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THE SUPERCONDUCTIVITY OF $YBa_2Cu_3O_{7-\delta}$ REACTED WITH NANO-SiC

W.N.A.W. Shaaidi, K.P. Lim, K.A. Matori, E. Saion,
S.A. Halim and S.K. Chen

Physics Department, Faculty of Science, Universiti Putra Malaysia,
43400 UPM Serdang, Selangor Darul Ehsan, Malaysia.

Corresponding author: one_ain@yahoo.com

ABSTRACT

We report on the influence of nano-SiC as an additive on the superconductivity of polycrystalline $YBa_2Cu_3O_{7-\delta}$ (YBCO) prepared via solid state reaction method. In particular, we studied the characteristic of superconducting transition temperature (T_c), crystal structure and microstructure of the YBCO system. X-ray diffraction patterns show the dominance of YBCO (123) phase in all the samples. The *a* and *c* axes increase slightly while the *b*-axis decreases with SiC addition causing the reduced orthorhombicity. Measurements of resistance versus temperature show that the normal state changes from metallic to semiconducting like behavior upon increasing the amount of additive from 1.5 wt.% onwards. The $T_{c\text{-onset}}$ was found to decrease from 91 K for pure samples to 78 K for the 2 wt. % sample attributable to the adverse effect of Si. The broadening in superconducting transition breadth, ΔT indicates degraded crystallinity or inhomogeneity in the samples caused by SiC additions.

Keywords: YBCO; lattice parameters; superconducting transition temperature

INTRODUCTION

To date, intensive research has been carried out to understand the mechanism of superconductivity in $YBa_2Cu_3O_{7-\delta}$ (YBCO) system. By undertaking a doping process, it is known that the additive can either go into the lattice structure, remains as an impurity or reacts with the host material to form second phases. From the practical point of view, the additives used must not degrade the superconducting transition temperature (T_c) as well as the grain connectivity so that a severe reduction in the critical current density (J_c) may not occur [1]. It has been shown that the second phase of nano-particles or defects may enhance the pinning properties of YBCO system [2-4]. Yang et al. reported on the fabrication of YBCO/nano-SiC composites [5]. They showed that the addition of nano-SiC into YBCO system changes the crystalline structure at the interfacial area and causes the dispersion of oxygen content. The J_c of the samples is also enhanced as a result of improved flux pinning due to homogeneous distribution of the nano-SiC particles [5]. However, the focus of their work is mainly on the J_c properties. It is our aim in this work to carry out a systematic study on the effect of nano-SiC additions on the T_c behavior of YBCO. We investigated a wide range of sample properties including the phase formation and crystal structure. The results are discussed with respect to the

variation of superconducting transition temperature.

METHOD

An appropriate amount of powder with a nominal composition of $YBa_2Cu_3O_{7-\square}\square$ was mixed with 0 - 2 weight percentages (wt.%) of nano-SiC (nanoparticle size 15 nm, purity of 99%). The mixed powders were ground for an hour in an agate mortar by using a pestle to ensure homogeneity. The resulting powders were divided into 1.0 gram each and they were pelletized by using a hydraulic press at a pressure of 5 tons. The pellets were then sintered at 950 ^oC for 12 hours and then at 450 ^oC for 24 hours, in air, before slowly cooled to room temperature. The samples were examined by powder x-ray diffraction (XRD) technique using a Phillips x-ray diffractometer equipped with Cu-K_α radiation source. The data was collected over the range 20^o - 80^o in scanning mode of $\theta - 2\theta$ with a scanning step size of 0.033^o. The crystal structure parameters were refined by using the Rietveld technique employing the X'Pert HighScore Plus software. The resistance as a function of temperature was measured using a standard four-point-probe set-up with a closed-cycle helium cryostat. In order to record the change in voltage as the temperature went down, a small current of 0.03 *A* was applied to the samples. $T_{c\text{-}offset}$ is defined as the superconducting transition temperature for the resistance to drop to zero while $T_{c\text{-}onset}$ is defined as the temperature at which the resistance drops abruptly showing a deviation from linearity of the resistance versus temperature plot. Microstructure was viewed by using a Scanning Electron Microscope (SEM-LEO 1455 VPSEM).

RESULTS AND DISCUSSION

XRD patterns of the pure and the nano-SiC added samples are shown in Figure 1. These data was refined by using the Rietveld method based on the orthorhombic structure with *Pmmm* (No. 47) space group in order to determine the lattice parameters. Peaks belonging to the impurity Y_2BaCuO_5 (211) were detected at around $2\theta = 26.09^o$, 29.79^o, 30.45^o and 35.56^o in 1.5 wt.% and 2.0 wt.% SiC added samples.

No significant shift of the Y-123 characteristic peaks was noticeable. Peaks belonging to unreacted SiC, Si or C related by products were not observed in the x-ray diffraction spectra probably because of the relatively small amount of those phases. Oxidation of SiC into SiO_2 is possible since the sintering process was carried out in air at high temperature [6]. The variation of lattice parameters is shown in figure 2. In general, the lattice constants of *a* and *c* increase whereas the *b*-axis decreases slightly with increasing the addition level of nano-SiC causing an expansion in unit cell. The increase in the unit cell volume shows that the addition of SiC has led to lattice distortion [4]. The orthorhombicity of the system was calculated according to the equation (b-a)/(a+b) [7]. As shown in figure 3, the decrease of orthorhombicity indicates the decrease of orthorhombic strain in the samples [7].

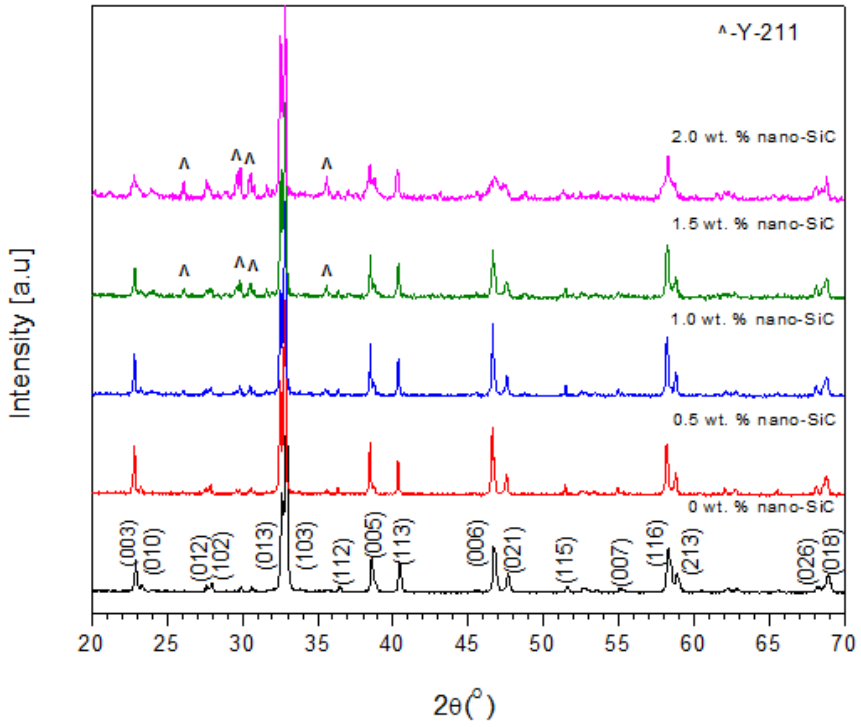

Figure 1: X-ray powder diffraction patterns of θ - 2θ scan

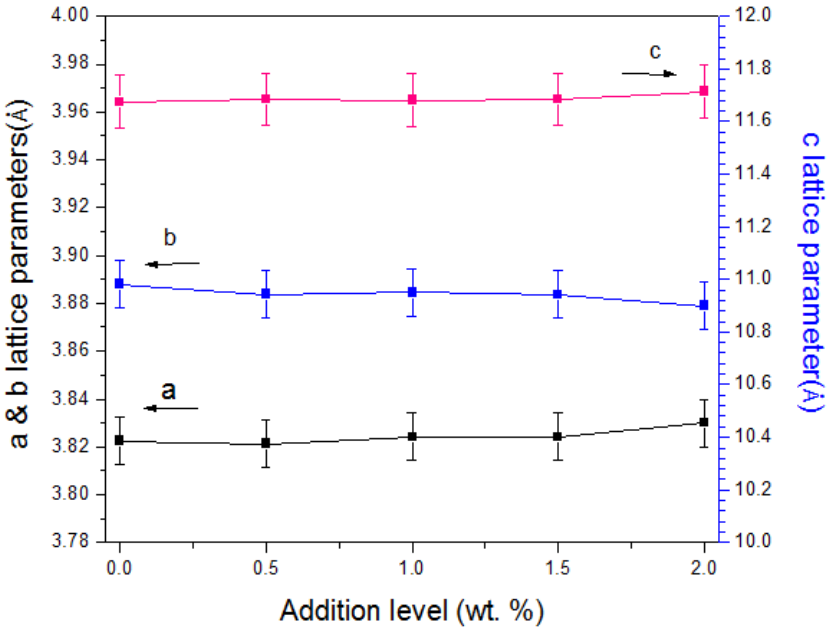

Figure 2: Evolution of lattice parameters with the addition level of nano-SiC

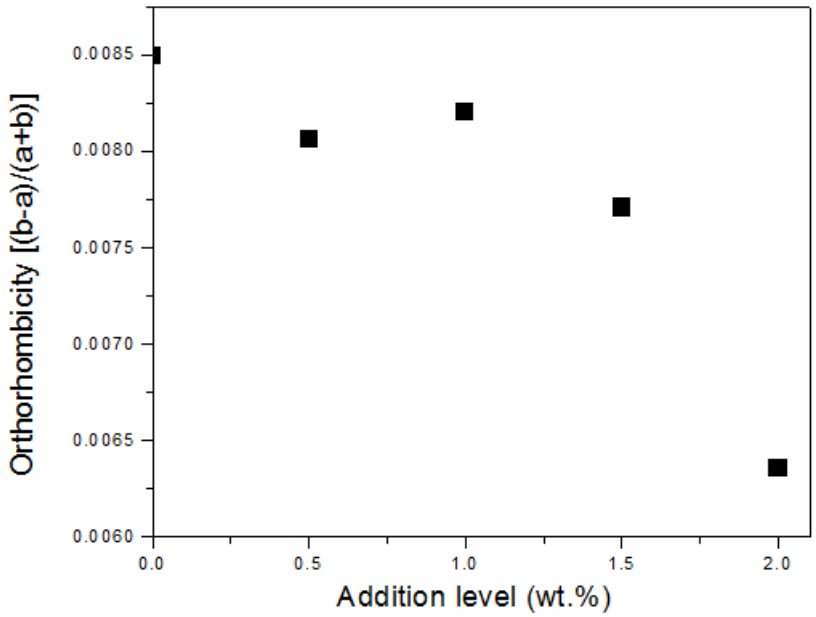

Figure 3: Dependency of orthorhombicity on nano-SiC addition

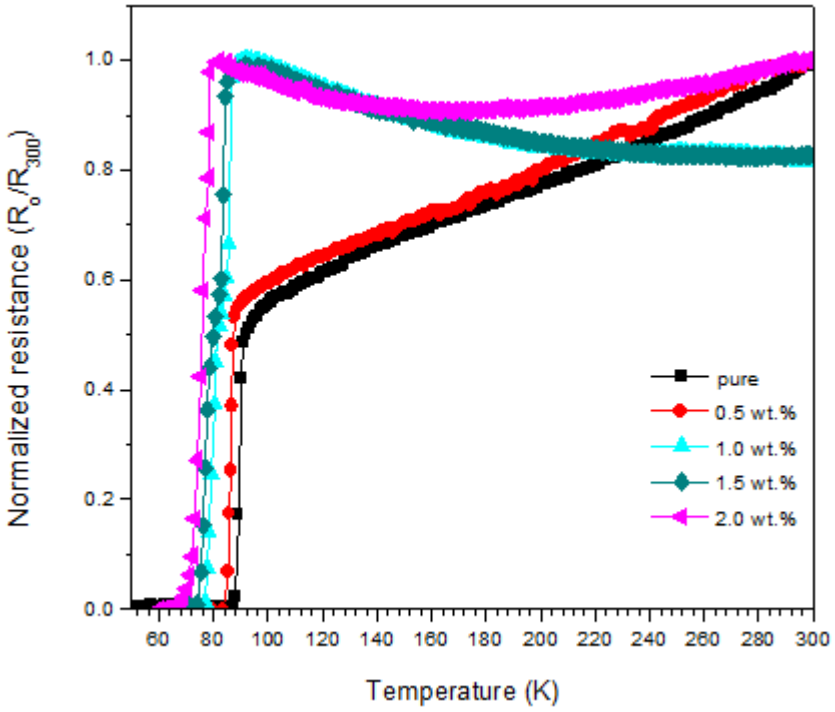

Figure 4: Normalized resistance versus temperature plots

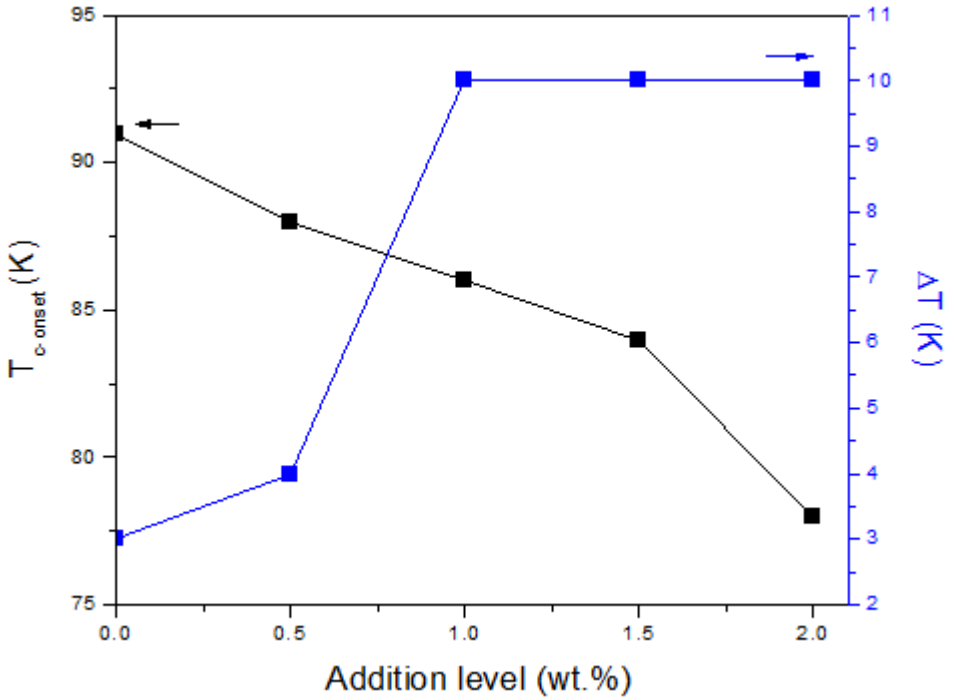

Figure 5: Variation of $T_{c\text{-}onset}$ and ΔT with addition of nano-SiC. Lines are guides for the eyes only

Figure 4 shows the normalized resistance versus temperature plots of YBCO added with various amount of nano-SiC. Above the $T_{c\text{-}onset}$ (normal state), the pure and the sample added with 0.5 wt.% of nano-SiC show a metallic behavior [7] with the resistance decreases almost linearly as the temperature decreases. However, a semiconducting-like behavior is observed for samples added with 1 and 2 wt.% of nano-SiC. This abnormality may be related to the structural change in the samples [8]. The $T_{c\text{-}onset}$ is depressed from 91 K for the pure sample to 78 K for the 2 wt.% nano-SiC added sample. It has been shown that the presence of carbon does not decrease the superconducting transition temperature considerably [9, 10]. This implies that the degradation of T_c could be due to the adverse effect of Si. According to figure 5, the decrease in $T_{c\text{-}onset}$ is accompanied by a broadened superconducting transition breadth, ΔT which is due to the sample inhomogeneity causing degradation in grain connectivity.

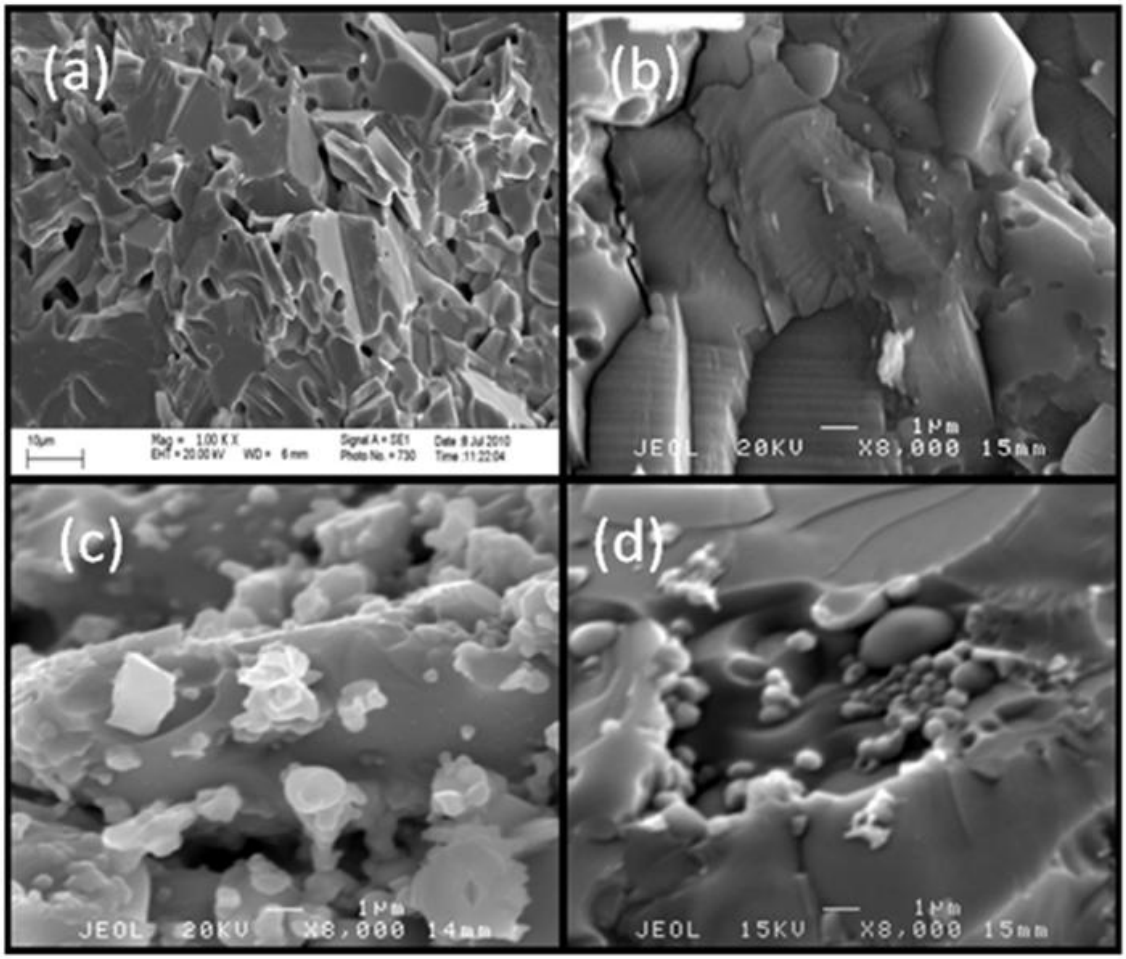

Figure 6: SEM micrographs of the (a) pure samples and samples reacted with (b) 0.5 wt.%, (c) 1.0 wt.% and (d) 2.0 wt.% of nano-SiC

Figure 6 shows the SEM micrographs taken on the fractured surface of the samples. For those SiC added samples (Figure 7(c)-(d)), it can be well recognized that the presence of nano-particles may be beneficial to the flux pinning properties. Moreover, a gradual increase of grain size with the addition of SiC nano-particles is also obvious [11].

CONCLUSION

Polycrystalline YBCO reacted with nano-SiC were prepared via solid state reaction method and they were measured for their crystal structure and superconducting properties. By increasing the wt.% of nano-SiC additions, the lattice parameters of *a* and *c* increase while the *b* axis decreases slightly causing an expansion in the unit cell volume and a reduction in the orthorhombicity. A transition from a metallic to semiconducting like behavior in the normal state is observed upon increasing the SiC additions. The T_c was found to decrease to 78 K in sample with 2 wt.% of SiC additions

attributed to the adverse effect of Si. The broadening in the superconducting transition breadth, ΔT, can be related to the degradation of grain connectivity as a result of sample inhomogeneity. SEM micrographs revealed the increased grain size with the increasing nano-SiC addition with the nano-particles distributed among the grains.

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