

DC conductivity in GeSb₂Te₄ and (GeSb₂Te₄)₉₀(SnSe₂)₁₀ phase change materials

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The dc electrical conductivity of the bulk amorphous GeSb₂Te₄ material has been investigated. Pure and samples doped by 10 at. % SnSe₂ have been measured. The conductivity in the samples has been compared with that of SnSe₂ bulk sample. The activation energy of the doped sample is 0.165 eV. During heating the conductivity of doped material increases, reaches a maximum and then decreases. The comparison with the pure SnSe₂ samples allows to explain this behavior by the release above 148 °C of a small amount of selenium not bonded in the network.

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The chalcogenides in the non-crystalline state are flexible electronic materials that are now largely used in optoelectronic devices, in switches, CD recording devices and are proposed for smart memories [1-11]. Many papers have been published recently on switching mechanism in chalcogenides and phase change materials properties, as well as modeling [12-15]. The Ge-Sb-Te materials have been recently proposed as phase change materials for random access memories [16-25]. The memory effect is based on the rapid phase change produced under the action of electrical current pulses. Two conduction states are typical for such materials: the high conductivity state, which corresponds to the crystalline state, and the low conductivity state which is proper to the amorphous state of the investigated material.

We have prepared two phase change materials: the first composition is GeSb₂Te₄ labelled L1, while the second one is (GeSb₂Te₄)₉₀(SnSe₂)₁₀ which has been labelled L2.

Pure elements (p.a. purity) have been introduced in a quartz ampoule in a proportion that corresponds to the stoichiometry of the ternary compound, adding appropriate amount of SnSe₂ in the case of the second, doped, composition. The ampoules were evacuated to 10⁻³ Torr, sealed and heated in a tubular furnace at around 1050 °C (a temperature above the melting point of germanium) for 24 h. The ampoules were periodically shaken during heating and thereafter quenched in air. Sn and Se were introduced in the doped composition as SnSe₂ compound previously prepared by synthesis from elements. Cylindrical ingots were obtained.

The SnSe₂ ingots were prepared by mixing Sn and Se elements (5n purity) in quartz ampoule and then heating up to the melting point of SnSe₂ (657 deg. C) [26]. Periodic shaking and rocking of the ampoule was made in order to get a homogeneous composition. Finally the

ampoule was cooled down to 0 °C in a mixture of ice and water. An ingot of 19 mm in diameter and length of ~ 60 mm was obtained. Disc-shaped samples have been cut from the ingot.

The X-ray diffraction data show that both L1 and L2 samples are vitreous. The sample SnSe₂ is a mixture of polycrystalline and amorphous phase. The main crystalline phase is hexagonal SnSe₂. A minor cubic SnSe₂ phase has also been found.

The direct current (dc) electrical conductivity measurements were carried out with conducting electrodes based on copper. The temperature dependence of the dc-conductivity ($\sigma_{dc}(T)$) has been measured at a heating rate of 5 °C/min, using a Keithley 2000 digital multimeter in four-wire resistance setup, to compensate resistance of connected wires.

Temperature was measured by means of an S(Pt-PtRh) type thermocouple and a Greisinger GMH 3210 thermometer [27]. The measured data were monitored in steps of 1 °C.

The charge carriers move under the applied electric field but the free movement is impeded by the scattering on the lattice vibrations. As a consequence an Arrhenius law is obtained:

$$\sigma_{dc} = \sigma_0 e^{-(E_a/kT)} \quad (1)$$

where σ_0 is a pre-exponential factor, E_a is the activation energy, k is Boltzmann's constant and T is temperature.

The results of the measurements are given in Fig. 1, where the conductivity σ_{dc} (in logarithmic scale) is plotted versus 1000/T.

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