THE ROLE OF DEFECTS IN SCATTERING OF PHONONS IN THE A^3B^5 ALLOYS

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On the base of thermal conductivities investigations the nature of defects in solid solution of GaSb-Ga_2Te_3, InAs-GaAs was analyzed in area 80-300K. It is shown that the heat is transporting by phonons in area 80-300K and the most probably centers of their scattering are cation vacancy and impurity-vacancy complexes.

The present work includes an information about the results of research of thermal conductivity (K) of solid solutions $In_{1-x}Ga_xAs$ ($0<x<0.08$) and $(GaSb)_{1-x}(Ga_2Te_3)_x$ ($0<x<0.05$) in temperature range of 80-300 K. Measurements were carried out by a method a stationary thermal flow.

The temperature dependencies of thermal conductivity ($K(T)$) of solid solutions under investigation are shown on the figures 1 and 2. As seen from figures the value of K is reduced with increase of the second component and its temperature dependence is weaken what is typical for alloys. In the temperature dependence of thermal conductivity the anomalous change was observed.

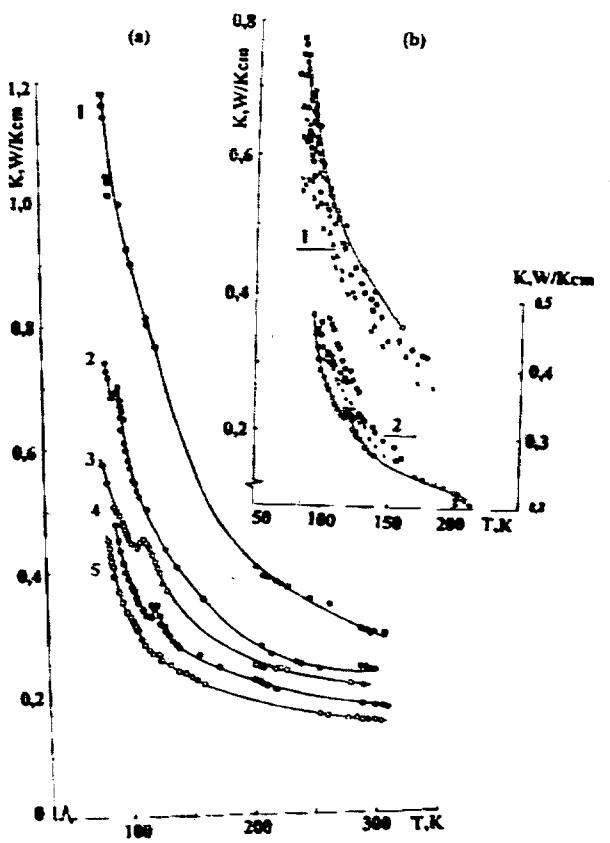

Fig.1. a) Thermal conductivity of $In_{1-x}Ga_xAs$ (x=0(1):0.1 (2): 0.02 (3): 0.04 (4): 0.08 (5) versus temperature.
b) Thermal conductivity of $In_{0.99}Ga_{0.01}As$ (1) and : $In_{0.96}Ga_{0.04}As$ (2): irradiated with electrons 6MeV energy and dose: ○ - F=0; ● - F=0.5·10^{17}e/cm^2: × - F=10^{17}e/cm^2: Ø - F=1.5·10^{17}e/cm^2: Δ - F=2·10^{17}e/cm^2

So in $K(T)$ of $In_{0.99}Ga_{0.01}As$ within the narrow interval near T~ 90 K an obvious dip is observed. The decreasing depth of the dip in $K(T)$ and the shift of the temperature corresponding to this anomaly to the range of high temperatures are related with increase of the content of GaAs. In the case of GaSb-Ga_2Te_3 the second dip also appeared with increase of the content of telluride.

In the investigated range of temperatures the heat mainly is transported by phonons.

The electrons share of thermal conductivity counted in accordance with the Widemann-Franz formula is 2% of K_{exp}. Received results on the lattice thermal conductivity were analyzed by the Callaway model, by taking into account a probability scattering of phonons on phonons ($\tau^{-1}=B\omega^2T^3$) and on disorder alloy ($\tau^{-1}=A\omega^4$). In the case of GaSb-Ga_2Te_3 the scattering of phonons on the vacancy doping by Ga_2Te_3 has been taken into account too. The value of A calculated in accordance by the Klemens formula is differed of its storing value. It is need to take into account the phonons scattering on the other defects. It is possible, that these defects are the reason of the observed anomaly in $K(T)$. In the compounds of A^3B^5 (InSb, GaAs, GaSb) the dips were observed in $K(T)$ at 20-40K [1] and explained by the resonance acoustic phonons scattering. At present the nature of the centers of resonance scattering is not clear. The resonance phonons scattering is observed at comparatively "high" temperature in range 90-110 K in A^3B^5 alloys, in contrast with the binary compounds. We assume that a nature of this resonance center is related to complexes of impurity-vacancy. Our investigation of thermal conductivity of $In_{0.99}Ga_{0.01}As$ irradiated by electrons at 6 MeV energy and $2\cdot10^{17}$ e/cm^2 dose proved this assumption (fig.1b). As seen, the thermal conductivity decreases with a dose up to 10^{17}e/cm^2 and further increase of a dose leads to growth of K, moreover $K(T)$ becomes weaken with the dose. The dip in $K(T)$ becomes more expressive with the dose increase. The electrons part of thermal conductivity presents an insignificant part (2%) of K_{exp} [2], in spite of the fact that the electrons concentration, the electrical conductivity and the thermal power are changed with irradiation. Therefore all these changes of K with irradiation are connected with the scattering of phonons. The displacement of arsenic atom interassembly under the radiation leads to the formation of charged vacancy. The rate of migration of charged atoms and vacancies are different. Therefore along with the recombination the probability of their interaction with impurities and defects exists. The thermal conductivity with a dose is calculated in accordance with the Klemens formula [3], assuming that the concentration of vacancies is proportional to a dose of radiation:

$$K=K_L[1-(\omega_0/\omega_D)\,arctd\,(\omega_D/\omega_0)]\,.$$

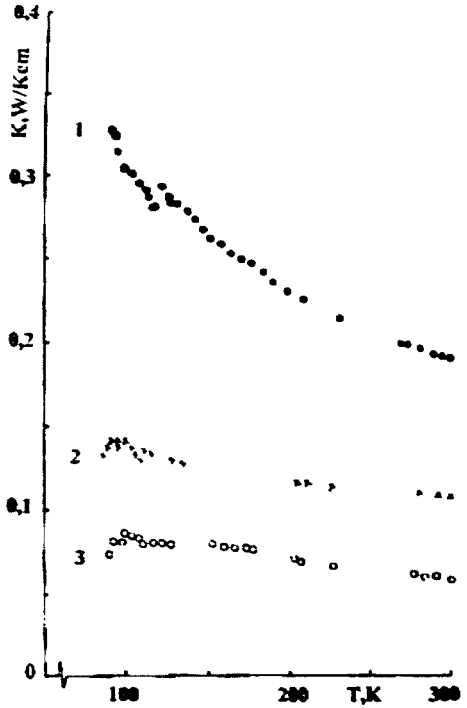

Fig.2. Thermal conductivity of $(GaSb_{3(1-x)}(Ga_2Te_3)_x$ (x=0.01 (1): 0.03 (2)

where $\omega_0^2/\omega_D^2=k_B/2\pi^2\ vK_L\omega_D A$. K_L is a lattice thermal conductivity, ω_D is a Debay frequency, v is a sound velocity.

In spite of fact that the change of thermal conductivity, conditioned by scattering of phonons on vacancies is more, than on arsenic atoms (at T=110K $F=10^{17}$e/cm^2, ΔK_0=0.024W/cmK and ΔK=0.05 w/cmK) their sum is almost twice less than results observed in experiment (ΔK). It means that at irradiation by fast electrons in InGaAs besides primary point defects the significant number of other defects probably complexes with vacancies participation arise. The role of complexes of impurity vacancy is evidently seen in $K(T)$ of solid solution of GaSb-Ga_2Te_3 (fig. 2). As known in this alloy by increase of telluride content the process of substitution of antimony by tellurium with the formation of cations vacancies and complexes occurs: vacancy – atom of Te and vacancy – 2 atoms of Te.

The existence of two dips in $K(T)$ probably indicatives to the scattering of phonons on both types of complexes.

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A^3B^5 ƏRİNTİLƏRİNDƏ DEFEKTLƏRİN FONON SƏPİLMƏLƏRİNDƏKİ ROLU

GaSb-Ga_2Te_3, InAs-GaAs bərk məhlulunda 80-300 K bölümündə istilikkeçiriciliyin tədqiqi ilə defeklərin təbiəti araşdırılmışdır. Göstərilən temperatur bölümündə istiliyin əsasən fononlarla daşınması və onların bərk məhluldakı kation tipli vakansiyalardan və aşqar-vakansiya komplekslərindən səpilməsinin üstünlük təşkil etdiyi göstərilmişdir.

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РОЛЬ ДЕФЕКТОВ В РАССЕЯНИИ ФОНОНОВ В СПЛАВАХ НА ОСНОВЕ A^3B^5

На основе исследований теплопроводности в интервале температур 80-300К проанализирована природа дефектов в твердых растворах GaSb-Ga_2Te_3 и InAs-GaAs. Показано, что в исследуемом интервале температур тепло в основном переносится фононами, и наиболее вероятными центрами их рассеяния являются катионные вакансии и примесь-вакансионные комплексы.

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