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**Carderock Division  
Naval Surface Warfare Center**

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CDNSWC-SME-92-08 March 1992  
Ship Materials Engineering Department  
Research and Development Report

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**Effect of the Addition of  $Al_2O_3$  and  $Ag_2O$  on the Morphology and Superconductivity of  $YBa_2Cu_3O_{6+X}$  Ceramic Materials**

by  
A. Srinivasa Rao

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## ABSTRACT

In order to produce  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  ceramic material with fine particle size and good superconducting properties, both  $\text{Al}_2\text{O}_3$  and  $\text{Ag}_2\text{O}$  were added to  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  during sintering. The results suggest that the addition of both  $\text{Al}_2\text{O}_3$  and  $\text{Ag}_2\text{O}$  does not decrease the average particle size of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$ ; however, the superconducting properties degrade with an increase in the  $\text{Al}_2\text{O}_3$  concentration. In composites containing high additive concentration, fine structure resembling that of fine pits is discernible on  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  particles.

## ADMINISTRATIVE INFORMATION

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## INTRODUCTION

The advancement of superconducting ceramic materials with zero resistance above liquid nitrogen temperature [1,2], has prompted a race for fabricating these brittle ceramics into useful components. Although the fabrication of superconducting ceramic thin films has been explored using various techniques, such as ion beam deposition, vapor phase deposition etc. [3-6], no significant advancement in the processing of bulk ceramics has been achieved to date. This project was undertaken in order to study the feasibility of extruding bulk superconducting

ceramic into wires or tapes using the superplastic deformation technology.

The important requirement that has to be met for maximum superplastic deformation is to maintain a small grain size (less than  $5 \times 10^{-7}$  m) [7,8]. In this study, the main focus has been to define and determine the processing parameters for producing bulk superconducting ceramic preform with fine grain size and high  $T_c$ . Some of the experimental results relating the effect of the addition of both  $Al_2O_3$  and  $Ag_2O$ , on the crystal structure, morphology and superconducting properties of  $YBa_2Cu_3O_{6+x}$  are presented here.

#### EXPERIMENTAL PROCEDURE

The basic  $YBa_2Cu_3O_{6+x}$  superconducting ceramic powder was prepared by solid state reaction of yttrium oxide, copper (II) oxide and barium carbonate. The precursor mixture was ball milled with distilled water for 2 hours using zirconia balls. The suspension was dried for 24 hours at  $110^\circ C$ . The dry powder was calcined at  $940^\circ C$  for 6 hours and cooled slowly (at the rate of  $2^\circ C/min$ ) to room temperature. Later the superconducting ceramic powder was ground using a mortar and pestle in order to ensure homogeneous composition.

Two additives, alumina and silver oxide were chosen for this investigation. It is because alumina was reported to exhibit superplastic deformation above  $1000^\circ C$  [7-8], which is close to the range of temperatures at which these superconducting ceramic

materials might be deformed. In addition, we have also reported earlier [9], that the addition of alumina to the superconducting  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  prior to the calcination (at  $920^\circ\text{C}$ ), inhibits the grain growth of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  during sintering process. The additive silver oxide was selected because,  $\text{Ag}_2\text{O}$  decomposes on heating to sintering temperatures, thus silver possibly may help the onset of superplasticity. Secondly, it was also observed that the free oxygen liberated during the decomposition process, was frequently taken up by the oxygen deficient  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  structure. The flow diagram of the processing of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$ / additive composites is shown in Figure 1. Pre-determined amounts (in the range 0 - 30 wt %) of both alumina and silver oxide (average size  $10 \times 10^{-6}$  m) were added to the  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  powder. The mixture was ball milled and dried using the above procedure. The dry homogeneous mixture of the additive and the superconducting powder was dry pressed into 1 cm discs. The green disc samples were sintered at  $920^\circ\text{C}$  in air for 2 hours, cooled slowly in air to  $600^\circ\text{C}$  (at the rate of  $1^\circ\text{C}/\text{min}$ ). The samples were annealed at  $600^\circ\text{C}$  for 6 hours and cooled to room temperature (at the rate of  $2^\circ\text{C}/\text{min}$ ).

The particle size and surface area of the powders was determined by sedigraph and single point BET apparatus respectively. The additive distribution, the particle morphology of sintered samples was analyzed using (back scattered and secondary) scanning electron microscopy. The structural characteristics and the electrical properties of the composites was determined using x - ray diffraction and four

probe resistivity methods respectively.

## RESULTS

### Pure $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$

Figure 2 shows a typical elongated rod like morphology of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  particles in sintered bulk ceramic, with a major axis length of approximately  $40 \pm 20 \times 10^{-6}\text{m}$  and (mostly) orthorhombic in crystal structure. The average particle size, powder density and surface area of the as-synthesized powder was approximately  $10 \times 10^{-6}\text{m}$ ,  $6.0 \text{ gm/cm}^3$  and  $0.22 \text{ m}^2/\text{gm}$  respectively. The above results (based on the particle size consideration alone) indicates that while superconducting  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  ceramic material in pure state is (too large to exhibit any significant superplasticity) not suitable for superplastic deformation, the particle size in as-synthesized powder form is suitable for the study of the effect of additives on grain size control during sintering.

### Alumina and Silver Oxide Additions

Earlier, it was shown [9] that additive alumina tends to reduce the particle size of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  (the maximum reduction being 400 % due to the addition of about 10 wt. % alumina) and silver oxide shows no effect on the reduction of the superconducting ceramic material particle size. In spite of the success with the reduction of the average particle size, the results indicate that the superconducting properties of alumina composites deteriorated. Figure 3 shows the electrical resistivity versus temperature profiles of pure  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$ , 5

wt.%  $\text{Al}_2\text{O}_3$  and 5 wt.%  $\text{Ag}_2\text{O}$  composites. From the above results it can be postulated that a combination of additives may improve both the electrical properties and the process of particle size reduction during sintering.

Figure 4 shows typical morphology of 2 wt.%  $\text{Al}_2\text{O}_3/5$ , 10 and 15 wt.%  $\text{Ag}_2\text{O}/\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  composites. The results suggest that the addition of both  $\text{Al}_2\text{O}_3$  and  $\text{Ag}_2\text{O}$  has no significant effect on the particle size of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$ . In order to obtain a semi-quantitative estimate of the particle size as a function of both alumina and silver oxide concentration, number of micrographs representing the morphology of all sintered composites were obtained from random areas. Figure 5 shows the average particle size of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  versus additives  $\text{Ag}_2\text{O}$  and  $\text{Al}_2\text{O}_3$  concentration. The results suggest that the particle size reduction depends upon the concentration of  $\text{Ag}_2\text{O}$ . At higher concentrations ( $\geq 10$  wt.%), the addition of  $\text{Al}_2\text{O}_3$  has very little effect on the particle size.

The results on the superconducting transition temperature of all the samples is shown in Figure 6. The results suggest that the addition of silver oxide to the alumina/ $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  system improves the superconducting transition temperature.

#### DISCUSSION

Optimization of processing methodology often produces sintered ceramic materials of required microstructure, particle size and mechanical and electrical properties. The results of the present investigation suggests that the processing method

used here, for the composite preparation has not produced the anticipated fine microstructure (average grain size of 500 nm). However, it has shown that the superconducting properties of  $\text{Al}_2\text{O}_3/\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  composites can be improved with the addition of  $\text{Ag}_2\text{O}$ . In addition, the important observation that has to be acknowledged is the identification of fine microstructure with in the grains of the superconducting  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$ .

Previous investigations [9] have indicated that the mechanism of particle size reduction due to the addition of  $\text{Al}_2\text{O}_3$  is very complex. However, based on the microstructural observations in  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$ , it can be postulated that the additive  $\text{Al}_2\text{O}_3$  probably attacks and erodes the surface of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$ . The question that was not answered was whether the erosion process is chemical or purely a physical phenomena. From the microstructural results of the present investigation, it may be possible to explain the mechanism of the particle size reduction process. The morphology of the particles of  $\text{Al}_2\text{O}_3/\text{Ag}_2\text{O}/\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  shown in Figure 4 does not show any abnormal anomaly. However, a careful examination of the microstructure of composites containing higher concentrations of both  $\text{Al}_2\text{O}_3$  and  $\text{Ag}_2\text{O}$  suggests that fine platelet like pits develop on the surface of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$ . No such features are discernible either on  $\text{Al}_2\text{O}_3$  or  $\text{Ag}_2\text{O}$  particles. Figure 7 shows a typical morphology of sintered composite containing 5 wt %  $\text{Al}_2\text{O}_3$  and 5 wt %  $\text{Ag}_2\text{O}$ .

If it is assumed that these fine pits were produced during

the initial stages of the erosion of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  by  $\text{Al}_2\text{O}_3$ , it is possible to suggest a simple mechanism for the particle size reduction process as follows : the additive  $\text{Al}_2\text{O}_3$  chemically attacks the lattice of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  and in doing so it results in the depletion of oxygen from the lattice. Chemical destabilization due to the removal of oxygen,  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  transforms into non superconducting  $\text{Y}_2\text{BaCuO}_5$ . A continued break in the lattice bonds and transformation of the chemical structure of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  produces fine particle size and also the deterioration of the superconducting properties of the composite. Although both of the final results were observed experimentally [9], no unequivocal direct evidence supporting the above mechanism has been achieved.

However, it can be suggested that if the oxygen depletion from  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  degrades the superconductivity, the above process can be controlled by supplying oxygen to  $\text{Al}_2\text{O}_3$  during sintering. Such process, then will not only improve the superconductivity, but may also inhibit the particle size reduction process. The results of the present investigation supports the above hypothesis that when oxygen (which is the decomposition product of  $\text{Ag}_2\text{O}$ ) is supplied to  $\text{Al}_2\text{O}_3$  during sintering, it inhibits both the particle size reduction and degradation of superconducting properties of the composite. In order to understand the detailed mechanism of this process, high resolution transmission electron microscope analysis of these fine features is being carried out and the results of that analysis will be reported at a later date.

## CONCLUSION

From the present investigation, the following conclusions can be derived :

1. Addition of both  $\text{Al}_2\text{O}_3$  and  $\text{Ag}_2\text{O}$  to  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  during sintering does not affect the particle size of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  significantly.
2. Addition of  $\text{Ag}_2\text{O}$  to  $\text{Al}_2\text{O}_3/\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  composites, improves the superconducting properties of the composite.
3. Composites containing higher concentrations of additives ( $\text{Al}_2\text{O}_3$  and  $\text{Ag}_2\text{O}$ ) show fine pit like features on  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  particles.

## REFERENCES

1. Bednorz, J. C. and Muller, K., "Possible High  $T_c$  Superconductivity in Barium - Lanthanum - Copper - Oxygen System," Z. Phys. B. Condensed Matter, 64, 189 (1986).
2. Wu, M. K., Ashburn, J. R., Tong, C. T., Hor, P. T., Meng, R. L., Cao, L., Huan, Z. J., Wang, Y. Q., and Chu, C. W., "Superconductivity at 93 K in a New Mixed Phase of Y-Ba-Cu-O Compound System at Ambient Pressure," Phys. Rev. Letts., 58, 908 (1987).
3. "Science and Technology of Thin Film Superconductors," eds. Mc Connell, R. D. and Wolf, S. A., Pub. Plenum Press (1988).
4. Yamane, H., Kurosawa, H., Iwasaki, H., Kobayashi, N. and Muto, Y. "Temperature Dependence of Electrical Resistivity for Y-Ba-Cu-O films Prepared by CVD," J. Ceram. Soc. Japan Int. Ed. 96, 776 (1988).
5. Shinohara, K., Munakata, F. and Yamanaka, M., "High  $T_c$  Superconductor Prepared by Chemical Vapor Deposition," Proc. of First Int. Symp. Superconductivity, Nagoya (1988).
6. Gonzalez-O, C., Schachner, H., Tippman, H. and Trojer, F. J., "Superconducting Thin Films of Y-Ba-Cu-Oxide by Sol - Gel and CVD Methods," Physica, C 153 - 155, 1042 (1988).

7. Carry, C. and Mocellin, A. "Superplastic Forming of Alumina," Proc. Brit. Ceram. Soc., 33, 101 (1983).
8. Venkatachari, K. R. and Raj, R., "Superplastic Flow in Fine - Grained Alumina," J. Amer. Ceram. Soc., 69[2], 135 (1986).
9. Rao. A. S., Aprigliano, L. F. and Arora, O. P., "Effect of Additives on the Morphology and Superconductivity of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  Ceramic Superconductors," TMS, 2nd Int. Conf. on High Temperature Superconductors, Anaheim, Ca (1989).

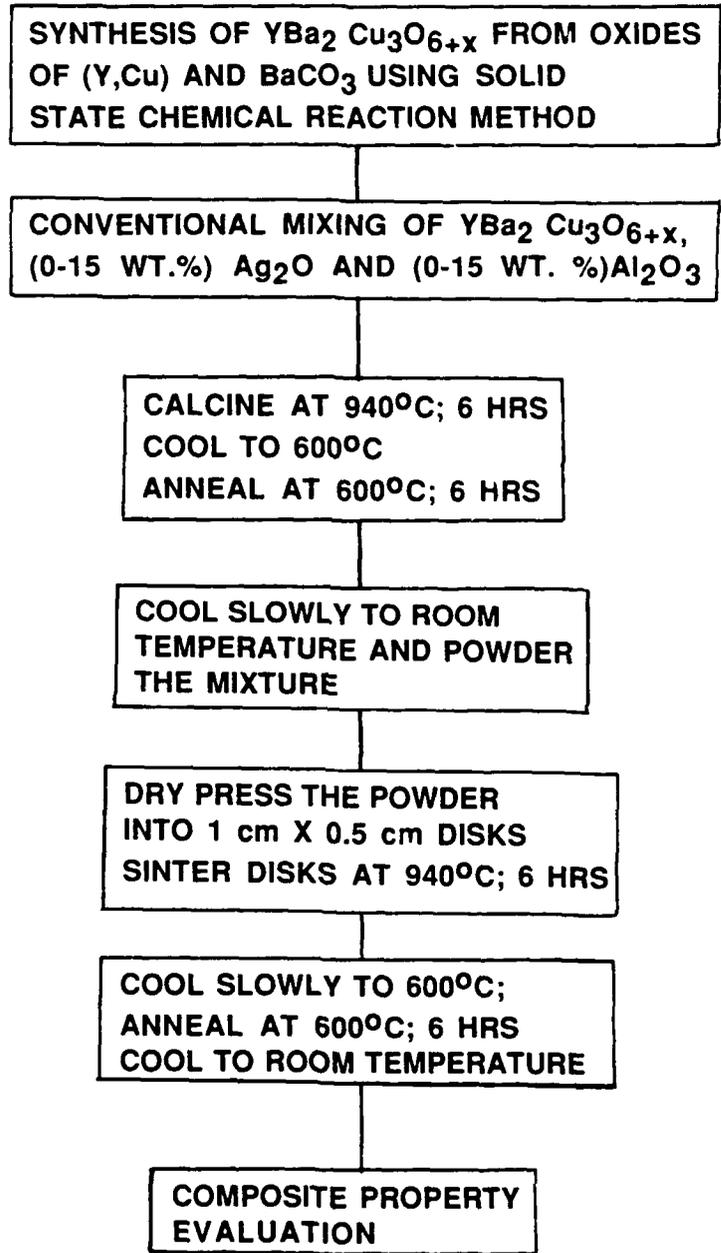


Figure 1. Flow Diagram of the Processing of  $\text{Al}_2\text{O}_3/\text{Ag}_2\text{O}/\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  Composites.

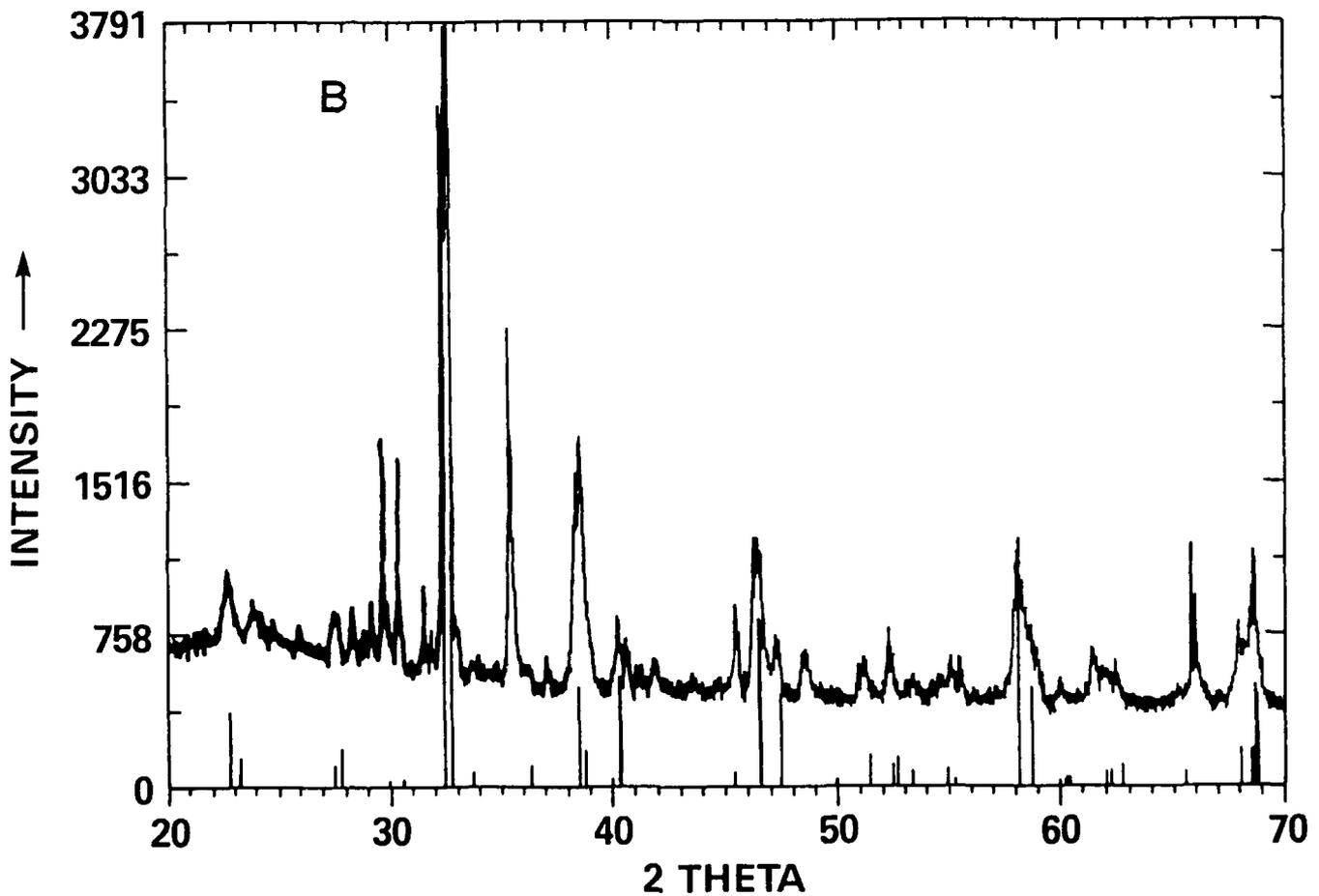


Figure 2. Typical (A) Morphology and (B) Structure of Sintered  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  Superconducting Ceramic.

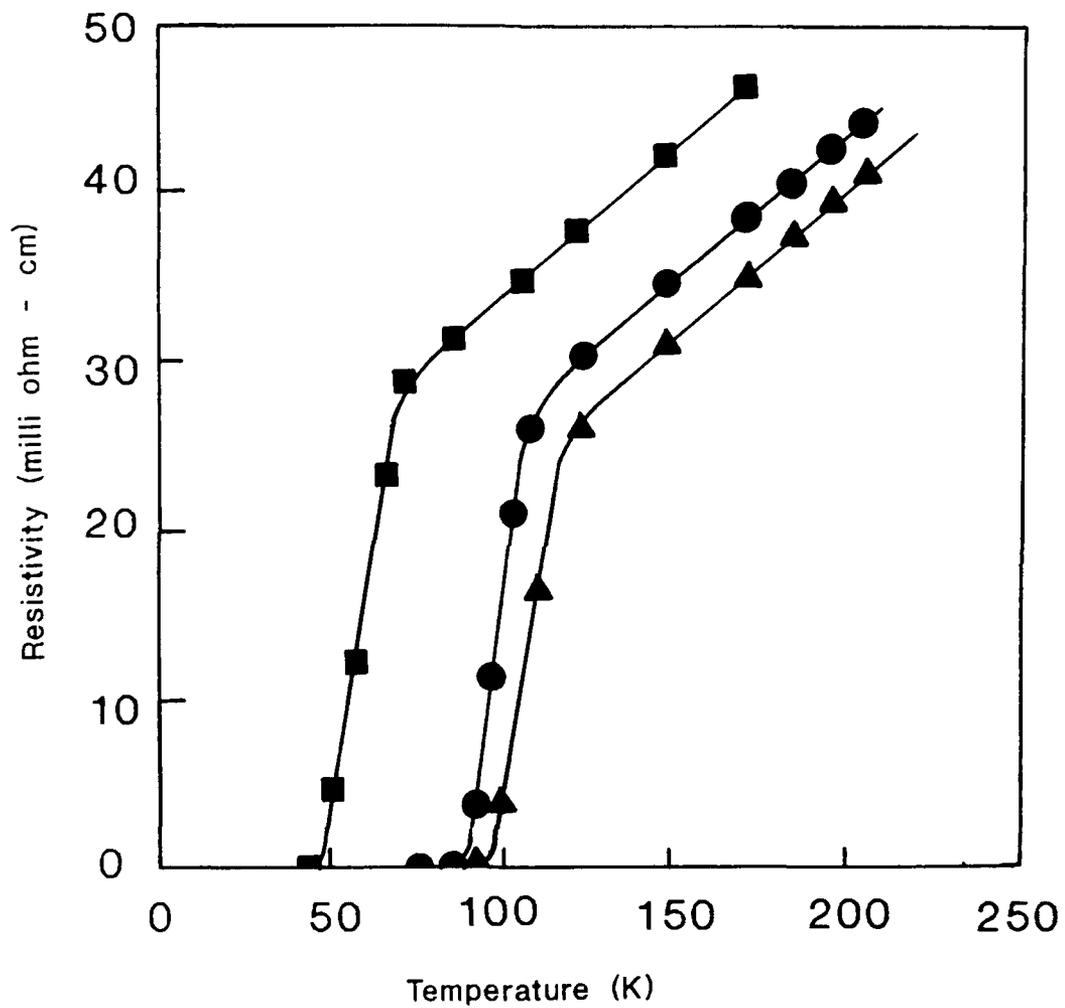


Figure 3. Electrical Resistivity versus Temperature Profiles of Sintered ( ● ) Pure  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$ , ( ■ ) 5 wt.%  $\text{Al}_2\text{O}_3/\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  and ( ▲ ) 5 wt.%  $\text{Ag}_2\text{O}/\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  Composites.

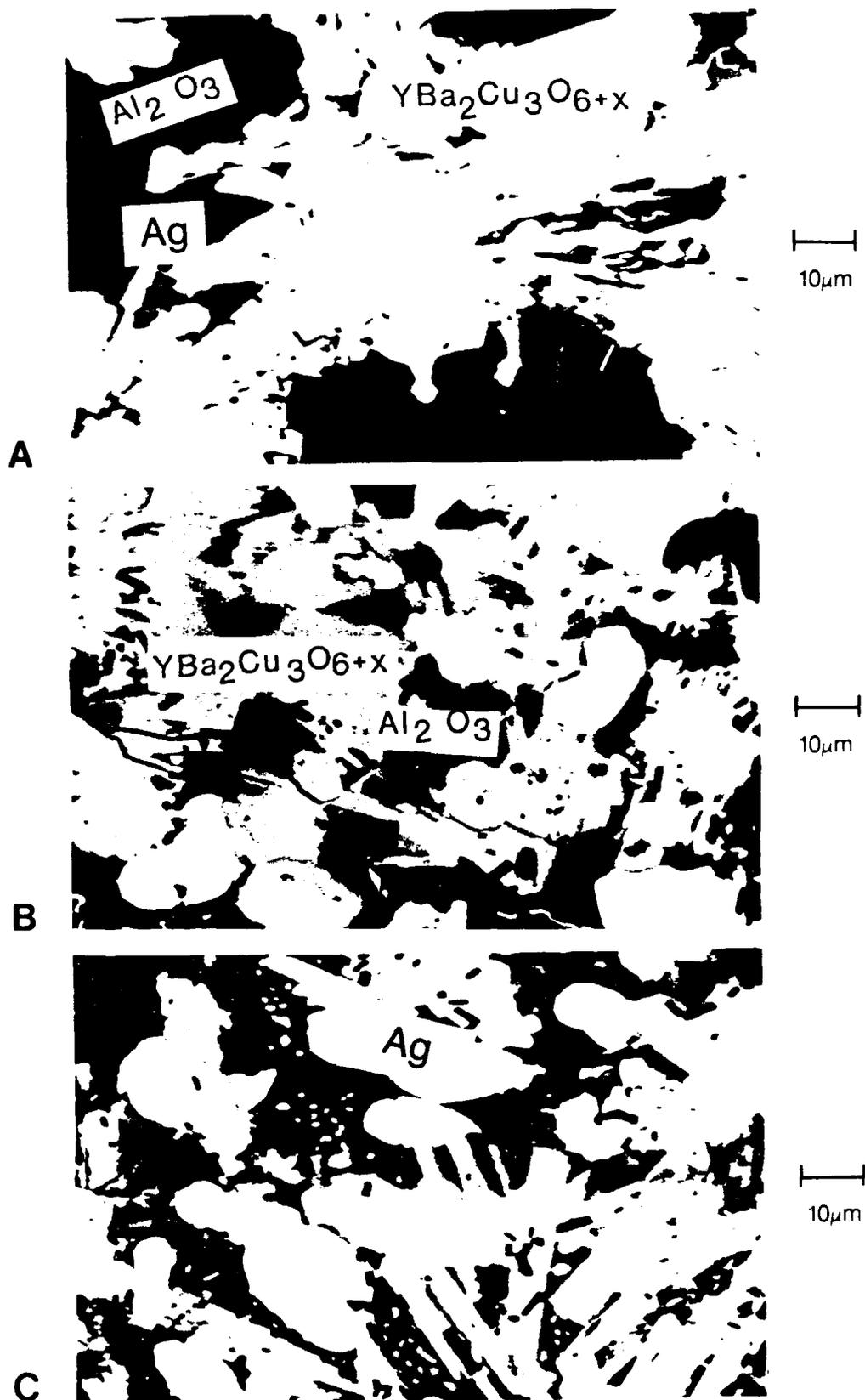


Figure 4. Scanning Electron Micrographs of the Morphology of  $\text{Al}_2\text{O}_3/\text{Ag}_2\text{O}/\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  Composites. Concentration of Additives :  $\text{Al}_2\text{O}_3$  2 wt.% and  $\text{Ag}_2\text{O}$  (A) 5, (B) 10 and (C) 15 wt.%.

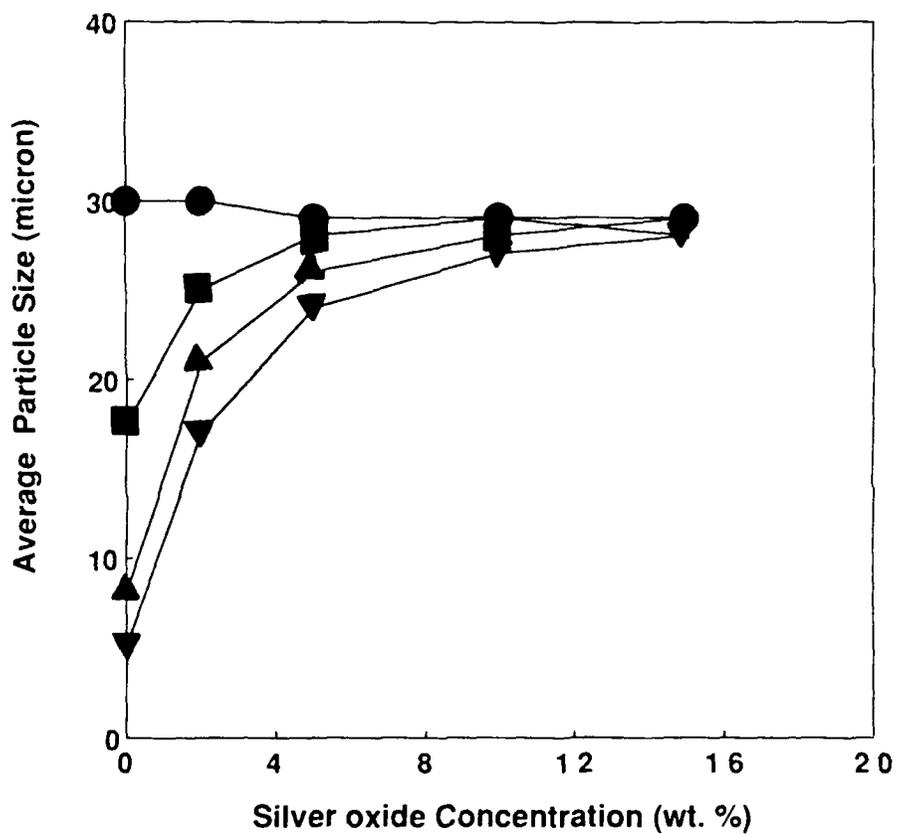


Figure 5. Average Particle Size of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  versus  $\text{Ag}_2\text{O}$  Concentration Profiles of  $\text{Al}_2\text{O}_3/\text{Ag}_2\text{O}/\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  Composites.  $\text{Al}_2\text{O}_3$  Concentration (●) 2, (■) 5, (▲) 10 and (▼) 15 wt.%.

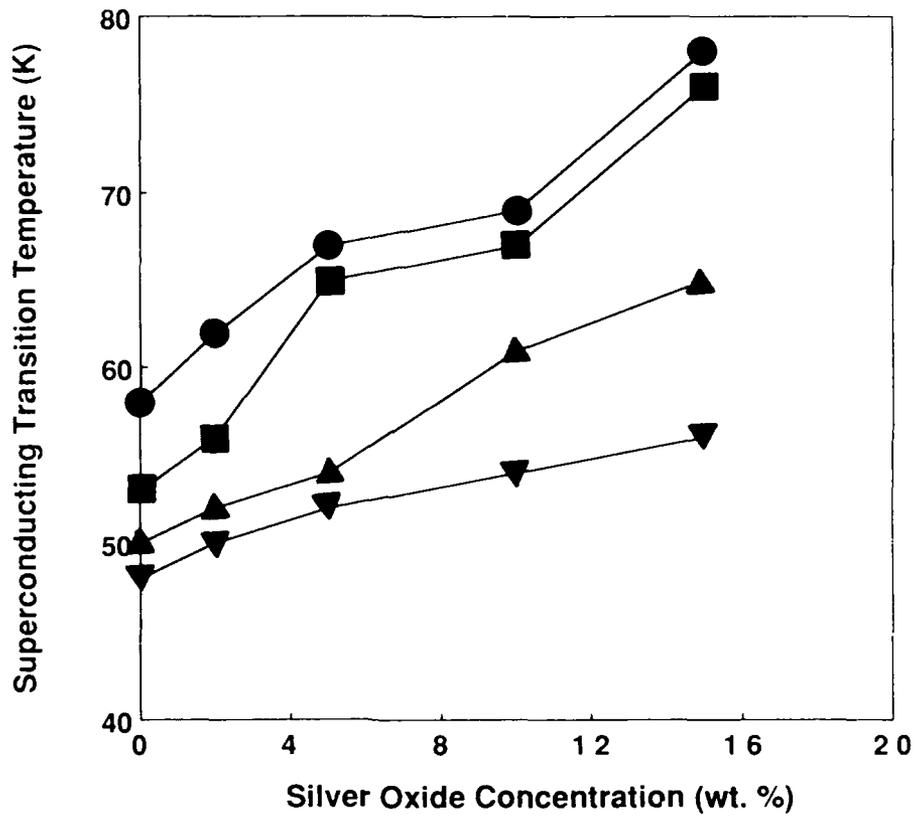


Figure 6. Superconducting Transition Temperature versus Ag<sub>2</sub>O Concentration Profiles of Al<sub>2</sub>O<sub>3</sub>/Ag<sub>2</sub>O/YBa<sub>2</sub>Cu<sub>3</sub>O<sub>6+x</sub> Composites. Al<sub>2</sub>O<sub>3</sub> Concentration (●) 2, (■) 5, (▲) 10 and (▼) 15 wt.%.



Figure 7. Scanning Electron Micrographs of the Morphology of Sintered 5 wt.%  $\text{Al}_2\text{O}_3$ / 5 wt.%  $\text{Ag}_2\text{O}$ /  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$  Composite.

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14. SUBJECT TERMS  SUPERCONDUCTORS, ADDITIVE Al <sub>2</sub> O <sub>3</sub> , Ag <sub>2</sub> O YBa <sub>2</sub> Cu <sub>3</sub> O <sub>6+x</sub> STRUCTURE, MORPHOLOGY			15. NUMBER OF PAGES	
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