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

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Version of record first published: 22 Sep 2006.

To cite this article: Nobuhito Imanaka , Fumihiko Saito & Gin-Ya Adachi (1990): Superconducting Characteristics of Metal-$YBa_2Cu_3O_{7-x}$ Composites, Molecular Crystals and Liquid Crystals Incorporating Nonlinear Optics, 184:1, 117-121

To link to this article: http://dx.doi.org/10.1080/00268949008031748

Mol. Cryst. Liq. Cryst., 1990, vol. 184, pp. 117–121
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Printed in the United States of America

SUPERCONDUCTING CHARACTERISTICS OF METAL-$YBa_2Cu_3O_{7-X}$ COMPOSITES

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Abstract Metal powder such as Au or Ag was mixed with a Y-Ba-Cu-O superconductor so as to improve its critical current density, Jc. The metals were uniformly dispersed into the superconductor without reaction. The Jc for $YBa_2Cu_3O_{7-X}$ mixed with Au(5 wt%) or Ag(3 wt%) was magnified by a factor of four or two in comparison with that for the $YBa_2Cu_3O_{7-X}$ superconductor without the metal mixing, respectively. The metal addition into $YBa_2Cu_3O_{7-X}$ influenced little to Tc^{zero}. The decrease of Tc^{zero} under the magnetic flux application was considerably inhibited by the metals mixing.

INTRODUCTION

Since the first report of a high-Tc oxide superconductor, great efforts have been concentrated on to identify the superconductor. One of the great advantage of the oxide superconductor is that the critical transition temperature (Tc) goes up to over 77 K of the liquid nitrogen temperature. However, the low transport critical current density (Jc) limits its application. This is mainly attributed to the existence of nonsuperconducting phases in grain boundaries[1] and of pores between grains. The Jc value of $YBa_2Cu_3O_{7-X}$ mixed with Ag_2O(4 wt%) has been reported to be 5 times as large as that of $YBa_2Cu_3O_{7-X}$ without Ag_2O addition.[1]

In this study, a metal such as Au or Ag was mixed with a $YBa_2Cu_3O_{7-X}$ superconductor powder for the purpose of suppressing the nonsuperconducting formation and filling the pores. The metal mixing effects on superconducting characteristics of the Y-Ba-Cu-O system were investigated.

EXPERIMENT

An appropriate amount of Y_2O_3, $BaCO_3$ and CuO(by molar ratio 0.5:2:3) was mixed thoroughly in an agate mortar. The mixture was calcined at 940°C for 5 h in an oxygen flow. The calcined sample was pulverized and then mixed with a proper amount of Au (purity>99.9%, grain size<150μm) or Ag (purity >99.9%, grain size<44μm) powder. The metal mixed superconductor powder was pressed

into pellets and then sintered in the same oxygen flowing atmosphere for 8 h at 940°C for the Au mixed composites, and 900°C for the Ag added composites, respectively. The electrical resistivity was measured by the standard four probe method. The samples were cut into rectangular shape for the measurement and lead wires were fixed to the sample with a silver paste. Transport critical current density (Jc) measurements were conducted with the same probe at the temperature of liquid nitrogen (77 K). The critical current density was calculated from the current at 1μV generation between the voltage terminals and the cross sectional area of the sample. The magnetic susceptibility was measured by a rf-SQUID susceptometer (HSSM-1000) from Hoxan Co.

RESULTS AND DISCUSSION

Observed peaks were only for the $YBa_2Cu_3O_{7-X}$ (Ortho-I) superconductor and Ag metal from an X-ray diffraction analysis. Ag powder did not react with the $YBa_2Cu_3O_{7-X}$ superconductor and existed as the Ag metal in the composites. From a scanning electron microscope(SEM) observation, a part of pores were found to be filled with the Ag metal.

The Tc^{zero} deviation with the Au or Ag wt% is presented in Figure 1. Tc^{zero} for a $YBa_2Cu_3O_{7-X}$ superconductor without Au addition, which is hereafter denoted as an Au standard, was 89.5 K.

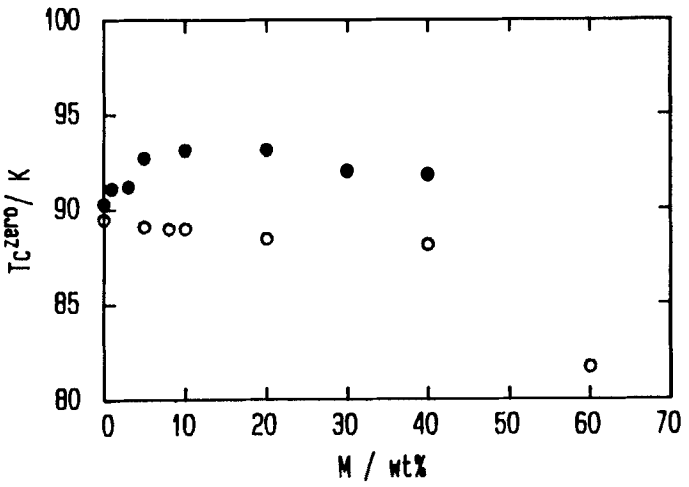

FIGURE 1 The Tc^{zero} deviation with metal content for the $YBa_2Cu_3O_{7-X}$-metal(M) composites. :○;M=Au:●;M=Ag

By the Au addition, Tc^{zero} slightly decreased. However, the difference between Tc^{zero} for the Au standard and the Au(40 wt%)mixed composite was at most 2 K. The Au mixing up to 40 wt% influenced little to the Tc^{zero} characteristics. The results for the Au mixed composites were quite similar to that reported by Streitz et al.[3] Tc^{zero} for the Ag standard sample was 90.2 K and was almost equal to that for Au standard. In the case of the Ag mixing, the Tc^{zero} increased and became 93 K at Ag 20 wt% mixing.

Figure 2 shows the Jc variation for the $YBa_2Cu_3O_{7-X}$-metal composites. Jc for the Au standard sample was 88 A/cm^2. By the Au 3 wt% mixing, Jc increased to 166 A/cm^2, and showed a maximum value of 307 A/cm^2 at 5 wt% addition. However, Jc for 8 wt% mixing decreased down to 161 A/cm^2. By the Au addition more than 8 wt%, Jc gradually decreased. In the case of the $YBa_2Cu_3O_{7-X}$-Ag composites, Jc for the Ag standard was 153 A/cm^2. By 1 wt% Ag addition, Jc increased abruptly up to 352 A/cm^2 and exhibited a maximum Jc (375 A/cm^2) by the 3 wt% Ag mixing. Compared with the Au mixed composites, Jc for the Ag mixed composites kept higher value around 360 A/cm^2 in a wide Ag content range from 1 to 10 wt%. By mixing 40 wt% Ag, the Jc decreased down to 200 A/cm^2. Au or Ag mixing enhanced the Jc value about 4 times or twice higher than that for the standard. However, a maximum Jc for the Ag 3 wt% was 375 A/cm^2 and larger than that for the Au 5 wt% addition.

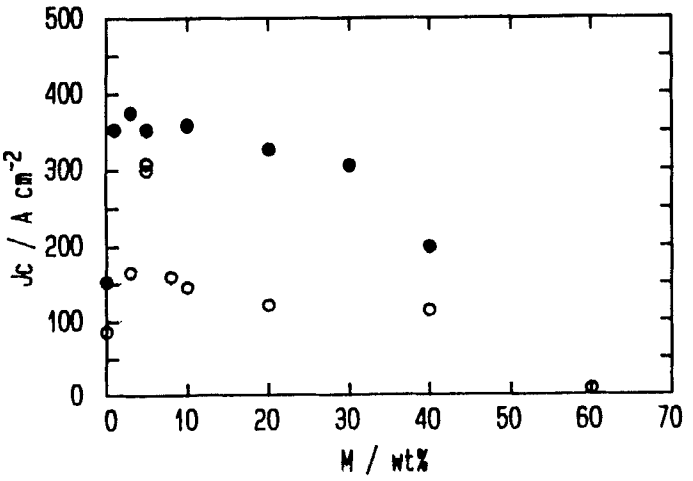

FIGURE 2 The variation of Jc with metal content for the $YBa_2Cu_3O_{7-X}$-metal(M) composites. : ○ ;M=Au: ● ;M=Ag

The Tc^{zero} deviation with the magnetic flux density for the Ag standard and the Ag 3 wt% mixed composite is presented in Figure 3. The Tc^{zero} for the Ag standard was greatly decreased by the application of 1500 G and gradually approached to 77 K by the application of magnetic flux . The Tc^{zero} decrease by the flux application of 1500 G for the Ag 3 wt% mixed composite was smaller than that for the Ag standard. Tc^{zero} was still higher than 85 K even at 6700 G. The SEM observation showed that sinterability enhanced by the Ag addition and resulted in the reduction of the weak-link between grains.

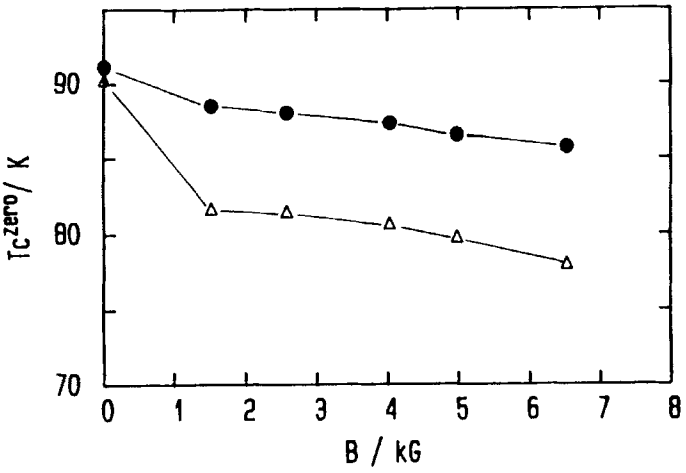

FIGURE 3 The Tc^{zero} deviation with magnetic flux density.
△ ; $YBa_2Cu_3O_{7-X}$ standard sample
● ; $YBa_2Cu_3O_{7-X}$-Ag(3 wt%) composite

Figure 4 presents the temperature dependence of the magnetic susceptibility for the Ag standard and the Ag 3 wt% mixed composite. The Ag mass is included in the total one of the composite. Therefore, the real mass susceptibility is obtained by subtracting the Ag mass from the total. Onset Tc (Tc^{on}) for the Ag 3 wt% mixed composite was almost the same as that for the Ag standard. The transition from a normal state to a superconducting one for the Ag 3 wt% mixed composite was sharp in comparison with that for the Ag standard. The volume fraction of the superconductor for the Ag 3 wt% mixed composite was larger than that for the Ag standard.

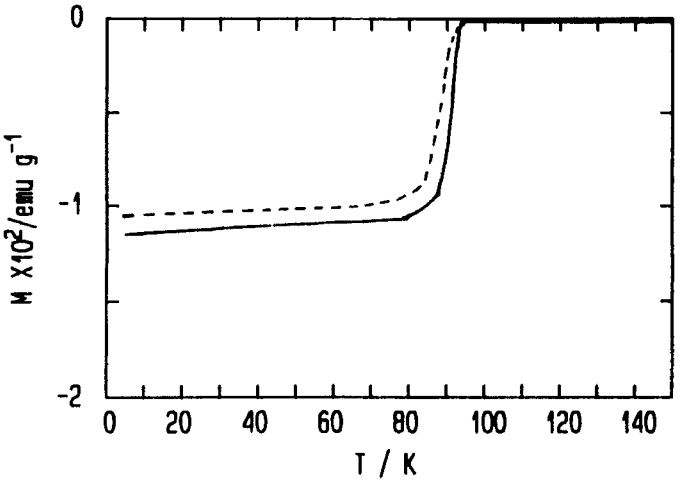

FIGURE 4 Temperature dependence of magnetic susceptibility for standard and Ag mixed composite.
- - - $YBa_2Cu_3O_{7-X}$ standard sample
----- $YBa_2Cu_3O_{7-X}$-Ag(3 wt%) composite

These results indicate that the Ag addition promotes the formation of the $YBa_2Cu_3O_{7-X}$ superconductor where X is nearly equal to zero. The increase of the superconducting volume fraction enhanced the Jc value.

CONCLUSION

The metal addition such as Au or Ag into $YBa_2Cu_3O_{7-X}$, greatly enhanced the Jc value. A maximum Jc for Ag 3 wt% was 375 A/cm^2 and was higher than that for the Au 5 wt% addition. Mixing the metal powder influenced little to the superconducting properties of Tc. The Au or Ag addition into the Y-Ba-Cu-O superconductor redressed the weak-link problem between the superconducting grains.

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