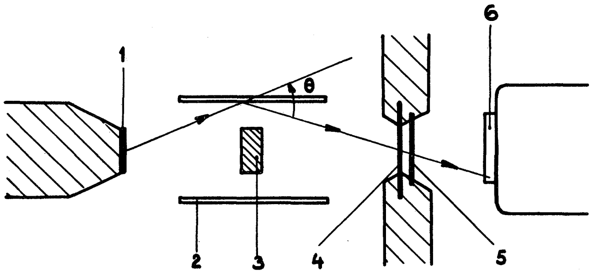

FIG. 1. (1) Sn^{119*} source; (2) scatterer; (3) bismuth stopper; (4) 40 mg cm^{-2} Sn^{119} foil (71.5 % Sn^{119}); (5) 62 mg cm^{-2} Pd foil absorbing Sn x rays; (6) 1.5 mm NaI(Tl) scintillator and photomultiplier.

for a fraction α of all the scattering processes; α is extracted from the form factors given by Compton and Allison.[4]

We have measured the relative decrease Δ of counting rate between room temperature $T_1 = 300°K$ and $T_2 = 80°K$. The recoilless scattering proportion at T_2 is approximately

$$\varphi_{T_2} = \frac{1}{\alpha} \frac{\Delta - \epsilon}{f_2 - \epsilon},$$

where f_2 is the ratio of recoilless emission of the Sn^{119*} source and ϵ is its self-absorption at T_2. Here $f_2 = 0.32 \pm 0.015$ and $\epsilon = 0.05 \pm 0.01$. We neglect the small recoilless emission at 300°K which introduces a negligible correction for φ_{T_2}.

The results are given in Table I. The agreement between the calculated and experimental values of φ is reasonably good, especially when we notice that the Debye temperatures are deduced from specific heat measurements rather than from x-ray diffraction.

Table I. Experimental and calculated values of φ_{T_2}.

	$1/\alpha$	Δ	φ_{T_2}	φ_{calc}
Pt	1.05	0.27 ± 0.03	0.72 ± 0.09	0.80
Al	2.15	0.19 ± 0.016	0.92 ± 0.09	0.62
C	4.13	0.10 ± 0.01	0.79 ± 0.09	0.68
CH_2	5.30	0.020 ± 0.01	0	

We have also, using a thin Sn^{119} foil as a scatterer, observed at low temperature the resonant Mössbauer scattering.[5]

This method extends the range of solids which can be studied by means of the Mössbauer effect or by x-ray diffraction.

It is a pleasure to acknowledge interesting discussions with Dr. Abragam, Dr. Cotton, and Dr. Jacrot.

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STUDY OF THE INTERMEDIATE STATE IN SUPERCONDUCTORS USING CERIUM PHOSPHATE GLASS

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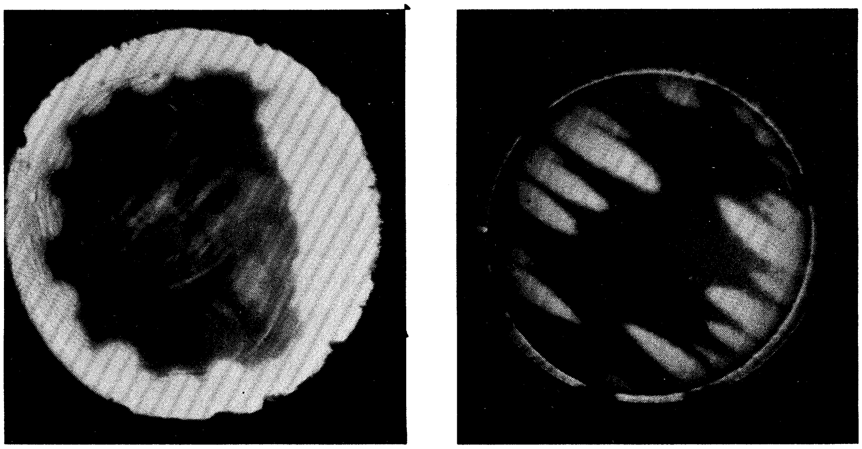
Alers[1] has recently used the magneto-optic Faraday rotation in some cerous nitrate-glycerol solutions to observe the intermediate state in a superconducting lead alloy. This technique, like the bismuth probe[2] and the superconducting[3,4] or ferromagnetic[5] powder methods, makes use of the diamagnetism of the superconducting state to investigate the topography of the superconducting and normal domains at the surface of a specimen. In all these methods, it is assumed that the local magnetic field distribution and variations at the surface reflect the amount of normal and superconducting material in the specimen itself. More recently, Alers[6] has reported large Faraday rotations in some paramagnetic glasses containing cerium meta-phosphate suggesting their use in studying the structure of the intermediate state in superconductors.

Utilizing this Faraday effect in similar glass prepared by A. Pincus and R. H. Pry of this laboratory, we have obtained some preliminary results on resolving the intermediate state in various superconducting metals. Included in these early studies was the effect of different conditions of metallurgy, strain, purity, crystallographic orientation, grain size, etc. The purpose of this note is to point out that new information on the dynamics and time-dependent phenomena of the intermediate state not previously seen by other techniques may now be observed. Because still photographs do not demonstrate the full power of this method, motion pictures are more useful in recording the kinetic details; e.g., wall motions, annealing behavior of frozen-in flux, etc. The technique also facilitates studies involving both the magnitude and the direction of frozen-in moments (not feasible by powder techniques), supercooling phenomena and critical field determinations.

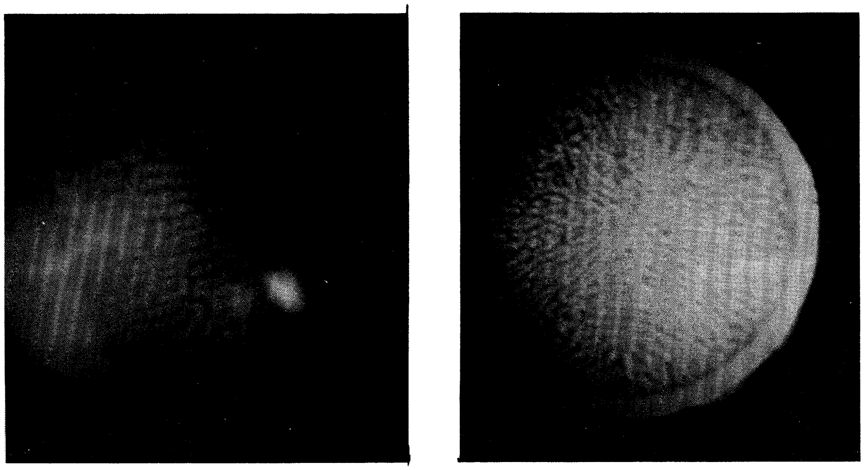
The success in the resolution (better than 0.2 mm) is due in part to the use of very thin glass (~0.25 mm thick). Photographs illustrating this are presented in Figs. 1 and 2. Light areas are normal and the dark regions are superconducting. The monochromatic light beam used (5451 A) was obtained from a Hg-arc source. The transverse magnetic field was provided by a superconducting niobium wire-wound solenoid.

Figure 1(a) shows the intermediate-state structure of a polycrystalline tantalum disk (7/8-inch diameter ×1/16 inch thick), cold-worked by compression after machining from a cast ingot. Figure 1(b) presents the intermediate-state pattern of a cold-rolled 7/8-inch diameter disk; the disk was cut from a polycrystalline tantalum sheet 0.009 inch thick produced by cold-rolling of an "as cast" ingot of vacuum arc-melted tantalum. The residual resistance ratios of each of these two materials were comparable (i.e., $R_{273^\circ\mathrm{K}}/R_{4.2^\circ\mathrm{K}} = 12$). These patterns could be



(a) (b)

FIG. 1. (a) Intermediate-state pattern of a tantalum disk (cold-worked) at 1.46°K. $H_{\mathrm{applied}} = 460$ oersteds. ($H_c = 1060$ oersteds.) (b) Intermediate-state pattern of a thin tantalum disk (cold-rolled) at 1.52°K. $H_{\mathrm{applied}} = 164$ oersteds. ($H_c = 1030$ oersteds.)



(a) (b)

FIG. 2. (a) Nonequilibrium pattern obtained on a rectangular plate of single-crystal zone-refined tin 10 minutes after transverse field had been slowly reduced from 222 oersteds to 32 oersteds at $T = 1.46^\circ$K. Pattern changes with time. ($H_c = 215$ oersteds.) (b) Nonequilibrium pattern obtained on a polycrystalline tin disk 21 minutes after transverse field had been reduced from 325 oersteds to 58 oersteds at $T = 1.40^\circ$K. Pattern changes with time. ($H_c = 264$ oersteds.)

altered by subsequent heat treatments which were also accompanied by decreases in critical field. Irregular patterns similar to Fig. 1(b) have also been observed for a cold-rolled sheet of niobium. In each of these observations, as the field is raised slowly and uniformly from zero to its critical value, large and irregular-shaped normal domains appear very suddently [see Fig. 1(a) and 1(b)]. These abrupt jumps of domain walls are similar to those observed by Schawlow[3] on a polycrystalline sample of vanadium and on a cold-worked sample of rhenium recently reported by Schawlow et. al.[7] with superconducting powder techniques. Experiments to elucidate the nature of these boundary motions are now in progress.

Figure 2(a) shows a domain pattern (nonequilibrium) evident in a zone-refined unstrained single crystal of tin (rectangular flat plate 1/2 inch × 1/2 inch × 7/8 inch) about 10 minutes after the applied field had been reduced from slightly above the critical field ($H_C = 215$ oersteds) down to about 32 oersteds at 1.46°K. To reduce the field abruptly to zero would result in similar patterns, appearing in a shorter time and annealing more rapidly; they, therefore, do not photograph as well. The corrugated pattern in Fig. 2(a) is similar, though not identical, to those observed by Balashova and Sharvin[5] on less pure monocrystalline tin spheres. Their observations were made at somewhat higher temperatures but were reported to have been made under equilibrium conditions. Equilibrium patterns of the intermediate state, in our case, reveal, for applied fields greater than about 150 oersteds, a single normal domain surrounded by a border area that is superconducting. The inner boundary of this area seems to move out uniformly with increasing applied field. The magnetic lines, presumably, pass through the superconducting area in small, unobservable channels. The details of these equilibrium patterns are not similar to Schawlow and Devlin's[8] observations on pure tin crystals, although the macroscopic anisotropic kinetic effects with increase in field observed by us are similar to their results.

Figure 2(b) shows another nonequilibrium pattern for a polycrystalline (1 mm average grain size) disk of tin (7/8-inch diameter × 0.270 inch). The sample was made from an ingot supplied by the Vulcan Detinning Company and listed as "extra pure fine grade" containing 0.0003% lead and 0.0001% iron. These patterns are similar to those reported by Schawlow[3]; however, details on their growth and annealing behavior have not been observed before.

Frozen-in flux has also been resolved in zone-refined single crystals of lead both in a strained and unstrained condition. The patterns are different in each case.

Details of the experimental technique and of the various results will be presented elsewhere.

The author has benefitted from discussions with many associates, in particular, with R. H. Pry for his suggestions and encouragement in the use of the glass and with C. P. Bean. He is indebted to D. T. F. Marple and S. Roberts for suggestions on the optical system. K. T. Aust and J. W. Rutter were kind enough to supply him with the various single crystals. W. A. Healy capably assisted in the experimental work.

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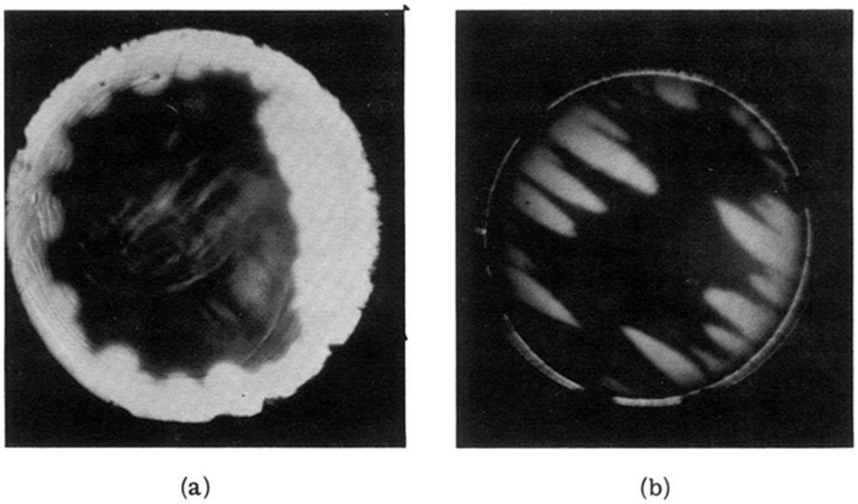
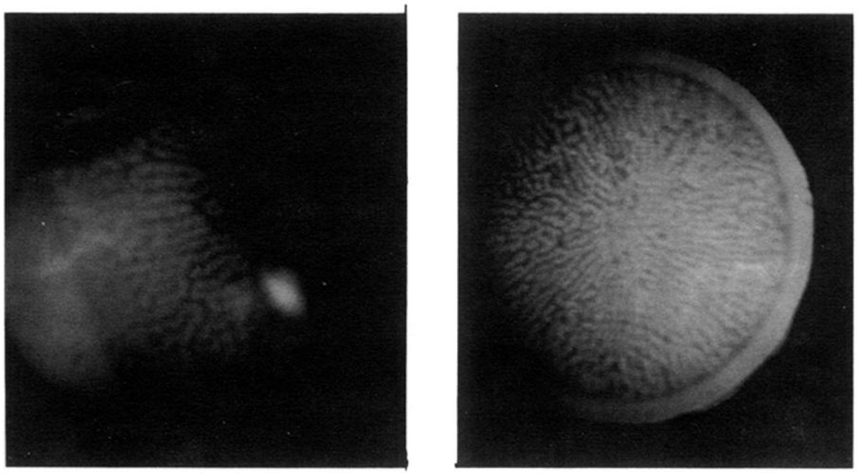

(a) (b)

FIG. 2. (a) Nonequilibrium pattern obtained on a rectangular plate of single-crystal zone-refined tin 10 minutes after transverse field had been slowly reduced from 222 oersteds to 32 oersteds at $T = 1.46°\mathrm{K}$. Pattern changes with time. ($H_C = 215$ oersteds.) (b) Nonequilibrium pattern obtained on a polycrystalline tin disk 21 minutes after transverse field had been reduced from 325 oersteds to 58 oersteds at $T = 1.40°\mathrm{K}$. Pattern changes with time. ($H_C = 264$ oersteds.)



(a)

(b)