RESISTIVITY EVIDENCE FOR A PHASE TRANSFORMATION IN "β-TUNGSTEN" TYPE SUPERCONDUCTORS

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Batterman and Barrett[1] have discovered by means of x rays a martensitic transformation in V_3Si. In the same temperature range where this transformation was discovered, an anomaly in the curve of resistivity versus temperature has now been observed. An example of such an anomalous jump in the resistivity is shown in Fig. 1 for a single crystal of V_3Si [ρ(room temp)/ρ(20.4°K) = 20]. The temperature of this resistivity anomaly falls within the range of temperature over which the change from the cubic β-tungsten structure to the tetragonal structure was found by x rays. It seems therefore that the jump in resistivity can be taken as evidence for the martensitic transformation. Using high-sensitivity resistivity measurements, similar resistivity anomalies were found in several other β-tungsten type superconductors, suggesting that this martensitic transformation may be a general property of the A-15 type superconductors. It was further established for every V_3X superconductor (where X = Si, Ga, Ge, and Sn) that T_m (martensitic transition temperature) $\simeq 1.5T_c$ (superconducting transition temperature).

Besides the anomalous jump shown in Fig. 1, a similar anomaly was found at 28.5°K in another V_3Si single crystal [ρ(room temp)/ρ(20.4°K) = 8.4] and at 26.5°K in an arc-cast V_3Si polycrystal [ρ(room temp)/ρ(20.4°K) = 20.7]. A 600 000Å thick film of V_3Si and a 50 000Å film of V_3Si produced by the hydrogen reduction of mixed chlorides also displayed a jump in resistivity at, respectively, 28 and 23.5°K.[2] The phenomenon seems to be a property of the V_3Si structure as it is independent of the method of production of the samples. The spread in the transition temperature from 23.5 to 28.6°K could very well be due to the different states of strain or degree of imperfections of the various samples, as it is a well-known fact that martensitic transformation temperatures are sensitive to many such factors.

A resistivity versus temperature curve was obtained for the following compounds: V_3Ga, V_3Ge, and V_3Sn, and the results are listed in Table I. As can be seen from this table, the ratio T_m/T_c is approximately equal to 1.5 for all V_3X compounds. This would suggest that the same phenomenon is responsible for superconductivity and for the martensitic transformation. The ratio could, of course, be different for other A-15 compounds, such as the Nb_3X's, for example. Furthermore, this relationship between T_m and T_c should not be taken to imply that T_m and T_c cannot be changed independently. For example, strain may have a much larger effect on T_m than on T_c. On the other hand, a magnetic field of 17.4 kG was applied on the V_3Ge sample depressing T_c from 6.9°K to 4.77°K, while T_m only changed from 10°K to 9.6°K and the jump in resistivity at T_m was essentially unchanged. (As T_m scatters slightly from experiment to experiment, the change in T_m with magnetic field is not significant.) The relationship between T_m and T_c can therefore only apply to a strain-free single crystal in the absence of external current or magnetic field. The interdependence of T_c and T_m could, for example, arise from a strong anisotropic electron-phonon interaction which would yield a high superconducting transition temperature and a lattice instability

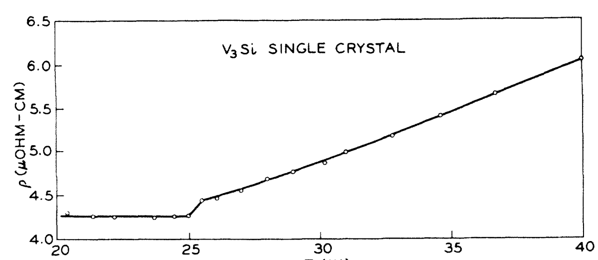

FIG. 1. Resistivity of a V_3Si single crystal as a function of temperature.

Table I. Superconducting and martensitic transition temperatures for some A-15 type superconductors.

	T_c (°K)	T_m (°K)	T_m/T_c
V_3Si	16.8	23.5-28.6	1.4-1.7
V_3Ga	14.1	20.6	1.5
V_3Ge	6.9	10.0	1.45
V_3Sn	3.7	5.4	1.46
Nb_3Sn	18.0	36.0	2.0

leading to a structure change. Furthermore, as a resistivity anomaly has been observed in Nb_3Sn at 36°K, this could lead one to suppose that the martensitic transformation is characteristic of most superconducting A-15 type compounds.

In conclusion, it has been shown that a resistivity jump occurs at approximately the temperature where the martensitic transformation was observed by x rays. This anomaly was observed in several A-15 type superconducting compounds and a relationship seems to exist between the martensitic transformation and superconductivity. One must, however, keep in mind that certain factors could affect superconductivity without affecting the phase transformation.

I would like to thank E. S. Greiner for the V_3Si single crystals, W. H. Haemmerle for his help in obtaining the data, and D. Dorsi for preparing some of the compounds.

[1]B. W. Batterman and C. S. Barrett, Phys. Rev. Letters 13, 390 (1964).

[2]These films have been fully discussed in the following two papers: J. J. Hauser, Phys. Rev. Letters 9, 423 (1962); J. J. Hauser and H. C. Theuerer, Phys. Rev. 129, 103 (1963).

FERROMAGNETIC RESONANCE ABSORPTION LINEWIDTH OF NICKEL METAL. EVIDENCE FOR LANDAU-LIFSHITZ DAMPING

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This Letter describes the observation of the narrowest resonance absorption linewidth yet reported for metallic nickel single crystals at 9 kMc/sec. In addition to this observation, an analysis, based upon the temperature and frequency dependence of the resonance, shows that the "exchange conductivity" linewidth mechanism of Ament and Rado[1] is operative in the samples of this study although not dominant as in the case of iron "whiskers" previously reported.[2] In the present study it is found that a damping mechanism is required and although the physical origin of this linewidth contribution is unclear, it seems to be accurately characterized by the Landau-Lifshitz[3] phenomenological relaxation frequency, λ, which enters the macroscopic torque equation as

$$d\vec{M}/dt = \gamma\vec{M}\times\vec{H} - (\lambda/M^2)\vec{M}\times(\vec{M}\times\vec{H}). \qquad (1)$$

This is a remarkable result since the form of the term comes simply from the expansion of $d\vec{M}/dt$ into the three orthogonal coordinates: $\vec{M}$, $\vec{M}\times\vec{H}$, and $\vec{M}\times(\vec{M}\times\vec{H})$. The first term vanishes with the requirement that M be a constant of the motion, the second gives the resonance condition, and the third describes the breadth of the resonance line in the absence of exchange effects.

The samples used in these experiments were very small (e.g., a millimeter in extent and a micron thick) single crystals of nickel [both of "whisker" (filament) and platelet geometry]. These samples were grown by the hydrogen reduction of nickel bromide and very generously supplied by Dr. R. W. DeBlois of this Laboratory. The samples are first selected for optical qualities, i.e., specular surfaces with no obvious imperfections, and are then examined at 9.2 kMc/sec at 25°C and selected for sharpness of resonance absorption. From a few hundred considered visually, about 50 samples were chosen and of these about 25 had linewidths under 150 oersteds (i.e., the field separation between inflection points of the absorbed microwave power vs magnetic field; both rf and dc magnetic fields lie in the sample surface). Most of the selected group had widths of 130 oersteds but the narrowest of the group had a 114-oersted linewidth, this being roughly 25% of the width usually observed for bulk metallic nickel at this frequency and temperature. The resonance lines here reported have a characteristic asymmetry that serves as a "thumb print" to indicate the presence of the inhomogenous broadening that results from the limited penetration of the rf fields by the metallic conductivity, coupled with the variation in the penetration depth as the resonance is traversed. The latter effect results from the field-dependent permeability, i.e., the resonance itself. If, for a moment, we neglect damping, this exchange-conductivity mechanism predicts for nickel at 9.2 kMc/sec, 25°C, and using an exchange stiffness, A, of 1×10^{-6} erg/cm a linewidth of 37 oersteds for unpinned surface spins. This value would be increased to 90 oersteds if