Pressure-induced superconductivity with transition temperature exceeding 10 K in new organic conductor β'-(BEST)$_2$CuCl$_2$

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In the study of charge-transfer complexes obtained by combining organic molecules such as ET [ET: bis(ethylenedithio)tetrathiafulvalene] with inorganic anions, more than a hundred types of superconductors have been discovered [1]. Among them, β'-(ET)$_2$ICl$_2$ (hereafter β'-ICl$_2$) has the highest transition temperature among organic superconductors, T_c=14.2 K under ultrahigh pressures of 8.2 GPa [2]. Other organic superconductors that exceed the T_c of 10 K are limited to a few, such as the series of κ-type salts. Therefore, further developments of materials with higher T_c are desired. In this study, we synthesized a new charge-transfer salt β'-(BEST)$_2$CuCl$_2$ [BEST: bis(ethylenediseleno)tetrathiafulvalene] (hereafter β'-CuCl$_2$), and found superconductivity of this salt under high pressures.

Although the conduction layer of β'-CuCl$_2$ has a β'-type arrangement with strong dimerization, its molecular arrangement differs from that of β'-ICl$_2$ with respect to the displacement pattern along the long axis of donor molecules. Instead, its pattern is similar to that of the recently reported β'-(ET)$_2$CF$_3$CF$_2$SO$_3$ [3]. Due to this difference, the electronic state, including the band structure and magnetism, is very different from β'-ICl$_2$ exhibiting antiferromagnetic ordering. β'-CuCl$_2$ is a semiconductor that exhibits thermally active behavior with a gap size of 0.07 eV at ambient pressure. Magnetization measurements showed a sharp decrease in magnetic susceptibility below 20 K, and magnetic torque measurements revealed that the material does not magnetically order down to 2 K. From these results, we considered that the spin-singlet state is the most possible to explain the experimental results.

To investigate whether β'-CuCl$_2$ exhibit superconductivity as well as the pressure-induced superconductor β'-ICl$_2$, electrical resistance measurements under very high pressure were performed on β'-CuCl$_2$ using a cubic-anvil pressure cell (Fig. 1). Metallic behaviors were observed at low temperatures above 4 GPa, and at 5.5 GPa, we found superconductivity at T_c=10.4 K, as shown in the inset of Fig. 1. It is worth mentioning that, considering that the ground state of β'-CuCl$_2$ salt is different from that of β'-ICl$_2$, β'-CuCl$_2$ is the third superconductor beyond T_c=10 K, following the families of β'-type trihalide and κ-type salts. In the presentation, we will also present the results of first application of the palm cubic-anvil pressure cell to organic materials to measure the electrical resistance under multiple extreme conditions (9 T, 50 mK, 5.5 GPa).

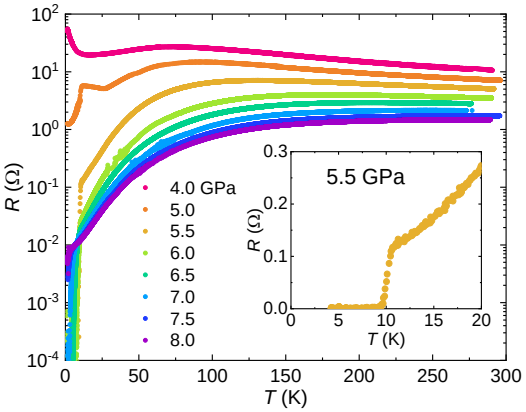

Fig. 1. Temperature dependence of resistance at various pressures obtained by palm cubic-anvil pressure cell. Pressures were calibrated at low temperatures. Inset shows the temperature dependence of resistance at 5.5 GPa.

References

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