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Fluctuation Effects on the Thermal Conductivity of "One-Dimensional" Superconductors*

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Thermal-conductivity measurements have been made on wires of Pb–5-at.% In prepared by evaporation. The cross-sectional area of these wires determined in part by electron microscopy is less than ξ^2, where ξ is the coherence length, and thus they can be considered "one-dimensional" superconductors. A well-defined peak in the thermal conductivity has been found over a restricted range of temperature close to the bulk T_c and we attribute this to fluctuation effects on the normal component of the electronic conduction. The qualitative aspects of our results agree quite well with a recent prediction of Abrahams, Redi, and Woo.

In recent years there has been great interest in the field of fluctuation effects on the properties of superconductors near their critical temperature. Almost all of the activity to date has been concerned with the rounding of the resistive transition near T_c due to fluctuations in the superconducting order

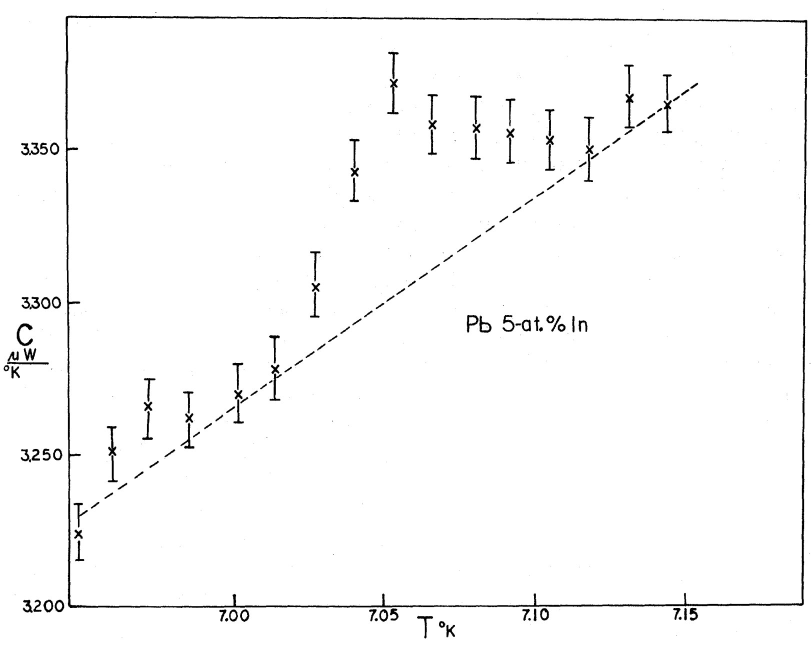

FIG. 1. Thermal conductance C plotted against temperature T for the sample with the largest cross-sectional area. The dotted line represents the conductance in a quenching magnetic field.

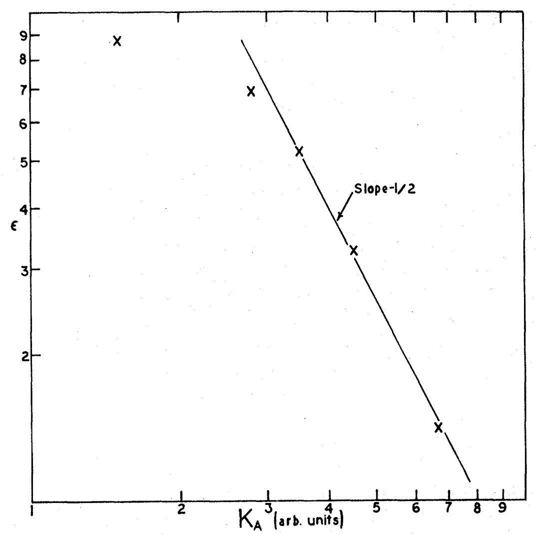

FIG. 2. Anomalous conductance K_A plotted against $\epsilon = \ln T/T_c \approx (T-T_c)/T_c$ for the same sample depicted in Fig. 1. The solid line has a slope of $-\frac{1}{2}$.

parameter.

We report here the first measurements of fluctuation effects on the thermal conductivity of a "one-dimensional" superconductor.[1] The thermal conductivity of evaporated wires of Pb–5-at.% In with cross-sectional areas less than 10^{-10} cm^2 was measured as a function of temperature near the bulk T_c of the alloy. These wires were prepared by shadow casting on a diffraction grating substate. The substrate was a 0.001-in.-thick acetate solvent casting of an instrument quality diffraction grating.[2] The sawtooth nature of the diffraction grating and the grazing angle of incidence of the evaporating metal ensure a series of independent wires of fairly uniform cross-sectional area. The wire density on the substrate was 1200 per millimeter. The cross-sectional areas of the samples were determined indirectly by electron microscopy. The acetate substrate with the evaporated wires was stretched on a 0.005-in. Mylar frame for mechanical support. The thermometers were $\frac{1}{10}$-W Allen-Bradley carbon resistors of either 3000- or 1000-Ω room-temperature resistance. The sample heater was 500 Ω of No. 46 constantan wire wound noninductively. Our temperature resolution at 7 °K was 0.00003 °K.

Three samples have been measured to date all showing the characteristic peak in the thermal conductivity between 7 and 7.1 °K. Figure 1 shows the data on the sample whose wires had the largest cross-sectional area ($1 \pm 0.2 \times 10^{-10}$ cm^2). The data on this sample were the best since we had a very careful calibration of the carbon resistors and the drifts in the sample heater power were negligible. The dotted line represents the thermal conductance of the sample plus background when the sample superconductivity is quenched in a magnetic field. The anomalous conductance (points minus dotted line) has a maximum of about 2.0% of the total conductance of the sample plus substrate. A calculation of the relative conductances of wires and background indicates that the wires represent between 10 and 20% of the total conductance. Thus a 2.0% rise in the total conductance corresponds to a wire conductance rise of between 10% and 20%. This is in reasonable agreement with the calculation of Abrahams, Redi, and Woo[3] for such a sample. They predict a 7% rise 1 mdeg away from T_c for a sample with similar properties.

In Fig. 2 we have plotted the anomalous conductance versus $\epsilon = \ln T/T_c \approx (T-T_c)/T_c$ on a log-log plot. We have taken T_c to be the temperature corresponding to the maximum anomalous conductance. The solid line has been drawn with a slope of $-\frac{1}{2}$ which is the predicted[3] dependence of the conductance on ϵ. Notice that the four points closest to T_c fall very close to this line again in agreement with the theoretical prediction.

Further experiments on other properties of these wires will be undertaken in the near future.

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