FISK-MD 54-0045

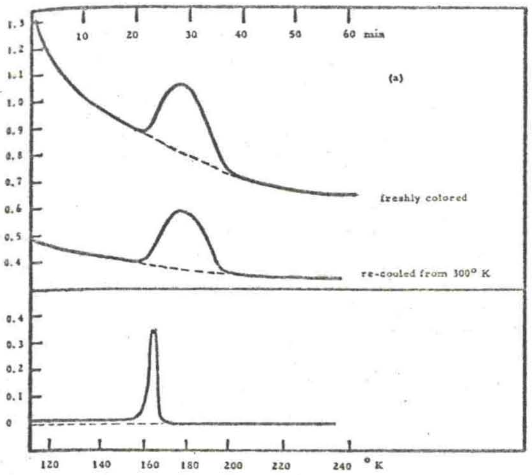

FIG. 1. F and V_1 absorption during warming after optical bleaching at 113°K.

a steep drop in the "F-absorption glow curve," i.e., the curve giving the absorption in the maximum of the F band as a function of time or temperature during gradual warming of the crystals. The unstable centers are removed by raising the crystal to room temperature so that the absorption glow curve obtained after recooling to 113°K shows only a slight fall entirely explained by the broadening and shift of the maximum of the F band with rising temperature.

Optical bleaching by F irradiation occurs at 113°K with a saturation value of 30 percent of the F centers bleached, and is followed by a partial recovery in the dark in which up to $\frac{1}{3}$ of the bleached F centers reappear within about 10 minutes. The effects are similar to those reported by Markham, Platt, and Mador[1] on x-rayed KBr at 78°K. But their explanation of the recovery in terms of a dissociation of F' centers cannot apply in our case where F irradiation has been found to reduce and not to enhance the F' band. Instead, we believe that the recovery is connected with a narrow (0.17 ev) absorption band at 8750A which we have found to appear during optical F bleaching.

The result of main interest concerns a large-scale restoration phenomenon which occurs if the crystals are first bleached at 113°K by F irradiation and then slowly warmed in the dark (2.3°K per min). The F-absorption glow curves observed under these conditions for a virgin crystal and a crystal recooled from room temperature (Fig. 1(a)) show a large peak around 175°K superimposed on the normal absorption glow curves discussed above. This means that F centers are temporarily recreated and subsequently bleached thermally. The thermal bleaching can be

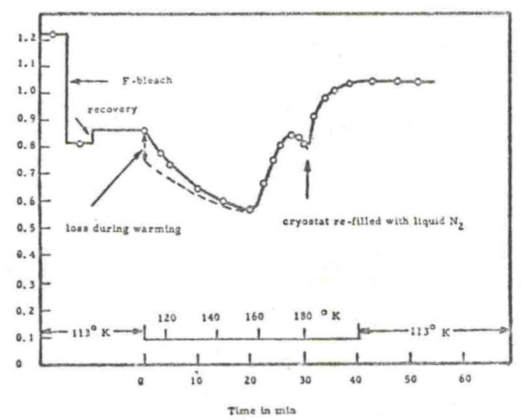

FIG. 2. Restoration of optically bleached F centers by warming and recooling.

prevented and the restored absorption be arrested by rapid recooling from a temperature near the restoration peak (Fig. 2). It is seen that nearly all the optically bleached F centers can be regained by this procedure.

Even more remarkable is the fact that simultaneously with the F centers, V_1 centers are recreated as revealed by a sharp peak in the absorption glow curve obtained by observing the absorption in the maximum of the V_1 band during warming. The curve shown in Fig. 1(b) refers to a crystal recooled from room temperature so that at the beginning of the experiment it did not contain any V_1 centers but only more stable higher V centers. The fact that the peak occurs slightly below that for the F centers and is very much sharper implies a very short lifetime of the restored V_1 centers in accordance with their low dissociation temperature of 128°K as observed by Dutton and Maurer.[2] It appears very significant that the height of the V_1 restoration peak, representing only a fraction of the total number of transient V_1 centers involved, is about twice as large as the height of the original V_1 band present in the crystals immediately after x-raying.

In explanation of the effects described we offer the following tentative suggestions: Crystals x-rayed at low temperature contain a large number of positive holes in so far optically unidentified V_x centers. Electrons released by F irradiation are trapped at these centers to form complex metastable centers (possibly associated with the peak at 8750A) which on breakup by thermal activation yield unstable F centers and V_1 centers in close proximity to each other.

* 1953–1954 at Duke University, Durham, North Carolina.

[1] Markham, Platt, and Mador, Phys. Rev. 92, 597 (1933).
[2] D. Dutton and R. Maurer, Phys. Rev. 90, 126 (1953).

Effect of Hydrostatic Pressure on the Superconducting Transition of Tin and Thallium

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THE dependence on pressure of the magnetic threshold field of superconductivity has been measured for tin and for thallium for pressures transmittable by liquid helium. The experimental technique consisted of measuring the difference of the threshold fields of two similar ellipsoidal single crystals at the same temperature. The pressure on one ellipsoid was held fixed while the pressure on the other was varied by means of tank helium gas. The transition was followed by means of 60-cycle ac susceptibility measurements.

The summary of results to date on tin and thallium is given in Table I, which contains a review of previous determinations of the pressure coefficients. The values for tin marked by asterisks are deduced from data on wires in tension, in which the hydrostatic stress is one-third the tensile stress for isotropic materials. The rather good agreement among the tin data between the pressure coefficients directly measured in hydrostatic experiments and those deduced from wire straining suggests that in the latter the shear components have a small or negligible effect on the superconducting transition in tin. This speculation is now being checked with a thin-walled tin cylinder stressed in pure shear.

No ready explanation is at hand for reconciling the results of the present work on thallium and those of Kan, Lazarev, and Sudovstov[1] with those recently reported by Chester and Jones,[2] differing as they do in both magnitude and sign. The technique employed by Chester and Jones results in massive plastic deformation at room temperature while that used by Kan *et al.* may produce some plastic deformation near the ice point. To examine the effects of mild plastic deformation, an ellipsoid was machined from a single crystal twisted 180° over the 1.2-cm length of the ellipsoid. The threshold curve and pressure coefficient for this sample were the same as for the undeformed crystal.

Bridgman's phase diagram[3] shows that only α thallium (h.c.p.) should be expected in these experiments. However, quenched β thallium (f.c.c.) is stable at room temperature.[4] An elongated specimen selected from particles produced by pouring molten thallium into liquid nitrogen had the same characteristics as previous samples.

TABLE I. Summary of data on the effect of hydrostatic pressure on the superconducting transition of tin and thallium.[a]

Authors	Pressure (atmos)	ΔT_c (°K)	$(\Delta T_c/\Delta P)\times 10^5$ deg atmos^{-1}
	For tin		
Sizoo and Onnes[b]	95	−0.0027	−3
	82[c]	−0.007	−8.6[c]
Alekseyevsky[d]	21[c]	−0.001	−5
Kan, Lazarev, and Sudovstov[e]	1730	−0.10	−5.8
Chester and Jones[f]	11 500	−0.52	−4.3
	17 500	−0.8	−4.5
Grenier, Spöndlin, and Squire[g]	60[c]	−0.0034	−5.5[c]
Present work	<115		−4.9±0.5
	For thallium		
Kan, Lazarev, and Sudovstov[h]	1370	0.008	0.6
	1730	0.025	1.4
Chester and Jones[f]	13 400	−0.06	−0.4
Present work	<48		1.3±0.2

[a] Presented at the Third International Conference on Low Temperature Physics and Chemistry, Houston, Texas, December 17, 1953.
[b] G. J. Sizoo and K. Onnes, Leiden Comm. No. 180b (1925).
[c] Hydrostatic value deduced from tensile stress.
[d] N. E. Alekseyevsky, J. Exptl. Theoret. Phys. (U.S.S.R.) 10, 746 (1940).
[e] Kan, Lazarev, and Sudovstov, Doklady Akad. Nauk. 69, 173 (1949).
[f] See reference 2.
[g] Grenier, Spöndlin, and Squire, Physica 19, 833 (1953).
[h] See reference 1.

These measurements, which will be reported in detail later, are being continued on specimens for which the crystal structure is known, using apparatus permitting appreciable increased accuracy of determination of the pressure coefficients at zero pressure.

[1] Kan, Lazarev, and Sudovstov, J. Exptl. Theoret. Phys. (U.S.S.R.) 18, 825 (1948).
[2] P. F. Chester and G. O. Jones, Phil. Mag. 44, 1281 (1953).
[3] P. W. Bridgman, Phys. Rev. 48, 893 (1935).
[4] S. Sekito, Z. Krist. 74, 189 (1930).

Resistivity Changes in Copper, Silver, and Gold Produced by Deuteron Irradiation Near 10°K*

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PREVIOUS research[1,2] on various metals indicates that radiation damage introduced near liquid nitrogen temperature will anneal when held at the irradiation temperature. The present experiment was designed to obtain damaged specimens in which no thermally activated motion of the lattice defects occurs during irradiation.

99.97±0.02 percent pure wires of copper, silver, and gold were irradiated with 12-Mev deuterons. The wire diameters were 5 mils for the copper and silver and 4 mils for the gold. The maximum temperature during bombardment was 12°K for the first run and 16°K for the second. Even though the temperature difference was small, the resistivity *versus* deuteron flux curves for the second run all lie slightly below those of the first.

TABLE I. Radiation-induced resistivity increases, in units of 10^{-7} ohm cm, after a flux of 10^{17} deuterons/cm^2.

Point	Copper	Silver	Gold
A extrapolating initial 12°K slope	2.3	2.6	3.8
B (observed 12°K value)	1.9	2.0	3.1
C extrapolating initial 135°K slope	0.9	1.4	2.6
D (observed 135°K value)	0.6	1.0	1.9

If the initial slope of the resistivity *versus* flux curves was valid up to large flux, the resistivity increases produced in copper, silver, and gold after 10^{17} deuterons per cm^2 would be those given as point *A* in Table I. However a slight decrease in slope does occur, and the observed increases are those denoted as point *B*. These changes are to be compared with the point *C* and *D* values obtained[1] with 12-Mev deuteron irradiation at 135°K, where point *C* represents the values obtained by extrapolating the initial slope to a flux of 10^{17} deuterons/cm^2 and point *D* the observed values for this flux.

After bombardment the specimens were allowed to warm, first to liquid nitrogen temperature and then to room temperature. The warmup rate was between 15 and 30°C per hour. The annealing out of damage during warmup was obtained by using a similar unbombarded specimen in a Wheatstone bridge circuit[2] so that the resistivity introduced by thermal oscillations can be eliminated if the two specimens are at the same temperature. Corrections for temperature differences of specimen and dummy were obtained by comparison with warmups made before irradiation and after annealing to room temperature.

On holding for 48 hours at or slightly below the bombardment temperature, no change in resistivity (i.e., to ±0.1 percent) was observed. In copper and silver, abrupt drops in resistivity indicated that some rather unique annealing process occurred at about 40°K and 30°K, respectively. In gold no large low-temperature drops were found. The first two rows in Table II indicate the magnitude of these processes and the third gives the percentage left after annealing to liquid nitrogen. Two possible processes that may explain these abrupt recoveries are the motion of interstitial atoms, which Huntington[3] calculated would have an activation energy in the range 0.07 to 0.24 ev, or the recombination of very close interstitial-vacancy pairs as suggested previously.[1,2]

TABLE II. Percentage of initial resistivity increase remaining after annealing to various temperatures.

Annealing temperature	Copper	Silver	Gold
35°K	90	78	97
45°K	50	77	93
77°K	41	69	86
220°K	25	32	55
300°K	7	10	10

A gradual decrease occurs in all three materials during the warmup to 220°K and then a more rapid process becomes important.[1,2] The latter process is complete at about 255°K in copper, at approximately 240°K in silver, and at roughly 285°K in gold. The percentage remaining at both 220°K and 300°K is given in Table II.

We would like to thank Dr. W. K. Jentschke and the cyclotron group as well as Dr. D. E. Mapother and the cryogenics group for aid and assistance. In addition we would like to thank Mr. Frank Witt for the cryostat design.

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[1] Marx, Cooper, and Henderson, Phys. Rev. 88, 106 (1952).
[2] A. W. Overhauser, Phys. Rev. 90, 393 (1953).
[3] H. B. Huntington, Phys. Rev. 91, 1092 (1953).

Line-Narrowing by Macroscopic Motion

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THE investigation of nuclear magnetism often demands extremely high resolution. A notable example is furnished by the structure in the groups of proton resonance lines discovered by Arnold and Packard.[1] The separation of the three components of