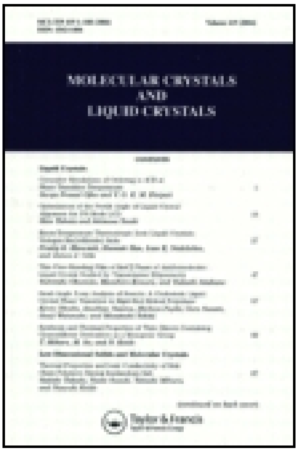

Molecular Crystals and Liquid Crystals Incorporating Nonlinear Optics
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl17

Effect of Annealing on Superconductivity in Bi-Pb-Sr-Ca-Cu-O System

Motohide Matsuda [a], Masasuke Takata [a], Tsutomu Yamashita [a] & Mamoru Ishii [b]

[a] Department of Electrical Engineering, Nagaoka University of Technology, Nagaoka, Niigata, 940-21, Japan

[b] Nihon Cement Co., Ltd., Koutou-ku, Tokyo, 135, Japan

Version of record first published: 22 Sep 2006.

To cite this article: Motohide Matsuda, Masasuke Takata, Tsutomu Yamashita & Mamoru Ishii (1990): Effect of Annealing on Superconductivity in Bi-Pb-Sr-Ca-Cu-O System, Molecular Crystals and Liquid Crystals Incorporating Nonlinear Optics, 184:1, 93-97

To link to this article: http://dx.doi.org/10.1080/00268949008031744

Mol. Cryst. Liq. Cryst., 1990, vol. 184, pp. 93–97
Reprints available directly from the publisher
Photocopying permitted by license only

Printed in the United States of America

EFFECT OF ANNEALING ON SUPERCONDUCTIVITY IN Bi-Pb-Sr-Ca-Cu-O SYSTEM

MOTOHIDE MATSUDA, MASASUKE TAKATA and TSUTOMU YAMASHITA
Department of Electrical Engineering,
Nagaoka University of Technology, Nagaoka, Niigata 940-21, Japan

MAMORU ISHII
Nihon Cement Co.,Ltd., Koutou-ku, Tokyo 135, Japan

Abstract The effect of annealing on the superconductivity in the Bi-Pb-Sr-Ca-Cu-O system was investigated. The samples annealed at temperatures ranging from 600°C to 825°C exhibited lower zero-resistance temperatures than that of the as-sintered sample and the tailing phenomenon in the R-T curves. This phenomenon was pronounced particularly for the sample annealed at 700°C. From the ac susceptibility measurement, the weak-coupling was confirmed to exist between the high-T_c grains in the annealed samples. Therefore, it was elucidated that the tailing phenomenon was caused by the weak-coupling generated between the high-T_c grains during annealing.

INTRODUCTION

Since the Ba-Y-Cu-O system was found to exhibit the superconducting transition above liquid nitrogen temperature,[1] several superconducting oxides with critical temperature above 100K were discovered.[2,3] The properties of ceramic superconductors are closely related to various preparatory conditions.[4-7] In our previous paper, it was reported that the $T_{c,zero}$ values of Bi-Pb-Sr-Ca-Cu-O superconductors were extremely dependent on the cooling rate.[8] Especially, the sample obtained at a very slow cooling rate (<10°C/h) showed $T_{c,zero}$ lower than 85K. This result suggested the existence of a certain temperature range in the cooling process where $T_{c,zero}$ was decreased. In the present work, we investigated the effect of annealing on the superconductivity in a Bi-Pb-Sr-Ca-Cu-O system by the ac susceptibility measurement.

EXPERIMENTAL

The samples were prepared by a solid-state reaction method. Commercial powders of Bi_2O_3(purity 99.99%), PbO(purity 99.99%), $SrCO_3$(purity 99.9%), $CaCO_3$(purity 99.9%) and CuO(purity 99.9%) were mixed in the molar ratio of Bi:Pb:Sr:Ca:Cu=1.6:0.4:1.6:2.0:4.0. The sintering was carried out at 845°C in air and a cooling rate of 100°C/h was adopted. Then, some of the samples were annealed at 300°C ~845°C for 24h in air.

The resistivity of the sample was measured in a closed-cycle helium refrigerator by a conventional four-prove resistive method, changing the current direction alternatively. The electrodes were prepared by evaporating gold films and the lead-in wires were attached to the gold electrodes using silver paste. The temperature was measured by a Pt-Co resistive thermometer. The ac susceptibility measurement was performed using an impedance analyzer (YHP-4192A) at 1kHz.

RESULTS AND DISCUSSION

Figure 1 shows the zero-resistance temperature ($T_{c,zero}$) as a function of the annealing temperature. The $T_{c,zero}$ values of the samples annealed at 600°C to 825°C were lower than that of the as-sintered sample. Moreover, the $T_{c,zero}$ values of all samples were reduced when the measuring current density was increased. The maximum decrease in $T_{c,zero}$ was observed in the sample annealed at 700°C. From the above results, it could be considered that the decrease in $T_{c,zero}$ of the sample obtained at a very slow cooling rate, as shown in the previous paper,[8] was caused by holding the samples at temperatures ranging from 600°C to 825°C for a long time.

Figure 2 shows the temperature dependences of the resistivity for the as-sintered sample and the sample annealed at 700°C. The normal-state resistivity of the sample annealed at 700°C was much higher than that of the as-sintered sample. In addition, the tailing phenomenon[9] was observed in the R-T curve for the sample annealed at 700°C though the as-sintered sample showed a sharp superconducting transition above 100K. This phenomenon was also observed for all samples annealed at temperatures ranging from 600°C to 825°C. As the cause of the tailing phenomenon observed in Fig.2(b), two possibilities can be thought as follows.

(1): A low T_c phase generated between the high-T_c grains during annealing.

(2): A weak-coupling generated between the high-T_c grains.

To elucidate which case occurred, the ac susceptibility measurement was performed. Figure 3 shows the temperature dependence of the ac susceptibility for the powder sample obtained by crushing after annealing at 700°C. Only one step was observed around 112K. If the low-T_c phase had been contained in the annealed samples, two steps

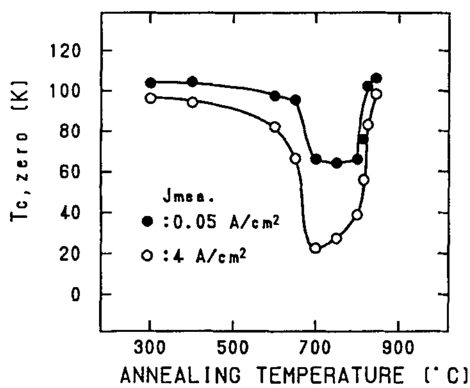

FIGURE 1 Zero-resistance temperature ($T_{c,zero}$) as a function of the annealing temperature. The measuring current densities are 0.05A/cm^2(●) and 4A/cm^2(○).

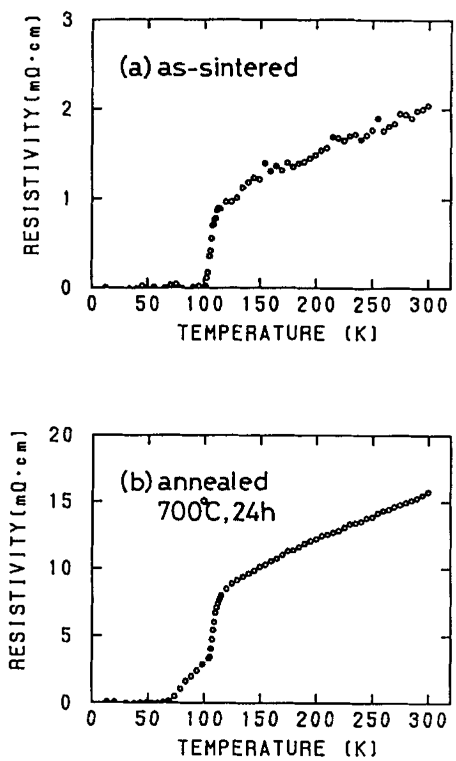

FIGURE 2 Temperature dependences of the resistivity for the as-sintered sample(a) and the sample annealed at 700°C(b). The measuring current density is 0.05A/cm^2.

would have been confirmed in the temperature dependence of the ac susceptibility. This result indicates that the annealed sample does not contain the low-T_c phase. In general, if the sample contains a weak-coupling, the temperature dependence of the ac susceptibility is strongly dependent on the ac field strength.[10] Accordingly, in order to verify the existence of the weak-coupling, the temperature dependences of the ac susceptibility for the bulk samples were investigated as a function of the ac field strength. The result is shown in Fig.4. The behavior of the ac susceptibility for the as-sintered sample rarely depended on the ac field strength. On the

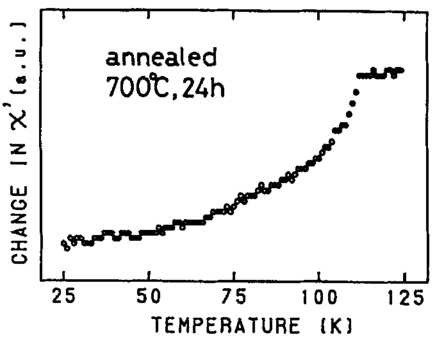

FIGURE 3 Temperature dependence of the ac susceptibility for the powder sample obtained by crushing after annealing at 700°C.

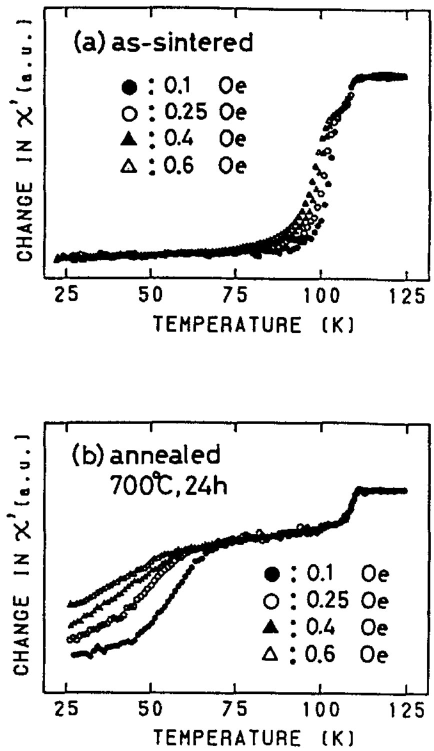

FIGURE 4 Temperature dependences of the ac susceptibility for the bulk samples as a function of the ac field strength. (a): The as-sintered sample. (b): The sample annealed at 700°C.

other hand, the aspect of the change in the ac susceptibility for the sample annealed at 700°C extremely differed from that for the as-sintered sample. The strong dependence on the ac field strength was observed below 80K, which is the evidence of the existence of the weak-coupling structure. These results indicate that the weak-coupling generates between the high-T_c grains during annealing. Therefore, it was ascertained that the tailing phenomenon in the R-T curves was caused by the weak-coupling generated during annealing.

CONCLUSION

We have investigated the effect of annealing on the superconductivity in the Bi-Pb-Sr-Ca-Cu-O system. The $T_{c,zero}$ of the samples annealed at temperatures ranging from 600°C to 825°C were lower than that of the as-sintered sample and the tailing phenomenon was observed in the R-T curves. From the ac susceptibility measurement, the weak-coupling was confirmed to exist between the high-T_c grains in the annealed samples. Consequently, it became clear that the tailing phenomenon was attributed to the existence of the weak-coupling.

REFERENCES

1. M. K. Wu, J. R. Ashburn, C. J. Torng, P. H. Hor, R. L. Meng, L. Gao, Z. J. Huang, Y. Q. Wang and C. W. Chu: Phys. Rev. Lett. 58, 908 (1987).
2. H. Maeda, T. Tanaka, M. Fukutomi and T. Asano: Jpn. J. Appl. Phys. 27, L209 (1988).
3. Z. Z. Sheng and A. M. Hermann: Nature 332, 138 (1988).
4. A. Kikuchi, M. Matsuda, T. Maeda, M. Ishii, M. Takata and T. Yamashita: Jpn. J. Appl. Phys. 27, L1231 (1988).
5. M. Matsuda, A. Kikuchi, M. Ishii, M. Takata, T. Yamashita and S. Okamoto: Jpn. J. Appl. Phys. 27, L1439 (1988).
6. A. Kikuchi, M. Matsuda, M. Takata, M. Ishii, T. Yamashita and H. Koinuma: Jpn. J. Appl. Phys. 27, L2300 (1988).
7. U. Endo, S. Koyama and T. Kawai: Jpn. J. Appl. Phys. 28, L190 (1989).
8. A. Kikuchi, M. Matsuda, M. Takata, M. Ishii, T. Yamashita and H. Koinuma: Jpn. J. Appl. Phys. 28, L371 (1989).
9. M. Matsuda, A. Kikuchi, M. Takata, M. Ishii, T. Yamashita and H. Koinuma: Jpn. J. Appl. Phys. 28, L940 (1989).
10. H. Mazaki, M. Takano, J. Takada, K. Oda, H. Kitaguchi, Y.Miura, Y. Ikeda, Y. Tomii and T. Kubozoe: Jpn. J. Appl. Phys. 27, L1639 (1988).