Switching effect in single crystals of Ga_2Se_3

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Conductivity switching, which is frequently observed in amorphous materials, is much less common in single crystals. The exception are layered single crystals such as GaSe[1], GaTe[2], InSe[3],etc. Single crystals of Ga_2Se_3 with a cubic structure of sphalerite type in their α-phase (below 600°C) also show memory or bistable conductivity switching. In the present work, the authors try to explain this phenomenon, which - to the authors' knowledge- has been here observed for the first time.

Single crystals of Ga_2Se_3 were obtained by direct synthesis of gallium and selenium in an evacuated quarts tube at 1025°C. Samples of the electrical resistivity of the order of $\varrho \gtrsim 10^{10}\,\Omega$ cm were shaped as plan-parallel platellets of a few tens of microns in thickness with electrical contacts (1 mm^2 in area) of indium or Ag paste on both sides. High-voltage power supply was used as a source during the measurements of static d.c.current-voltage (I-V) characteristics,while a series resistor R_s of a few hundreds kΩ limited the current through the sample in the ON state.

Static d.c.I-V characteristics of Ga_2Se_3 samples were taken at room temperature and below, i.e.in the range between 80 and 330 K, keeping the specimens in dark in order to eliminate the effect of light (the samples are photosensitive). At low applied electric fields, Ohm's law holds (below 10^3V/cm). At higher fields, up to $\sim 10^4$V/cm,the relation between I and V has the power-law form $I \propto V^n$, where $1 < n < 3$. At fields in the range from 10^4 to 10^5V/cm, the Poole-Frenkel conduction has been found ($\log I \propto V^{1/2}$). At electric fields higher than $\sim 10^5$ V/cm, a sudden transition from the high-resistivity or OFF state to the low-resistivity or ON state occurs (fig.1). Ratio from the OFF-state resistance to the ON-state resistance, R_{OFF}/R_{ON}, is of the order of 10^4-10^6. The ON state is maintained also when the applied voltage is completely removed, indicating that the switching is bistable or memory switching. The OFF state can be restored by applying a weak current pulse or simply by heating up to 30-40°C; however, this temperature rises as the number of switching cycles increases (after 20 switching cycles it reaches 80°C). Measurements at low temperatures indicate that memory switching is present below room temperature (measured up to 80 K).

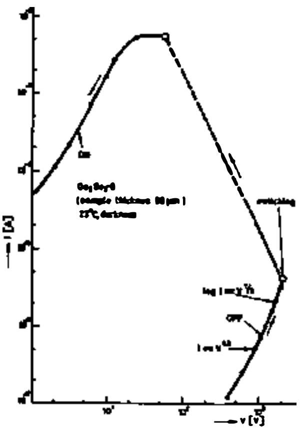

Fig.1. Static d.c. I-V characteristics of a Ga_2Se_3 single crystal in the OFF state (before first switching) and in the ON state.

Studying the switching effect in bulk Ga_2Se_3 single crystal samples with indium contacts placed at the surface at the distance of about 100 μm, it was found that the transition from the OFF to the ON state was accompanied by the creation of a visible "bridge" or filament between the electrodes. Thus also in the case of thin platellets one can assume creation of filaments during the transition from the OFF to the ON state. These filaments are responsible for the low resistance of the ON state. Measurements of R_{ON} versus temperature of the samples in the ON state reveal the metallic character of conduction[4], since the average temperature coefficient of resistivity in the ON state was obtained as positive and equal to $\alpha = 3.8 \times 10^{-3} K^{-1}$. This behaviour indicates that the ON state is sustained through a metallic material. However, electrical measurements alone cannot give sufficient information on the switching phenomenon in Ga_2Se_3 and its filamentary character. It is, therefore, necessary to use other methods (scanning electron microscopy), which can give structure and composition analysis of the filaments formed. These experiments are now under way. In this way it is possible to obtain a better insight into the origin and nature of this phenomenon.

BIBLIOGRAPHY

/1/ A.Levialdi and N.Romeo, Nuovo Cim.63B(1969)41.

/2/ W.I.Milne and J.C.Anderson, J.Phys.D: Appl.Phys.6 (1973)2115; C.Paorici, N.Romeo and L.Tarricone, J.Phys.D: Appl.Phys.9(1976)245.

/3/ M.Peršin and B.Čelustka, Fizika 8(1976)13.

/4/ T.Ota and K.Takahashi, Solid-State Electr.16 (1973)1089.