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Microstructure and Superconducting Properties of $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 Ceramic Composite

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In this work, we have synthesized and studied structural and microstructural characteristics of $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 composites Ba_2HoNbO_6 has an $A_2BB'O_6$ complex cubic perovskite structure with lattice constant a = 8.439Å. Ba_2HoNbO_6 is chemically and physically compatible with $LaBaCaCu_3O_{7-\delta}$ superconductor. So, we infer that Ba_2HoNbO_6 could be a potential substrate material for the fabrication of the $LaBaCaCu_3O_{7-\delta}$ superconducting films.

Key words $LaBaCaCu_3O_{7-\delta}$, Ba_2HoNbO_6, ssuperconducting composites,

I. INTRODUCTION

Investigation on new substrate materials for high temperature superconducting films is a significant concern in materials research. Recently, complex perovskite oxides are being investigated for such applications [1-4]· In the present work, we have synthesized and studied structural and microstructural characteristics of a complex cubic perovskite oxide Ba_2HoNbO_6, using x-diffractometry and scanning electron microscopy, respectively, for its use as a substrate material for the fabrication of $LaBaCaCu_3O_{7-\delta}$ superconducting films. $LaBaCaCu_3O_{7-\delta}$ is one of the important family of high temperature superconductors exhibiting superconductivity around 78K [5]. Chemical stability of Ba_2HoNbO_6 with $LaBaCaCu_3O_{7-\delta}$ was examined by x-ray diffractometry of $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 composites. Back-scattered scanning electron microscopy was used to study the interface interaction between Ba_2HoNbO_6 and $LaBaCaCu_3O_{7-\delta}$ grains in the $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 composites. Congruent melting aspect of the Ba_2HoNbO_6 was studied to know whether this material could be grown as single crystal by melt growth processes. The effect of Ba_2HoNbO_6 addition on the superconductivity of $LaBaCaCu_3O_{7-\delta}$ was investigated by measuring magnetic susceptibility of $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 composites. These studies show that Ba_2HoNbO_6 has favorable substrate characteristics and it could be a potential substrate material for the fabrication of high T_c $LaBaCaCu_3O_{7-\delta}$ superconducting films.

II. EXPERIMENTAL DETAILS

Ba_2HoNbO_6 has been prepared by solid state reaction process. Stoichiometric mixture of high purity (99.99%) constituent chemicals Ho_2O_3, $BaCO_3$, Nb_2O_5 were mixed thoroughly, pelletized and calcined at a temperature of 1100°C for 40h. The calcined material was reground, pressed as circular discs and sintered at 1200°C for 60h. Single phase $LaBaCaCu_3O_{7-\delta}$ with nominal composition $La_1Ba_1Ca_1Cu_3O_{7-\delta}$, was also prepared by solid state reaction process. Details of synthesis and characterization of $La_1Ba_1Ca_1Cu_3O_{7-\delta}$ material are reported in our earlier publication [6].

X-ray diffraction (XRD) spectra of the materials were recorded by a Siemens D5000 x-ray diffractometer, using Cu-Kα radiation (λ = 1.5406 Å). SEM micrographs were recorded by a Leico-Cambridge model stereoscan 440 electron microscope. For the study of chemical compatibility, Ba_2HoNbO_6 - $LaBaCaCu_3O_{7-\delta}$ composites, with 0 to 30wt% of Ba_2HoNbO_6 component, were synthesized. For the synthesis of composites, component materials were mixed in desired wt% ratios and the mixture was pelletized as circular discs at a pressure of 2ton/cm^2. These discs were heat treated at 950°C for 24h in flowing oxygen and cooled down slowly at a rate of 2°C/min to room temperature for proper oxigenetion.. Chemical stability of Ba_2HoNbO_6 with $LaBaCaCu_3O_{7-\delta}$ was examined by x-ray diffraction. Back-scattered electron microscopy was used to examine the interface interaction between Ba_2HoNbO_6 and $LaBaCaCu_3O_{7-\delta}$ grains. Effect of Ba_2HoNbO_6 addition on superconductivity of $LaBaCaCu_3O_{7-\delta}$ superconductors was investigated by a. c. magnetization measurements of $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 composites in the temperature range 5 to 300K, using a Quantum Design SQUID magnetometer.

III. RESULTS AND DISCUSSION

X-ray diffraction (XRD) spectrum of single phase Ba_2HoNbO_6 is shown in Figure 1. The XRD spectrum of Ba_2HoNbO_6 is similar to that expected for $A_2BB'O_6$-type ordered complex cubic perovskites, reported in JCPDS files. As for many perovskite of the general formula $A_2BB'O_6$, an ordered arrangement of B and B' cations is most probable when large differences exist in either their charges or their ionic radii [3]. This is due to the fact that in a substitutional solid solution BB', there is random arrangement of B and B' cations on equivalent position in the crystal structure. If upon suitable heat treatment the random solid solution rearranges into a structure in which B and B' occupy the same set of positions but in a regular way, such structure is described as superstructure [6]. In the superstructure the positions occupied by B and B' is no longer equivalent and this is exhibited in the XRD spectrum by the presence of superstructure reflection lines.

As seen from Figure1, the XRD pattern of Ba_2HoNbO_6 consists of strong peak, characteristics of primitive cubic perovskite plus few weak lines arising from the superlattice. The significant presence of superstructure reflection lines (111) and (311) clearly reveal the Ho^{3+} and Nb^{3+} cations ordering on B and B' positions in $A_2BB'O_6$ structure of Ba_2HoNbO_6.. In Ba_2HoNbO_6, Ba^{2+} cation (ionic radius 1.34 Å) with the largest ionic radius in this composition, occupies A position and Ho^{3+}(ionic radius 0.89 Å) and Nb^{3+} (ionic radius 0.69 Å) cations occupy B position due to their smaller ionic radii compared to that of Ba^{2+} cation. Due to the ordering of B and B' cations on octahedral site of the primitive ABO_3 unit cell, there is doubling in the lattice parameter of the basic cubic perovskite unit cell.

Based on above considerations, we have indexed the XRD peaks of Ba_2HoNbO_6 as an ordered complex cubic $A_2B'B'O_6$ crystal structure. The lattice parameter of Ba_2HoNbO_6, calculated fro XRD data, is $a = 8.439$ Å. Lattice matching of the superconductor with the substrate is an important aspect for the fabrication of good quality superconducting films. Ba_2HoNbO_6 has a double cubic perovskite structure. As discussed earlier, (½)a of $Ba_2HoNbO_6 = 4.219$Å. $LaBaCaCu_3O_{7-\delta}$ has a tetragonal crystal structure with lattice parameters a = 3.869Å and c = 11.617Å.

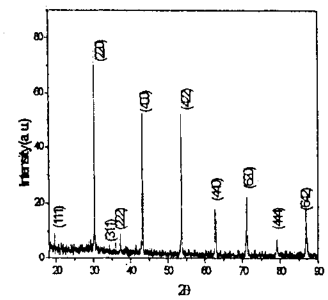

FIGURE 1 XRD spectrum of Ba_2HoNbO_6.

Therefore, Ba_2HoNbO_6 has ~ 9% lattice mismatch with $LaBaCaCu_3O_{7-\delta}$ superconductor.

It may be noted that currently MgO is most widely used substrate for microwave applications. It has a cubic crystal structure (lattice constant a = 4.208 Å) and has a comparable lattice mismatch with $LaBaCaCu_3O_{7-\delta}$ superconductor..

The SEM micrographs of Ba_2HoNbO_6 and $LaBaCaCu_3O_{7-\delta}$ show that materials present homogenous surface morphology. Average particle sizes of the Ba_2HoNbO_6 and LaBaCaCu3O7$_{-\delta}$ materials are estimated to be 3 - 5 microns and 3 – 10 micron, respectively. In the fabrication and processing of high T_c superconducting films, grain interface interaction between the grains of the substrate and superconductor material is an undesirable factor. Even MgO, most widely used substrate for high T_c superconducting films, does form an interlayer of barium salt at the superconductor-substrate interface, if the temperature of processing is higher than 700°C [7].

In present work, back scattered electron micrographs of the Ba2HoNbO6, $LaBaCaCu_3O_{7-\delta}$ single-phase materials and the $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 composite materials were recorded using quarterback scattering detector. The back-scattered electron SEM micrographs of $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 composite, presented in Figure 2, shows that there is no detectable interface interaction between Ba_2HoNbO_6, and $LaBaCaCu_3O_{7-\delta}$ grain and Ba_2HoNbO_6 grains are distinguishably distributed in the $LaBaCaCu_3O_{7-\delta}$ matrix

Chemical stability of Ba_2HoNbO_6 with $LaBaCaCu_3O_{7-\delta}$ superconductor was investigated by x-ray diffractometry on $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 composites. Figure 3 shows the XRD spectra of these composites. As seen from the XRD results, all the XRD peaks correspond either to Ba_2HoNbO_6 Chemical stability of Ba_2HoNbO_6 with $LaBaCaCu_3O_{7-\delta}$ or $LaBaCaCu_3O_{7-\delta}$ and there is no extra peak corresponding to any impurity phase These results show that there is no chemical interaction between these materials and Ba_2HoNbO_6 is chemically compatible with $LaBaCaCu_3O_{7-\delta}$ superconductors.

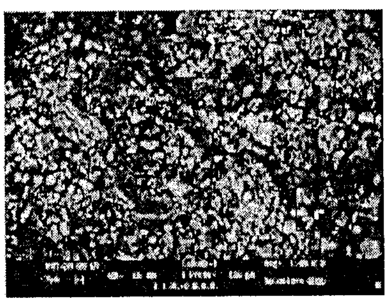

FIGURE 2 Back-scattered SEM micrographs of $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 composite containing 30wt% Ba_2HoNbO_6 component

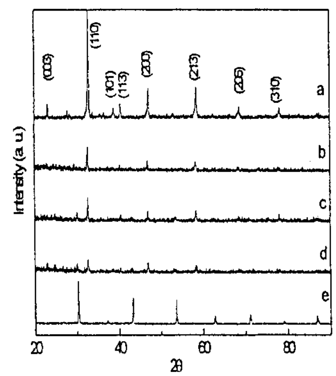

FIGURE 3 XRD spectra of the $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 composites containing (a) 0wt%, (b) 5wt%, (c) 20wt%, (d) 30wt%, and (e) 100wt% Ba_2HoNbO_6

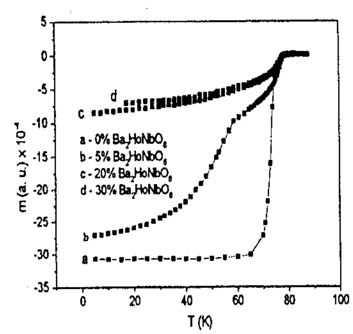

FIGURE 4 a.c. magnetization versus temperature curves of $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 composites

Figure 4 shows the temperature dependence of the real part of the ac magnetization for $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 composites. All the composites gave a T_c of 78K, same as of pure $LaBaCaCu_3O_{7-\delta}$ superconductor. However, with decreasing superconductor volume fraction the magnitude of magnetization decreases in all the composite samples. Accordingly, we infer that addition of the Ba_2HoNbO_6, an insulating ceramic material, has no deteriorating effect on the superconducting properties of the $LaBaCaCu_3O_{7-\delta}$ superconductors.

IV. CONCLUSIONS

In conclusion, we have studied structural and microstructural characteristics of $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 composite. Ba_2HoNbO_6 has fairly good lattice matching (lattice mismatch ~9%) with this superconductor. X-ray diffractometry, scanning electron microscopy and magnetic measurements made on $LaBaCaCu_3O_{7-\delta}$-Ba_2HoNbO_6 composites show that Ba_2HoNbO_6 is chemically compatible with $LaBaCaCu_3O_{7-\delta}$. These favorable characteristics show that Ba_2HoNbO_6 could be used as a potential substrate material for the fabrication of the $LaBaCaCu_3O_{7-\delta}$ superconducting films.

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