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FLUCTUATION PAIR CONDUCTIVITY IN DISORDERED SUPERCONDUCTING TRANSITION METAL FILMS*

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ABSTRACT

Curie-Weiss behavior is observed for the fluctuation conductivity of superconducting transition metal films above T_c. Resistive transition widths are larger than predicted by Aslamazov-Larkin theory.

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Fluctuation conductivity has been studied extensively in non-transition metal superconductors.[1-4] The most consistent results have been obtained on vapor-quench deposited films measured in situ.[5] We have measured the pair conductivity of a number of 5-d transition metal films prepared by electron beam evaporation onto sapphire substrates cooled to 4°K. Chamber pressure during evaporation was kept well below 10^{-6} torr. Measurements on the films, which were fine-grained or amorphous, were done in situ.

The fluctuation conductivity, σ', displayed a Curie-Weiss dependence on the temperature:

$$\frac{\sigma'}{\sigma_n} = \frac{R_n^s\, g}{\tau}$$

where R_n^s is the normal state sheet resistance, σ_n is the normal state conductivity, $\tau = (T-T_c)/T_c$, and g is the width parameter. The values of g range from two to three times the Aslamazov-Larkin[6] value of $1.52\times10^{-5}\Omega^{-1}$; the alloy films display the larger widths. Results are summarized in Table I; the critical temperature of amorphous transition metal films will be discussed elsewhere.[7] Figure I displays σ_n/σ' plotted as a function of T for a tungsten film. R_n^s was measured well above the transition and was reasonably constant at higher temperatures, indicating that activated conduction was not taking place[8] and that R_n^s could be considered a constant without affecting the data analysis.

R_n^s, T_c and the product, gR_n^s were used in a three parameter fit of the transition, $R^s = R_n^s\, \tau/(\tau + gR_n^s)$.[5] Only data which originally appeared to fall on a straight line in a plot of σ_n/σ' as a function of T reduced from the raw data were used in the fit; typically τ ranged from .01 to .04 in this region where the Curie-Weiss behavior was obvious.

The values of g were derived by dividing out the measured R_n^s from gR_n^s.

The larger values of g obtained for the alloy films may indicate that compositional inhomogeneities and resultant spreads in critical temperatures caused some of the broadening of the transitions in these films.

Still unexplained are the extra widths observed in the pure tungsten and rhenium films. The edges of the film were defined by a mask, so that thickness variation across the sample may give rise to broadening. However the critical temperature of the films declines with thickness so this possibility is unlikely.[5] Strain broadening may also cause the large values of g.[9] The consistency of the data and the fact that the films were deposited at 4°K tend to refute this argument.

Broadening due to the anomalous Maki-Thompson mechanism[10,11] cannot be ruled out completely, as it gives the same type of behavior, although it should be of minor consequence in amorphous films.[12]

The thicker films display a sharpening of the transition at several hundredths of a degree above the critical temperature used to fit the data, as shown in Fig. I. Disordered lead films which yielded values of g in close agreement with the A-L value, also showed this sharpening.

We note that the transition between the two and three dimensional regimes should in principle be easier to observe in transition metals: the BCS coherence length ξ_o, which enters into the expression for the Ginzberg-Landau coherence length for dirty superconductors near T_c, $\xi = 0.85(\xi_o l)^{1/2}/\tau^{1/2}$, is an order of magnitude smaller for transition metals. Hence the condition for the change from the two dimensional regime to the three dimensional regime, $d \sim \xi$ will occur closer to T_c for transition metal films compared to non-transition metal films with

the same mean free path, l, and thickness, d. The sheet resistances of our films indicate mean free paths comparable to amorphous non-transition metal films; the break in the resistive transition occurs at temperatures too small to be consistent with $d \sim \xi$, however. The onset of the critical region is a more likely explanation for the sharpening of the transition.

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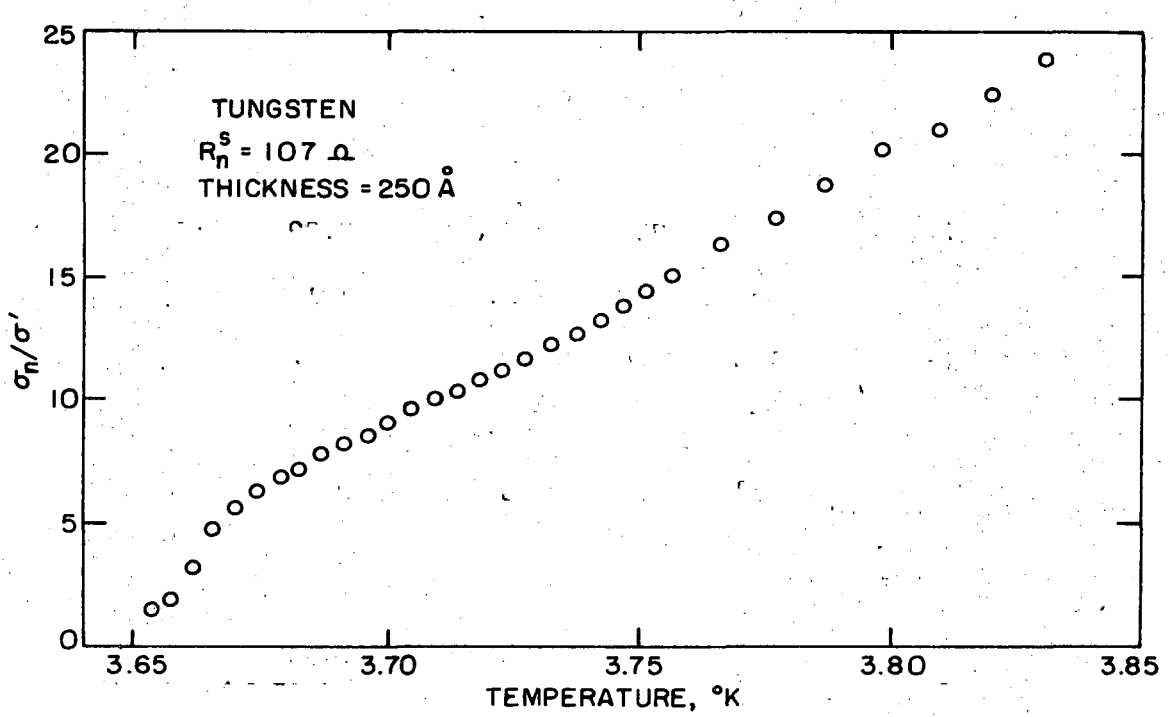

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Fig. 1

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