STUDY OF LOCAL STRUCTURE Se–As GLASSY SEMICONDUCTOR SYSTEM AND THE MECHANISM OF CURRENT PASSAGE THROUGH THE Al-$Se_{95}As_5$<EuF_3>-Te STRUCTURE

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The local structure features of $Se_{95}As_5$ chalcogenide glassy semiconductor doped with EuF_3 rare-earth impurity and the mechanism of current passage through Al– $Se_{95}As_5$<EuF_3>–Te structure have been investigated by the X-ray, Raman micro-spectroscopy methods and current-voltage characteristics. The basic structural elements and chemical bonds formed the amorphous matrix, and the features of current flow in strong electric fields through the Al– $Se_{95}As_5$<EuF_3>–Te structure in two directions of the applied electric field have been determined.

Keywords: conductivity, amorphous structure, x-ray diffraction, Raman spectroscopy.
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1. INTRODUCTION

A strong increase in the number of works devoted to studies of the structure and electronic properties of chalcogenide glassy semiconductor (CGS) materials is due to the wide scope of their application and the emergence of new applications over time. In particular, CGS materials are widely used as active media in lasers, optical amplifiers and converters, and are considered promising materials for memory elements, recording information carried out due to the glass-crystal phase transition caused by an electric field. However, the success of applied tasks depends on the ability to control and manage electronic properties. It is known that the electronic properties of CGSs are closely related to the features of the local structure on a short- and medium-order range. The study shows that the local structure can be directionally changed by changing the chemical composition and alloying [1].

2. CONTENT

The present work is devoted to the study of the local structure of the $Se_{95}As_5$ glassy semiconductor containing of EuF_3 impurity and the mechanism of current flow through Al-$Se_{95}As_5$<EuF_3>-Te structure. The choice of the object is due to the fact that amorphous selenium with the addition of arsenic as a resistant material to crystallization is considered more promising for use than amorphous selenium with better photoelectric parameters, but easily crystallizing. However, the addition of arsenic to selenium affects the photoelectric properties. It is known that the electronic and photoelectric properties of CGS (selenium with arsenic addition also belongs to this class of materials) is controlled by the centers of effective correlation energy (U^- -centers) manifesting themselves in the form of charged defects (D^+ and D^-), the concentration of which can be changed by introducing impurities manifesting in the form of charged centers [2]. It is considered that the EuF_3 impurity of should contribute to the manifestation of positive europium ions, which will lead to a change in the concentration of intrinsic charged defects, also Eu^{3+} and F^- as are chemically active elements, formed bonds between selenium and arsenic atoms will cause a change in the amorphous matrix. These factors will affect the electronic and photoelectric properties of the investigated material [3].

3. RESULTS AND DISCUSSION

X-ray diffraction patterns shown in Fig. 1 of two bands indicate amorphous films. In addition, the diffraction pattern contains a peak, the so-called first sharp diffraction peak (FSDP), the presence of which is associated with the existence of ordering in the arrangement of structural elements outside the region of the first coordination sphere and is called the middle-region-order (MRO). Within the framework of the Elliot void-cluster model, using the FSDP parameters, the correlation length and the "quasiperiod" of atoms density fluctuations in the MRO, also the diameter of the nanovoids, have been estimated. It was shown that the EuF_3 impurity mainly affects the values of the R "quasiperiod" and D diameter of the nanovoids.

The Raman spectrum of amorphous selenium consists of a broad maximum at a frequency of 254 cm^{-1} and a narrow maximum at 237.8 cm^{-1} corresponding to vibrations of the Se_8 ring molecules and - Se-Se- chain molecules (Fig. 2a). Adding arsenic to amorphous selenium leads to a significant change in its Raman spectrum (curve 1, Fig. 2b). The peak at 254 cm^{-1} is noticeably attenuated, which is associated with the rupture of part of the ring molecules. The appearance of peaks in the frequency range 209÷220 cm^{-1} is associated with the formation of various molecular fragments (for example, As_4Se_4 type). A peak at 225 cm^{-1} is also observed in all CGS systems containing As and Se atoms and is attributed to the pyramidal structural elements of $AsSe_3$.

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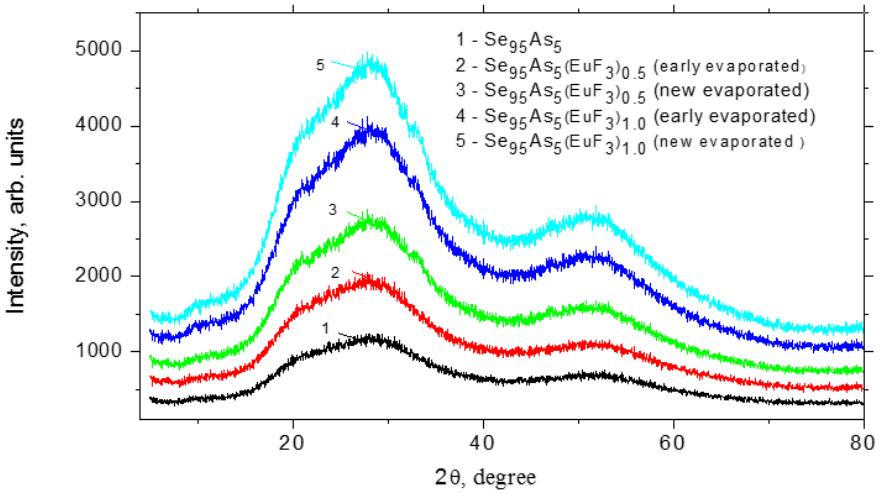


Fig.1. X-ray diffraction patterns of CGS films.

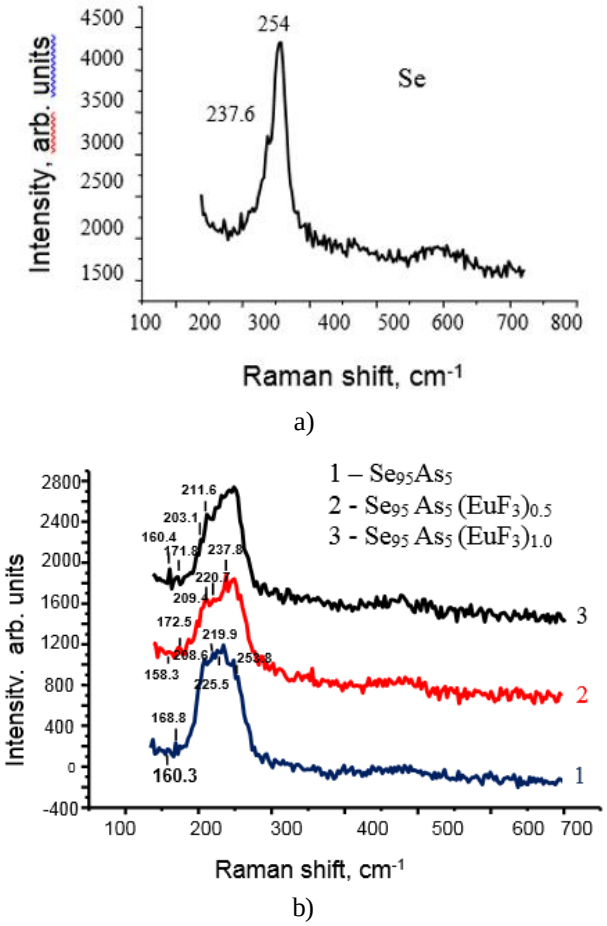
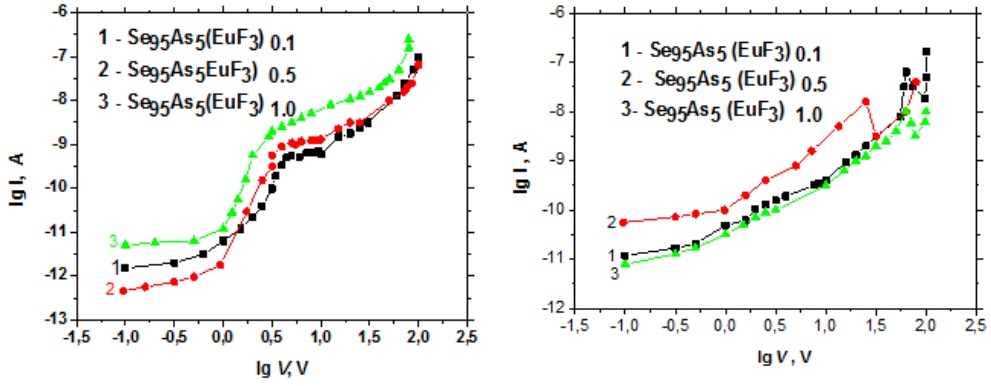


Fig.2. Raman spectra of the Se (a) and Se-As, Se-As-EuF_3 (b) films.

The weak maximum at 168.8÷172 cm^{-1} observed in all spectra (Fig. 2b) is attributed to vibrations of the As-As homopolar bond.

An investigation of the current–voltage (I–V) characteristics of the Al– $Se_{95}As_5$<EuF_3>–Te structure (Fig. 3) showed that the current flow in it when a positive potential is applied to Te electrode is carried out by the mechanism of monopolar injection currents limited by the space charge (Fig. 3a), and with reverse polarity, an N-type I-V characteristic have been observed (Fig. 3b).

The I-V characteristic at a positive potential in the tellurium electrode (Fig.3a) begins with an ohmic law with an increase in the applied voltage and passes into the region corresponding to a power law, i.e. $I \sim V^n$, where n exceeds the value 2. Next, the section is observed where $I \sim V^2$. Finally, the quadratic region is replaced by the region where the increase in current with voltage is described by a close exponential dependence, which is usually associated with the ionization of local centers [4].



a) b)

Fig. 3. The I – V characteristics of the Al– $Se_{95}As_5$<EuF_3>–Te structure upon application of positive (a) and negative (b) potentials to Te at room temperature: 1- $Se_{95}As_5$ (EuF_3), 2-$Se_{95}As_5$(EuF_3).

With a negative potential at the tellurium electrode, with increasing applied voltage, the linear dependence is replaced by a nonlinear law, and finally, at electric field intensities exceeding 10^5 V/cm, an N-shaped I-V characteristic is observed (Fig.3b).

This behavior of the I–V characteristics of CGSs in strong electric fields was associated with tunneling ionization of the U^- - centers [5].The essence of this model is that, at the first stage of the process, the electron is thermally excited to a certain energy level, then the excited electrons tunnel through the potential barrier created by the electric field of the D center during ionization of the D^0 center, or by the short-range field of the neutral D^0 center at ionization of the D^- center. According to [6], in a strong electric field, ionization of neutral and negatively charged U^- - centers occurs, also the processes electron capture by ionized centers:

$$D^- \leftrightarrow D^0 + e,$$

$$D^0 \leftrightarrow D^+ + e.$$

The decrease in current is apparently due to the fact that after reaching a certain concentration of free charges carriers, they are avalanche-like by U^- - centers, or the recombination of electrons and holes. The absence of an N-shaped region in the current-voltage characteristic upon application of a positive potential to the tellurium electrode is explained by the fact that strong injection of charge carriers through the contacts prevails over capture and recombination processes.

4. CONCLUSION

Using the theory of injection currents and the mechanism of current flow through amorphous chalcogenide films at strong electric fields proposed by the authors of [7], the energy position and concentration of local centers have been determined, the ionization of which leads to an exponential increase in current strength.It was shown that low concentrations of EuF_3impurities (up to 0.1 at%) decrease the concentration of these centers, and high (more than 0.1 at%) increase them. The behavior of EuF_3 impurities in low concentrations is explained by the chemical activity of REE and fluorine ions, which can form chemical compounds with selenium and arsenic, as a result of which the concentration of the original intrinsic defects decreases. The behavior of EuF_3 impurities in high concentrations occurs according to the model of charged intrinsic defects [8]. If we assume that rare-earth element impurities mainly manifest themselves in the form of positively charged ions, as a result, their presence should provide a decrease in the concentration of D^+ centers, and the concentration of D^- - centers should increase, which was established experimentally.

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