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Influence of γ-quanta on $TlInSe_2$ crystal electrical properties

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The influence of γ-quanta on the current flow in $TlInSe_2$ single crystals and the process of filling and emptying localized levels in crystals has been experimentally studied. Investigations show that the current -voltage characteristics (CVC) of $TlInSe_2$ single crystals obey Lampert theory and are determined by currents limited by the space charge. It is shown that the defects occurring from γ-quanta in $TlInSe_2$ single crystals result from radiation processes.

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Keywords: $TlInSe_2$ single crystals, Defective crystals, Ionizing radiation, Current-voltage characteristic

1. Introduction

Nowadays rapid development of microelectronics and nuclear energy engineering sets the aim to oblain new semiconductive compounds and study their electrophysical properties. One of these aims is to produce perfect semiconductive compounds sensitive to ionizing radiation and not to lose properties over a wide temperature range [1-3].

At present one of the materials being extensively studied in this area is $A^{III}B^{III}X_2^{VI}$ (A-Tl; B-Ga, In; X-S, Se, Te) –typed semiconductive compounds with the laminated and chain structures. Pecularities of chemical bonds and electron properties in compounds like these are due to unpaired and valence electrons. $A^{III}B^{III}X_2^{VI}$ -typed compounds with partial valence electrons crystallize in lattices with laminated and chain structures. Semiconductive compounds being involved in this category have a number of intriguing physical properties as the properties of ferroelectric semiconductor, effects of memory and snitching and etc. High sensitivity of these imperfect crystals to ultraviolet, visible, infrared, X-ray and γ-rays increases more interest in their research [4,5].

One of the crystalline materials of $A^{III}B^{III}X_2^{VI}$ -typed compounds having basic properties and considerable interest is $TlInSe_2$ compound. İn papers [6-9] dielectric and photoelectric properties of $TlInSe_2$ have been stuied. Distinction in concentration of defect distribution (10^{16}-10^{17} cm^{-3}) in differant directions about c axis arises anisotropy of crystal chemical and physical properties. The nature of defect formed in crystals, their influence on electric, optic and photoelectric properties has been the focus of attention. As far as for examining these mechanisms it is important to obtain single crystal with perfect stucture and investigate their physical properties at differant ambient condidions.

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2. Experimental method

TlInSe2 single crystals have been manufactured by method of directed crytallization under svitable temperature conditions. İn $A^{III}B^{III}X_2^{VI}$ -typed compounds the pecularities of chemical and electron properties are generated by unpaired valence electrons. X-ray diffraction study shows that TlInSe2 compounds have a consistent chain structure and crystallize in TlSe structure. Obtained single crystals possess tetragonal structure and lattice parametres are: a=8,0750A0, c=6,8470A0. Crystal conductivity type has been determined by the sign of thermal power and it is established that TlInSe2 has p-type conductivity [10-13]. The concentration of free charge carriers and specific electroconductivity determined from electroconductivity and Hall effect are 2·1011cm3 and 105-107 o·cm, respectively. Sample sizes for investigations are 0,3x2x10mm3. Measurements have been carried in special metal cryostat within T 80-600K.

This paper deals with the influence of γ- quanta on current flow in TlInSe2 single crystals and the process of filling and emptying the localized levels in crystals. The samples after initial measurements have been inserted into guartz ampoule and later after evacuating and sealing are kept in γ-irradiation chamber of Co60 source. Dose of irradiation is from 50 up to 100 krad.

3. Experimental results and their discussion

İnvestigations show that dark current –voltage characteristic (CVC) of p-TlInSe2 single crystals over a wide temperature range and applied external being electric fields is explained by exponential function typical of currents limited by space change. Analysis of obtained remlts shows that in p-TlInSe2 single crystals the processes of injected charge carrier interaction with the shallow trapping levels, their transport and recombination take place in the presence of vacancy –typed defects with high concentration.

This is expressed by the fact that in high electric fields the temperature dependence and obtained results are not in agreement with theoretical points. By investigating p-TlInSe2 single crystal current –voltage characteristics room temperature and electric intensity within 10-103 V/cm it is found out that they follow I~Vn law in linear and superlinear ranges. İn mentioned range the value of n degree changes within 1÷4 (Fig.1). On CVC first section Ohm's law is observed, on the second section the square low (I~V2) is obeyed, on the third section with the increase of applied voltage the sharp growth of current is noted. Obtained results have been analyzed on the base of theories of injection current and conductance in solid svlutions [13-15].

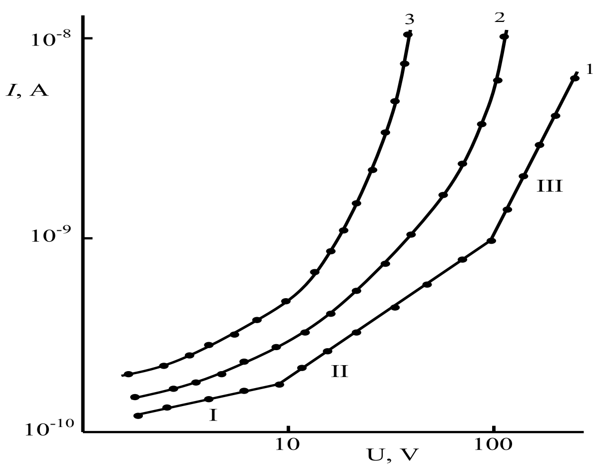

Fig. 1. Current –voltage characteristics of $TlInSe_2$ single crystals at different temperatures: 1-100; 2-300; 3-400.

İnvestigations show that TlInSe2 single crystals current-voltage characteristics obey Lampert theory and are determined by currents limited by space charges. İt is known from Lampert theory that the sharp change of current in high electric fields can occur as a result of trapping centre ionization under the effect of electric field. Energy of trapping centre ionization also depends on electric intensity:

$$\Delta F = kT \cdot \ln \frac{U_M}{U_{1-2}}$$

where UM is the maximum value of voltage across the sample, U1-2 is the voltage going from ohmic region to the square one in CVC.

Analysis of obtained results reveals that sharp increase of current in electric field E<103 V/cm is related to the increase of additional charge carrier concentration and advent of ionization under the effect of strong electric field. Obtained results conform with Frenkel's teory.

From TlInSe2 single crystal CVC study it is established that current flow mechanism at low values of electric field (E<103 V/cm) is related to monopolar injection limited by space charge. In high field region (E>103 V/cm) it is concerned with the process of trapping level ionization under the effect strong electric field. To determine the mechanism of radiation –induced defects on the involvement of injection current with filling and emptying localized energy levels in TlInSe2 single crystals the initial samples under consideration are exposed to radiation by γ- rays from Co60 source.

CVC of irradiated samples are taken at different temperatures and electric fields within 10-103 V/cm. It is established that at values 50 krad of γ-quanta absorbed dose and electric intensity E<102 V/cm the value of dark current decreases comparing with the initial value before the irradiation but the value of voltage going from ohmic region to square one increases. In turn it shifts ohmic region of CVC to the high voltage region. Decrease of free carrier concentration (p) at irradiation dose 50 krad is due to the formation of donor levels in crystal that brings about the decrease of difference in energy between acceptor and donor levels.

In Fig.2 there have been shown CVC for Ag-TlInSe2-Ag structure unirradiated and radiated by γ-quanta at T 300 K. In figure curve 1 refers to the unirradiated sample, curve 2 and 3 refer to the irradiated one after 24 hour and 240 hours of irradiation. CVC of TlInSe2 irradiated sample first grows linearily by approxiamately 34V, then from 30V up to 50 V the current intensity decreases up to minimum value and then inereases rapidly with the voltage. It s established that in time after irradiation CVC are displased to the left and in 240 hours they approximate to the characteretic of unirradiated sample [curve 3]. It is seen from graphical dependencis that by increasing extermal electric intensity the probability of electron capture rises and at certain value of intensity there has been observed not sguare dependence but N-like one. Such dependence of current on voltage points to the gradual current reduction in process of domain formation in the sample. Unusual dependence like this is observed in highly compensated semiconductor with deep trapping centres. Experimental and theoretical data indicate that unlike unirradiated crystals in crystals irradiated by γ-quanta there have been arisen polar domains that lead to the appereance of differential resistance on CVC. In very strong electric fields the negative differential dependence is replaced by sguare one at the expense of injected of charge carrier contacts into the crystal.

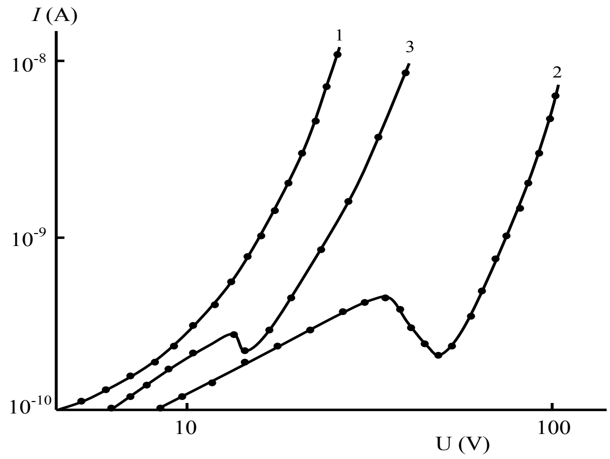

Fig. 2. Current –voltage characteristics of Ag-TlInSe2-Ag structure (1-unniradiated, 2,3- 24 hour and 240 hours after irradiation, respectively).

From CVC it is seen that in TlInSe2 single crystals irradiated by γ-guanta the value of negative differential resistance decreases in time and in 10 days disappears completely. It points to the fact that structural defects produced by under the effect of γ-quanta in TlInSe2 single crystals irradiated by dose of 50 krad are unstable.

As a result of conducted investigations it is determined that in CVC sguare region of TlInSe2 irradiated single crystals the charge carrier transfer in fields E 102 V/cm as in initial crystals is referred to the monopolar injection. By increasing irradiation dose the rate of filling and emptying rises. And thermofield ionization observed within the sharp current growth is caused by the effect of γ-quanta and is evident in strong electric fields (E>103 V/cm). This is associated with the increase of donor centre concentration from irradiation. According to Frenkel's theory energy of charge carrier ionization depending on the electric field magnitude behaves in line with 2e(eE/e)1/2 law [16]. Procuding from the obtained experimental results one can state that defects occuring from γ-quanta in TlInSe2 single crystals are similar to the original defects in nature and result from radiation processe.

Thus during irradiating TlInSe2 samples by γ-quanta the radiation stimulating processes related to the activation of intrinsic defect migration are taken place. To control these processes allows crystal electric parameters purposefully to be varied.

4. Conclusion

It is established that during irradiating TlInSe2 crystals by γ-quanta the radiation – stimulating processes resulting from activation of intrinsic defect migration have been taken place. To control these processes allows crystal electric parameters purposefully to be varied.

It is revealed that thermoelectric properties of solid svlution crystals with laminated and chain structure depend sharply on defect concentration to disturb the periodicity of crystal lattice, to create local changes of atom arrangements.

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