Pressure Induced Phase Transition on Sr_{14}Cu_{24}O_{41} with Doped Two-Leg Cu-O Ladders

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Abstract: We measured electrical resistivity under hydrostatic pressure ($P \leq 8.5$ GPa) for single crystals of Sr_{14-x}Ca_xCu_{24}O_{41} ($x = 0-10$) and Sr_{13}Y_xCu_{24}O_{41}. The resistivity for $x = 0$, which shows activation-type insulating behavior at ambient pressure, becomes metallic above 8 GPa. At 5 GPa, the temperature dependence of this resistivity shows a feature suggestive of a CDW transition. This feature is not observed for both Ca- and Y-substituted compound. Superconductivity under pressure is seen only for $x \geq 10$. From these results, we have determined an $x$-$P$ phase diagram of Sr_{14}Cu_{24}O_{41} system. The phase diagram indicates that Ca-substitution ($x$), regarded as "chemical pressure", plays a different role than hydrostatic pressure ($P$). This diagram also indicates that the Sr_{14}Cu_{24}O_{41} compound occupies a special position, such as CDW and an insulator-to-metal transition.

Keywords: Two-leg ladder, Sr_{14}Cu_{24}O_{41}, Transport properties, M-I transition, Hydrostatic pressure

INTRODUCTION

Two-leg Cu-O ladder system has drawn much attention, since theoretical works predicted a finite spin gap reminiscent of the underdoped high-$T_c$ cuprates, and suggested a possibility of superconductivity when doped with holes [1]. Sr_{14}Cu_{24}O_{41} system is one of the realizations of such system. This system has a spin gap with $\sim 500$ K [2], and a superconductivity for $x = 13.6$ with $T_c = 12$ K under high pressure by Uehara et al. [3]. Superconductivity is also observed for $x = 11.5$ single crystal at 3.5 GPa with $T_c = 9$ K [4].

Considering that the superconductivity so far occurs only in heavily Ca-substituted compound under high pressure, it is indispensable to make the $x$-$P$ phase diagram and to understand the respective role of Ca-substitution and hydrostatic pressure. In this study, we measured electrical resistivity under hydrostatic pressure ($P \leq 8.5$ GPa) for the single crystals of Sr_{14-x}Ca_xCu_{24}O_{41} ($x = 0-10$) and Sr_{13}Y_xCu_{24}O_{41}. To generate hydrostatic pressure, a cubic-anvil-type apparatus was used.

RESULTS AND DISCUSSIONS

In Fig. 1, we show the temperature dependence of the electrical resistivity for Sr_{14}Cu_{24}O_{41} under high pressure along the (a) c-axis (along the ladders) ($\rho_c$) and (b) a-axis (across the ladders) ($\rho_a$). What we notice first is that an insulator-to-metal transition occurs at pressure of $\sim 6.5$ GPa. At 5 GPa, the resistivity shows a steep increase at $T \sim 80$ K, suggestive of a CDW transition. This charge-
Fig. 1. The pressure dependence of $\rho_c$ and $\rho_s$ for Sr$_{14}$Cu$_{24}$O$_{41}$.

Fig. 2. The $x$ dependence of $\rho_c$ at 5 GPa and 8 GPa.

Fig. 3. The phase diagram of Sr$_{14}$Cu$_{24}$O$_{41}$ system expected by our results. $n_h$(Ladder) indicates the hole density of the ladder estimated by the optical measurements [8].