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Study of the switching phenomena of $TlGaS_2$ single crystals

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ABSTRACT

Single crystals of $TlGaS_2$ were prepared by a special modified Bridgman technique and used to investigate the switching phenomena. The particular interest shown in switching studies of p-type $TlGaS_2$ compound is associated with the possibility of its uses as an effective switching and memory elements in electronic devices. The switching effect observed in such crystal shows a memory character. Using a crystal holder and cryostat we measured the switching phenomenon at different ambient conditions such as temperature, light illumination as well as sample thickness. Pronounced parameters for switching for sample of thickness 0.17 cm were determined from the experimental data such as threshold voltage $V_{th} = 400$ V, threshold current $I_{th} = 37$ μA, holding voltage $V_h = 350$ V, holding current $I_h = 42.3 \times 10^{-4}$ A, threshold power $P_{th} = 1.48 \times 10^{-2}$ W, threshold field $E_{th} = 196.429$ V/cm as well as the ratio between the resistance in the off state R_{OFF} to the resistance in the conducting state R_{ON} as 130.253. The factors affecting these parameters have also been investigated.

1. Introduction

In the past three decades, significant interest in chalcogenide semiconductors has been shown by various workers owing to their interesting physical properties as well as their wide technological applications. For the last few years there has been a considerable interest in the investigation of the physical properties of layered ternary crystals with chemical formula $TlBX_2$, where B = Ga or In and X = S or Se [1]. $TlGaS_2$ as a member of this class of crystals is a semiconductor with an indirect band gap of about 2.46 eV at room temperature [2]. This crystal is expected to have a potential application for optoelectronic devices and nonlinear optics [3]. This compound has attracted widespread attention for its structural [4,5], electrical [6], photoconductive [7], and optical properties [8–10]. Moreover, thermally stimulated current [11], thermal expansion [12], electron paramagnetic resonance [13] EPR, heat capacity [14] and Raman scattering [15] have also been reported.

At present, the nature of switching phenomenon is not yet clear and the available experimental data have not been explained unambiguously [16]. Conflicting explanations of the experimental data are mainly due to the complex nature of the switching phenomenon, consisting of a series independent stages during which different mechanisms can act [17]. That is why an investigation of this phenomenon of a single crystal semiconductor is of special practical interest, and can be useful for the development of the switching theory. In spite of the availability of the above results, the behavior of switching phenomenon, the effect of temperature, illumination intensity, and sample thickness on the switching behavior parameters have not been well established, at least to the best of our knowledge. The aim of the present work is to report detailed information about the behavior and mechanism of switching phenomenon, switching parameter and factors affecting it. Analysis of the above mentioned study will help reveal the properties of $TlGaS_2$ crystal for the sake of technological applications.

2. Experimental aspects

$TlGaS_2$ monocrystals were synthesized from particular-high purity elements (at least 99.9999%) taken in stoichiometric proportions. The investigated single crystals were grown in our crystal growth laboratory by a modified Bridgman method from a stoichiometric melt of starting material sealed in evacuated ($\approx 10^{-6}$ mbar) and carbon coated quartz ampoules with a tip at the bottom for promoting the growth of single crystals. The ampoule was loaded with the required amounts of high purity elements 30.2099 g thallium (60.4198%), 10.3015 g gallium (20.6030%) and 9.4886 g sulfur (18.772%).

The loaded ampoule was held in the hot zone of a three zoon furnace, each zone is 20 cm length, and on the starting of the tope zone the temperature was kept at 1000 °C for 24 h to homogenize the melt, the ampoule was shaken during heating to accelerate the diffusion of the contaminates through each other. Then the ampoule was moved down with a rate of 2.3 mm h^{-1} through a

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