INFLUENCE OF IR-RADIATION ON KINETIC EFFECTS IN $Cd_XHg_{1-X}Te$

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The results of influence of an electron beam irradiation on galvano-tehmomagnetic properties in monocrystals $Cd_xHg_{1-x}Te$ ($0 \le x \le 0,25$) in the wide range of temperatures (4,2 ÷300K) and magnetic fields ($60 \le H \le 22.000$ers.) were analyzed in given work.

It is shown, that action of irradiation on Hall effects is most essential at week fields and low *T*. Comparison of results $\sigma(T)$, $R(T,H)$ with the two – zoned theory has to reveal quantitatively influence of an irradiation on concentration and mobility of carriers of a charge and to conclude, that the electron beam irradiation of CMT crystals leads to increase of electron concentration, caused by vacancies of tellurian with donor type. It is established, that $Cd_xHg_{1-x}Te$ (with x = 0,12 ÷0,15) can be used as sensitive elements in termomagnetic receivers of IR irradiation. It is established, that at T<40K in $Cd_xHg_{1-x}Te$ ($x \le 0,15$) concentration of acceptor centers which are included in a conductivity zone, greater more that concentration of donors.

The acceptor levels plays role of traps for both – for ionizing electrons and for electrons induced by irradiation. It was set up, that electron been irradiation with integral doze $5,6{*}10^{17}$ elec/cm^2 to increase of specific sensitivity of receivers of IR radiations up to twice at T=300K.

Introduction

The first studies of influence of radiation defects on physical properties of CMT appeared in the beginning of 70-ies [1,2]. In [2], the irradiation was made by electron beam at 25K. After the irradiation, samples of p-type were converted to n-type and the electroconductivity grew by 4 order. However after heating of samples, the initial properties almost were restored. In [3] irradiation was made by integrated beam Φ-$4{*}10^{17}$sm^{-2} at 77K. The increase of n and reduction of photoconductivity is revealed. Short term heating at 300-320K eliminate the entered radiation infringements. It was shown, that created at low temperature irradiation defects, has a small thermal stability and anneals basically at temperatures 50-75K [2] and 150-225K [4]. It is known, that using of temperatures of the irradiation leads to formation of various types of stable defects [5].

Meanwhile, practical use of the irradiation demands knowledge of physical properties of radiation defects and their thermal stability at 300K. In this sense, the works [6, 7], in which n and p-type samples were irradiated at 300K are interesting: in n-type samples p insignificantly decreased, and conductivity remained almost constant, whereas in p-type samples was a change of type and σ passed through a minimum. Authors [6, 7] analyzing the obtained results, conclude, that the electron beam irradiation at 300K, irrespective at initial type of conductivity, leads to formation of new donor centers in CMT crystals. MOD-structure is investigated in [8]. More detailed researches were carried out in [9-15]. As seen from brief review, the study of influence of the electron beam irradiation on kinetic phenomena CMT has only incidental character up to our researches. Coefficients of electro conductivity and Hall have been considered only at 300K and in the certain value of magnetic field and irradiation doze for limited structure and concentration. Thus, the methodical shortcomings were tolerated. In particular, many authors argue on change of a sign of the conductivity, influence of the irradiation on the mobility on the dates of σ and *R* at one certain the magnetic field, meant at this product $R\cdot\sigma$ as mobility. As known, there is a simultaneously participation of electrons and holes in conductivity of CMT, therefore dependences of $R(H)$, $\sigma(H)$ and other factors are complex. Change of sign of *R* at any value H does not mean change of conductivity type and $R\cdot\sigma$ not always is the mobility of one of carriers of charge and etc.

The features of zone structure of crystals, state of admixture levels were not considered at interpretation of the obtained results. For example, in some studies, there are such conditions: the electron beam irradiation results in growth acceptor centers, reduce or has no effect on mobility etc.

With the aim of elimination of the listed blanks of the problem, the complex researches of the influence of electron beam irradiation on electric, galvanomagnetic and thermomagnetic properties of CMT of various structures and concentration of carries of the charge at wide interval of temperature and magnetic fields has been carried out, and a role of electron RD and opportunities of practical use of electron processing has been studied.

1. Influence of an electron beam irradiation on conductivity and galvanomagnetic phenomena in $Cd_xHg_{1-x}Te$ (CMT)

The galvanomagnetic effects are one of the sensitive phenomena to external influences. By studying the influence on them of temperature, the magnetic field and irradiation is possible to obtain exhauste date on concentration, mobility, mechanism of dispersion, etc.

The influence of the electron irradiation an CMT with energy 3,5 Mev, an integrated beam to $\Phi=1,46\cdot10^{18}$cm^{-2}, on *R* for structures x=0, 0.1, 0.12, 0.15, 0.20, 0.25 at T=4,2÷300 K will be considered in this study. The characteristic curves of dependences R (H,T,Φ) for samples x=0.12 and 0.15 are submitted in Fig.1.2. Apparently, the lead to significant change of factors, and irradiation is most effective at low *T* and weak *H*. As seen from curves $R(H)$, the irradiation lead to increase of *R* at investigated range of *T*. The point of inversion of sign of *R* is displaced to high values of *H* by rising of the irradiation doze. Rising of the $R(H_0)$ sign inversion at high fields *H* should be connected with, reduction of mobility and hole concentrations or with increase in concentration and mobility of electrons, according to expression (1).

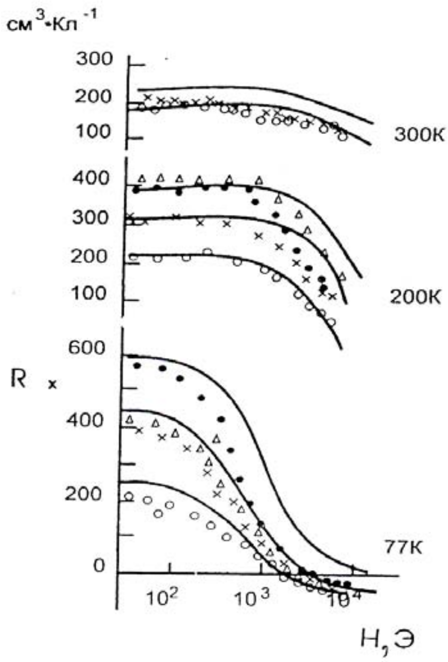

Fig. 1. Field dependences of Hall coefficient for samples of $Cd_{0,12}Hg_{0,88}Te$. Continuous line – calculation ,°-Φ=0; •-Φ=5,6 10^{17} cm^{-2} ;Δ-Φ=1,5.10^{18} cm^{-2}, x-D=10^{10} rad

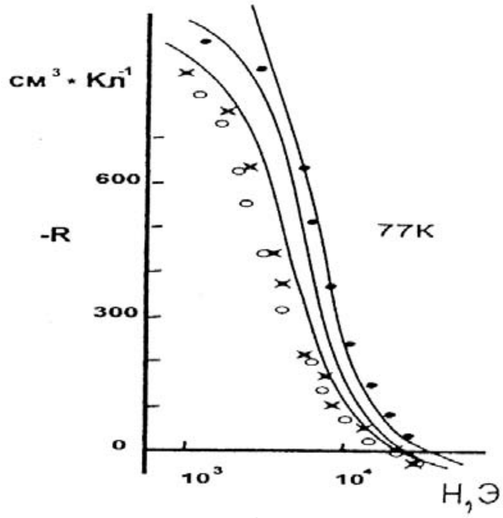

Fig. 2. Field dependences of Hall coefficient for samples of $Cd_{0,12}Hg_{0,88}Te$. Continuous line – calculation,o-D=0; •-Φ=7,2.1017cm^{-2}; x-D=10^{10}rad

As in two-zone model, the influence of *n* on *R* is most essential, the growth H_0 is caused, basically by increasing of n. The *R(H)* in any magnetic field, according to theory looks like:

$$eR(H)=\frac{\dfrac{p\mu_p^2}{1+\tau_p^2}-\dfrac{n\mu_n^2}{1+\tau_n^2}}{\left(\dfrac{p\mu_p}{1+\tau_з^2}+\dfrac{n\mu_n}{1+\tau_n^2}\right)\left(\dfrac{p\mu_p\tau p}{1+\tau_з^2}-\dfrac{n\mu_n\tau_n}{1+\tau_p^2}\right)^2} \quad (1)$$

where $\tau_i=\mu_i H; i=p,n$

The strong dependence of *R(H)* should be observed at $\mu<<1$ and not too great value of *p/n*. Analysis of temperature dependences *R(T)* shows, that the *R(T)* differ both quantitatively and qualitatively at the strong and weak fields. *R* monotonously decrease by reduction of *T* at *H*=8.7 kErs and there is the inversion of the sign of *R* at *T*=80K.

The course of *R(T)* radically changes in process of decreasing of H.

R grows with reduction of *T* up to 200K at *H*=1,5 kErs occurs through a maximum, and with further downturn of *T* up to 77, the value of *R* decreases.

At weak fields (*H*=60 Ers) character of curves *R(T)* strongly differ before and after the irradiation: before of the irradiation, has a weak maximum, it disappears in process of the irradiation and monotonous growth of *R* by increasing of *T* is observed. The location of the maximum and value of *R* changes on depending of *H*. With growth of *H* the maximum is displaced aside high *T* and value of maximum decreases.

The growth of maximum in *R(T)* is connected with competing action of electrons and holes.

At weak fields a leading role plays electrons, at high *H*, holes, that results in shift of position of a maximum aside of high *T*, which causes reduction of the value of a maximum. The shift of a maximum aside low *T* and growth of its value is observed at irradiation.

So, the observable effect is explained by growth of *n* at an irradiation.

As is known, at the mixed conductivity, irrespective of the from izoenergy surfaces and the constancy of time of a relaxation, in week fields always *S(H)* looks like $\Delta\rho/\rho_0 \sim H^2$ and it strongly depends on values of mobility and concentration of each of carries of a charge. In case of the mixed conductivity in approach τ=*const*, in any *H* we have:

$$\frac{\Delta\rho}{\rho_0}=\frac{\sigma_1\sigma_2(\sigma_1\sigma_1-\sigma_1R_2)^2}{\dfrac{\sigma_1+\sigma_2}{H}+\sigma_1^2\sigma_2^2(R_1+R_2)^2} \quad (2)$$

Where $\sigma_1,\sigma_2,R_1,R_2$-factors of electro-conductivity and the Hall electrons and holes.

The characteristic data on dependence $\frac{\Delta\rho}{\rho_0}(H)$ at various *T* and dozes of an irradiation are submitted on Fig. 3.

The passage $\frac{\Delta\rho}{\rho_0}(T)$ through a maximum at 200K showed be take attention. It is connected, by that, the $\frac{\Delta\rho}{\rho_0}$ should get the maximal value at $\rho\mu_p^2 \cong n\mu_n^2$. For submitted samples CMT, such conditions, are carried out in nearly of 200K. As we seen, the electron irradiation in an interval 200-300 *T* does not affect almost on $\frac{\Delta\rho}{\rho_0}$. At helium temperature the $\frac{\Delta\rho}{\rho_0}$ grows, but the most essential increase of $\frac{\Delta\rho}{\rho_0}$ occurs at *T*=77 K. It is connected with increasing of *n* at the irradiation.

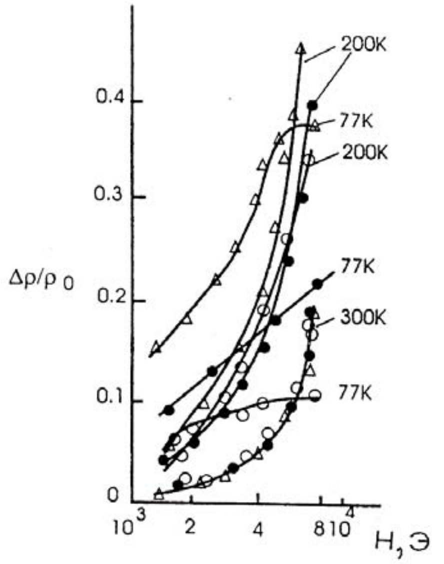

Fig.3. Field dependences of cross magnetoresistance of $\Delta\rho/\rho_0$ of sample of $Cd_{0,12}Hg_{0,88}Te$ before and after e-irradiation; o-Φ=0; •-Φ=5,6.10^17 cm^-2; Δ-Φ=1,5.10^18 cm^-2 at different temperatures.

From the submitted results follows, that it is possible to pick up such structure CMT and ratio of *n* and *p*, that the $\frac{\Delta\rho}{\rho_0}$ gets the much greater value, than in the investigated crystals. Using of high value of $\frac{\Delta\rho}{\rho_0}$ and its increase under action of an electron irradiation, it is possible to create various converters. In particular, having compensated a voltage in a zero field it is possible to create the high-sensitivity gauge of a magnetic field.

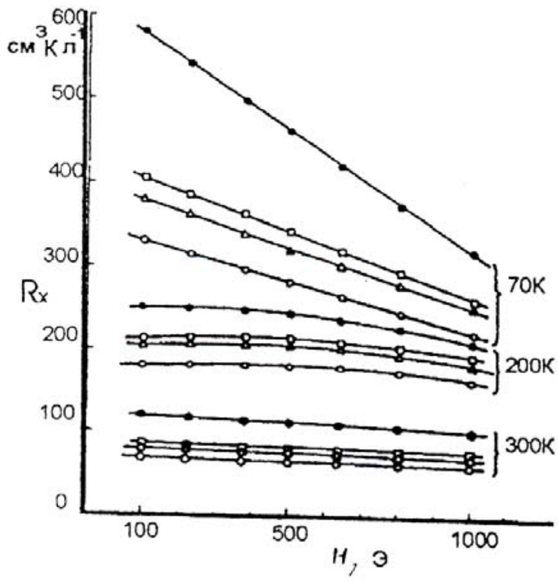

Fig.4. Restore of R_x at thermal treatment (t=1 hour, $T_{annealing}$=430K) in sample of $Cd_{0,12}Hg_{0,88}Te$ after e-irradiation; o-Φ=0 (before thermal treatment; Δ-after thermal treatment (Φ=0); •-Φ=7.10^17 cm^-2; □-after annual.

For an establishment of temperature anneals for the defects entered by an irradiation, samples after measurements were exposed izochronic annuals. As heat treatment in itself influences on electric properties of CMT, samples previously (up to an irradiation) were exposed to heat treatment.

On Fig.4 characteristic curve actions of an electronic irradiation on *R(H)*, and also izochronic annuals before and after an irradiation are submitted. It is visible, that the annuals during one hour at 160^{0}C practically liquidates RD. Similar results are received and from the analysis of other kinetic factors. We shall note, that before our researches there were no quantitative data of irradiation influences on *n, p,* μ_n, μ_p. This rather challenge as in conductivity simultaneously paricipate electrons and holes.

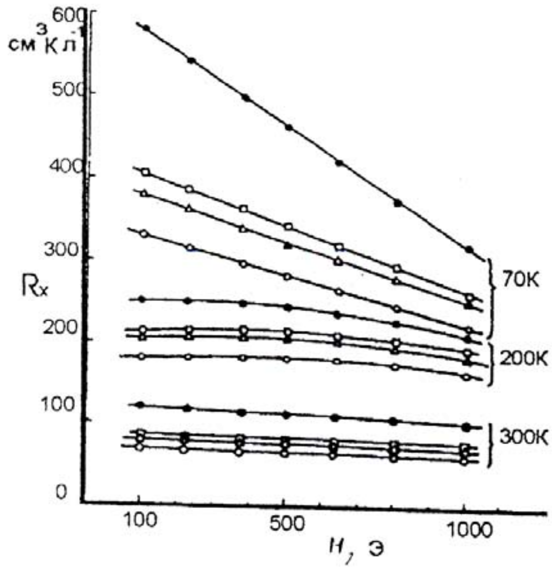

Fig. 5. Temperature dependences of parameters of charge carriers in $Cd_{0,15}Hg_{0,85}Te$; dotted-Φ=0; continuous-Φ=7,2.10^17 cm^-2.

In [16,22-24] we have described the technique of the definition of parameters of charge carries in CMT. It has been applied here, for quantitative definition of *n, p* and μ_n and μ_p before and after an irradiation which results are presented in Fig.5.

With the purpose of check of reliability of the received results about R(H), experimental data have been compared with theoretical curves designed under the formula (1) by attraction of the found parameters n^{μ_n}, p^{μ_p}. The characteristic dependences *R(H)* compared with calculation curves are presented in Fig. 1 and 2.

It is seen, that the character of curves *R(H)* before and after an irradiation does not vary, and the consent of experiment with the theory in weak and strong fields is good enough, and the deviation in intermediate fields is observed. This question was analyzed in detail in [16,17]. Same situation is observed for other irradiated samples.

Apparently, the irradiation reduce of mobility of electrons in 1.4 times and of holes in 15-20%. At this, the irradiation does not influence on mechanism of dispersion.

The most interesting fact is the temperature dependence of concentration, arisen of a result of the irradiation. This question was not discussed in literature, but it is most attractive. It seems, that if the irradiation results in increase of concentration of electrons (at $T \geq 200$K, $n \approx 10^{13}$ cm^{-3}) and with downturn of *T* they should not decrease as donor impurity in CMT are ionized at the lower temperatures [18-20]. Hence, concentration of electrons at 4.2K before and after an irradiation should grow strongly.

However, the ratio of concentration of electrons remains to be constant in wide range of *T*. From our data follows, that this process occurs and induced by electrons (as result of before and after an irradiation).

2. Influence of the electron irradiation of thermo-emf and thermomagnetic pheno-mena

It is known, that the determining factors in thermo-emf and thermomagnetic pheno-mena are the concentration and mobility of electrons. As electron irradiation of crystals CMT results in increase in concentration of electrons and some reduction of mobility. Therefore, the study of the influences irradiation of thermoelectric and thermomagnetic phenomena can give the additional information on the nature of electroactive defects, arising during the irradiation with this purpose the study of thermo-emf, magneticthermo-emf and the cross-section thermomagnetic effect in temperatures of 4,2-300K and magnetic fields $0 \le H \le 22$ kErs has been carried out.

The characteristic dependences α *(T)* before and after an irradiation for a samples with *x*=0.12 and *x*=0.15 are presented in Fig. 6.

As seen, in area, where $\alpha>0$, the irradiation reduced value of α, and in area where $\alpha<0$ leads to increase of α. Thus, the sign of inversion of thermo-emf is displaced in area of low temperatures, and in the sample with *x*-0.15 in the same direction, the position of the maximum of dependence α *(T)* is placed also. There results and data on galvanomagnetic properties, confirm a conclusion on increase of electron concentration at irradiation.

It is necessary to know the temperature dependence of parameters of charge carries for the quantitative analysis of thermo-emf.

These parameters which have been determined, are involved for the analysis of the data α (T, Φ).

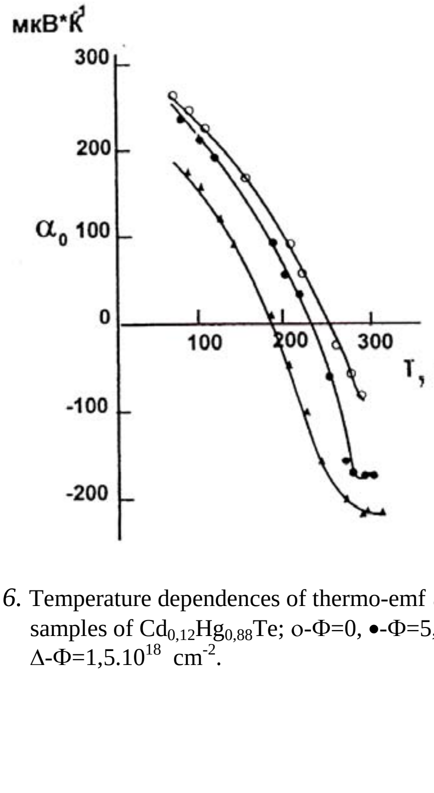

Fig. 6. Temperature dependences of thermo-emf α_0 for samples of $Cd_{0,12}Hg_{0,88}Te$; o-Φ=0, •-Φ=5,6.10^{17} cm^{-2}, Δ-Φ=1,5.10^{18} cm^{-2}.

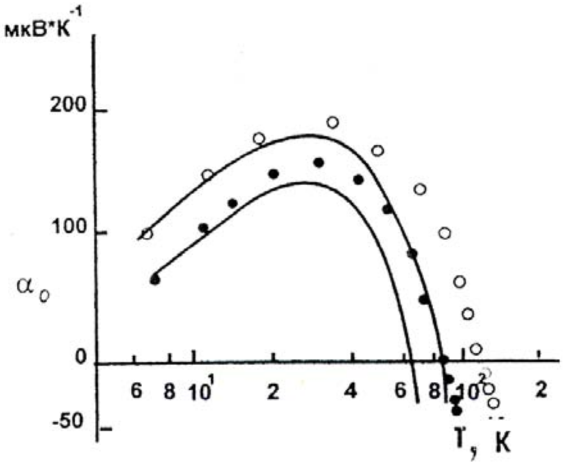

Fig. 7. Temperature dependences of thermo-emf α_0 for samples of $Cd_{0,12}Hg_{0,88}Te$; continuous lines – calculation; o-Φ=0; •-Φ=5,6.10^{17} cm^{-2}.

The continuous lines in Fig.7 present the results of calculation of α *(T)*, made according two-zonal model. As seen, that the calculated curves well describes the experimental data: The reduction of α and displacement of positions of maximum and point of inversion of the sign of α. The appreciable deviatation of calculated results from experiment at *T*>50K is connected with unsplit condition of zone structure $Cd_{0.15}Hg_{0.85}Te$, at which the nonparabolic zones of conductivity strongly amplifies ($\beta \ge 1$), that results in growth of an error of definition of zone parameters (*Eg*, m, η) and Fermis corresponding integrals.

As shown by calculations, up to an irradiation, at low *T* (*T*<25K) in spite of the fact, that $\alpha_n > \alpha_p$, the holes dominate at thermo-emf with growth of *T* (since 4.2), the α_n, α_p and σ_n grow, and the growth α_p outstrips α_n. Strong growth $\alpha_p(T)$ is connected with the constancy *P(T)*. At performance of conditions, growth $\alpha_n \approx \alpha_p$ (at *T*=25 K), the α *(T)* passes through a maximum the further reduction of α *(T)* (despite of $\alpha_p > \alpha_n$) is caused by strong growth of σ_n and σ_0.It not only compensates the reduction of α_n, but also reduces α_p. The condition $\alpha_n \approx \alpha_p$ is carried out already at $T \approx 18$K, that explains shift of position of the maximum α *(T)* at low *T* range. Increasing of $\sigma_n(T)$ at radiation process causes also displacement of the point of inversion of the sigh of α at low *T*. The behavior of field dependences of magneticthermo-emf α *(H)*, measured at various temperatures is interesting. The researches have shown that, the irradiation leads to increase of α *(H)* in all range of it (and $\alpha(H)<0$) at room temperature. The $\alpha(H)>0$ before irradiation at *T*=200K, the irradiation with doze up to $\Phi = 5.6 \cdot 10^{17}$cm^{-2} decrease the magneticthermo-emf, and the increase of doze up to $1.46 \cdot 10^{18}$cm^{-2} leads to change of sign of α *(H)* at low fields (*H*<2kErs). At (*H*>2kErs) the $\alpha(H)>0$, but quantity of magneticthermo-emf less than initial. Character of charge magneticthermo-emf at $T \ge 200$K shows the increase *n* (hence σ_n and σ_0) at the irradiation. It is difficult to explain a course α *(H)* at the irradiation doze up to $\Phi = 5.6 \cdot 10^{17}$cm^{-2} and T=100K. In week fields ($H \le 2$kErs) magneticthermo-emf less than initial value, that corresponds to behavior α *(H)* at high *T*, but value α *(H)* at (*H*>1.5kErs) exceeds the value α *(H)* up to an irradiation. After an irradiation up to $\Phi = 1.46 \cdot 10^{18} cm^{-2}$ the value of α *(H)* decreases in all interval of *H* [25].

The *H-E* effect is most sensitive to the mechanism of dispersion, presence of other type of charge carries, to charge of their concentration and mobility. Dependences *Eg* from *H* and T for a sample with *x*=0.15 indicated, that the *Eg* grows by growing of *H* or passes through a maximum.

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E.İ. Zülfiqarov

ELEKTRON ŞÜALANMASININ $Cd_XHg_{1-X}Te$ KRİSTALINDA KİNETİK EFFEKTLƏRƏ TƏSİRİ

Məqalədə geniş temperatur (4,2-300K) və maqnit sahələrini (60≤H≤22.000E) diapazonunda $Cd_xHg_{1-x}Te$ monokristalında kinetik effektlərə elektron şüalanmasının təsirinin nəticələri analiz edilmişdir.

Göstərilmişdir ki, kiçik sahələr və aşağı temperaturlarda şüalanmanın Holl effektinə təsiri daha çoxdur.$\sigma(T),R(T,H)$ asılılıqlarının nəticələrinin ikizonalı nəzəriyyə ilə muqayisəsi şüalanmanın yükdaşıyıjıların konsentrasiyası və yürüklüyünə təsiri aydınlaşdırmağa və belə bir nətijəyə gəlməyə imkan verdi ki, KRT kristallarının elektronlarla şüalandırılması elektronların konsentrasiyasının donor tipli tellurun vakansiyaları ilə şərtlənən artımına gətirib çıxarır. Müəyyən edilmişdir ki, $Cd_xHg_{1-x}Te$ (x=0,12÷0,25) kristalları İQ-şüalanmanın termrmaqnit qəbuledijilərində əsaə element kimi istifadə oluna bilər. Aşkar edilmişdir ki, T<40 K olduqda $Cd_xHg_{1-x}Te$ (x≤0,15) kristalında keçirijilik zonasındakı akseptor mərkəzlərinin konsentrasiyası donorların konsentrasiyasından çox-çox böyükdur. Akseptor səviyyələri həm ionlaşdırıjı elektronlar, həm də şüalanmanın yaratdığı elektronlar üçün tələ rolunu oynayırlar.

Э.И. Зульфигаров

ВЛИЯНИЕ ЭЛЕКТРОННОГО ОБЛУЧЕНИЯ НА КИНЕТИЧЕСКИЕ ЭФФЕКТЫ В $Cd_XHg_{1-X}Te$

В работе анализированы результаты влияния электронного облучения на гальвано-термомагнитные свойства в монокристаллах $Cd_xHg_{1-x}Te$ ($0 \le x \le 0,25$) в широком диапазоне температур (4,2÷300K) и магнитных полей ($60 \le H \le 22.000$ э.).

Показано, что действия облучения на эффект Холла наиболее существенно при слабых полях и низких *T*. Сопоставление результатов $\sigma(T),R(T,H)$ с двухзонной теорией позволило количественно выявить влияние облучения на концентрации и подвижность носителей заряда и заключить, что электронное облучение кристаллов КРТ приводит к возрастанию концентраций электронов, обусловленные вакансиями теллура донорного типа. Установлено, что при T<40K в $Cd_xHg_{1-x}Te$ ($x \leq 0,15$) концентрация акцепторных центров, входящих в зону проводимость, на много больше концентрации доноров. Акцепторные уровни играют роль ловушек как для ионизирующихся электронов, так и для электронов наведенных облучением.

Received: 12.05.2004