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STUDIES OF DIODE PROPERTIES IN SOLID HELIUM

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Résumé.- On présente des résultats concernant des transports de charge dans ³He et ⁴He 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 ³He avec les énergies d'activation pour des défauts ponctuels étudiés par d'autres méthodes.

Abstract.- The results of some investigations of charges movement in solid ³He and ⁴He 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 ³He 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 mm² with a gap L=1 mm between them) in solid helium have been studied. Judging from the heat conductivity measurements (in ⁴He 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 ⁴He and ³He+0.2% ⁴He at different applied voltages U obtained in our experiments.

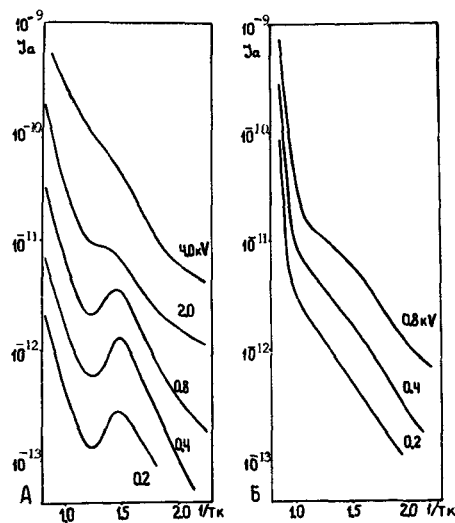


Fig. 1 : Dependences J(T)
A. ⁴He P=32 atm B. ³He P=60 atm.

It is seen that in h.c.p. ⁴He 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 ~ 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. ³He (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 peculiarities on curves J(T) in perfect crystals of the pure ⁴He 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 μ_{\pm} (or current through the diode) are proportional to $\mu_{\pm} \mu_v \exp[-(\delta+\Delta)/T]$. With lowering the temperature one passes to quantum diffusion region. The vacancy mobility first increases with decreasing the temperature as $\mu_v \sim T^{-(7+9)}$ 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 $\mu_{\pm} \sim T^{-(7+9)} \exp(-\Delta/T)$ 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 (⁴He) or changes in slopes at low temperatures in less pure crystals (³He +0.2% ⁴He).

Figure 2 gives dependencies of charge mobilities μ_{\pm} in b.c.c. ³He on temperature for samples

grown at various pressures.

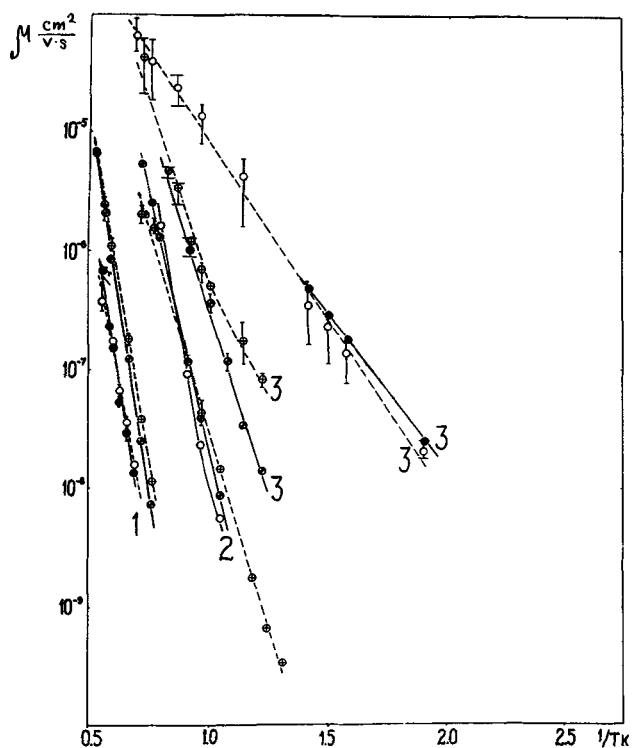


Fig. 2 : Dependences μ_{dyn} (O - positive, O - negative) solid lines and μ_{stat} (O - positive, O - negative charges) dotted lines from temperature in solid ^3He . Sample I-P=95 atm, 2-72atm, 3-54atm.

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 $\mu(T)$ and could differ an order at low temperatures where an exponential dependence was replaced by a weaker one /3/.

Activation energies of charges Δ_{\pm} in ^3He estimated from the slopes of $\mu_{\pm}(T)$ curves and characteristic activation energies of point defects Δ_1 obtained by other methods (data are from the reference /6/) are shown in figure 3. At high pressures $P \geq 60$ atm Δ_{\pm} are close to each other and higher than Δ_1 (approximately 1.5 times higher). At low $P < 60$ atm energies $\Delta_+ > \Delta_-$ (at $P=48$ atm $\Delta_+ \approx 2\Delta_-$), and $\Delta_- \approx \Delta_1$. It should be noted that in ^4He at the smallest pressures $P \leq 32$ atm the situation is opposite

($\Delta_+ \approx \Delta_- / 3$ at $P = 25.6$ atm) /7/.

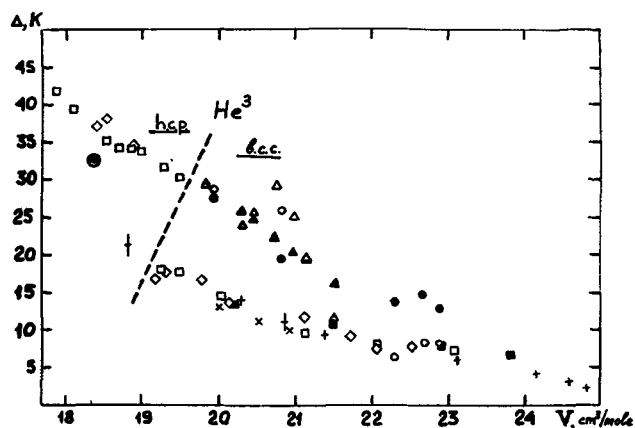


Fig. 3 : Dependences Δ from molar volume V in solid ^3He . O - Δ_+ ; O - Δ_- our data /3/; Δ - Δ_+ , Δ - Δ_- - from /4/; O - Δ_+ from /5/; , , , x, + - Δ from /6/.

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