TEMPERATURE DEPENDENCE OF THE LINE AMPLITUDE OF THE SIZE EFFECT IN CADMIUM

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As is well known, one of the conditions for observing the radio-frequency size effect in metals is $l \geq L$, where l is the electron mean free path and L the length of the electron trajectory, which in the case of the size effect on the extremal trajectory in a parallel magnetic field, is $\approx \pi d$, where d is the sample thickness. The dependence of the amplitude of the size-effect line on the mean free path varies with the relation between l and L. Thus, when $l \gg L \approx \pi d$, an important role in the size effect on the extremal trajectory is played by the number of times the electron returns to the skin layer, and when $l \approx \pi d$, when the number of returns is ~1 (in analogy with the case of the limiting point [1]), the amplitude increases exponentially with increasing l. This is connected with the fact that the number of electrons returning to the skin layer and carrying information will decrease exponentially with increasing $L/l = wt$, i.e., $A = a_0 \exp(-wt)$, where A is the line amplitude, w the probability that the electron will become scattered in a unit time, i.e., that it will leave the skin layer or collide with the sample surface, $t = 2\pi/\Omega$ is the time within which the electron returns to the skin layer, and Ω is the Larmor frequency. If the size effect is observed when the electron passes only from one side of the plate to the other, then $t = \pi/\Omega$.

Inasmuch as the interelectron collisions make no noticeable contribution to the scattering in the investigated temperature region (1.6 - 5.1°K), the electron is scattered by impurities and lattice defects, and also by phonons. All that depends on the temperature T is the probability of the electron phonon collisions, and we can write:

$$A(T) = a_0 e^{-2\pi w/\Omega} = a_0 e^{-2\pi w_p/\Omega} e^{-2\pi w_f/\Omega} = A_0 e^{-2\pi w_f/\Omega}; \quad A_0 = a_0 e^{-2\pi w_p/\Omega}, \qquad (1)$$

where w_p is the probability of scattering by impurities and lattice defects and w_f is the probability of electron-phonon scattering. Since $\Omega = eH/m^*c$ and the field at which the size effect is observed is $H = 2c\hbar k/ed$, we get

$$A(T) = A_0 \exp\left[-\frac{\pi d}{\hbar}\frac{m^*}{k} w_f(T)\right], \qquad (2)$$

whence

$$w_f(T) = [\ln A_0 - \ln A(T)] \frac{\hbar}{\pi d}\frac{k}{m^*}, \qquad (3)$$

where k is the electron wave number.

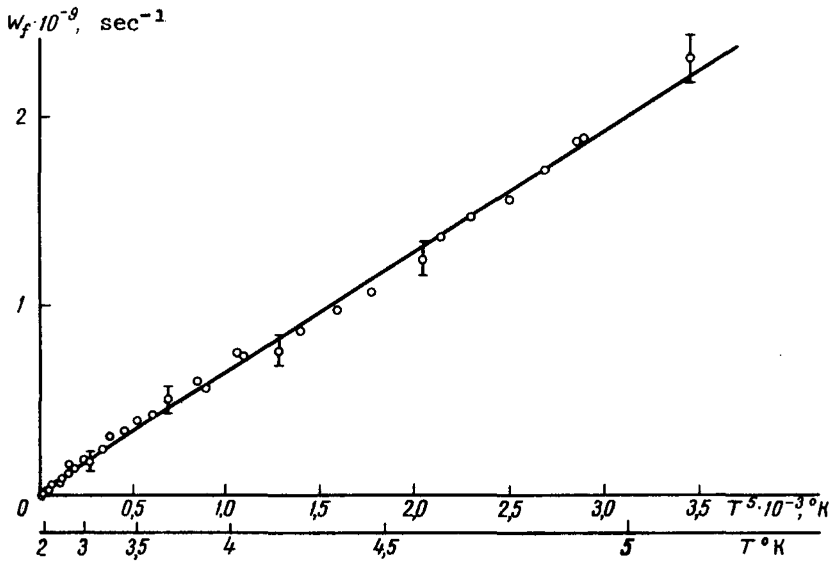
At low temperatures the electrons are scattered by phonons at small angles, $\nu \sim T/\theta_D$, where θ_D is the Debye temperature (see [2]). If the scattering angle ν is sufficiently large and even one scattering takes the electron out of the play, then the scattering probability will be simply proportional to the number of phonons, i.e., $(T/\theta_D)^3$. This takes place when $\nu > \varphi \sim \sqrt{\delta/d}$, where φ is the effective angle at which the electron enters the skin layer.

When $\nu < \varphi$ single scattering is incffective and it is necessary to introduce the number of collisions $p \sim \nu^2/2 \approx 1/2(\theta_D/T)^2$, just as in the case of the static conductivity. Then the probability of the effective collisions becomes smaller by a factor p and depends on the temperature like $(T/\theta_D)^5$.

Thus, depending on the experimental conditions and the Debye temperature of the metal, we can be in one of two temperature regions: $T < T_1 \sim \theta_D\sqrt{\delta/d}$ where $w_f(T) \sim T^5$, and $w_f(T) \sim T^3$ where $T > T_1$. In the intermediate temperature region we may observe any exponent in the interval 3 - -5.

The temperature dependence of the size-effect line amplitude at the limiting point in In and Sn was investigated in [3,4], where it was found that $w_f(T)$ varies like T^3 for indium and like $T^{3.3}$ for tin.

According to the authors' estimates, the experiment was carried out under the conditions when each electron-phonon collision was effective. The exponent 3.3 is apparently connected here with the fact that this interval is closer to the temperature T_1 (T_1 for the case of the limiting point differs from T_1 for the case of an extremal trajectory.



Probability of effective electron-electron collisions vs. temperature.

We have investigated the temperature dependence of the size-effect line amplitude in cadmium at the central section of the "lentil" of the third electron zone, the k/m* ratio for which has been well investigated in [5]. The amplitude was taken to be the distance between the minimum and maximum values of the $\partial R/\partial H$ line, where R is the active part of the surface impedance. With this we got $\delta/d \sim \Delta H/H \sim 3 \times 10^{-2}$, where ΔH is the width of the line between the maximum and the minimum, and H is the field at which the effect is observed. At this value of δ/d we have $T_1 \sim 50$°K. The investigated temperature interval lies much lower, and a T^5 dependence could be expected for $w_f(T)$. As seen from the figure, the effective-collision probability, plotted in accord with the formula of [3], is well approximated by the equation $w_f(T) = \alpha T^3$ where α, determined by least square in a field H making an angle 20° to the $[10\bar{1}0]$ axis, is equal to $(6.37 \pm 0.16) \times 10^5$.

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COMPRESSION OF ALKALI-EARTH METALS BY STRONG SHOCK WAVES

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The authors of [1] observed, on the shock-compression curves of many rare-earth metals, adiabat kinks due most probably to the formation of low-compressibility electronic configurations as a result of the transition of 6s- or 4f-electrons to the d-levels. The occurrence of similar situations is to be expected in the compression of calcium, strontium, and barium, as a result of the displacements of their s-electrons to the d-levels of these elements, which are close in energy.

We present here the shock-compression curves of four alkali-earth elements (Mg, Ca, Sr, and Ba), obtained in a wide range of pressures.

To produce high shock pressures in the investigated metals, we used previously developed explosive devices [2,3], which produced shock waves of fixed intensity in the sample-covering screens. The shock-compression parameters were determined by the reflection method [4,5], whereby the wave velocities in the samples were determined experimentally, the pressures (p) and mass velocities (U) were determined by graphic constructions in pressure-velocity diagrams, and the densities (ρ) were determined from the mass-conservation equation.

The determined shock-wave kinematic parameters are shown in Fig. 1. The abscissas are the mass velocities and the ordinates the wave velocities.

The plots in the diagrams determine the experimentally obtained relations for the investigated metals. The D-U plot of magnesium is a straight line, and that of calcium consists of two linear segments of different slope, meeting in a kink at U ~ 3.8 km/sec. More noticeable is a kink on the strontium curve, at U ~ 2.8 km/sec. The increase in the slopes