December 2008 Volume 3 Issue 2-3

Physical CHEMISTRY
An Indian Journal

Trade Science Inc.

Full Paper

PCAIJ, 3(2-3), 2008 [93-96]

Synthesis and mechanical properties of BSCCO glassy plates

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Received: 11th July, 2008 ; Accepted: 16th July, 2008

ABSTRACT

$Bi_2Sr_2Ca_{x-1}Cu_xO_{6+}\delta$ (BSCCO, x=1, 2, and 3) glassy plates have been synthesized by melt-quenched method and the mechanical properties are measured. The microstructures of BSCCO glassy plates are observed by the scanning electron microscope (SEM). The crystal structures of the glasses are measured and simulated by x-ray diffraction (XRD) technique and visualization of crystal structure (VICS) technique, respectively. The elastically properties and Vickers hardness are measured and evaluated by ultrasonic sound velocity measuring device and micro-hardness tester, respectively. It found that, the BSCCO glassy plates are composed of $Bi_2Sr_2CuO_6$ (Bi-2201), $Bi_2Sr_2CaCu_2O_8$ (Bi-2212) and $Bi_2Sr_2Ca_2Cu_3O_{10}$ (Bi-2223) phases, these phases confirmed by the XRD analysis and calculated by Powder Cell technique. The glassy plates have been a good value of bulk modulus (K), Young's modulus (E), shear modulus (G) and Vickers hardness (Hv), these properties are corresponded to a good thermoelectric materials.

KEYWORDS

BSCCO superconductors;
Glassy plates;
Mechanical properties;
Thermoelectric materials.

1. INTRODUCTION

The amorphous materials for superconductors like $Bi_2Sr_2CuO_6$ (Bi-2201), $Bi_2Sr_2CaCu_2O_8$ (Bi-2212), and $Bi_2Sr_2Ca_2Cu_2O_{10}$ (Bi-2223) phases are several application studies. Therefore, developmental investigations of the various mechanical properties of amorphous materials or glass ceramics phases are very important of applicable superconductivity and thermoelectricity. The superconductivity of Bi-2201, Bi-2212, and Bi-2223 bulk samples have the critical temperature (T_c) of 10, 85, and 110 K, respectively[1,2]. The lattice parameters of three phases are interesting, a=b=0.39 nm and c=2.46, 3.06 and 3.71 nm, respectively[2].

Furthermore, Seebeck coefficient (S) for BSCCO thermoelectric materials are either positive or negative depending on the chemical compositions, substitutional some materials, and preparative conditions[3,4,5,6]. The thermoelectric properties of BSCCO glass ceramics are would be to investigation.

The paper is to synthesis the $Bi_2Sr_2Ca_{x-1}Cu_xO_{6+}\delta$ (x=1, 2, and 3) glassy plates by melt-quenched method. Furthermore, mechanical properties of the glassy plates have also been measurement and evaluation for prediction the thermal conductivity.

2 EXPERIMENTAL

The $Bi_2Sr_2Ca_{x-1}Cu_xO_{6+\delta}$ (x=1, 2, and 3) glassy plates are prepared by the melt-quenched method[7,8]. The Bi_2O_3, $SrCO_3$, $CaCO_3$, and Cu_2O initial powders are high purity (99.99%) and mixed in an agate mortar for 2 h. The mixture was melted in an α-alumina crucible at 1,200^{0}C for 30 min. Molten mixture was quickly poured onto a cold copper plate box and pressed with another cold copper plate to obtain rapidly quenched glassy plates. The as quenched glassy plates are analyzed by x-ray diffraction (XRD) and the XRD patterns are calculated by using Powder Cell software. The morphologies of the as quenched glassy plates are observed by scanning electron microscope (SEM). The densities (d) of the as quenched glassy plates are determined from the measured weight and dimensions. The longitudinal and shear sound velocities of glassy plates are measured by an ultrasonic pulse-echo method to evaluate the shear modulus (G), Young's modulus (E) and Debye temperature (Θ). The Vickers hardness (Hv) of glassy plates are measured by a micro-hardness tester. The thermal conductivity (k) of glassy plates are predicted from the Debye temperature values.

3 RESULTS AND DISCUSSION

Amorphous materials preparation

The as quenched glassy plates are the large size of 20×20×5 mm, the face of glasses are sparkle like a precious as shown in figure 1, indicate ceramic or amorphous behavior. It might be due to a good thermoelectricity for low thermal conductivity. In fact, the glasses have even lower thermal conductivity compared with crystalline materials because the amorphous structure scatters phonons to mean-free paths of atomic dimensions. Thus the ideal thermoelectric material resembled a "phonon glass and an electron crystal"[7,8].

Phase identification

The XRD patterns of the as-quenched materials are show in figure 2, indicate amorphous behavior. The main peaks of the Bi-2201 glassy plate was corresponded the XRD patterns of JCPDS card No. 46-543. The crystal structure of the glassy plates are the tetragonal structure, the lattice parameters of a=b=

Figure 1: The as-quenched glassy plates of $Bi_2Sr_2Ca_{x-1}Cu_xO_{6+\delta}$ (x=1, 2, and 3)

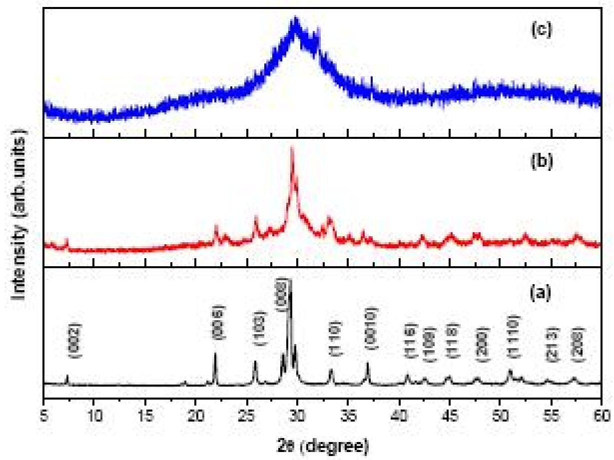


Figure 2: X-ray diffraction patterns of (a) Bi-2201, (b) Bi-2212, and (c) Bi-2223 glassy plates

0.3854 nm and c=2.4311 nm, the volume of unit cell of 3.6117×10^{-22} cm^3, the theoretical density of 7.80313 gcm^{-3} and 80 % of theoretical density. On the other hand, the Bi-2212 and Bi-2223 glassy plates are obtained broad peaks of XRD patterns like the amorphous materials, it very difficultly to identification peak. Therefore, we identified the main peak of XRD patterns by using the Powder Cell calculation. It found that, the lattice parameter of Bi-2212 glassy plate is a=b=0.38 nm, c=3.0178 nm and a=b=0.3879 nm, c=3.8643 nm for Bi-2223 glassy plates. However, the main peak XRD patterns of Bi-2212 and Bi-2223 glassy plates are high intensity at around $2\theta\approx30^0$, indicate the short-range atomic order[3].

The a, b and c lattice parameters of Bi-2201 glassy plate is similarly, small slightly for Bi-2212 and Bi-2223 glassy plates are compared with J.M.Terascon et al.[9] as shown in figure 4 because of lattice parameters of Bi-2212 and Bi-2223 glassy plates are obtained data from only calculation.

Crystal structure

We have simulated the crystal structure of BSCCO

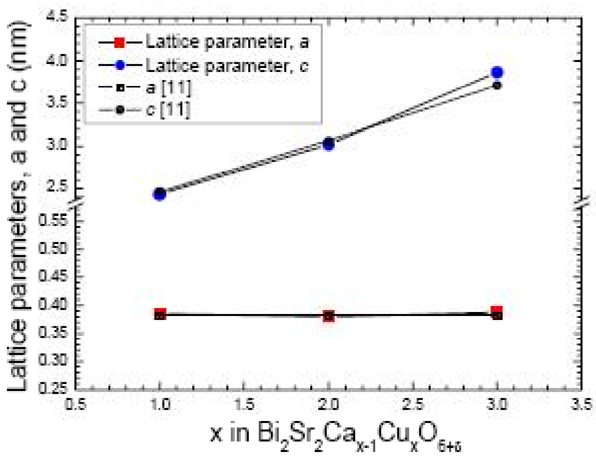
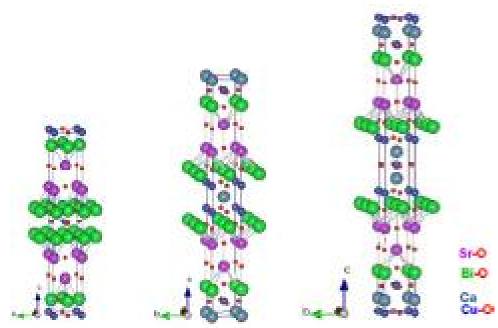


Figure 3: Variation of the lattice parameters a and c with different contents of Cu in $Bi_2Sr_2Ca_{x-1}Cu_xO_{6+}\delta$ (x=1, 2, and 3) samples and comparisons with the Ref.[11]



c = 2.4311 nm c = 3.0178 nm c = 3.8643 nm
(a) (b) (c)

Figure 4: Crystallographic cells of (a) Bi-2201, (b) Bi-2212, and (c) Bi-2223

Figure 5-8 ??

system by using the VICS technique as shown in figure 3.

It found that, the Bi-2201 has a CuO_2 layer is sandwiched in between two BiO and SrO layers. The Bi-2212 has the $CaCuO_2$ layer inserted in between the SrO layers. The Bi-2223 has added $CaCuO_2$ layer, and three CuO_2 layers sandwiched in between the SrO layers.

Microstructure

The powder of glassy plates are observed the microstructure by the SEM as shown in **figure** 5, indicate the glass ceramics behavior.

The surface morphologies of Bi-2201, Bi-2212, and Bi-2223 glassy plates are show in **figures** 6(a-c), respectively.

TABLE 1: Characteristic of BSCCO glassy plates

Property	Bi-2201	Bi-2212	Bi-2223
Density (gcm^{-3})	6.2730	5.8137	4.6422
Atomic weight (g)	2.81823×10^{-21}	2.95138×10^{-21}	3.05769×10^{-21}
Lattice parameter a (nm)	0.3854	-	-
Lattice parameter b (nm)	0.3854	-	-
Lattice parameter c (nm)	2.4311	-	-
Volume of unit cell (cm^3)	3.6117×10^{-22}	-	-
Theoretical density; TD (gcm^{-3})	7.80313	-	-
% of T.D	80	-	-
Longitudinal sound velocity; v_L (ms^{-1})	3327.2	3643.9	3981.1
Shear sound velocity; v_S (ms^{-1})	1920.9	2103.8	2298.5
Vickers hardness; Hv (GPa)	3.7821	3.3926	3.8022
Young's modulus; E (GPa)	57.8691	64.3278	61.3134
Bulk modulus; K (GPa)	38.58	42.89	40.88
Shear modulus; G (GPa)	23.15	25.73	24.53
Poision's ratio	0.25	0.25	0.25
Compressibility; β (10^3GPa)	25.92	23.32	24.46
Debye temperature; Θ(K)	270.72	284.99	306.00

Vickers hardness

The Vickers hardness of Bi-2201, Bi-2212, and B-2223 glassy plates are determined according to the following formula:

$$Hv=1.844F/l^2 \quad (1)$$

where F is the applied load in N, l is the average length of diagonal of an indentation in mm.

It can be observed that at all the applied loads, there is a marked hardness increase such as at 0.49 N, from 4.3 to 4.7 GPa; this initial increase might be due to accounted for by the fact that the presence of large volume fraction of superconducting phases strengthen the connecting bridge between grains[12].

The relationship between the Vickers hardness and Young's modulus of BSCCO glassy plates are shown in **figure** 8.

The Bi-2201, Bi-2212, and Bi-2223 glassy plates have been related the Young's modulus and the Vickers hardness given by:

$$E=16.8067\,Hv \quad (2)$$

and the Hv/E values are nearly the ceramic properties.

In addition, we predicted the thermal conductivity (K) by the following:

$$k = \frac{3^{1/3}}{2^{1/6}\pi^{4/3}\gamma^2}\frac{k_B^3}{(2\pi)^3\hbar^3}M\alpha\Theta^2\frac{\Theta}{T} \quad (3)$$

where γ is the Grüneisen constant, k_B is Boltmann constant, M is the mass of a unit cell, $\hbar$ is constant, and α is annihilation operators of the dimension of displacement[13].

The equation (3), indicate that the K depends directed to Debye temperature, following by:

$$K \propto \Theta \quad (4)$$

It might be due to the predication of the k of BSCCO glassy plates are maybe $K_{Bi-2201}<K_{Bi-2212}<K_{Bi-2213}$, we will measure it soon.

4. CONCLUSIONS

The initial composition of $Bi_2Sr_2Ca_{x-1}Cu_xO_{6+}\delta$ (x = 1, 2, and 3) melted at 1,200^{0}C for 30 min and quenched at room temperature to obtained the glassy plates. It is due to the formation of the crystal structure, the glass ceramic, and the amorphous behavior as analyzed from XRD patterns, Powder Cell, VICS, and SEM studies. The BSCCO glassy plates have been the Hv/E values correspond the ceramic properties.

Finally, the thermal conductivity of BSCCO glassy plates are predicted by the Debye temperature. It might be the $K_{Bi-2201}<K_{Bi-2212}<K_{Bi-2213}$, and corresponding to a good thermoelectricity

5. ACKNOWLEDGMENTS

This work had financial support from Research and Development Institute, Sakon Nakhon Rajabhat University, Thailand. Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering, Osaka University, Japan for using apparatus measured mechanical properties.

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