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Structural and superconducting properties of the composite $LaBaCaCu_3O_{7-\delta}$–$Ba_2HoHfO_{5.5}$

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Abstract

We have successfully fabricated HTS – ceramic insulator composite system $LaBaCaCu_3O_{7-\delta}$–$Ba_2HoHfO_{5.5}$ in which particles of the superconductor and insulator materials could coexist with well defined separated phases left intact by stringent high-temperature processing conditions. Addition of $Ba_2HoHfO_{5.5}$ did not have any deteriorating effect on the superconducting properties of the $LaBaCaCu_3O_{7-\delta}$ superconductor.

Keywords: $Ba_2HoHfO_{5.5}$; $(CaLa)(BaLa)_2Cu_3O_{6+x}$; Superconducting composite

The fabrication of the high-T_c ceramic superconductor (HTS) – ceramic insulator composites is a difficult task due to chemical interaction between the component materials at the high processing temperatures, which affects the superconducting properties drastically [1,2]. Using an insulating ceramic $Ba_2HoHfO_{5.5}$ [3], we have successfully fabricated HTS – ceramic insulator composite system $LaBaCaCu_3O_{7-\delta}$–$Ba_2HoHfO_{5.5}$ in which particles of both materials could coexist.

$LaBaCaCu_3O_{7-\delta}$ and $Ba_2HoHfO_{5.5}$ powder materials were prepared by solid-state reaction process [3,4]. $LaBaCaCu_3O_{7-\delta}$–$Ba_2HoHfO_{5.5}$ composites, with 0–50 wt% of $Ba_2HoHfO_{5.5}$ component in the respective composites, were synthesized by mixing the component materials in desired wt% ratios, pelletized and heat treated at 975°C for 24 h in flowing oxygen. Samples were cooled down slowly at a rate of 2°C/min to room temperature for proper oxygenation. The composites were characterized by X-ray diffraction (XRD), EDX, SEM and by magnetic measurements.

Structural characteristics of the $LaBaCaCu_3O_{7-\delta}$–$Ba_2HoHfO_{5.5}$ composites were examined by X-ray diffractometry. Their XRD spectra show that all the XRD peaks correspond either to $LaBaCaCu_3O_{7-\delta}$ or $Ba_2HoHfO_{5.5}$ and there is no detectable extra peak due to any impurity phase resulting from a chemical interaction between the two materials. It indicates that $LaBaCaCu_3O_{7-\delta}$ and $Ba_2HoHfO_{5.5}$ components are chemically compatible and retain their structural characteristics distinguishable in the composites. For the structural compatibility, lattice matching of the component materials is an important factor. $LaBaCaCu_3O_{7-\delta}$ has a tetragonal crystal structure with lattice parameters $a = 3.8694$ Å and $c = 11.6168$ Å. $Ba_2HoHfO_{5.5}$ has an $A_2BB'O_6$ type ordered complex cubic perovskite structure, with lattice constant $a = 8.316$ Å. Based on the doubling of primitive ABO_3 simple cubic perovskite cell, (half of lattice constant of $Ba_2HoHfO_{5.5} = 4.158$ Å) there is fairly good lattice matching between $Ba_2HoHfO_{5.5}$ and $LaBaCaCu_3O_{7-\delta}$ materials (lattice mismatch $\sim 9\%$). SEM micrographs of $LaBaCaCu_3O_{7-\delta}$ and $Ba_2HoHfO_{5.5}$ materials and $LaBaCaCu_3O_{7-\delta}$–$Ba_2HoHfO_{5.5}$ composites show that the surface of the samples presents a crystallinity, that is typical of a polycrystalline ceramic material with homogeneous surface morphology and particle size distribution.

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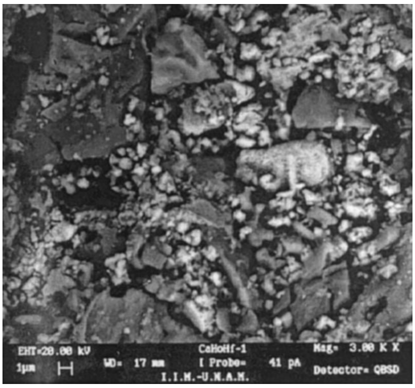

Fig. 1. Back scattered electron SEM micrograph of a typical 1:1 wt% $LaBaCaCu_3O_{7-\delta}$–$Ba_2HoHfO_{5.5}$ composite.

The average particle size of $LaBaCaCu_3O_{7-\delta}$ and $Ba_2HoHfO_{5.5}$ grains were estimated to be 10–15 μm and 1–2 μm, respectively. Fig. 1 shows typical back-scattered electron micrograph of a 1:1 wt% $LaBaCaCu_3O_{7-\delta}$–$Ba_2HoHfO_{5.5}$ composite. As seen from the micrograph, there is no detectable interface interaction between $Ba_2HoHfO_{5.5}$ and $LaBaCaCu_3O_{7-\delta}$ grain interfaces. $Ba_2HoHfO_{5.5}$ grains are distinguishably distributed in the $LaBaCaCu_3O_{7-\delta}$ matrix.

The temperature dependence of the AC magnetization of $LaBaCaCu_3O_{7-\delta}$–$Ba_2HoHfO_{5.5}$ composites are shown in Fig. 2. In every case, there is sharp superconducting transition in $LaBaCaCu_3O_{7-\delta}$–$Ba_2HoHfO_{5.5}$ composites at 80 K, corresponding to the T_c of the $LaBaCaCu_3O_{7-\delta}$ superconductor. $Ba_2HoHfO_{5.5}$ addition did not have any deteriorating effect on the superconducting properties of $LaBaCaCu_3O_{7-\delta}$.

In conclusion, we have successfully fabricated a high-temperature superconductor–insulator composite system $LaBaCaCu_3O_{7-\delta}$–$Ba_2HoHfO_{5.5}$, in which particles of both materials could coexist with well-defined separated phases left intact by stringent high-temperature processing conditions. Addition of $Ba_2HoHfO_{5.5}$ did not have any deteriorating effect on the superconducting properties of the $LaBaCaCu_3O_{7-\delta}$ superconductor. An important implication of this study is that the $Ba_2HoHfO_{5.5}$ could be used as a substrate material for the fabrication of the $LaBaCaCu_3O_{7-\delta}$ superconducting films.

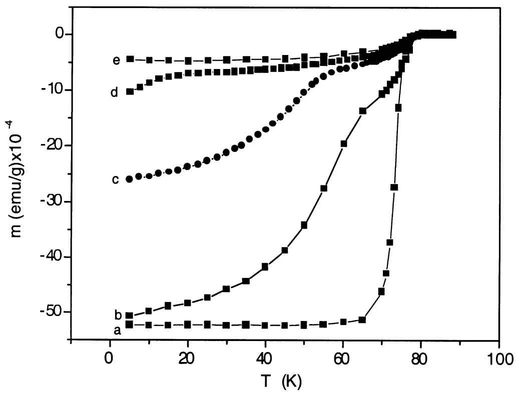

Fig. 2. AC magnetization versus temperature curves of $LaBaCaCu_3O_{7-\delta}$–$Ba_2HoHfO_{5.5}$ composites containing (a) 0 wt%, (b) 10 wt%, (c) 20 wt%, (d) 30 wt% and (e) 50 wt%, $Ba_2HoHfO_{5.5}$ component.

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