. 3b is a micrograph of an amorphous bit produced by the write pulse in the crystalline matrix. The amorphous bit is created by the laser of 20 mW and 150 ns. Besides a decrease in reflectance, amorphization leads also to a decrease in density and therefore to a local increase in film thickness [18]. The diameter of the amorphous bit is around 650 nm and the height is approximately 4.4 nm. Fig. 3c shows an image of an erased bit produced by a subsequent pulse of 4 mW and 80 ns. After the irradiation, the height of the erased bit has already recovered to the same height as the crystalline background, indicating that complete erasure is realized.

4. Conclusions

In summary, despite a low transition temperature the ternary $AgSbSe_2$ alloy possesses desired phase change properties including larger resistance change, a single crystalline structure and smaller volume change upon crystallization. Basic functionality of a reversible switching by a pulsed laser is successfully demonstrated, indicating that selenide might play an active role in the application of phase change memory.

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*Corresponding author: wang@phys.soton.ac.uk