RADIO FREQUENCY SIZE EFFECT IN CYLINDRICAL INDIUM SAMPLES

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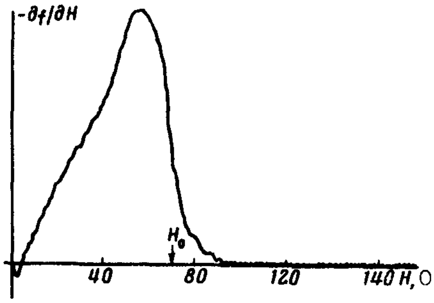
In measurements of the surface impedance of potassium samples of cylindrical shape, Blaney [1] observed, in particular, a monotonic increase of the derivative of the surface impedance $\partial z/\partial H$ with increasing magnetic field in the region where the Larmor radius r_H exceeds the sample radius R, and a sharp decrease at $r_H \simeq R$. The measurements were performed on samples in which the electron mean free path ℓ was of the same order as $R = 0.05 \pm 0.15$ mm. Meierovich [2] constructed a theory of the observed phenomenon for the case of a spherical Fermi surface and obtained for $\partial z/\partial H$ an asymptotic expression that explains qualitatively the results noted in [1].

We present here the results of measurements of the impedance of single-crystal cylindrical indium samples as a function of the magnetic field. The sample was placed inside the inductance coil of the tank circuit of a radio-frequency oscillator in such a way that the rf currents flowed around the cylinder in an azimuthal direction; the generation-frequency deviation $\Delta f \sim -\Delta X$ ($X = -\mathrm{Im}\, Z$) and its variation were determined by a modulation method. The curve shown in the figure pertains to a sample of 3 mm diameter and ~20 mm length, in which the fourfold axis was at angle ~90° to the cylinder axis, and one of the twofold axes was at an angle ~60°. The sample was grown in a quartz polished cylindrical mold and taken out of it after slow cooling to the temperature of liquid nitrogen. The ratio $\rho_{room}/\rho_{4.2°K} \simeq 30{,}000$ corresponded to $\ell \simeq 0.2$ mm. When the temperature T changed from 4.2 to 3.4°K, the sample resistance decreased by a factor 2.5 ($\rho \sim T^5$).

The experiment showed the following: 1) the field H* at which $\partial x/\partial H$ has a maximum is determined by the sample radius, namely, $H^* \sim 1/R$. 2) The connection of H* and of the amplitude A of the derivative at the maximum with the angle ϕ between the magnetic field and the cylinder axis is given by $H^* \sim H_0^*/\cos\phi$ and $A \sim A_0\cos\phi$; when ϕ increases, the line shape becomes more symmetrical with respect to H*. 3) The shapes of the curves are not effected by variation of the frequency (1 - 10 MHz) and of the amplitude of the high-frequency field. 4) For the sample referred to in the figure, the shape of the curve remains unchanged and the amplitude A increases by 1.6 times when the temperature is decreased from 4.2 to 3.4°K. 5) This peculiarity could not be observed in samples of 3 mm diameter and having $\rho_{room}/\rho_{4.2°K} = 6000$. A dependence similar to that shown in the figure was observed also for samples placed in the instrument together with the quartz mold in which they were grown; a slight displacement of the sample in the mold with subsequent heating to room temperature led to the vanishing of the effect.



Plot of $-(\partial f/\partial H) \sim (\partial x/\partial H)$ against H. The arrow marks the field H_0 at which $R = p_F^* c/eH_0$, where p_F is the Fermi momentum calculated for indium in accordance with the free-electron model, T = 3.4°K, and f = 4.2 MHz.

The general form of the dependence of $\partial x/\partial H$ on H, apart from the minimum, is the same as for potassium [1]. This indicates apparently that the observed dependence is due to spherical "pieces" of the Fermi surface of indium. The very existence of the radio-frequency size effect in indium, a metal with a complicated Fermi surface, gives grounds for hoping that this effect can be used to determine the curvature of the Fermi surface. According to [2], the independence of $\partial z/\partial H$ of H at $H > H_0$ indicates that the electrons are diffusely scattered from the surface of the sample.

From the curves shown in the figure it is seen that a minimum of $\partial x/\partial H$ is observed in a field on the order of several Oersteds. The conditions for the existence of the minimum were not investigated in detail, but it has been established that it is more sensitive to the quality of the sample than the maximum. Its physical nature is not clear, and possibly its existence is due to surface levels [3, 4].

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THERMOELASTIC DEFORMATION OF A SOLID SURFACE BY A LASER BEAM

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The action of laser radiation on a solid target, accompanied by destruction of its surface, ejection and evaporation of material, and formation of plasma, has been investigated experimentally many times. Such phenomena are typical of high-power laser pulses.

We describe here the behavior of a solid surface under the influence of a continuous laser beam which does not damage the surface, but distorts its profile as a result of thermoelastic deformations. The theoretical problem of thermoelastic deformation of a surface was considered in [1 - 4] in a different formulation.

The radiation source was a single-mode cw CO_2 laser with a fixed power $P_0 = 14$ W, operating in the TEM_{00q} mode. The intensity distribution in the beam was axially symmetrical and described by a Gaussian curve $I(r) = I_0\exp(-2r^2/w^2)$, where w is the half-width of the distribution and I(r) the laser power density (W/cm^2). The target was a fused-quartz disk whose diameter (12 cm) and thickness (1.5 cm) were sufficient to make the mathematical model of an elastic heat-conducting half-space applicable to the heat-transfer process and to the mechanical deformations.

We have observed experimentally that laser radiation causes the surface of the irradiated body to bulge at the spot where the beam is incident. A laser interferometry measurement in conjunction with a motion-picture camera yields the deformation at any point of the surface as a function of the time and of the dimension of the irradiation zone. The figure shows the deformation V (in microns) in a direction normal to the surface at the center of the beam, as a function of the irradiation time t (in seconds). Plots I, II, and III correspond to different laser-beam densities at w = 0.35, 0.55, and 0.65 cm.

The curves show that during the initial heating the deformation V is directly proportional to the irradiation time. This part of the curve is given by the formula