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SUPERCONDUCTING PROPERTIES OF BULK Bi(Pb)-Sr-Ca-Cu-O WITH NANOPOWDER $CoFe_2O_4$ ADDITION

[1]K. T. Lau*, [2]R-Abd Shukor, [3]M. M. Awang Kechik, [1]Mohamad Nizam Ayof, [1]Agus Setyo Budi, [4]Safarudin Gazali Herawan, [2]Weesiong Chiu, [2]S. Radiman

[1] Dept. of Science and Mathematics, Centre of Academic Services
Kolej Universiti Teknikal Kebangsaan Malaysia, Locked Bag 1200, Ayer Keroh, 75450 Melaka
* Email: ktlau@kutkm.edu.my

[2] School of Applied Physics, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor

[3]Department of Physics, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor

[4] Faculty of Mechanical Engineering
Kolej Universiti Teknikal Kebangsaan Malaysia, Locked Bag 1200, Ayer Keroh, 75450 Melaka

Abstract:

The efforts to improve the superconducting properties of high temperature superconductor in the aspect of supercurrent transport ability have been made by introducing artificial pinning sites. Several techniques include heavy ion bombardment, proton irradiation, neutron irradiation and atomic substitutions had been used and found its own difficulties when applied in large-scale production. One of solution to overcome these problems is the addition of nanometer size particles as pinning centres to the superconductor which had been found effective to improve the pinning strength of superconductor In this paper, the superconducting properties of bulk Bi(Pb)-Sr-Ca-Cu-O with nano-powder $CoFe_2O_4$ addition will be investigated by T_c measurements and SEM micrograph.

Keywords:

Nanopowder $CoFe_2O_4$, bulk Bi(Pb)-Sr-Ca-Cu-O, microstructure, superconducting property

1 Introduction

Much effort has been done to improve the superconducting properties of high temperature superconductor (HTSc) in the aspect of supercurrent transport ability, which includes enhancing the pinning strength of the materials. Thus stronger pinning properties of HTSc will give way to more applications using high magnetic field. Several techniques include heavy ion bombardment, proton irradiation, neutron irradiation and atomic substitutions had been used to increase the pinning strength of HTSc [1-5], yet addition of nanometer size particles [6-9] have been favoured in term of their reliability in the large scale production. It was reported [6] that particle size of MgO nanoparticles may play a significant role in the efficiency of the flux pinning centres. Contrast to the expectation, ultra-fine MgO (10 nm) did not enlarge the critical current density compared with 200 nm MgO.

It is believed that flux line network and magnetic texture can interact effectively if their characteristics scales are of same order of magnitude. In a magnetic system with characteristic length L, where coherence length $\xi < L <$ penetration depth λ, strong interaction between flux line network and magnetic subsystem can be expected [10]. In our previous work, we had shown that addition of magnetic nanopowder γ-Fe_2O_3 in Bi-Sr-Ca-Cu-O/Ag superconductor tapes enhanced its self-field critical current density J_c to four times larger than the J_c for Bi-Sr-Ca-Cu-O/Ag superconductor tapes without the addition in the same heat-treatment [7]. Thus it is interesting to investigate the effect of addition of other types of magnetic nanopowder in the superconducting properties of Bi-Sr-Ca-Cu-O superconductor. In this paper, we report the effect of magnetic nanopowder $CoFe_2O_4$ addition on superconducting properties of bulk Bi(Pb)-Sr-Ca-Cu-O superconductor.

2 Experimental Details

Bi(Pb)-Sr-Ca-Cu-O superconductor powder was prepared through co-precipitation using metal acetates of bismuth, strontnium, lead, calcium and copper (purity $\geq$ 99.99%), oxalic acid, de-ionized water and 2-proponal. More detail about the co-precipitation technique was described in [11]. The calcined powders were separated and then were mixed and ground for half an hour with nanopowder $CoFe_2O_4$ according to the following weight percentage (%wt) : 0, 0.01, 0.05 and 0.1. The powders were then made into pellets of 13 mm diameter under a pressure of around 5000 kg/cm^2 for 5 minutes and were labelled as samples Bi-0, Bi-0.01, Bi-0.05 and Bi-0.1. All the samples were heated at 845 °C for 50 hours in air (≈ 21% O_2) followed by furnace cooling to room temperature. The sinthesis of $CoFe_2O_4$ is shown in [12].

Electrical resistance (dc) measurements were carried out using the standard four-point probe method. Particle sizes and microstructures of nano powder $CoFe_2O_4$ were studied by using transmission electron microscope (TEM) with LEO 912AB equipped with energy filter. The microstructures study of bulk Bi(Pb)-Sr-Ca-Cu-O superconductor was done using scanning eletron microscope (SEM) model LEO 1450VP

3 Result and Discussion

Figure 1 shows microstructure of $CoFe_2O_4$ nanoparticles before it was added to the bulk Bi(Pb)-Sr-Ca-Cu-O superconductor. The particles have spherical-like shape with an average diammeter less than 50 nm and are believe to show significant ferromagnetic behaviour. More detail about the properties of $CoFe_2O_4$ nano particles are shown in [12].

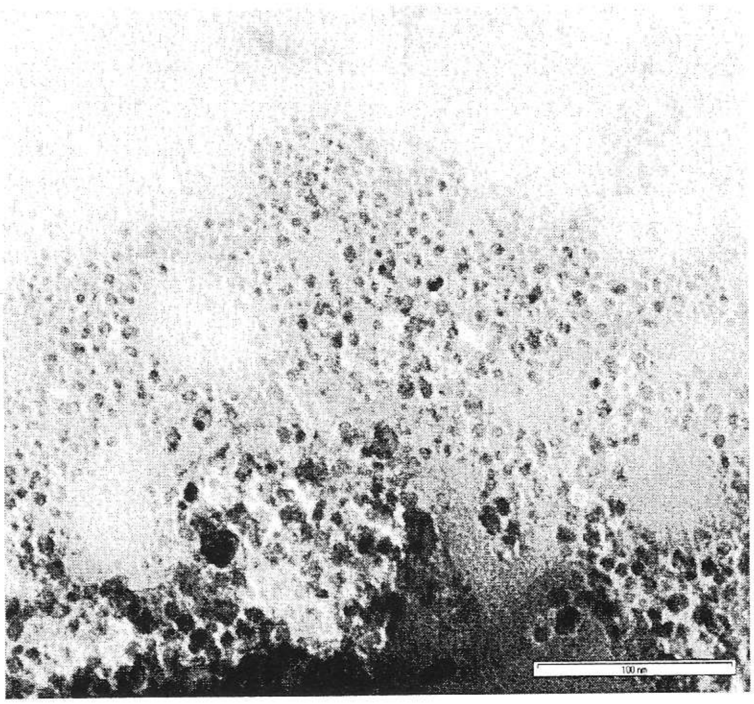

Figure 1. Microstructure of $CoFe_2O_4$ nano particles

The dependences of electrical resistance on the temperature of the samples are shown in Figure 2. All the samples show metallic normal state behaviour before their resistance start to drop at onset critical temperature T_{conset}. Offset critical temperature $T_{c\ zero}$ (the temperature when resistance reach zero) for Bi-0, Bi-0, Bi-0 and Bi-0.1 are 96 K, 95 K, 95 K and 32 K. Anyway, the resistances at varies temperature (during the normal state) are noticed higher for samples with higher %wt $CoFe_2O_4$ addition, except for sample Bi-0.01 which is slightly lower than Bi-0. Consistent with the change in the normal state resistance, critical temperature $T_{c\ zero}$ of the samples is smaller for higher %wt $CoFe_2O_4$ addition. These results indicate that $CoFe_2O_4$ suppress superconductivity in bulk Bi(Pb)-Sr-Ca-Cu-O superconductor.

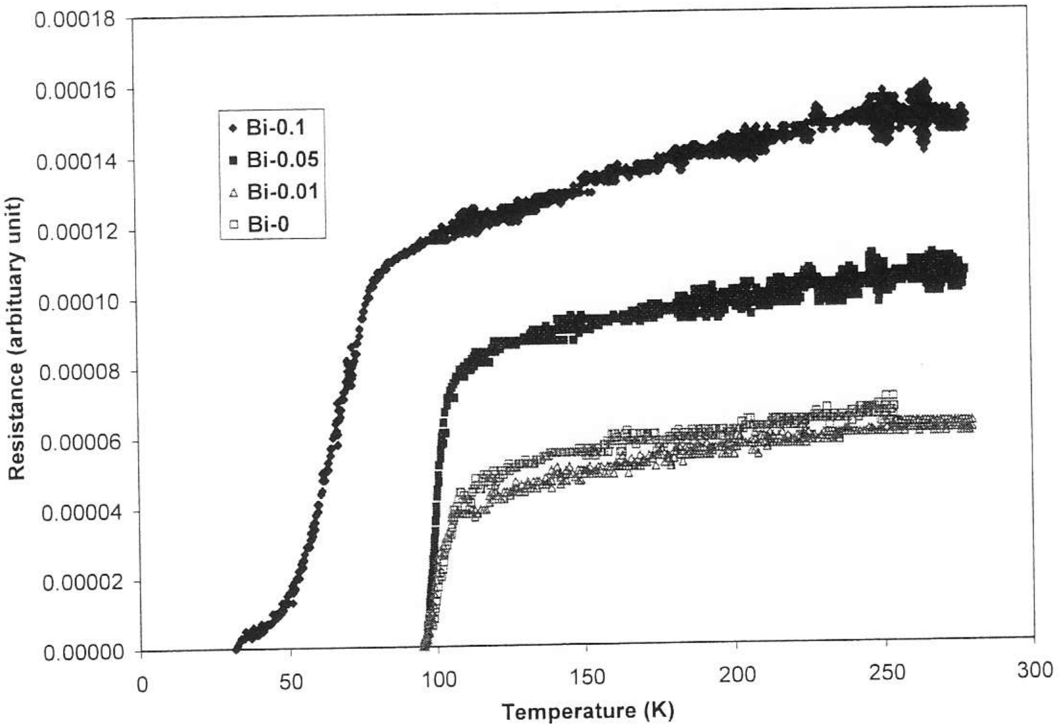

Figure 2. The dependence of electrical resistance on the temperature of the samples

In order to investigate the effect of $CoFe_2O_4$ addition on the microstructure of bulk Bi(Pb)-Sr-Ca-Cu-O superconductor to its superconducting property, SEM micrographes were taken for sample Bi-0.01 and Bi-0.1. The micrographes in Figure 3(a) and Figure 3(b) show clearly the reduction of average size of superconductor grains for Bi-0.1 compared with the grains in Bi-0.01. Large plates of superconductor grains (> 10 nm long) which are randomly distributed around the sample Bi-0.01 can not be seen in sample Bi-0.1. Average grains size of Bi-0.1 are found less than 5 nm. Both samples do not show sign of grains alignment which indicates majority of supercurrent links are consisted of weaklinks. It is clearly shown that $CoFe_2O_4$ addition obstructs the growth of large superconductor grains, which deteriotes the quality of the connectivity of the grains.

It is commonly known that the superconducting properties of superconductors are affected by their microstructures which have a big role in the connectivitiy between superconductor grains and pinning mechanism of superconductor. Good connectivity is important as it will determine the maximum amount of supercurrent allowed to flow from one superconductor grains to another without dissipation. Pinning strength is related to the strength of pinning centres (which are non-superconducting) in the superconductor to hold magnetic fluxes from causing dissipation. The change in the microstructure due to $CoFe_2O_4$ addition may be the reason for the deterioration of superconductivity in bulk Bi(Pb)-Sr-Ca-Cu-O superconductor where its $T_{c\,zero}$ reduced from 96 K to 32 K.

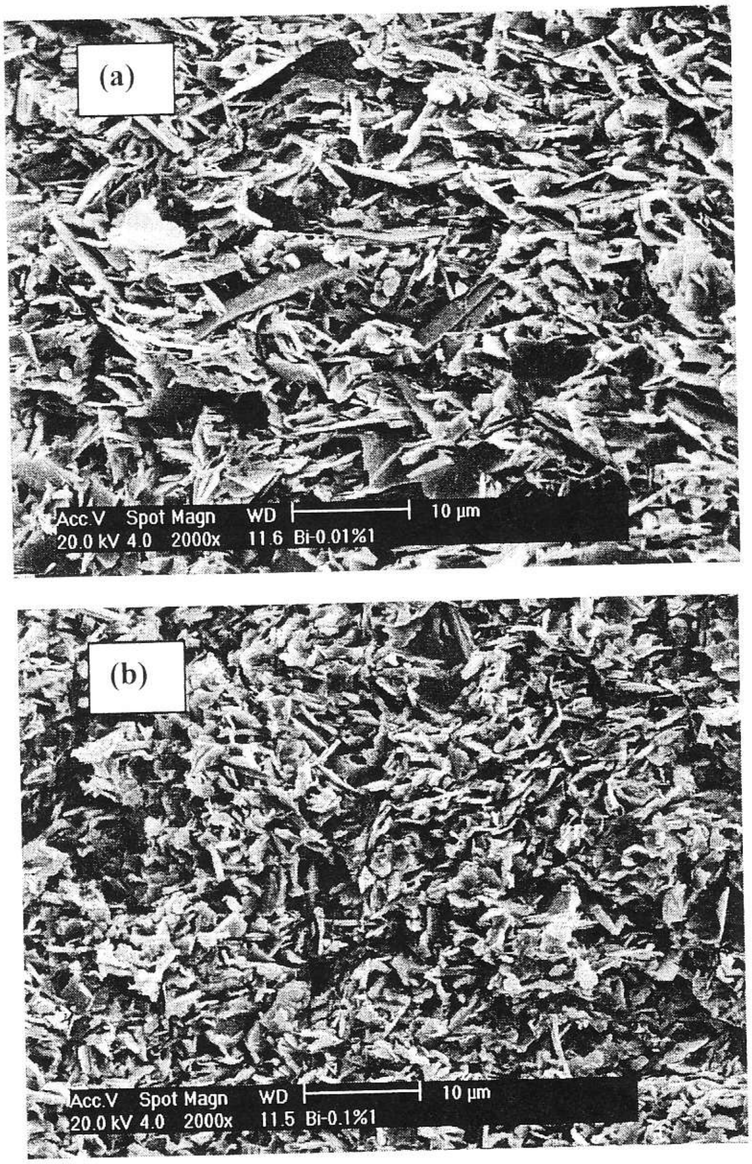

Figure 3. Microstructure of bulk Bi(Pb)-Sr-Ca-Cu-O superconductor (a) Bi-0.01 (b) Bi-0.1

Conclusion

Our offset critical temperatures $T_{c\ zero}$ indicate that $CoFe_2O_4$ addition suppress superconductivity in bulk Bi(Pb)-Sr-Ca-Cu-O superconductor. $T_{c\ zero}$ decreases from 96 K for 0 %wt addition to 32 K for 0.1 %wt addition. The change in the microstructure of the superconductor at the same time may be the reason for the deterioration of superconductivity in bulk Bi(Pb)-Sr-Ca-Cu-O superconductor. Further study need to be done to investigate the cause of microstructures change of the superconductor. One possibility is that the direction of phase formation in the sample had been altered by addition of the $CoFe_2O_4$ nanopowder to form other non superconducting phases.

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