THE SILVER SELENIDE SINGLE CRYSTAL GROWTH AND DEVICES ON ITS BASE

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Silver selenide (Ag_2Se) single crystals on the base of which metal-semiconductor-metal (MSM) and metal-oxide-semiconductor (MOS) structures are prepared, grown by method of isothermal recrystallization from solid phase and their investigations in temperature interval 77 – 410K are carried out. It is shown that MSM structure W- Ag_2Se-W behaves itself as varistor and Ag-Ag_2Se-Ag structure behaves itself as diode in 376 – 400K region. The polar-dependent switching effect taking place in temperature interval 77-400K is obtained in MOS structure Al-Al_2O_3-Ag_2Se-Ag.

Keywords: crystal growth, diode, varistor, switching.
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INTRODUCTION

The silver selenide (Ag_2Se) is included in number of semiconductors with narrow forbidden band and is related to group of semiconductor compounds of $A^{I}_{2}B^{VI}$ type with very interesting electrophysical properties many of which are studied by different investigators and obtained results are represented in the review in series of works [1-5]. In these and other works it is shown that Ag_2Se has the two low-temperature (rhombic and tetragonal) and one high-temperature (cubic) modifications; the temperature of its polymorphous transformation varies in limits 126-133°C [6] and forbidden band width varies in limits 0,025-0.09 eV [7].

From the analysis of the reference it is revealed that single crystal silver selenide and also its possibility of its usage in the capacity of the main material in different semiconductor devices aren't studied enough [8 – 11].

The present work is dedicated to single crystal silver selenide growth and its application in different devices.

EXPERIMENTAL TECHNIQUE

The method of isothermal crystallization from the solid phase is used by us for obtaining of Ag_2Se single crystals. With that end in view the initial single crystal silver selenide synthesized from Ag-99,999 and Se-B5 and is put into quartz ampoule evacuated up to10^{-5} millimeter of mercury the volume of which is chosen in definite ratio that causes the optimal conditions for the free crystal growing. The ampoule is treated by continuous vibration up to substance melting point at which it is endured during 30 – 40 minutes. Further the furnace is cooled with velocity 100 – 130 grad/h after which the ampoule is put from vertical furnace into horizontal one. The recrystallization process is carried out during 80 – 100 hours in isothermal conditions at 350-400°C. As a result the following fact is observed: the crystallization is begun from ampoule point in ampoule put along furnace, whereas the single crystals crystallize near with polycrystals in transversally put ampoule. Ag_2Se single crystals of high purity with n-type conduction, concentration and mobility of electrons ~10^{18} cm^{-3} and ~ 2000 $cm^2/V\cdot sec$ correspondingly are obtained by the given method. The monocrystallinity of obtained crystal from which the sample is cut for electric measurements in the form of narrow parallelepiped, is tested by Laue method. Ag, W, Mo are applied in the capacity of metallic contacts. The sample forbidden band width defined from temperature dependence of electric conduction is equal to 0,008 eV.

RESULTS AND DISCUSSION

The complex investigations of series of silver chalcogenide electric properties including Ag_2Se carried by us during many years show that these compounds can be applied in computer engineering, automation devices in the capacity of commutators and also the multifunctional logic devices. The oscillogram of VAC of MSM-structure Ag-Ag_2Se (single crystal) – Ag taken from ПИХТ-1 curve tracer screen in 77-410 K interval is shown in fig.1.

It is seen that VAC in 77 – 376K interval is ohmic and symmetrical at both polarities applied to voltage sample (a). VAC higher ~376K becomes asymmetrical one. i.e. behaves itself as diode.

Such state saves up to ~400K, i.e. the temperature of polymorphous transformation in Ag_2Se. The appearance of such "diode state" in Ag_2Se single crystal in 376 – 400K interval is caused by the fact that the germs of new metastable tetragonal phase the specific resistance of which is bigger than the resistance of low-temperature modification appear in this temperature region inside low-temperature phase.

Thus, the contact of more high-ohmic (n) with low-ohmic tetragonal Ag_2Se (n^+) takes place, i.e. n^+- n transition with current symmetrical dependence on voltage appears.

Further, the characteristics of varistor type is obtained on single crystal Ag_2Se with tungsten and molybdenic contacts.

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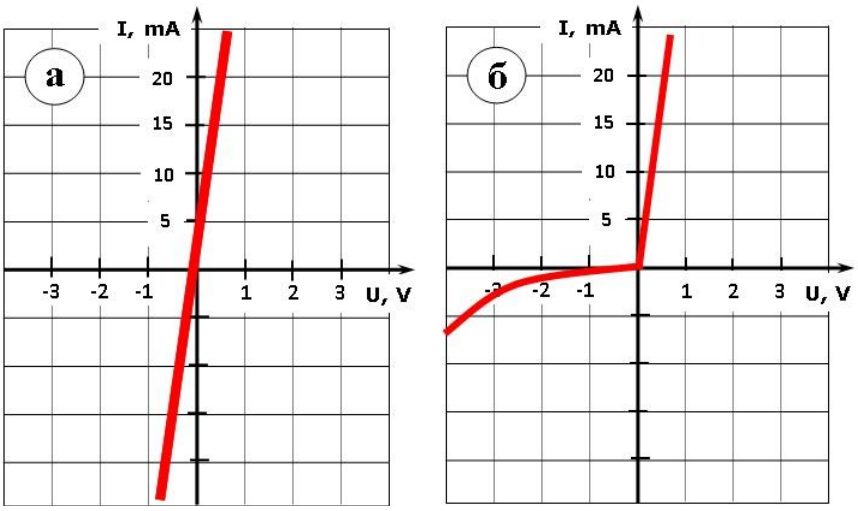

Fig. 1. The oscillogram of VAC of Ag- Ag_2Se (single crystal) – Ag MSM-structure at - 376 (a) and 76-400K (b) (value of the big scale division horizontally is 1V, vertically is 5MA).

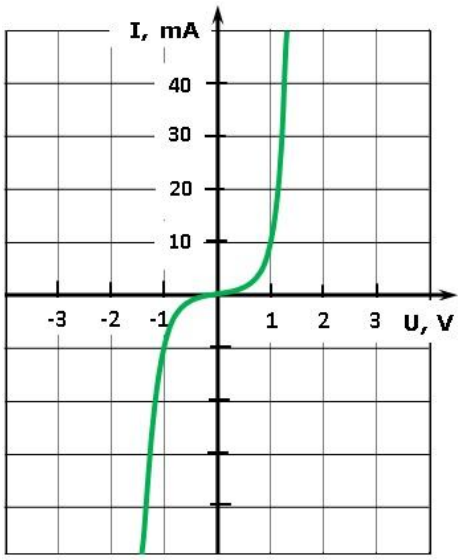

Fig. 2. The oscillogram of VAC of W- Ag_2Se-W varistor at room temperature. Scale: horizontally is 1V/grad and horizontally is 10MA/grad.

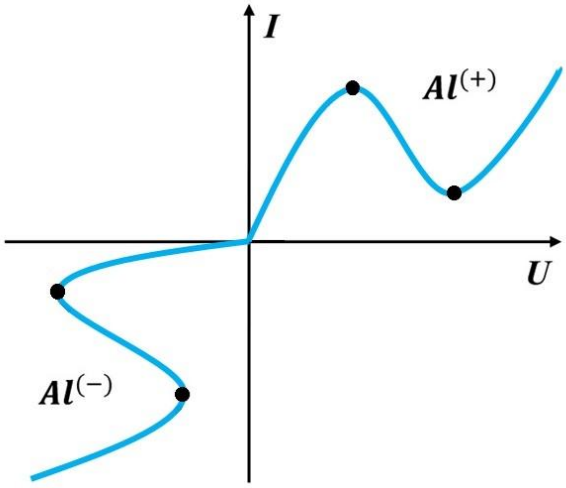

Fig.3. VAC symbolic representation with the negative-resistance region of Al-Al_2O_3-Ag_2Se-Ag structure.

VAC oscillogram of one of such varistors W-Ag_2Se-W taken at room temperature is presented in fig.2.

The nonlinearity factor (relation of static resistance to differential one) strives to eternity at small voltages. The mode of operation of such varistors is based on physical processes on contact metal – semiconductor of high purity. The low-voltage varistors can be applied in frequency multipliers, modulators, for voltage stability and etc.

The polar-dependent effect of switching and member (fig.3) [12] initiated by electron processes, i.e. by collisional ionization of band – deep trap level type is obtained in MOS-structures Al-Al_2O_3-Ag_2Se-Ag. The transient characteristics are defined: delay time ($10^{-6}-10^{-5}$ sec), turn-on time ($10^{-9}-10^{-8}$ sec) and number of switchings (10^5). Note that the observable phenomenon takes place in temperature wide interval (77 – 400K) with application of both polycrystal and single crystal Ag_2Se. As it is seen from fig.3 the transition of inductive (S-form) (III quadrant) into capacitive (N-form) (I quadrant) impedance at change of voltage polarity on Al electrode is observed. This structure can be used in logic and memory devices, in automatics and telemechanics because of control possibility by switching parameters.

CONCLUSION

The single crystals of silver selenide (Ag_2Se) are grown by method of isothermal recrystallization from solid phase and MSM- and MOS-structures are prepared on their base. By investigation of VAC these structures in temperature interval 77 – 410K it is shown that MSM-structures W- Ag_2Se-W behave themselves as varistor, Ag-Ag_2Se-Ag structure behaves itself as diode and MOS-structure Al-Al_2O_3-Ag_2Se-Ag behaves itself as switching element with memory.

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