

Thermal conductivity in $\text{HgBa}_2\text{Ca}_4\text{Cu}_5\text{O}_y$ (Hg-1245)

T.Watanabe^{a,1}, K.Tokiwa^a, S.Ito^a, S.Mikusu^a, Y.Hashinaka^a, A.Iyo^b, Y.Tanaka^b

^a Tokyo University of Science, 2641 Yamazaki, Noda, Chiba, Japan

^b AIST, 1-1-1 Umezono, Tsukuba, Ibaraki, Japan

Abstract

As the temperature is lowered below T_c (107K), a remarkable increase of the thermal conductivity, having a broad maximum, was observed. The behavior of the temperature dependence of the enhancement below T_c seems to be correlated to specific characteristics relating to a coexistence of magnetic and superconducting state in this compound.

Key words: multilayered, cuprate, thermal conductivity,

1. Introduction

In multi-layered copper oxide superconductor $\text{HgBa}_2\text{Ca}_4\text{Cu}_5\text{O}_y$ (Hg-1245) containing five CuO_2 planes in the unit cell, it was revealed for the first time that both superconducting and antiferromagnetic CuO_2 planes coexist in the unit cell based on results from the experiments of NMR[1], μSR [2] and specific heat[3]. With decreasing temperature, the outer CuO_2 planes (OP) with a pyramidal structure indicate superconducting at T_c of 107K, on the other hand, the inner CuO_2 planes (IP) with a square structure are not superconducting and antiferromagnetic[1]. It was observed that, with decreasing temperature, a state of magnetic ordering begins developing at $\sim 60\text{K}$ and then antiferromagnetic long range order appears below $\sim 45\text{K}$ in the IP[2]. An anomaly was also observed at $\sim 42\text{K}$ in the measurement of specific heat[3]. This phenomenon originates from the remarkably different carrier distribution between the OP and the IP, that is, slightly light-doped OP and strongly light-doped IP. This fact has been emphasized by characteristics of Hg-1245 which has a different five CuO_2 planes in the unit cell and a low carrier concentration.

In this paper, the results of the thermal conductivity κ in Hg-1245 have been presented, and distinctive characteristics pointed out.

2. Experimental

Samples were prepared carefully by sintering at 1050°C under a high pressure of 4.5GPa. All samples synthesized were characterized to be nearly single phase of Hg-1245 system, including a slight impurity phase of CaO by x ray diffraction. From the plots of the temperature dependence of the resistivity, however, a small fraction of the Hg-1234 phase ($T_c \sim 120\text{K}$) was recognized. The values of $T_{c,mid}$ for Hg-1245 samples prepared for measurements were 108.0K(No.8), 110.0K(No.11), 106.7K(No.23) and 107.6K(No.37), respectively. The mean value of the Hall number per CuO_2 was ~ 0.12 and represent an under-doped state in these samples. Thermal conductivity was measured in the temperature range between 8 and 250K using a steady state method, employing a gold iron cobalt differential thermocouple and a small thin resistor as heater. Typical sample dimensions were $\sim 1 \times 1.5 \times 2.5\text{ mm}^3$ and the temperature difference across the sample was 0.1-0.3 K.

¹ Corresponding author. Tokyo University of Science, 2641 Yamazaki, Noda, Chiba, Japan E-mail: tanukiwa@rs.noda.tus.ac.jp

3. Results and Discussion

The temperature dependence of κ in the four samples of Hg-1245 mentioned above is shown in Fig. 1. As shown in Fig.1, the value of κ slightly increases with decreasing temperature and much more rapidly just below T_c , having a peak. Although this is similar behavior to the cases of other oxide superconductors, the observable features of the data in Fig.1 are that the temperature dependence of the enhancement below T_c is broad and κ increases conspicuously against T_c from $\sim 140\text{K}$ (fairly higher than T_c). This is clearly different from that in Hg-1223 which is shown as reference data in Fig.1.

The carrier doping is in an under-doped state for these Hg-1245 and then inner CuO_2 planes (IP) are pointed out to be insulating due to considerably low carrier distribution. Therefore, the phonon conduction seems to contribute mainly to the magnitude of measured κ in the Hg-1245. Generally, the contribution of phonons in κ is much larger than that of carriers in the normal conduction state for high- T_c oxide superconductors[4,5]. In Hg-1245, it is estimated that phonon contribution is also remarkably large below T_c , conjecturing from the curve of polynomial fit to normal state data as shown in Fig.1. Thus we think that the enhancement in below T_c in Hg-1245 is mainly due to the phonon contribution, and the carrier contribution is small. This behavior is different from the result estimated in YBCO experimentally and theoretically, in which quasiparticles largely contribute below T_c in addition to phonon contribution due to an increase of the quasiparticle lifetime[4–6]. As shown in Fig.1, the increasing of κ with temperatures below T_c seems to be controlled below $\sim 70\text{K}$ and κ decreases rapidly from $\sim 40\text{K}$. It is noted that these temperatures roughly correspond to those where some magnetic states are thought to be developed in Hg-1245 as mentioned in the introduction.

4. Conclusion

The temperature dependence of κ in under doped Hg-1245 is mainly governed by the phonon contribution above and below T_c . It seems that its behavior is correlated to characteristics of the peculiar superconductor Hg-1245.

Acknowledgements

This work was supported by CREST of JST and T.W, K.T, S.I, S.M, T.H also acknowledge support

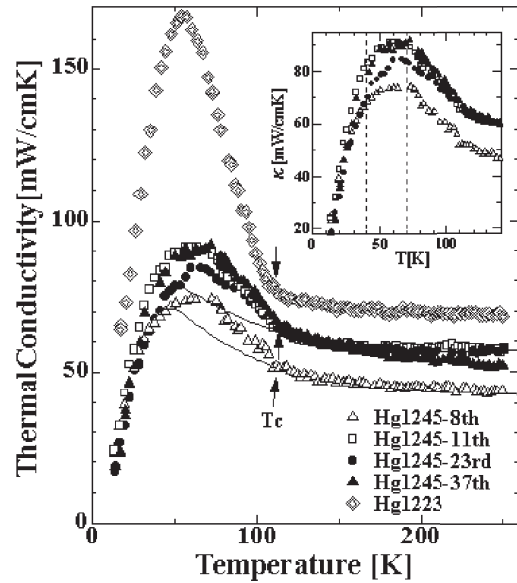


Fig. 1. T dependence of κ in several samples of Hg-1245 and sample of Hg-1223 ($T_c \sim 120\text{K}$). Solid lines show curves of polynomial fit to the normal state. Inset: The same data below 140K .

from TANAKA KIKINZOKU KOGYO Ltd., Japan.

References

- [1] H.Kotegawa et al., Phys. Rev. Lett., (to be submitted).
- [2] K.Tokiwa et al., The 23 th LT conference 2002.
- [3] K.Tokiwa et al., (in preparation)
- [4] P.J.Hirschfeld and W.O.Putikka, Phys. Rev. Lett., 77 (1996) 3909.
- [5] K.Krishana, J.M.Harris and N.P.Ong, Phys. Rev. Lett., 75 (1995) 3529.
- [6] B.Zeini et al., Phys. Rev. Lett., 82 (1999) 2175.