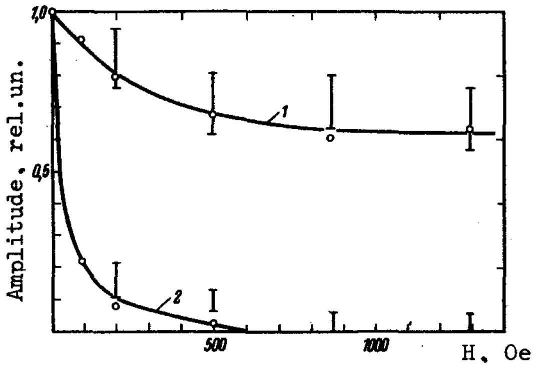

Fig. 2. Influence of external constant field H on the amplitudes of the NMR signal of Fe^{57} (curves drawn through the circles) and on the DBR spectrum (segments): 1 - H $\perp$ (111), 2 - H $\parallel$ (111). In all cases h $\parallel$ (111). The NMR and DBR amplitudes at H = 0 are taken as unity.

The fact that the amplitudes of the NMR signal and the DBR spectrum have the same dependence on the direction and magnitude of H indicates, first, that the NMR signal is due to the motion of the domain boundaries and, second, that both effects are due to the same type of boundary. It also follows from the results reported in Secs. 1, 2, and 3 that the motion of the domain boundaries in hematite occurs only when h and H have a component parallel to the (111) plane. This is connected with the fact that the ferromagnetic moment of the domains in hematite is "rigidly" coupled to the basal plane. Inasmuch as the domain structure of hematite has not been firmly established as yet, it is still difficult to indicate the type of boundary with which the NMR signal is connected. It is apparently due to the easily-moving boundaries parallel to (111), which were observed most clearly in a recent investigation reported by Eaton and co-workers [7].

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INFLUENCE OF MAGNETIC SURFACE LEVELS ON THE IMPEDANCE OF POTASSIUM AT RADIO FREQUENCIES

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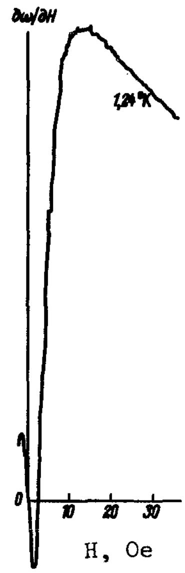
Submitted 14 January 1969
ZhETF Pis. Red. 9, No. 4, 246 - 249 (20 February 1969)

In measurements of the surface impedance Z = R + iX of potassium in the radio-frequency range $\omega/2\pi \approx 10^6 - 10^7$ Hz we observed a nonmonotonic dependence of X on H in weak magnetic fields H from 0 to 50 kOe. The samples were placed inside the coil of the tank circuit of a radio-frequency oscillator; the change of the sample impedance changed the oscillation frequency ($d\omega \sim -dX$), and the change was registered by a modulation method. The figure shows one sample of the obtained curves. The curves are outwardly very similar to those obtained in analogous experiments on bismuth [1] but, unlike in bismuth or gallium [2], the shape of the potassium curves does not depend on the amplitude of the high-frequency field, so that the appearance of the minimum of $\partial\omega/\partial H$ near the zero field was certainly not connected with nonlinear effects.

The samples were in the form of flat plates. They were made of metal with relative residual resistance $\rho_0/\rho_{room} \approx 1.8 \times 10^{-4}$, either by pouring liquid metal in a dismountable glass mold, or by squashing a piece of potassium between two glass plates. In both cases, the glass was covered with a layer of mineral oil to prevent the metal from sticking of the metal upon solidification. The finished sample was washed with benzene, which was then pumped out, after which the sample was cooled in vacuum to the temperature of liquid nitrogen, at which it was usually stored. The samples were also inserted in the apparatus at the temperature of liquid nitrogen. The surfaces of the samples were thus free during the course of cooling to helium temperatures.



Derivative, with respect to the field, of the imaginary part of the surface impedance of a potassium plate 0.6 mm thick. Frequency 6.25 MHz, $\vec{j} \perp \vec{H}$.

The experiments have established the following:

1. The height and width of the extremum depends very strongly on the electron mean free path in the metal and on the state of the surface of the sample, being a more sensitive criterion of the sample quality than the radio-frequency size effect (which is observed in the same experiments [3]). The presence of moisture or of oil residue between the sample and the substrate, which may freeze upon cooling, leads to the vanishing of the effect. When the temperature is lowered from 4.2 to 1.3°K, the maximum of $\partial\omega/\partial H$ increases several times; the minimum appears approximately at 3.5°K, and its depth also increases rapidly with decreasing temperature.

2. Extrema are observed at any polarization of the high-frequency currents $\vec{j}$. A decrease of the angle between $\vec{H}$ and $\vec{j}$ shifts the minima towards stronger fields.

3. Inclining the field weakens the effect, which vanishes when the angle between the field and the surface of the sample is large ($\geq 50°$).

4. Variation of the frequency from 1 to 10 MHz has no noticeable effect on the shape of the curves.

We propose that the observed phenomenon is connected with the presence of magnetic surface levels [4, 5]. The qualitative explanation reduces to the following: when the field H is parallel to Oz and the normal to the surface N is parallel to Ox, the spectrum of the electrons glancing along the surface has in the quasiclassical approximation the form [4]:

$$\epsilon_n(p_y, p_z) = \frac{p_y^2}{2m} + \frac{p_z^2}{2m} + \left(\frac{3\pi}{2}\right)^{2/3}\left[\frac{p_y^2}{2m}(\hbar\Omega)^2 n^2\right]^{1/3} = \phi(p_{\parallel}) + \epsilon_0 Y_n,$$

where ϵ_n, m, p_y, p_z, and p are the energy, mass and the different electron-momentum components, $\Omega = eH/mc$ is the cyclotron frequency, $\epsilon_0 = (p_y^2/2m)^{1/3}(h\Omega)^{2/3}$, $Y_n = (3\pi/2)^{2/3}n^{2/3}$, and n are integers. In the quasiclassical part of the spectrum, at very large values of n, the levels are equidistant and the quantity $p_{xn} \sim \sqrt{2m\varepsilon_0 Y_n}$ has the meaning of a momentum. In the case of transitions in an electric field of frequency ω and wave vector k, the following conservation laws should be satisfied:

$$\hbar\omega \approx \epsilon_0 (Y_{n'} - Y_n) \approx \pi\epsilon_0 s/\sqrt{Y_n} \qquad (s = 1,2,3,..)$$
$$\hbar k \approx \sqrt{2m\epsilon_0}(\sqrt{Y_{n'}} - \sqrt{Y_n}) \approx \pi/2\sqrt{2m\epsilon_0}\, s/Y_n$$

whence, eliminating Y_n, we get

$$s \approx \omega^2/\pi k v_y \Omega$$

(v_y - component of the Fermi velocity v_F).

Inasmuch as the frequency ω enters the kinetic equation in the form of the combination $\omega + i/\tau$, and in our case $\omega\tau << 1$, we can replace ω by $1/\tau$ for the purpose of obtaining a qualitative estimate. In the case of the anomalous skin effect, the only significant Fourier components of the field are those for which $k \sim 1/\delta(1 + i\sqrt{3})$. As a result we obtain the follosing condition for the magnetic field:

$$\Omega_s \sim \delta/\tau^2 v_F s \qquad s = 1,2,3 \ldots$$

Naturally, this condition determines not the narrow peaks in the impedance, as in transitions between two definite levels [5], but a smoothly oscillating function Z(H)

$$\Delta Z \sim Z_0 e^{-2\pi i s} \sim Z_0 \exp\left\{\frac{-\delta(1 - i\sqrt{3})}{\tau^2 v_F \Omega}\right\}.$$

The first extremum, corresponding to transitions with s = 1, occurs in a field $H \sim \delta mc/e\tau^2 v_F \sim 10$ Oe, as is indeed observed in the experiment. We are dealing in essence with that part of the spectrum, in which the level width is of the order of the distance between them. It is therefore not surprising that we have observed only two minima of $\partial\omega/\partial H$. The smallness of $\omega\tau$ explains also the weak dependence of the effect on the frequency, namely, under these conditions ω enters only via the skin-layer depth $\delta \sim \omega^{-1/3}$. Finally, the fact that the free path is small and the electron has time to cover in practice only one arc of its trajectory is apparently the cause of the absence of a strong dependence of the effect on the inclination of the field at small inclinations.

The sphericity of the Fermi surface of potassium causes, of course, a weakening of the effect, since $0 \leq v_y \leq v_F$ and averaging causes only the electrons of the vicinity of the central section to be effective. However, the fact that it has been impossible to date to observe surface levels of alkali metals at high frequencies is connected, in our opinion, not with averaging but with the methods of preparing the samples - the cold hardening of the sample surface upon cooling.

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