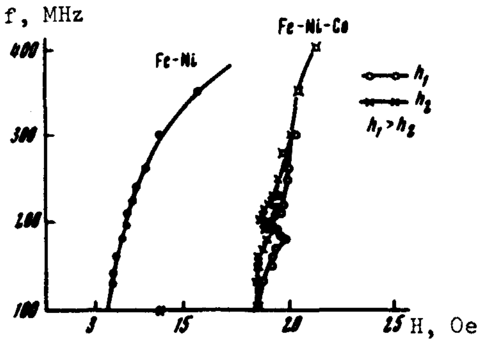

Fig. 1

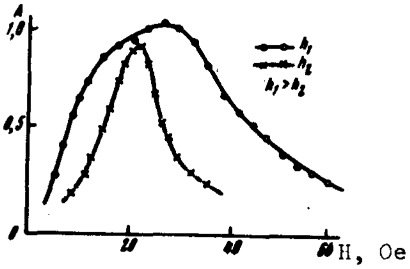

Fig. 2

Fig. 1. Frequency dependence of FMR of thin films of two compositions. The magnetic field is applied in the plane of the film and perpendicular to the anisotropy axis.

Fig. 2. NMR signal of a thin film containing Co^{59} vs. the external magnetic field applied perpendicular to the easy axis.

This is, in our opinion, direct evidence of the presence of coupled oscillations, since energy is transferred more effectively from the electron system to the nuclear one (the gain of the radio-frequency field at the nucleus is sharply increased, since the susceptibility of the electron system is increased in the FMR). Of course, such a simplified treatment of the observed effects is not quite correct, since it is difficult to distinguish between NMR and FMR in the region of coupled oscillations. One can hope that further development of the theory of coupled electron-nuclear oscillations with allowance for the damping and for the nonlinear phenomena will afford a more accurate explanation of the experimental facts.

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SCATTERING BY QUASISTATIONARY STATE IN TELLURIUM

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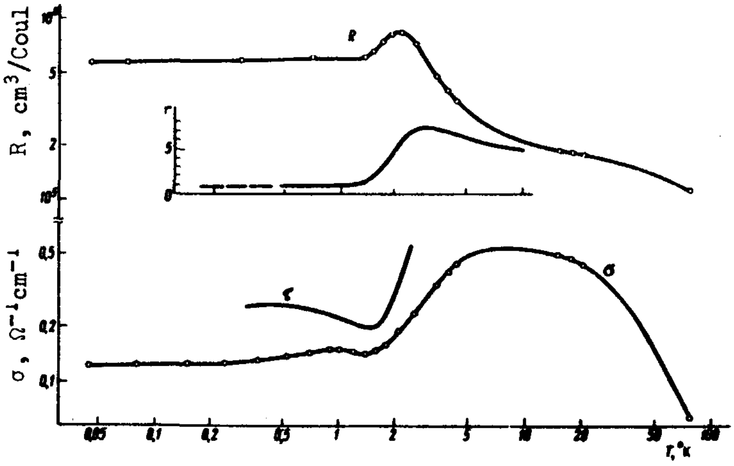
It was noted in an investigation of the galvanomagnetic properties of tellurium at ultralow frequencies [1] that the temperature dependence of the electric conductivity has a nonmonotonic character below 4°K [2]. A nonmonotonic behavior of $\sigma(T)$ in the same temperature region was observed recently by other authors [3]. A careful investigation of the electric conductivity of a number of longitudinal tellurium samples ($j \parallel C_3$) with minimum impurity concentration (from 6.5×10^{13} cm^{-3} at 77°K) has revealed the presence of a minimum of $\sigma(T)$ at 1.4 - 2.8°K. The figure shows the $\sigma(T)$ dependence for the most perfect crystal (with maximum mobility at T = 4.2°K). The appearance of this minimum cannot be explained within the framework of the models of the known scattering mechanisms. If it is assumed that the maximum of the electric conductivity in the region 4 - 6°K is due to the replacement of the acoustic scattering mechanism by scattering from ionized impurities, then the electric conductivity



Comparison of the temperature dependences of the experimental values of the electric conductivity σ and of the Hall coefficient R with the calculated values of the relaxation time τ in resonant scattering (in arbitrary units) and of the Hall factor r.

should decrease monotonically with decreasing temperature below the maximum, and exhibit saturation as a result of the onset of degeneracy (it is assumed that the concentration does not change with temperature, as is evidenced by the constancy of the Hall coefficient at infralow temperatures (see the figure)).

The anomalies observed in the galvanomagnetic properties of tellurium at low temperatures were previously explained by using the hypothesis that the valence band has a complicated structure (for example, has the form of a torus [1]), or that an impurity band is present. It can be now regarded as established that the valence band is relatively simple near the maximum, having the form of four ellipsoids of revolution about the C_3 axis of the crystal [4]. The hypothesis that an impurity band is possessed by samples with low concentration encounters certain difficulties, all the more since all the anomalies become stronger with increasing carrier density.

We propose here that the possible cause of the minimum on the σ(T) dependence is resonant scattering by a quasistationary-level in the continuous spectrum. Such a level can result from the complicated character of the scattering potential of a defect in the anisotropic crystal. The presence in the continuous spectrum of a quasistationary level with energy E_0 and characteristic lifetime $\tau = \Gamma/\hbar$ leads to elastic resonant scattering of the carriers, with a relaxation time that depends on the energy E in the vicinity of E_0 in accordance with the formula

$$\frac{1}{\tau_p} = \frac{2\sqrt{2}\pi n_0 \hbar^2}{(m^*)^{3/2} E^{1/2}} \, \frac{\Gamma^2/4}{(E - E_0)^2 + \Gamma^2/4}.$$

We assume here that only s scattering is significant, $\alpha(2m^*kT)^{1/2}/\hbar \ll 1$, and we omit the terms connected with potential scattering by the same center (α is the amplitude of the potential s-scattering) [5]. The figure shows the result of a calculation of the temperature dependence of the averaged relaxation time $\langle\tau\rangle$ for the resonant-level parameters E_0 = 6°K and $\Gamma/2$ = 1.4°K. We see that resonant scattering can explain the appearance of a minimum on the electric conductivity curve. If account is taken of the presence of other types of scattering (by the lattice vibration, or potential and Coulomb scattering), then we can describe the observed regularities quantitatively. It turns out here that for samples with low hole concentration the resonant scattering at T < 4°K is predominant. The scattering-center concentration obtained with such a calculation is $n_0 = 2 \times 10^{15}$ cm^{-3}. We note immediately that the parameter that allows us to disregard the interference of scattering by different centers is $n_0 f^3 \ll 1$ (f is the amplitude of the resonant scattering), and that in our case this relation holds true even under resonance conditions, when the scattering amplitude is maximal and is equal to the wavelength of the electron with resonant energy. The corrections to the state density, due to the resonant scattering, which were not taken into account in the calculation, are likewise small relative to this parameter.

By numberical integration with a computer we determined the Hall factor $r = \langle\tau^2\rangle/\langle\tau\rangle^2$ for purely-resonant scattering at the same values of E_0 and $\Gamma/2$. The r(T) temperature dependence is shown in the figure. The Hall factor at the maximum is quite large, $r_{max} \simeq 7$. Such a large value of r may be the reason for the strong field and temperature dependences of the Hall coefficient, previously observed for analogous samples [1 - 3]. The presence of other scattering mechanisms, naturally, lowers the value of r at the maximum, without changing the character of the curve. It is interesting to note that, according to the experiment, the calculated minimum of the electric conductivity occurs at a lower temperature than the maximum of the Hall factor.

In [1] is given the concentration dependence of the mobility u under conditions of strong degeneracy (T = 0.1°K). If the presence of the minimum of u(n) is attributed to resonant scattering, then an analysis of the experimental dependence of the mobility in the direction of the C_3 axis on the Fermi energy leads to a value $E_0 = 8°K$, which is in good agreement with the value of E_0 obtained from the temperature dependence of σ. At the present time, a detailed analysis of the entire aggregate of experimental data is under way, with allowance for the singularities of the resonant scattering as $E \to 0$.

As to the nature of the quasistationary level, it is apparently connected with neutral defects, the role of which in Te has already been noted earlier [6]. An investigation of samples having different mobilities at low hole concentration has shown that with decreasing mobility (increasing number of defects) the minimum spreads somewhat, retaining approximately the same magnitude. On the other hand, if the concentration of holes in the samples with high mobility is increased, then the maximum vanishes already at $p = 2.5 \times 10^{14}$ cm^{-3} and the curve assumes the usual form.

Thus, the hypothesis of resonant scattering of holes makes it possible to explain in succession the most clearly pronounced low-temperature anomalies of the galvanomagnetic coefficients of Te.

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