THE ANALYSIS OF ELECTRICAL PROCESSES IN SEMICONDUCTOR CADMIUM SELENIDE LAYERS, CAUSED BY THE STRUCTURAL TRANSFORMATIONS. POSSIBLE APPLICATIONS

GRINEVICH V.S., SMYNTYNA V.A.

Odessa I.I.Mechnikov State University, Ukraine ,Odessa, 270100, per. Mayakovskogo, 7

Summary

The physical conditions of functioning of sensitive element for the elastic deformations registration in the microvolume of electronic systems are analysed. The sensitive element is a semiconductor pollycrystalline film containing crystallites of two structure phases of $(\alpha+\beta)$CdSe. The considerable mechanical tensions arise at the intergrain boundary of the said α and β crystallites. The result of that can be registered electrically in the form of the sharp change of current (equilibrious conductivity) in the circuit containing the sensitive element.

1. Introduction

The perspective tendency connected with construction of elastic deformations sensors on the base of pollycrystalline semiconductor layers exists in the modern solid state microelectronics. It is well known that pollycrystalline layers contain the same structure modifications like their single crystall analog, where crystallites may change their structure type under the definite conditions. In our case the structure transformations take place under several external actions, e.g. heating, cooling and under dependent on them elastic tensions. They infuence the electronic properties of the layers and may be electrically registered. One of the little investigated phenomenon caused by the structure transformations in the pollycrystalline CdSe layers is the Anomalous Temperature Dependence of Equlbrious Conductivity (ATDEC)[1].The main features of ATDEC phenomenon is a sharp change of current,(1-2) orders of magnitude, in a thin temperature interval (150-200)K.
The sharp current change is proposed to lay into the basis of sensor operating for the elastic deformations registration. As it was established, these deformations caused the current peculiarities. In the present article after the analyses of all experimental results it was established: 1. The ATDEC phenomenon localization in the bulk of the film and 2. The physical model of it. Besides that it was made a conclusion about the possibility to use the system where ATDEC may be initiated as a sensitive element of the elastic tensions sensor.

2. Experimental results and discussions.

In the present work the system investigated was a pollycrystalline semiconductor CdSe layers, containing crystallites of two structural modifications $(\alpha+\beta)$CdSe. The layers were deposited in HV using the method of "quasi-closed volume" on glass substrates supplied by transparent SnO_2 strips which played the role of Ohmic contacts. The layers' structure was controlled by the X-ray methods.

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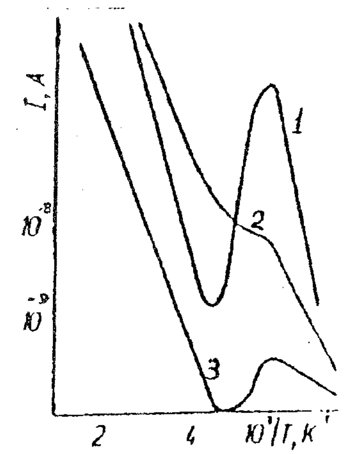

Fig. 1
Dark current temperature dependence in pollycrystalline layers of CdSe:
1 - Initial structural state (as prepared) $(\alpha+\beta)$ CdSe.
2,3 - structural states with decreased quantities of $(\alpha+\beta)$CdSe pollycrystalline pairs.

As it may be noticed at Fig.1 the maximum development of the ATDEC phenomenon takes place when the layer contains a great amount of $(\alpha+\beta)$CdSe crystallites, and disappears in the monophase layers. In order to determine the part of CdSe layer structure, responsible for ATDEC the set of independent experiments were undertaken in the temperature interval (150-300)K, typical for the phenomenon.

By the X-ray methods it was established that after several cycles of cooling-heating procedure of the CdSe layer, defects appeared and accumulated in the intergrain boundary of the layers, and the interplanar distances in the lattice cell changes too. These processes usually have place under the action of cyclic tensions [3]. V-I measurements gave the possibility to establish the existence of square law dependence of current limited by the space charge,

$$I \sim \exp(-E_d/kT)V^2$$

The analyses of the dependence evidences about the presense of donors with depth 0.4eV in the JGB region. This situation is typical for the barrier structure of the film. It is important that the square I-V law is registered only for two phased layers in the (150-300)K temperature interval of measurements. For monophase αCdSe layers the I-V characteristics are trivial for the whole temperature interval. The conclusion about the barriers presence is supported by measurements of temperature dependence of AC in the frequency interval (10-10^6) Hz. The evaluated barriers heights are: E_{dr}= 0.05-0.1eV, E_{recomb}=0.14eV. After the transition of $(\alpha+\beta)$CdSe into α-CdSe, the barriers height-reduces by 2-3 times.

Taking into consideration the geometry of contacts and the sample itself (thickness of the layers $< 10\mu m$, distance between contacts - $2\cdot10^{-3}$ m, crystallites dimensions $< 1\cdot10^{-6}$ m) and the electric field applied one may concludes that the barriers are in the intergrain boundary (IGB) space.

There are a considerable amount of defects identified in photoelectrical and photoluminiscent experiments as centres with and E_c-0.4eV. In the same IGB space considerable mechanical tensions of (10^5-10^6)Pa are registered, which arise because of heat expansion coefficients difference for α and β CdSe crystallites [4]. The analysis of the totality of the results gave the possibility to make the conclusions that ATDEC phenomenon was located in IGB region and was strongly dependent on the height of the barriers, that is E_c -0.4eV centre. According to Hall experiments it was established that the electron subsystem of the object inve stigated was responsible for the ATDEC phenomenon. Thus, the anomalous rise and decay of electroconductivity in (150-300)K interval may be considered as caused by the change of energetic position in the forbidden zone of CdSe of some donorlike centre. Change of donorlike centre's energetic position may be caused by several reasons:

1. Change of hydrogen like centre's ionization energy because of $\varepsilon = \varepsilon(t)$ dependence in the expression $E = 13.52z^2/\varepsilon^2 \cdot m^x/m$ [eV] [5]2.Increasing of donors's energetic depth according to the dependence dE_d/dP [6], P-pressure.

Our analysis of these two reasons shows that non of them is realizable for our CdSe layers. From our point of view the most possible mechanism is the change of space position of lattice defects in the IGB space. There are some types of defects in semiconductors which may occuppy several equivalent positions in the lattice.

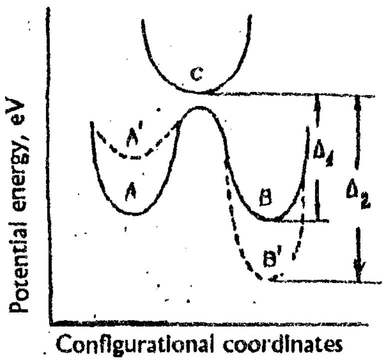

Fig.2. The change of ionisation energy Δ_1, Δ_2 of donorlike centre caused by the transition from a symmetrical to nonsymmetrical configuration of atoms in CdSe lattice.

The defects charge state variations are usually followed by the relaxation of the region surrounding the defect (it is the change of equilibrious configurations of atoms). The ionisation energy of donors for the symmetric atoms configuration is Δ_1. Under the action of elastic origin forces the positions A and B became not equivalent and, hence the donors' ionization energy changes, Fig.2. The analysis of termostimulated conductivity experiments supports the idea of such "deepening" of the centre.
Using different rates of heating it was established, that peaks are "solved" at a lower rate of heating better than at higher one. Because of mechanical tensions arised the transitions takes place from the state 1 to state2, Fig.2. These transitions necessitate the definite time. After the transition of the defect from the equilibrious position A to the equilibrious position B, electrons are thrown to the conductivity zone in correspondence with the new configuration of atoms. This provides the distinctive peaks on the TSC curve .

Conclusion

The ATDEC phenomenon was registered in pollycrystalline (α+β)CdSe layers. It is stated in the work that the reason for ATDEC is the change of the space position of defect atoms in the IGB that causes the increasing of the energetic depth of the centre. The possibility of electric registration of the phenomenon investigated gives the possibility to use the system (α+β)CdSe as a sensitive element of elastic deformations.

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