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THE ENHANCED SUPERCONDUCTIVITY OF Cu-1234 UNDER HIGH PRESSURE

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The evolution of superconducting transition of $CuBa_2Ca_3Cu_4O_{10+\delta}$ (i.e. Cu-1234) superconductor has been studied by using diamond anvil cell technique. The Tc of Cu-1234 can be enhanced continuously from ambient reaching to 123 K at 15 GPa. This seems the one more system besides Hg-12(n-1)n which demonstrate the positive pressure effect on Tc over a wide pressure range above 10 GPa.

Keywords: Cu-1234 superconductor; high pressure effect; Tc enhancement.

1. Introduction

Since the historical discovery of high Tc superconductor (HTS)[1] by J. G. Bendnorz & K. A. Müller, a considerable new compounds of HTS have been found. Almost all of HTS demonstrated unusual positive in-situ pressure enhancement of Tc. The most exciting cases are from the Hg-12(n-1)n homologous series, which shown an overwhelming pressure enhancement on Tc for either under-, optimally, or over-doped superconductors.[2] Moreover so far the record high Tc 160 K has been reached in the Hg-1223 superconductor at an applied pressure of ∼30 GPa.[2] The results indicated that pressure might be a unique probe to test the possible superconducting mechanism since any established theoretical model should be able to account for the peculiar pressure behavior. $CuBa_2Ca_{n-1}Cu_nO_{2n+2+\delta}$ (i.e. Cu-12(n-1)n) is a superconducting homologous series synthesized at high pressure high temperature.[3] Among the as prepared Cu-12(n-1)n superconductors the Cu-1234 whose structure is shown in Fig.1 possesses the relative high Tc ∼116K. Here we report for the first time that the Tc of the as-prepared Cu-1234 superconductor could be enhanced from the ambient 116 K up to 123K at 15GPa.

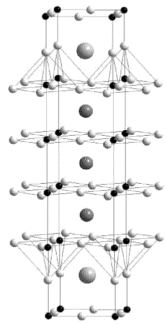

Fig. 1. The crystal structure of Cu-1234, the consecutive [CuO_2] planes being highlighted.

2. Experimental Details

The Cu-1234 sample was synthesized under high pressure high temperature using precursor materials similar to the procedure described in Ref.[3]. Except a minor impurity, x-ray diffraction pattern shows the sample is mainly of the Cu-1234 phase with lattice parameters being a=3.86Å, c=17.89Å. The in-situ high pressure experiments were performed using a screw type diamond anvil cell made of Be-Cu alloy. The Cu-1234 specimen was carefully cut into a ~150 μm × 50 μm × 50 μm rectangular chip using a YSZ laser beam. The specimen was then inserted into the gasket chamber together with NaCl pressure transmitting medium and ruby pressure calibration grains. Since the specimen is too tiny to manipulate the electrode by ordinary electrical discharging method or by silver pasting way, the 10 μm diameter gold wires were finally directly placed on the sample surface. The Au wires were further extracted to the Pt foils which extend outside the chamber in connection with the whole measuring circuits.

3. Results and Discussion

Figure 2 shows the resistance measurement results as a function of temperature of the Cu-1234 sample at various pressures from ambient up to 15 GPa. To address the Tc evolution with pressure, the resistance in Fig.2 were renormalized to R(T)/R(160K) for each plot. The transition temperature was defined as the across point between the two extrapolated slopes before and after the resistance drop as shown in the figure. It is clear that with increasing pressure the transition temperature of the sample gradually shifted higher. This tendency can be very well repeated in either cooling or heating process for each pressure load. The enhancement from 116 K at ambient to 123K at 15GPa was observed in the experiment as shown in the Fig.2. The Tc increasing is clearly not from the crystal structure phase transition as we have previously checked the Cu-1234 sample which is stable at least at 30 GPa at room temperature by using x-ray synchrotron radiation method. The Tc evolution versus pressure was plotted at Fig.3. The average increasing rate of dTc/dP in the

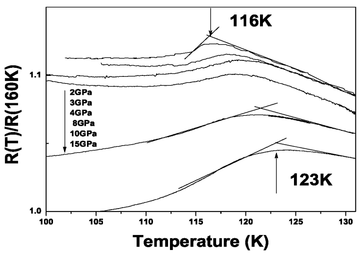

Fig. 2. The R-T curve of the Cu-1234 superconductor at variant pressure.

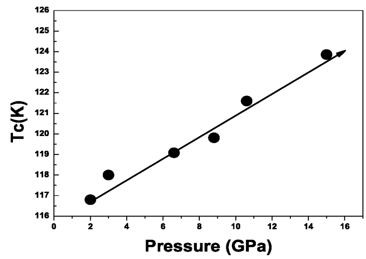

Fig. 3. The critical transition temperature Tc of Cu-1234 superconductor at variant pressure.

measuring pressure range is <1K/GPa, which is comparable to those observed in YBCO- 90 K superconductor. This can be ascribed to the fact that they have the similar charge reseivior structure. However it is noteworthy that the Tc of YBCO-123 quickly becomes saturated at pressure above 2 GPa and then decrease for further increasing pressure, while Cu-1234 is still keeping the Tc increase tendency beyond 15 GPa. The Cu-1234 superconductor seems an additional example besides the Hg-12(n-1)n which demonstrated the sustainable pressure enhanced Tc over a large pressure range above 10 GPa. It is reasonable to understand the pressure effect on HTS in terms of contributions coming from the charge reservoir block together from the [CuO_2] conducting plane. Considering the similarity of charge reservoir block of Cu-1234 with YBCO-123, it is speculated that a charge transfer type pressure enhancement plays substantial role in the low pressure range, while the pressure tuning to the coupling between the [CuO_2] conducting plane might become pronounced at elevated pressure range which is helpful to reach a uniform charge carrier distribution among the consecutive [CuO_2] conducting layers. The deep understanding of high pressure effect on Cu-1234 superconductor over a relative large pressure range needs to be further investigated by multi way physical measurements to figure out a suitable theoretical model.

Acknowledgements

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