MECHANICAL FORCES ON A SUPERCONDUCTING FILM

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Various observations on superconductors in recent years have been interpreted in terms of magnetic flux lines moving across the superconductor against a resistive force and leading to an electromotive force.[1-3] In addition, Pearl[4] has used a moving magnet to produce an electromotive force in a thin lead ribbon while earlier work[5] showed no electromotive force induced in an ellipsoid rotating in a magnetic field.

We have studied the mechanical forces on a superconducting tin film in a magnetic field perpendicular to its surface, by means of a torsion pendulum.

Figure 1 shows the arrangement of the tin films on the nylon disk which constitutes the pendulum. The circles show the approximate extent of the magnetic fields, which are produced by toroidal shaped coils. The gap is about 1.5 cm compared with $\frac{1}{2}$ cm diam of the windings so there is a good deal of fringing of the field where it passes through the film. The film was evaporated on glass slides and is estimated to be about 8×10^{-5} cm thick. The magnetic field is roughly 30 G/A.

The observations indicate both a dissipative force and a conservative force as the films swing through the magnetic fields.

In one type of experiment the pendulum is displaced about 90° from its equilibrium position and let go. The extreme excursions to both sides are recorded. At 4.2°K the damping is independent of the magnetic field and is due to the torsion fiber alone.

At 3.4° the magnetic field has an obvious effect. Above 1.5 A in the magnet the observations take the form shown in Fig. 2. There is a pronounced additional damping due to the magnetic field and, in addition, when the amplitude has decreased to a sufficiently small value, the inertia of the disk is insufficient to carry it through the field. It then oscillates back and forth, with very little damping, about a center near the edge of the film.

In other experiments the pendulum is set into oscillation without a field, and the field is turned on as the center of the films are near the centers of the fields. Then the pendulum receives a sharp impulse which throws the film out of the field, in the direction it had been moving, after which it oscillates as described above.

In other cases the field is turned on when the pendulum is almost at rest, and it receives a similar impulse whose direction is presumably determined by minor lacks of symmetry.

The period of the pendulum increases slightly as the amplitude decreases. As it approaches the amplitude at which it cannot swing through

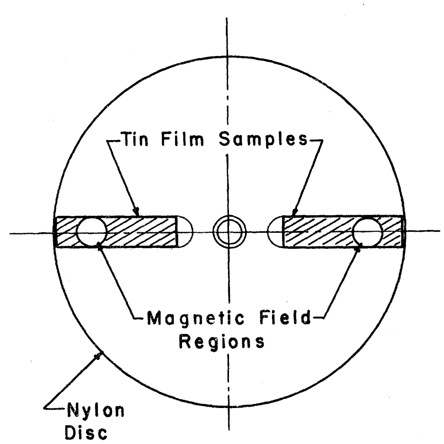

FIG. 1. The tin films are located symmetrically on the nylon disk which is $2\frac{7}{8}$ in. in diameter. The magnetic field probably fringes significantly outside of the circles showing its location.

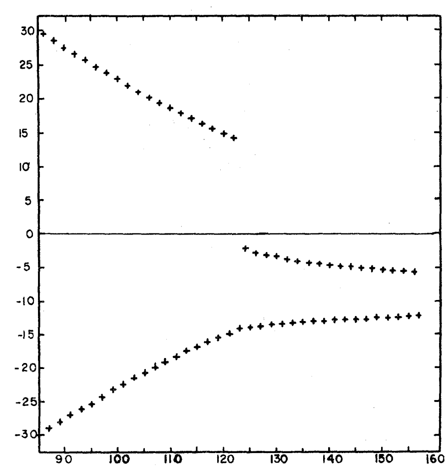

FIG. 2. The ordinates are the maximum displacements, in degrees, of the swings to either side plotted against the number of the swing. The earlier swings are omitted.

the center, the period increases to more than twice its normal value. After the off-center oscillations begin, the period decreases rapidly to less than its original value.

The apparatus is not such as to permit highly quantitative description of the results, but two conclusions seem to be justified: (1) The conservative force is apparently associated with currents in the film at the boundary between normal and superconducting areas. (2) The dissipative force cannot be due to ordinary eddy currents since it is not observed at 4.2°. The resistance of the film in the normal state is high enough, because of its small thickness, to make this contribution negligible. The force must be associated with the motion of normal superconducting boundaries.

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ANOMALOUS STRESS EFFECTS IN RESONANT-MODE INFRARED ABSORPTION*

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In this paper we report about the anomalous behavior that the resonant-mode infrared absorption exhibits under the application of uniaxial or hydrostatic stress. The main feature of the effect consists in the large shift that the peak frequency suffers under the application of the stress. Indeed this shift is predicted to be in some cases 20 times larger than the shift suffered by the host lattice frequencies.

In the absence of any concentration effect, it is well known[1-3] that the absorption peak occurs at the frequency for which the real part of the resonance denominator of the scattering matrix for a single imperfection vanishes. If, in addition to the change of mass, the change of nearest-neighbor (n.n.) force constant is also considered, it is an easy matter to generalize the theoretical results of previous authors[1,3] concerning the pure change of mass, and the resonant frequency ω_r for the optically active mode turns out to be a root of the equation

$$1+\epsilon\alpha(\omega_r)+\bar{\lambda}\beta(\omega_r)+\epsilon\bar{\lambda}\gamma(\omega_r)=0. \tag{1}$$

$\epsilon=\Delta M_\pm/M_\pm$ measures the local change in mass, $\lambda\equiv M_\pm\bar{\lambda}$ the local change in nn force constant of central type, while $\alpha(\omega)$, $\beta(\omega)$, and $\gamma(\omega)$ denote the real part of Brillouin-zone summation involving the frequencies and the polarization vectors of the host crystal. In an ionic crystal with rock-salt structure, $\alpha(\omega)$, $\beta(\omega)$, and $\gamma(\omega)$ turn out to be

$$\alpha(\omega)=\omega^2\operatorname{Re}\mathcal{G}_1(\omega),$$

$$\beta(\omega)=\operatorname{Re}\{\mathcal{G}_1(\omega)-2\chi^{1/2}\mathcal{G}_2(\omega)+\chi\mathcal{G}_3(\omega)\}$$

$$\gamma(\omega)=\omega^2\chi\operatorname{Re}\{\mathcal{G}_1(\omega)\mathcal{G}_3(\omega)-\mathcal{G}_2{}^2(\omega)\};$$

$$\mathcal{G}_1(\omega)=N^{-1}\sum_{\vec{q}j}(\omega_{\vec{q}j}{}^2-\omega^2-2i\omega0^+)^{-1}e_x{}^2(\pm|\vec{q}j),$$

$$\mathcal{G}_2(\omega)=N^{-1}\sum_{\vec{q}j}(\omega_{\vec{q}j}{}^2-\omega^2-2i\omega0^+)^{-1}e_x(\pm|\vec{q}j)\times e_x(\mp|\vec{q}j)\cos(2\pi aq_x),$$

$$\mathcal{G}_3(\omega)=N^{-1}\sum_{\vec{q}j}(\omega_{\vec{q}j}{}^2-\omega^2-2i\omega0^+)^{-1}\times e_x{}^2(\mp|\vec{q}j)\cos^2(2\pi aq_x). \tag{2}$$

In the above expression, ω is the circular frequency, $\vec{q}$ the wave vector, j the branch index, n the number of primitive cells comprising the lattice, and a the lattice constant. $\vec{e}(\pm|\vec{q}j)$ is the polarization vector of pisitive (+) or negative (−) ions and $\chi=M_\pm/M_\mp$ the host-crystal mass ratio; the choice of the upper or lower sign depends whether we are concerned with positive or negative impurities.

For a fixed value of the resonant frequency,