INFLUENCE OF MAGNETIC FIELD ON THE ABSORPTION OF ULTRASOUND BY SUPERCONDUCTING TIN IN THE INTERMEDIATE STATE

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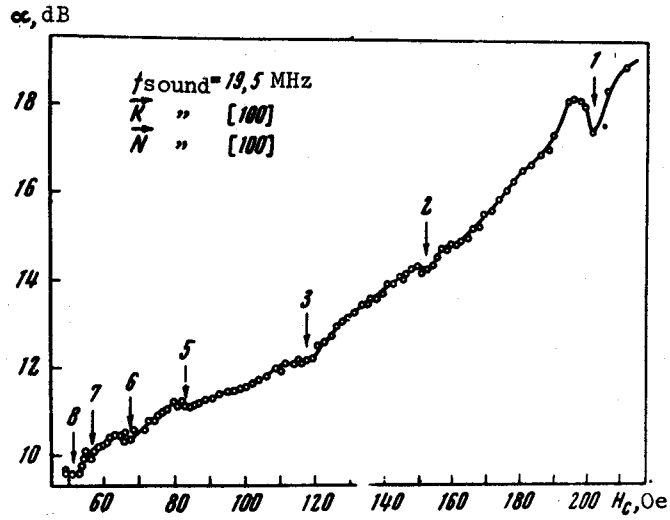
Andreev has shown [1] that when the conditions for the existence of geometric-resonance oscillations in the normal state are observed [2], a nonmonotonic dependence of ultrasound absorption on the magnetic field should likewise be observed in the intermediate state. The occurrence of these singularities is due to resonant absorption of sound, which takes place when the dimensions of the electron orbits coincide with the thickness of the normal layer.

The general expression for the oscillating part of the absorption is (the symbols are defined in [1]):



$$\Delta\Gamma \sim \Gamma_0^{(N)} \eta ka \left(\frac{a}{R}\right)^{1/2} \sum_{n=1}^{\infty} \frac{n^{1/2}[1-(-1)^n \cos ka]}{(n^2 - k^2a^2/\pi^2)^2} \sin\left[\frac{\pi R_{ext}}{a} n \pm \frac{\pi}{4}\right]. \quad (1)$$

The physical nature of oscillations of this kind consists in the fact that an electron moving in a normal layer and reflected from the interphase boundary remains in the perturbing field for only part of the sound wavelength. The period of the perturbing field is equal to double the thickness of the normal layer and the expression given above for $\Delta\Gamma$ is none other than the usual geometric resonance at the harmonics obtained when this field is expanded in a Fourier series.

In [1] there is predicted an oscillation of the ultrasound absorption with a slowly varying period

$$\delta H = 2a^2 / \frac{\partial a}{\partial H} R_{ext} . \quad (2)$$

For tin with its characteristic values of R_{ext} [3], the period of the oscillations is $\delta H \sim H_c$ so that it is impossible to observe these oscillations under the usual experimental conditions [4].

There is, however, another possibility of observing the oscillations, for if we vary H_c and at the same time maintain η constant, we should observe for $\Delta\Gamma$ a curve quite similar to the plot of the ordinary geometric resonance, with an oscillation period that is the inverse of the critical field H_c.

The figure shows the plot of the ultrasound absorption coefficient of tin in the intermediate state as a function of the critical field. The sample and the geometry of the experiment were the same as in [4], and the tin was 99.999% pure. The exact plot of the critical field against the temperature was taken from [5].

It is seen that the sound absorption has a nonmonotonic character, although the observed singularities are not strongly pronounced. The latter, of course, could hardly be expected, for there is little likelihood that all the normal layers in the sample have the same thickness.

It follows from (1) that the main contribution to the absorption will be made by the harmonic with $n \sim ka/\pi$, and when $ka/\pi \ll 1$ by the harmonic with $n = 1$. In this case we can obtain from the periodicity conditions the following expression for the quantity a_0/n, where a_0 is the thickness of the normal layer at 0°K:

$$a' = \frac{a_0}{n} = \frac{c p_{ext} \Delta\left(\frac{\sqrt[4]{1 - T/T_c}}{H_c}\right)}{e}, \tag{3}$$

where account is taken also on the basis of [6], of the temperature dependence of the thickness of the normal layers. We see from this formula that for the observed oscillation increment Δ the functions $\phi(T) = (1 - T/T_c)^{1/4} H_c^{-1}(T)$ should be constant. This is in fair agreement with experiment (see the table), although oscillation No. 4 was not observed.

Values of T, H_c, and $\phi(T)$ Corresponding to the Minima of the Absorption Coefficient in the Figure

Oscillation No.	1	2	3	5	6	7	8
T, °K	2.10	2.36	2.85	3.12	3.25	3.33	3.37
H_c, Oe	204	152	117	82.5	67	57	50.5
$\phi(T) \cdot 10^3$	3.97	4.96	5.96	7.72	8.92	10.00	11.00

For the investigated orientation, the value of p_{ext} obtained from the period of the magnetoacoustic oscillations [3] is equal to 0.525×10^{-19} g-cm/sec. From this we can determine the value of a'. It remains to determine the number of the harmonic that contributes to $\Delta\Gamma$. Since in our case $ka'/\pi < 1$, it is easy to verify that the most acceptable value is $n = 1$, i.e., $a' = a_0$. The thickness of the normal layers is then 33 μ, which is in fair agreement with the results of [4] for the corresponding values of the normal-phase concentration η.

It should be noted that the picture of sound absorption in the intermediate state depends significantly on the dislocation structure of the sample, and reproducible results can be obtained only for well-annealed samples.

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