STUDIES OF DIODE PROPERTIES IN SOLID HELIUM

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Résumé.- On présente des résultats concernant des transports de charge dans ^{3}He et ^{4}He solides. On a mesuré des caractéristiques de diode statiques J(U) à température constante, la variation thermique J(T) pour différentes tensions continues U et des caractéristiques dynamiques transitoires J(t) en réponse à des tensions appliquées en fonction de Heaviside. On compare les énergies d'activation de la diffusion des charges dans ^{3}He avec les énergies d'activation pour des défauts ponctuels étudiés par d'autres méthodes.

Abstract.- The results of some investigations of charges movement is solid ^{3}He and ^{4}He are reported. It has been measured the static characteristics of diode J(U) at a constant temperature T, current dependencies J(T) at different voltages U applied and dynamic transitional characteristics J(t) on step connection of U. Activation energies of charges diffusion in ^{3}He are compared with the activation energies of point defects obtained by another methods.

Properties of a diode assembled of rectangular plates (characteristic dimensions of a charges source and a collector S=6x35 mm^2 with a gap L=1 mm between them) in solid helium have been studied. Judging from the heat conductivity measurements (in ^{4}He maximum up to 10 Wt/cm.K, mean free paths of phonons up to 1 mm) the samples of rather high perfection were grown.

Figure 1 shows the typical current dependencies J(T) in crystals ^{4}He and ^{3}He+0.2 %, ^{4}He at different applied voltages U obtained in our experiments.

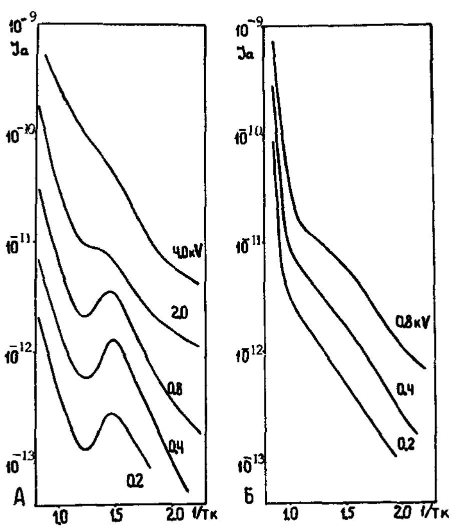

Fig. 1 : Dependences J(T)
A. ^{4}He P=32 atm B. ^{3}He P=60 atm.

It is seen that in h.c.p. ^{4}He samples (pressure range was P=32÷52 atm) with increasing the applied electrical field it appeared a maximum on curves J(T) at temperatures near 0.7 ÷ 0.8 K for charges of both signs /1/. A relative height of the maximum has reached $\approx$ 4, slopes of curves J(T) on the right and the left from the maximum differ markedly. Under the same conditions in the samples of b.c.c. ^{3}He (P=48÷95 atm) maxima were not observed. Assuming that the drift of charges is defined by their interaction with vacancies in the helium lattice the appearance of pecularities on curves J(T) in perfect crystals of the pure ^{4}He might be explained by the changing of the drift mechanisms. For example, in the case of a classical thermoactivated movement the vacancy mobility $\mu_v \sim \exp(-\delta/T)$, their number $n_v \sim \exp(-\Delta/T)$ thus the charges mobilities $\mu_\pm$ (or current through the diode) are proportional to $\mu_\pm \sim \mu_v \sim \exp[-(\delta+\Delta)/T]$. With lowering the temperature one passes to quantum diffusion region. The vacancy mobility first increases with decreasing the temperature as $\mu_v \sim T^{-(7\div9)}$ due to the scattering on phonons and then it does not depend on temperature and is defined by the concentration of scattering centers (impurity atoms, dislocations). So $\mu_\pm \sim T^{-(7\div9)}\exp(-\Delta/T)$ in the phonon scattering restricted region and $\mu_\pm \sim \exp(-\Delta/T)$ at lower temperatures. As a result one may expect the appearance of maxima in J(T) curves of pure samples (^{4}He) or changes in slopes at low temperatures in less pure crystals (^{3}He +0.2% ^{4}He).

Figure 2 gives dependencies of charge mobilities $\mu_\pm$ in b.c.c. ^{3}He on temperature for samples grown at various pressures.

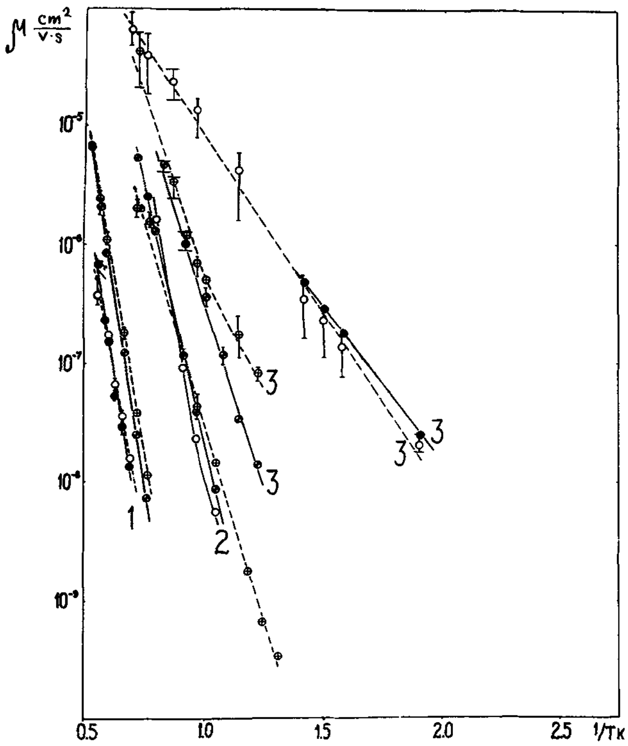

Fig. 2 : Dependences μ_{dyn} (O -positive, O -negative) solid lines and μ_{stat} (O -positive, O -negative charges) dotted lines from temperature in solid ^{3}He. Sample I-P=95 atm, 2-72atm,3-54atm.

Mobilities were estimated using both static volt-ampere J(U) characteristics of diode (for calculation of μ_{stat} the Thomson square-law formula was used /2/ and dynamic ones J(t) at a constant temperature (μ_{dyn} was calculated from the time arriving of the current impulse to the collector).

The values of μ_{stat} and μ_{dyn} turned out to be near the same on the activation parts of the curves μ(T) and could differ an order at low temperatures where an exponentional dependence was replaced by a weaker one /3/.

Activation energies of charges $\Delta_\pm$ in ^{3}He estimated from the slopes of $\mu_\pm$(T) curves and characteristic activation energies of point defects Δ_i obtained by other methods (data are from the reference /6/) are shown in figure 3. At high pressures P $\geq$ 60 atm $\Delta_\pm$ are close to each other and higher than Δ_i (approximately 1.5 times higher). At low P < 60 atm energies $\Delta_+ > \Delta_-$ (at P=48atm $\Delta_+ \approx 2\Delta_-$), and $\Delta_- \approx \Delta_i$. It should be noted that in ^{4}He at the smallest pressures P $\leq$ 32 atm the situation is opposite ($\Delta_+ \approx \Delta_-/3$ at P = 25.6 atm) /7/.

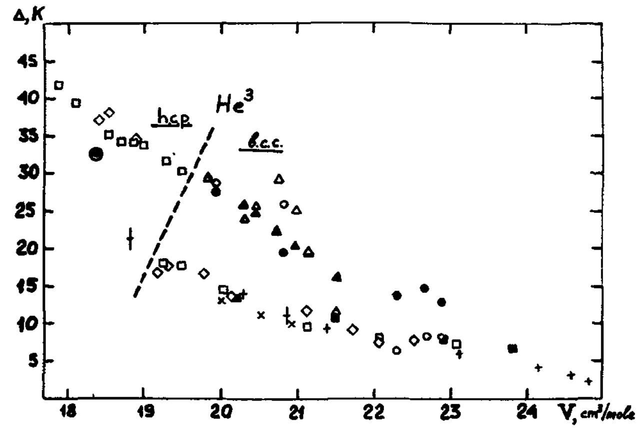

Fig. 3 : Dependences Δ from molar volume V in solid ^{3}He. O – Δ_+ ; O – Δ_- our data /3/ ; Δ – Δ_+, Δ– Δ_- – from /4/ ; O – Δ_+ from /5/ ; , , , x, + – $\bar{\Delta}$ from /6/.

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