DETERMINATION OF DEBYE SCREENING LENGTH FROM CONDUCTIVITY OF PBTE FILMS

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ABSTRACT

In this paper were prepared epitaxial layers of *PbTe*, which physical properties practically did not differ from properties of monocrystals. IR-lasers and receivers of radiation, optical filters and thermogenerators are created on the basis of such layers. However number of questions concerning growth of epitaxial layers of the given group materials is investigated insufficiently. The laws of oxygen molecules capture, during layers growth and influence of segnetoelectric substrate polarization on conductivity of layers concern to such questions.

Measurement of film parameters, prepared on segnetoelectric substrates, allows carrying out experimental determination of Debye screening length.

Keywords: materials, influence, molecules, polarization, segnetoelectric.

I. INTRODUCTION

In modern science and engineering with monocrystals of various semiconductors are widely applied also of thin films prepared by vacuum evaporation and other methods.

A huge success of physics of semiconductors has served as stimulus to development of semiconductor electronics and modern semiconductor technology. Application of semiconductors in various areas of cybernetics, automatics and telemechanics providing the successful decision of huge number of tasks of the large economic value, represents all growing requirements to essential expansion of nomenclature of a new semiconductor materials and increase of their quality.

The various methods for preparation of epitaxial films have enabled essential expansion of their application areas. The idea about an opportunity of use epitaxy for preparation monocrystalline films of semiconductors and creation on their basis *p-n* junctions was stated in 1954. The set of works is published in literature from that moment. The outstanding place among these works takes epitaxy of A^4B^6 group materials. These materials belong to narrow gap semiconductors and are widely used in engineering. In 1964 were prepared epitaxial layers of *PbS* and *PbTe* by S.A.Semiletov's group, which physical properties practically did not differ from properties of monocrystals. IR-lasers and receivers of radiation, optical filters and thermogenerators are created on the basis of such layers. However number of questions concerning growth of epitaxial layers of the given group materials is investigated insufficiently. The laws of oxygen molecules capture, during layers growth and influence of segnetoelectric substrate polarization on conductivity of layers concern to such questions.

Films of *PbTe* were prepared on $LiNbO_3$ and Debye screening length is determined from conductivity of films.

II. RESULTS AND DISCUSSION

It is known, that at interaction of an external electrical field with the charge carriers in semiconductor are redistributed, therefore there is a volumetric charge $\rho(r)$ and electrical field E connected with a volumetric charge by the Poisson equation [1]:

$$div\varepsilon\varepsilon_0 E(r) = \rho(r) \qquad (1)$$

Expressing an electrical field E by potential we can write

$$\nabla^2\varphi(r) = -\rho(r) / \varepsilon\varepsilon_0 \qquad (2)$$

The potential energy of electrons $V(r)$ bends zones so, that $E(r) = E + V(r)$ or,

$$E_c(r) = E_{(c)} + V(r) \qquad (3)$$

$$V(r) = V_S e^{-x/L_D} \qquad (4)$$

The zones bent downwards for the $\rho - PbTe$ films. For the film prepared on negative, domains, the power zones are bent upwards (Figure1).

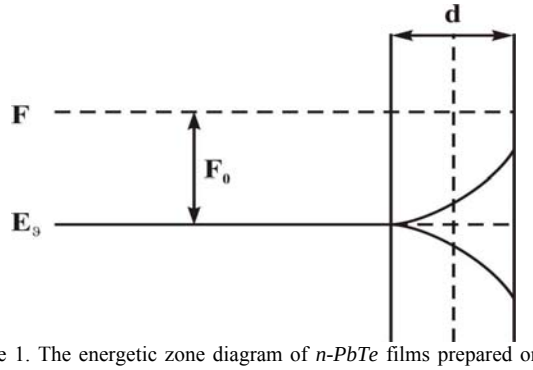

Figure 1. The energetic zone diagram of *n-PbTe* films prepared on the negative and positive domain of $LiNbO_3$.

We shall consider the characteristics of conductivity change of the $\rho - PbTe$ films prepared on different domains of $LiNbO_3$, for definition of Debye screening length (Figure 2).

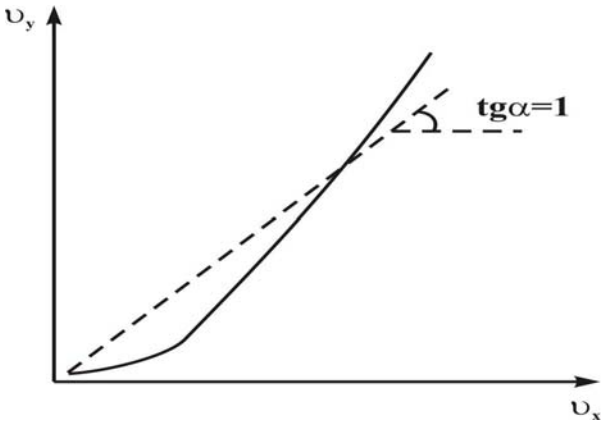

Figure 2. Change of conductivity of the *n-PbTe* films on different domains of $LiNbO_3$.

Let's on experimental curve allocate some points appropriate to thickness interval of *45-75 nm*, which where $tg\alpha < 1$, that is characteristic for *p-PbTe* films prepared $LiNbO_3$ with various polarization. Film of *p-PbTe* prepared on positive domains at small thickness $(d \le 50\ nm)$ has intrinsic conductivity about $\sim 10^{16}\ cm^{-3}$ and at $d \ge 50\,nm$ the structure was worsened. Therefore we have chosen some pairs of points in thickness interval of $50\,nm < d < 75\,nm$. The concentration of holes in samples with thickness of *60 nm*, prepared on positive and negative domains was:

$P_+^1 = 3{,}8 \cdot 10^{16}\,cm^{-3}$, $P_-^1 = 1{,}4 \cdot 10^{17}\,cm^{-3}$,

and for the thickness of *70 nm*,

$P_+^2 = 6 \cdot 10^{16}\,cm^{-3}$, $P_-^2 = 2 \cdot 10^{17}\,cm^{-3}$

The concentration holes in a source were $\sim 10^{17}\ cm^{-3}$ at *300 K*, i.e. film is nondegenerate [2]. Then the formulas for concentration of charge carriers in semiconductors maybe write as [3;4]

$$P_- \sim e^{-F_-/kt} \qquad (5)$$

$$P_+ \sim e^{-F_+/kt} \qquad (6)$$

where P_- and P_+ - are the concentration of holes in *PbTe* films prepared on negative and positive domains of $LiNbO_3$, and *F-* and *F+* - are the appropriate Fermi levels.

As the semiconductor is in a thermodynamic balance condition and Fermi level in it is constant, distance between it and energy zones varies at change of carrier concentration. We spend readout of Fermi levels from edge of valence zone (Figure 1) and thus for Fermi levels of these two $\rho - PbTe$ films we can write down:

$$F_- = F_0 - ue^{-d/L_D} \qquad (7)$$

$$F_+ = F_0 + ue^{-d/L_D} \qquad (8)$$

where u – is the potential energy connected to action by surface polarization. Substituting (7) and (8) in (5) and (6) and resulting in linear approximation $(L_D \ge d)$ averaging of a Fermi level by film thickness, we can write for carriers concentration:

$$P_- \sim e^{-\frac{F_0 + ue^{-d/2L_D}}{kt}} \qquad (9)$$

$$P_+ \sim e^{\frac{F_0 - ue^{-d/2L_D}}{kt}} \qquad (10)$$

Further having divided (9) on (10) and taking the logarithm we have

$$\ln(P_- / P_+) = 2ue^{-\frac{d/2L_D}{kT}} \qquad (11)$$

The expression for curve points appropriate to film thickness of $d_1 = 60\,nm$ and $d_2 = 70\,nm$, can be write as,

$$\ln(P_-^1 / P_+^1) = 2ue^{-\frac{d_1/2L_D}{kT}} \qquad (12)$$

$$\ln(P_-^2 / P_+^2) = 2ue^{\frac{d_2/2L_D}{kT}} \qquad (13)$$

Having divided the equation (12) on (13) and take the logarithm, we have,

$$\ln\frac{\ln(P_-^1 / P_+^1)}{\ln(P_-^2 / P_+^2)} = \frac{d_2 - d_1}{2L_D} \qquad (14)$$

Equation for calculation the Debaye screening length can be written:

$$L_D = \frac{d_2 - d_1}{2\ln\frac{\ln(P_-^1 / P_+^1)}{\ln(P_-^2 / P_+^2)}} \qquad (15)$$

Substituting experimental values of d_1 , d_2 and hole concentration for investigated films we find value of L_D*~100 nm*. Designed on the formula of $L_D = \sqrt{\varepsilon\,\varepsilon_0 kT / ne^2}$, this parameter is about $107 \cdot 10^{-9}\,m$. Here for *PbTe* ε *~400*, $n = 10^{17}\,cm^{-3}$, $T = 300K$.

III. CONCLUSION

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REFERENCES

1. P.S.Kireev, Physics of semiconductors, M., 1975, p.454.(in Russian)
2. Miqnotte C. Structural studies of erbium-implanted $NiNbO_3$ single crystals. Nucl Instrum. And Meth Phys. Res. B. 2002, 187, №1, c.95-110.
3. Mantas P.Q. Dielectric response of materials: extension to the Debye model:
   J. Eur. Ceram. Soc. 1999. 19, №12. c.2079-2086.
4. A.V. Novoselova, V.P. Elmonov in: Current topics in Materials Science, Noth-Holland, 1981, v.7, p.643. (in Russian)