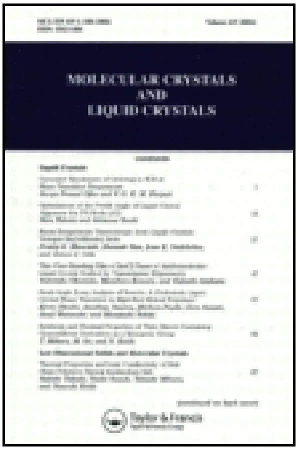

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Effect of uniaxial pressure in organic superconductor κ-(BEDT-TTF) 2 Cu(NCS) 2

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EFFECT OF UNIAXIAL PRESSURE IN ORGANIC SUPERCONDUCTOR κ-(BEDT-TTF)$_2$Cu(NCS)$_2$

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The effect of uniaxial pressure on the superconducting transition temperature, T_c, was studied in organic superconductor κ-(BEDT-TTF)$_2$Cu(NCS)$_2$. When the pressure was applied along the c-axis in the conducting $b-c$ plane, $\partial T_c/\partial p$

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was found to show a positive value. In other words, T_c increased by application of pressure, in contrast to other cases including the uniaxial pressure perpendicular to the conducting plane and the hydrostatic pressure. Detailed experimental studies on the temperature dependence of magnetization under uniaxial pressure using SQUID magnetometer are presented.

Keywords: organic superconductor; uniaxial pressure

INTRODUCTION

In most organic superconductors including κ-(BEDT-TTF)$_2$Cu(NCS)$_2$, the transition temperature (T_c) is suppressed by application of isotropic hydrostatic pressure. When their electronic structures are quasi-two dimensional, it is natural to expect that the effect of lattice parameter change on T_c would also be anisotropic, i.e. difference between in-plane and out-of-plane pressure effect should exist. The application of anisotropic pressure in quasi-two dimensional organic superconductor κ-(BEDT-TTF)$_2$Cu(NCS)$_2$ by direct application of uniaxial pressure in the direction perpendicular to the conducting $b-c$ plane [1] or application of tensile stress along the conducting $b-c$ plane [2] of single crystals were reported. Direct application of uniaxial stress along a needle-like single crystal of (DM-DCNQI)$_2$Cu was also reported [3]. Later, a more advanced method was invented, in which uniaxial pressure was applied indirectly after encapsulation of oriented crystals into epoxy [4].

In this work, we employed a new uniaxial strain method, recently developed by Maesato *et al.*, [5] which enables us to apply purely uniaxial strain without introducing any change in the lattice parameters in perpendicular directions due to Poisson's effect. We are studying the effect of uniaxial pressure on T_c in organic superconductors including κ-(BEDT-TTF)$_2$Cu(NCS)$_2$.

EXPERIMENT

A single crystal with typical dimensions $a \times b \times c = 0.3 \times 2 \times 0.8\,\text{mm}^3$ was encapsulated into epoxy to form a cylinder with diameter of 3 mm. It was oriented so that crystallographic c-axis, determined by polarized infrared reflectivity anisotropy, is parallel to the cylindrical axis along which a uniaxial pressure was applied. Then it was installed into a high-pressure clamp cell with a small diameter designed to fit into the Quantum Design SQUID magnetometer.[6] High pressures up to 3 kbar was applied at room temperature and clamped before loading into the SQUID magnetometer. The effective pressure at low temperature was calibrated by monitoring the

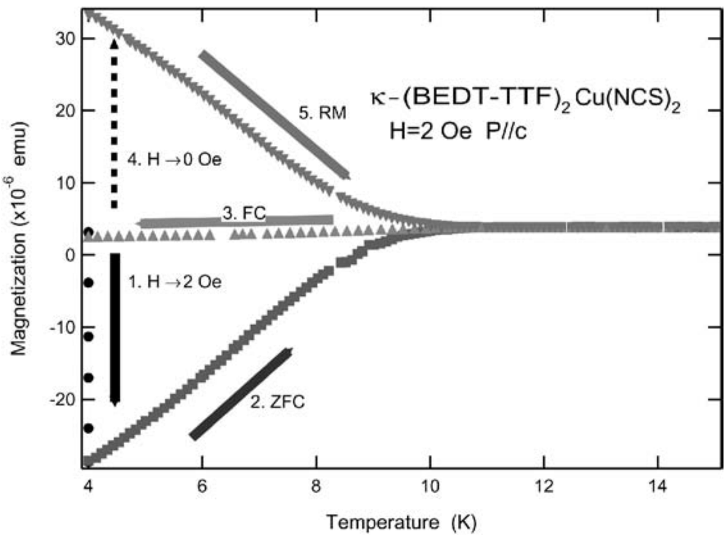

FIGURE 1 A typical magnetic temperature (T) – magnetic field (H) cycle of magnetization measurements. After cooling down with H = 0, (1) increase H from 0 to 2 Oe, (2) measure ZFC magnetization with increasing T at H = 2 Oe, (3) measure FC magnetization with decreasing T at H = 2 Oe, (4) decrease H to zero, (5) measure RM with increasing T at H = 0. (See color plate I)

superconducting transition of Sn located within the same pressure cell, using the known pressure dependence of T_c of Sn.

Figure 1 shows a typical magnetic field-temperature cycle of our magnetization measurements. First we cool our sample down to low temperature (4 K) without magnetic field and apply a small magnetic field (1–2 Oe) at low temperature. Then we start to measure the temperature dependence of zero-field-cooled (ZFC) magnetization with increasing the temperature. Next, we measure the temperature dependence of field-cooled (FC) magnetization with decreasing the temperature under the same magnetic field. Then we decrease the magnetic field to zero at low temperature and measure the temperature dependence of the remanent magnetization (RM) with increasing the temperature without magnetic field.

RESULTS AND DISCUSSION

Figure 2(a) shows typical temperature dependence of magnetization for ZFC and RM conditions under different uniaxial pressure. Both magnetic field and uniaxial pressure are applied along the *c*-axis. Figure 2(b) is a blow up of ZFC and RM magnetization near T_c to show the onset of the

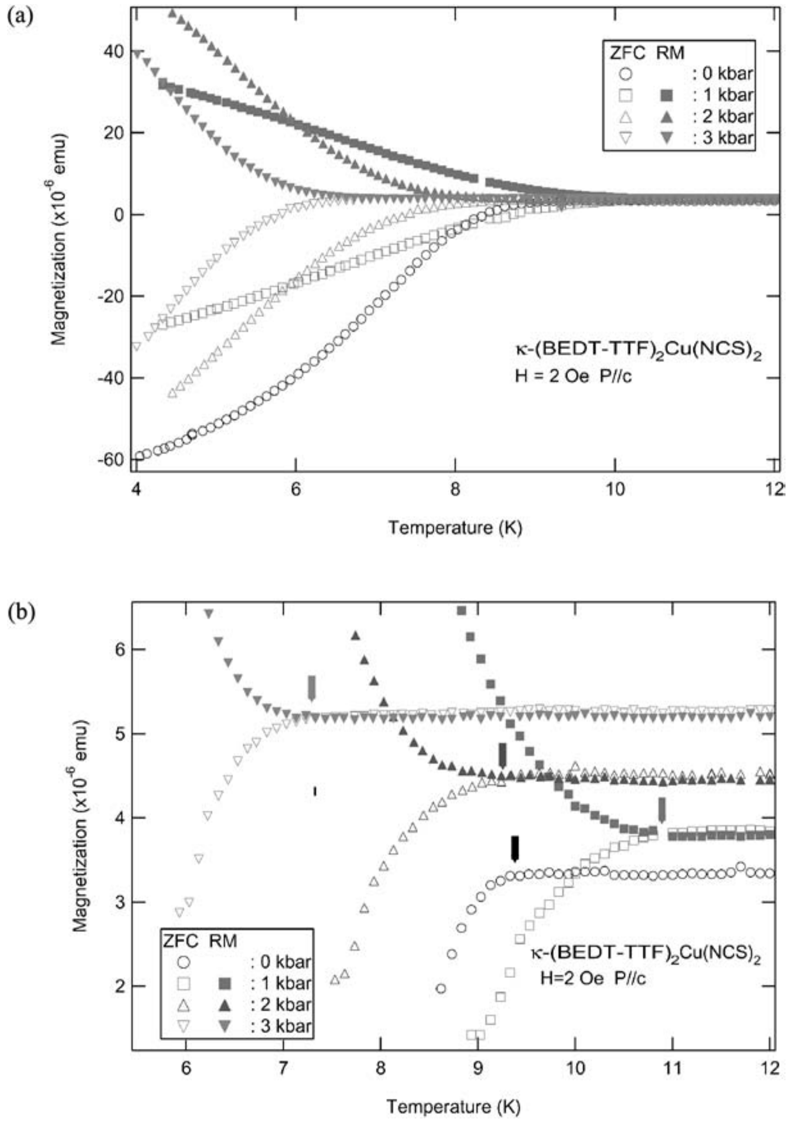

FIGURE 2 Temperature dependence of magnetization for ZFC and RM conditions. (a), above, shows an overall results, and (b), below, is a blowup to show the deviation between ZFC and RM signals near T_c. (See color plate II & III)

superconducting transition. In this paper, we define T_c as a temperature where two magnetization signals (ZFC and RM) start to deviate from each other as indicated as arrows in the figure. In Figure 3, T_c is plotted as a function of uniaxial pressure applied along the *c*-axis of the crystal. Although we don't have enough data points yet, it is clear that T_c initially shows an increase and then decrease at higher pressure.

The uniaxial pressure coefficient of T_c (dT_c/dp) can be determined from the results of high-resolution measurements of the thermal expansion coefficient, combined with the results of specific heat via the Ehrenfest relation. When uniaxial pressure is applied along the *c*-axis of κ-(BEDT-TTF)$_2$Cu(NCS)$_2$, the coefficient has a positive value of $dT_c/dp_c = +1.46$ K/kbar according to Kund et al., [7] while Lang et al., [8] reported a negative value of $dT_c/dp_c = -1.1$ K/kbar. Recently, a large positive value of $dT_c/dp_c = +3.44$ K/kbar is reported for deuterated κ-(BEDT-TTF)$_2$Cu(NCS)$_2$ by Muller et al. [9].

Our result in Figure 3 above, although a very crude and primitive one, clearly shows that the coefficient is positive in the low pressure region, consistent with Kund et al. [7] Difference from the recent result by Choi et al. [10] could partly be due to the difference in the pressurization method, namely, with or without Poisson's effect.

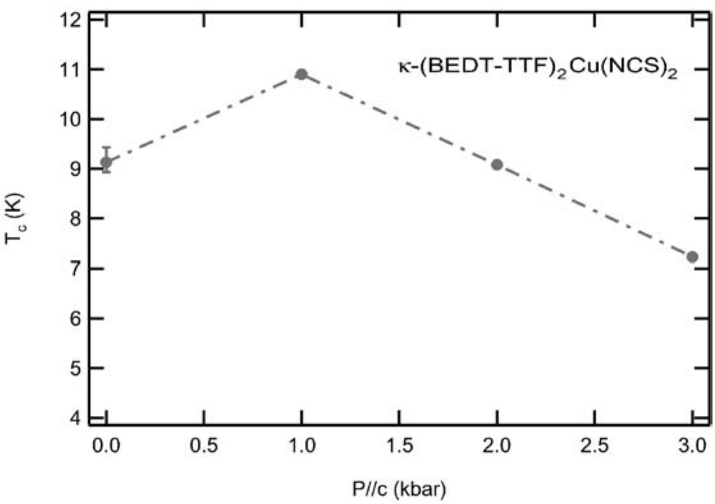

FIGURE 3 T_c as a function of uniaxial pressure applied along the *c*-axis of κ-(BEDT-TTF)$_2$Cu(NCS)$_2$. (See color plate IV)

SUMMARY

We have shown, in this very brief report of on-going investigations, that uniaxial pressure can increase T_c of a quasi-two dimensional organic superconductor when the pressure is applied along a direction in the conducting plane. We plan to perform further systematic studies on various organic superconductors including deuterated κ-(BEDT-TTF)$_2$Cu(NCS)$_2$ in order to search for the highest value of T_c.

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