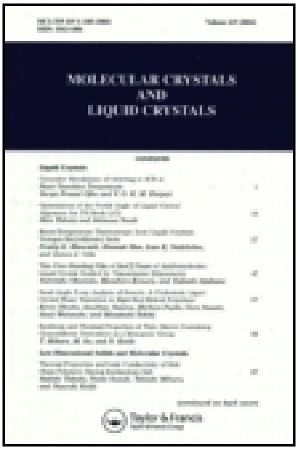

Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl16

Superconducting and Electrical Properties of $(Bedt\text{-}Ttf)_2I_3$ at Ambient Pressure

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Version of record first published: 17 Oct 2011.

Mol. Cryst. Liq. Cryst. 1985, Vol. 119, pp. 357-360
0026-8941/85/1194-0357/$10.00/0

SUPERCONDUCTING AND ELECTRICAL PROPERTIES OF $(BEDT\text{-}TTF)_2I_3$ AT AMBIENT PRESSURE

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Abstract Studies of the rf field penetration depths and electrical conductivity are described for the sulfur-based ambient pressure organic superconductor $(BEDT\text{-}TTF)_2I_3$.

INTRODUCTION

The organic charge-transfer salt $(BEDT\text{-}TTF)_2I_3$, derived from the organic donor bis(ethylenedithio)tetrathiafulvalene, is the first ambient pressure S-based organic superconductor. Until very recently,[1] this material was the only known ambient pressure organic superconductor beyond the Se-based salt $(TMTSF)_2ClO_4$. The existence of superconductivity in $(BEDT\text{-}TTF)_2I_3$ [abbreviated as $(ET)_2I_3$] was first reported in 1984 by Yagubskii et al.[2] In this article, we briefly describe the results of rf penetration depth measurements and four-lead conductivity measurements on crystals of $(ET)_2I_3$ (space group $P\bar{1}$, Z = 1). Details of the electrocrystallization and crystallographic structure of these crystals are given elsewhere.[3]

PENETRATION DEPTH MEASUREMENTS

In rf penetration depth measurements, one detects the onset of superconductivity by the increase in rf resonant frequency of an LC circuit due to exclusion of the rf field by the Meissner currents (persistent shielding currents) induced in a superconductor suspended in the coil. These inductive measurements provide a convenient and very sensitive method for determining the bulk superconducting transition temperature (T_c) without the use of attached leads. We have recently reported[4] the details of such measurements for $(ET)_2I_3$ which confirm the existence of superconductivity in triclinic crystals having both distorted hexagon and needle morphologies. We illustrate here for the first time a comparison between the superconducting transition curves for $(ET)_2I_3$ and $(TMTSF)_2ClO_4$ determined from the rf measurements.

Figure 1 shows the resonant frequency of the rf coil as a function of temperature for $(ET)_2I_3$ (distorted hexagon crystals) and $(TMTSF)_2ClO_4$ from 1.6 K to ~ 0.45 K, the lowest temperature achieved with the crystals immersed in pumped liquid He^3. The onset of superconductivity in $(ET)_2I_3$ is not clearly delineated due to the slow increase in frequency.

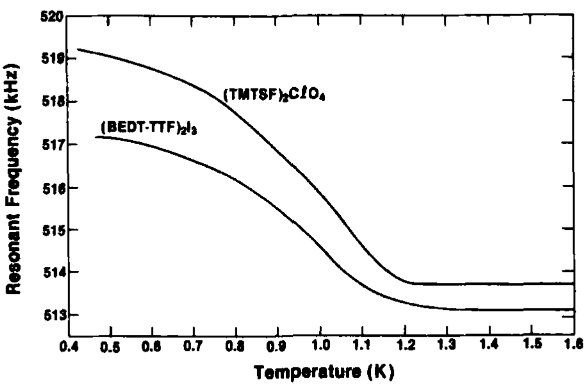

FIGURE 1
rf frequency vs temperature for $(ET)_2I_3$ and $(TMTSF)_2ClO_4$ in zero applied field.

Careful measurements with $(ET)_2I_3$ immersed in superfluid He^4, however, established the transition temperature (T_c) as 1.40 ± 0.02 K for both morphologies. The onset of superconductivity in slowly cooled (~ 0.5 K/m) $(TMTSF)_2ClO_4$ is more clearly indicated in the figure by a stronger increase in frequency below the transition temperature $T_c = 1.21 \pm 0.01$ K. The interesting feature for both samples, unlike typical metals, is the gradual transition to the superconducting state which remains incomplete down to ~ 0.45 K.

CONDUCTIVE MEASUREMENTS

Conductive measurements were carried out on the needle-shaped crystals of $(ET)_2I_3$ using the four-lead technique with low-frequency ac current (50 μA at ~ 37 Hz) and lock-in detection of the voltage drop along the needle axis (a-axis). The electrical leads consisted of fine gold wires attached to the crystal with gold conducting paste. Figure 2 shows the normalized resistivity (R_T/R_{300}) as a function of temperature from 300 K down to 1.3 K. The conductivity is clearly metallic throughout this range. The room temperature conductivity of this sample was extimated to be ~ 10 $ohm^{-1}cm^{-1}$. The conductivity ratio $\sigma_{4.2}/\sigma_{300}$ was found to be 425, which is comparable to that reported by Yagubskii et al.[2]

The inset diagram in Figure 2 illustrates the temperature region below 30 K on an enlarged temperature scale. This diagram shows marked changes in the slope of the resistivity near 8 K and 4 K, very similar to the data reported by Yagubskii et al. The resistivity decreases rapidly beginning at 1.55 K, but it does not drop to zero below 1.4 K, which is the temperature we obtained for the onset of bulk superconductivity from the rf measurements. In addition, the data of Yagubskii et al. show a rather broad conductive transition to the superconducting state, incomplete above 0.5 K, which is generally consistent with the broad transition obtained in our inductive measurements.

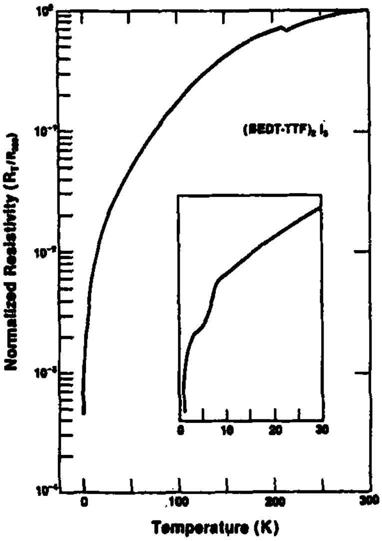

FIGURE 2 Resistivity vs temperature for a needle-shaped crystal of $(ET)_2I_3$.

Acknowledgment Work supported by the U.S. Department of Energy, Office of Basic Energy Sciences, Division of Materials Sciences, under Contract W-31-109-ENG-38.

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