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Ba_2ErNbO_6: A new perovskite ceramic substrate for Bi(2223) superconducting thick films ($T_c(0)$ = 110 K)

S U K NAIR, P R S WARRIAR* and J KOSHY†

Department of Physics, University College, Trivandrum 695 034, India
†Regional Research Laboratory, Trivandrum 695 019, India

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Abstract. Barium erbium niobate (Ba_2ErNbO_6) has been developed as a new substrate for $(Bi,Pb)_2Sr_2Ca_2Cu_3O_x$ [Bi(2223)] superconductor film. Ba_2ErNbO_6 (BENO) has a cubic perovskite structure with lattice constant, a = 8·318 Å. The Bi(2223) superconductor does not show any detectable chemical reaction with BENO even under extreme processing conditions. Dip coated Bi (2223) thick film, Ba_2ErNbO_6 substrate, gave a T_c (0) of 110 K and current density of ~ 4×10^3 A cm^{-2} at 77 K and zero magnetic field.

Keywords. Barium erbium niobate; perovskite; substrate; sintering; superconducting film.

1. Introduction

High-T_c superconducting thick films have wide applications in microwave integrated circuits, transmission lines and other high frequency devices (Khare *et al* 1991; McN Alford *et al* 1991). Among the different copper oxide superconductors discovered so far, $(Bi,Pb)_2Sr_2Ca_2Cu_3O_x$ (Bi2223) superconductors have gained considerable attention and a great deal of effort has been made for the production of high quality superconducting films of these compounds for suitable electronic applications. Substrates play a vital role in the preparation of high quality films. The crucial factor in the selection of substrate material for high temperature superconducting films is the chemical non-reactivity between superconductor and substrate material at the processing temperature (Humphereys *et al* 1990; Rowell 1991; Phillips 1996). In the course of our research work on the development of new substrate materials for high T_c superconductors (HTSC) (Koshy *et al* 1993, 1995; Kurien *et al* 1995, 1998, 1999), we identified a new substrate material, BENO, which is found to be chemically non-reacting with Bi(2223) superconductors. Dip coated Bi(2223) thick film on polycrystalline BENO substrate gave a T_c (0) of 110 K and J_c of ~ 4×10^3 A cm^{-2} at 77 K and zero magnetic field.

2. Experimental

BENO was synthesized following the conventional solid-state reaction technique. The structure of the material was studied by X-ray diffraction technique. The dielectric constant (e') and loss factor (tan d) values of polycrystalline BENO at room temperature and liquid nitrogen temperature were studied in the frequency range 30 Hz–10 MHz. The differential thermal analysis of BENO was carried out in the temperature range 30–1100°C. Differential scanning calorimetric studies were carried out and specific heat capacity of the material was deducted from differential power curve. The thermal diffusivity of BENO was carried out by photoacoustic technique.

Single phase Bi(2223) powder used in the present study was prepared by solid state route. The chemical reactivity between Bi(2223) and BENO was studied by mixing Bi(2223) and BENO in the ratio 4 : 1 vol.% and the pellets of composite were annealed in air at 850°C for 12 h and slow cooled at the rate of 1°C/min up to 800°C from the sintering temperature of 850°C and then furnace cooled to room temperature. The chemical reactivity of BENO with Bi(2223) was studied by XRD technique.

The Bi(2223) thick film on BENO substrate was prepared by dip-coating technique and the structure of the dip coated thick film was examined by XRD technique. The superconductivity of the film was studied by temperature resistance measurements using four-probe technique.

3. Results and discussion

Figure 1 shows the XRD pattern taken on sintered BENO sample. All peaks in the XRD pattern of the sintered BENO sample have been indexed for a cubic perovskite structure ($A_2BB'O_6$) with lattice constant, a = 8·318 Å. The variation of (e') and tan d with frequency of BENO is as shown in figure 2. The loss factor value for BENO samples measured at liquid nitrogen temperature were found to be much less than the value obtained at room temperature. The physical properties of BENO are summarized in table 1.

*Author for correspondence (sukn@rediff.com)

The chemical reactivity of BENO with Bi(2223) at the processing temperature of 850°C was studied by X-ray diffraction technique. The XRD pattern of Bi(2223)–BENO composite containing 4 : 1 vol.% of Bi(2223) and BENO annealed at 850°C for 12 h is shown in figure 3c. The XRD pattern of the two phases (figure 3c) in the annealed sample is compared with those of pure Bi(2223) (figure 3b) and pure BENO (figure 3a). It is clear from figure 3c that there is no new additional phase formed, not even Bi(2223), within the precision of the XRD technique, other than Bi(2223) and BENO in the composite. These results indicate that BENO is chemically compatible with Bi(2223) superconductor even at severe heat treatment conditions.

The suitability of BENO as a substrate for Bi(2223) superconductor was confirmed by dip-coating thick film of Bi(2223) on polycrystalline BENO substrate. The XRD pattern of Bi(2223) on BENO substrate is as shown in figure 4. In figure 4 except for the characteristic peaks of BENO all other peaks are those of Bi(2223) superconductor.

The superconductivity of Bi(2223) thick film on polycrystalline substrate was studied by temperature-resistance measurement, using the standard four-probe technique. Figure 5 shows the temperature vs resistance curve of Bi(2223) thick film developed on BENO substrate. The critical current density of Bi(2223) thick film on BENO was measured at 77 K using 1 μV cm^{-1} criterion under zero applied magnetic field. The dip-coated Bi(2223) thick film

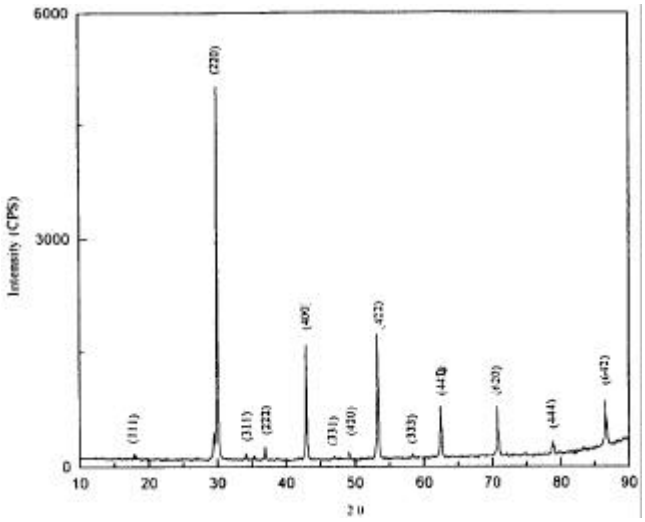

Figure 1. Powder X-ray diffraction pattern on sintered Ba_2ErNbO_6.

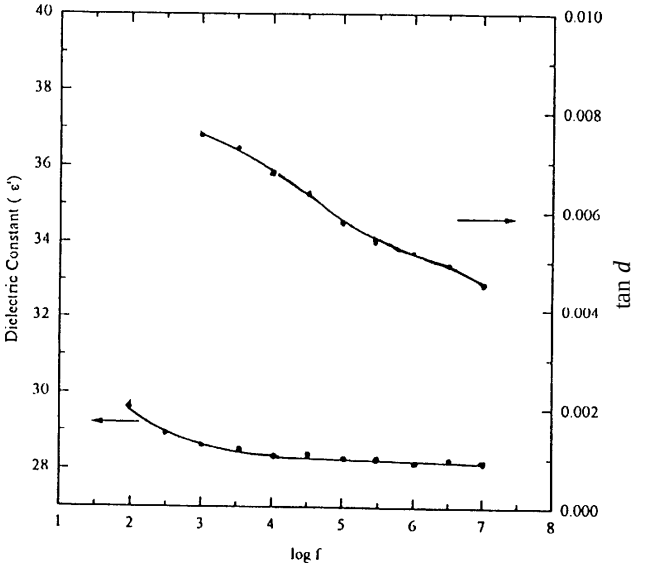

Figure 2. Variation of dielectric constant (e') and loss factor (tan d) of Ba_2ErNbO_6 with frequency.

Table 1. The physical properties of Ba_2ErNbO_6.

Lattice parameter (Å)	a = 8·318
Theoretical density (g cm^{-3})	6·858
Sintered density (g cm^{-3})	6·804
Specific heat capacity (Jkg^{-1} K^{-1})	262·5
Thermal diffusivity (cm^2 s^{-1})	0·294
Thermal conductivity (Wm^{-1} K^{-1})	52·51
Dielectric constant (e') at 10 MHz	28
Dielectric loss (tan d) at 10 MHz	$4·5 \times 10^{-4}$ at 77 K

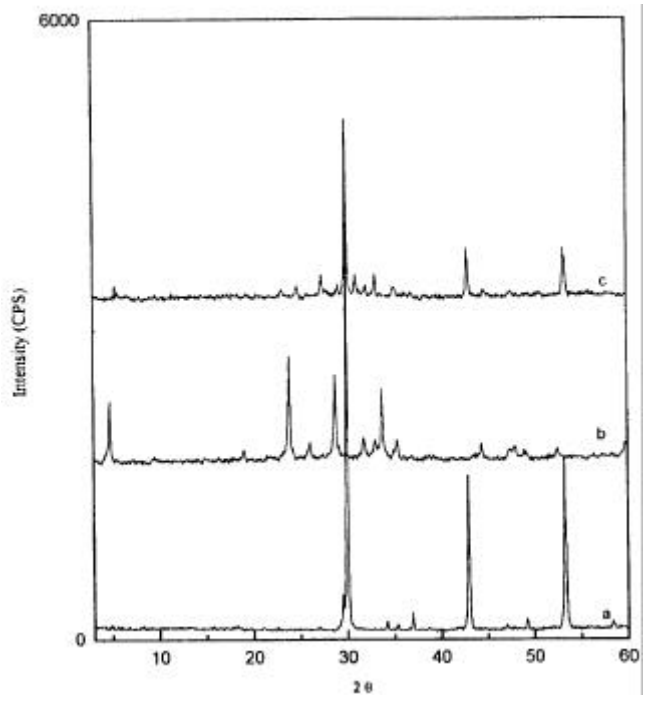

Figure 3. Powder X-ray diffraction pattern of a. phase pure Ba_2ErNbO_6, b. phase pure Bi(2223) superconductor and c. 1 : 4 volume mixture of Ba_2ErNbO_6 and Bi(2223) annealed at 850°C for 10 h.

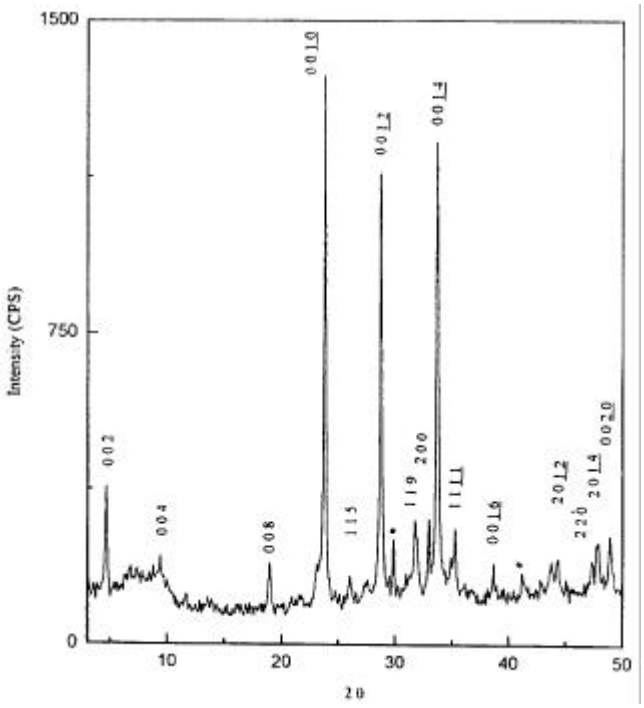

Figure 4. X-ray diffraction pattern of dip-coated Bi(2223) thick film on Ba_2ErNbO_6 substrate (substrate peaks are marked 'o').

on BENO gave a current density of 4×10^3 A cm^{-2} and had excellent adhesion with the substrate.

4. Conclusions

Ba_2ErNbO_6 has been synthesized, characterized and sintered as single-phase material by solid-state reaction method. It has an ordered cubic perovskite structure with lattice constant, a = 8·318 Å. The dielectric constant (28), loss factor value ($4{\cdot}5 \times 10^{-3}$) and thermal conductivity (52·51 W m^{-1} K^{-1}) of sintered BENO were in a range suitable for its use as a substrate for microwave applications. The DTA studies reveal that no phase transition occurs in BENO in the temperature range 30–1100°C. It was found that BENO does not react with Bi(2223) superconductor and the superconducting Bi(2223) thick film prepared by dip coating in polycrystalline BENO gave $T_c(0)$ of 110 K. The critical current density of Bi(2223) thick film developed on BENO was 4×10^3 A cm^{-2} at 77 K and zero magnetic field.

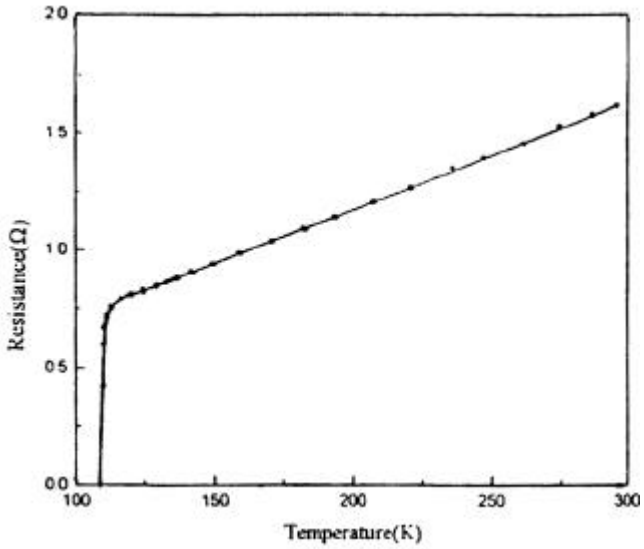

Figure 5. Temperature vs resistance curve of dip-coated Bi(2223) thick film on Ba_2ErNbO_6 substrate.

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