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The Influence of Ag Addition on The Mechanical Properties of Bi-2212/Ag Ceramic Composites by Fabricated Hot Pressing Technique

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ABSTRACT: The effect of Ag addition on the mechanical properties of $Bi_2Sr_2Ca_1Cu_2O_{8+\delta}$ (Bi-2212) ceramic composites has been analyzed. Bi-2212+ x wt% Ag (x = 0.0, 0.05, 0.15, 0.25 and 0.50) samples have been fabricated by hot pressing technique. The mechanical properties such as strength and deformation characteristics are derived using Vickers microhardness measurements result. Vickers microhardness test carried out at different applies loads (0.245-4.90 N). All prepared samples exhibited indentation size effect (ISE).The Vickers microhardness was found to be load dependent. The results show that the values of microhardness, strength and elastic parameters of the samples increased with an increase in the Ag addition. The results exhibit that, it is possible to control the mechanical properties of the Bi-2212 ceramic composites by increasing the Ag addition.

KEYWORDS: Bi-2212, Ag, Mechanical properties, Hot pressing

I. INTRODUCTION

The mechanical properties such as hardness, strength and elasticity as well as magnetic, electric and superconducting properties of high temperature oxide superconductors are very important for many technological applications [1]. Due to their brittle nature and the weak links between grains, the poor mechanical characteristics of this kind of materials imposes limitations for fabrication wires and tapes [2]. Some attempts to improve their mechanical properties have been performed by means of Ag addition on Bi-Sr-Ca-Cu-O (BSCCO) compounds [3-8]. The mechanical properties of materials depend on their internal structure. To improve mechanical properties, internal structure modifications can be improved extremely with different substitution/addition of dopants or by means of heat treatment such as atmospheric annealing or vacuum treatment [9,10].

This experimental study was carried out to determine load dependent and independent Vickers micro-hardness, Elastic modulus, yield strength, brittleness index and for Bi-2212 with different amounts of Ag addition. Micro-indentation technique has been performed on Bi-2212/Ag ceramics fabricated by hot pressed method. The effect of Ag addition on mechanical properties has been investigated.

II. MATERIALS AND METHODS

Initial samples have been prepared by cold pressing at about 250 MPa for 2 minutes from $Bi_2Sr_2Ca_1Cu_2O_{8+\delta}$ powders prepared by the standard solid-state reaction method using high purity chemicals Bi_2O_3 (99.99%), $SrCO_3$ (99.9+%), $CaCO_3$ (99+%), CuO (99+%) powders, and x wt % Ag (x=0.0, 0.05, 0.15, 0.25 and 0.50). These samples were subsequently hot-pressed at around 20 MPa at 800 ºC for 12 hours by using cylindrical die. The produced hot-pressed discs are 25 mm diameter and 2 mm thick. After the hot-pressing process, the discs were annealed for 72 h at 860 ^oC to

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recover the Bi-2212 phase, followed by 24 h at 800 °C to adjust the oxygen content and, finally, quenched in air to room temperature. This process is necessary as at 800 °C under pressure, Bi-2212 phase is partially decomposed in Bi-2201 and secondary phases [3]. Samples with 0, 0.05, 0.15, 0.25 and 0.50 Ag% after this will be named as A_0, A_1, A_2, A_3 and A_4, respectively. The microhardness measurements were performed for characterization of mechanical properties of Bi-2212/Ag ceramics. Vickers microhardness of the studied samples was measured using ZHVµ series Zwick microhardness tester at room temperature. Vickers indenter that is made from diamond with a shape of square pyramid applied on the cleaned and polished surfaces of the samples under loads varying from 0.245 to 4.9 N for 15 s. The pyramidal indenter is also applied the different locations on the samples to avoid surface effects and overlap. For statistical reasons, 3 indentations were made under each load and the arithmetic mean of the measured values was taken as result. The diagonal lengths of indentation were measured with an accuracy to be ± 0.1 µm.

Vickers microhardness is calculated using the Eq. 1.

$$H_V = 1854.4 F/d^2 \tag{1}$$

where H_v is microhardness in (Pa), F is applied load in (N) and d is the mean diagonal length of the indentation impression in (µm).

In most materials, the elastic modulus, E is related to the Vickers microhardness (apparent) by the relation,

$$E = 81.9635\, H_V \tag{2}$$

Elastic stiffness coefficient (C_{11}) and brittleness index (B_i) can be theoretically computed by the using hardness values,

$$C_{11} = H_V^{7/4} \tag{3}$$

$$B_i = H_v/K_{IC} \tag{4}$$

Yield strength (σ_y) is calculated using the following expressions,

$$\sigma_y \approx H_V/3 \tag{5}$$

III. RESULTS AND DISCUSSION

Hardness that is defined as the resistance against to plastic deformation, indentation or penetration. It has a relationship between other mechanical properties such as elastic modulus, yield strength, elastic shear stiffness and brittleness index. These properties can be theoretically computed by the using hardness values. Elastic modulus is a measure of elastic deformation under the force. It can be defined by the ratio of strength to strain. The elastic modulus is defined as the slope of its strain-stress curve in the elastic deformation region. A yield strength or yield point is the material property defined as the stress at which a material begins to deform plastically. Elastic stiffness is resistance to deformation or strain. Brittleness index that represents ductility of material is defined as the property of rupture without plastic deformation. The values of H_v, E, σ_y, B_i and C_{11} were calculated using Eqs. (1-6). The variation of H_v as a function of Ag addition at certain applied loads (0.245-4.90 N) for the samples is shown in Fig. 1. It is observed that from Fig. 1, H_v, values increased with increasing Ag addition.

The variation of H_v as a function of the applied loads, F (N) for the samples are given in Fig. 2. It can be seen from the curves in Fig. 2 that H_v values are load dependent. This indicates that the hardness value depends on the applied load and there is a relation between the load and size of the indenter. H_v values decrease non-linearly as the applied load increased, then these reach a plateau region at around 1.96 N for all studied samples. The penetration depth increases at higher loads (F > 1.96 N) and the effect of inner layers becomes more important. This non-linear behavior has also been observed in the literature for BSCCO samples and is termed indentation size effect (ISE) [8]. Brittleness is

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expressed in terms of the brittleness index. The variation of brittleness index with Ag% content at 0.245 N is shown in Fig. 3. B_i values decreased with increasing Ag addition, indicating that the samples become more toughness and more hard and ductile.

Another interesting mechanical parameter is the elastic shear stiffness, which gives us an idea about tightness of bonding between neighboring atoms.

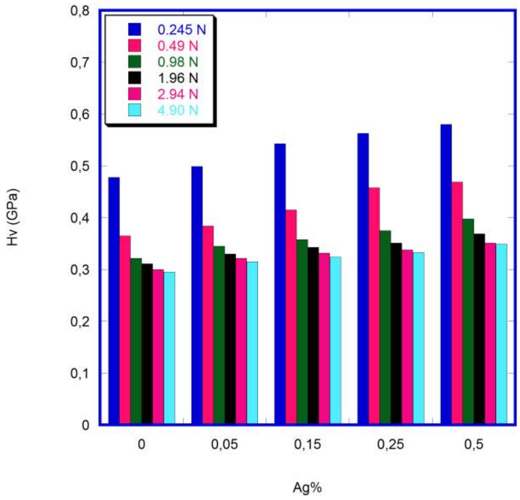

Fig. 1 The variation of microhardness with Ag% content

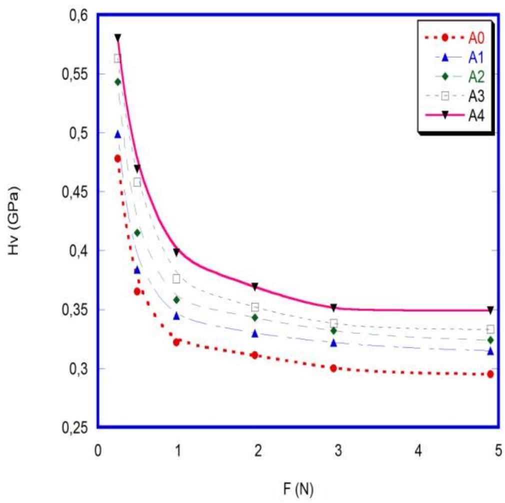

Fig. 2 The variation of apparent Vickers microhardness with applied load

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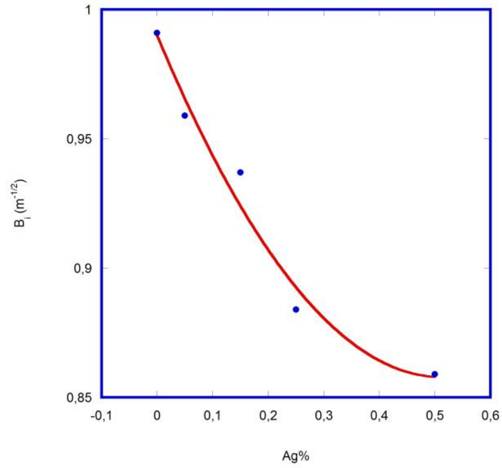

Fig. 3 The variation of brittleness index with Ag% content

The calculated values of elastic shear stiffness at load 0.245 N for each sample are shown in Fig. 4. From this figure, it can be observed elastic shear stiffness increases as the concentration of silver increases. This trend can be explained as follows: the arrangement of dislocations and their collective interactions increased with the increase in silver content, which result attain a high value of elastic shear stiffness.

The variation of elastic modulus with Ag% content at 0.245 N is shown in Fig. 5. The variation of yield strength with Ag% content at 0.245 N is shown in Fig. 6. As can be seen from Figs. (5-6), elastic modulus and yield strength increased with increasing Ag amount. From these data, it is clear that Ag addition improves the mechanical behavior of these samples. On the other hand the mechanical properties of all samples were found to be load dependent.

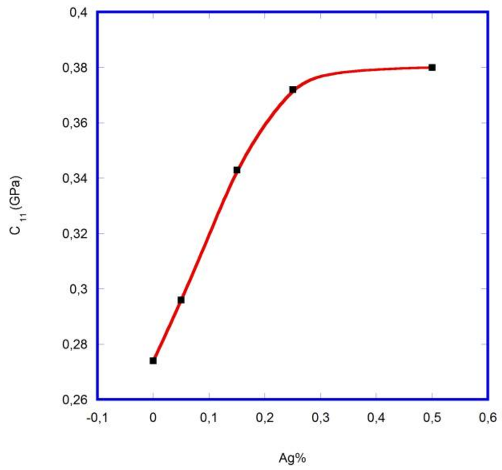

Fig. 4 The variation of elastic shear stiffness with Ag% content

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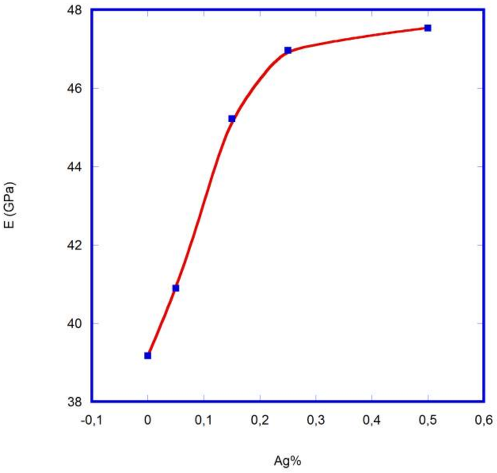

Fig. 5 The variation of elastic modulus with Ag% content

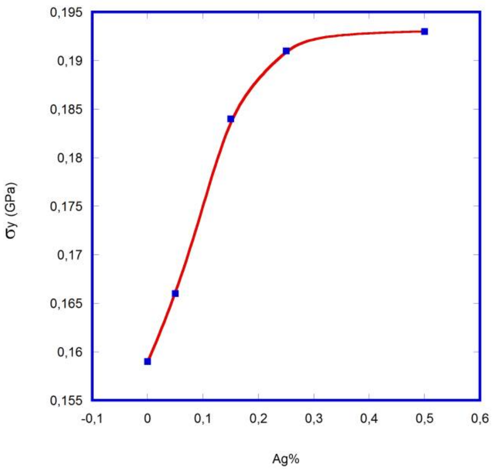

Fig. 6 The variation of yield strength with Ag% content

In order to describe the ISE and RISE (reverse indentation size effect) behavior of several relationships been given in the literature. The simplest way is Meyer's law. It is frequently used model to explain the ISE and RISE behavior of materials. There is a relationship between applied load and diagonal length of indentation in this law.

$$F = Ad^n \tag{7}$$

where F is applied load, d is indentation diagonal length, n is Meyer's number, A is the standard hardness constant.

The value of n is used a measure of ISE or RISE. ISE behavior occurs when the n value is less than 2, indicating that the hardness increases with decreasing of the applied load, if n value is greater than 2, RISE behavior is obtained, indicating that the hardness increase with increasing the applied load. When n is equal 2, hardness is independent from the applied load.
The values of n and A can be obtained from the plots of $\ln F$ versus $\ln d$ for all the samples. The slope of the $\ln F$-$\ln d$ graph gives n and vertical intercept is proportional to A. The results obtained from the samples and linear regression

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coefficient, r^2 are given in Table 1. Each set of data shows an excellent linear relationship. From Table 1, it can be noticed that Meyer number is less than 2 for the all samples, which proves load dependent displacement has ISE behavior [11-12].

Table 1. Regression analysis according to Meyer's law

Samples	n	ln A (GPa)	r^2	H_v (GPa)
A_0	1.74	-7.474	0.99859	0.295-0.30
A_1	175	-7.457	0.99847	0.315-0.322
A_2	172	-7.264	0.99843	0.324-0.332
A_3	169	-7.107	0.99872	0.333-0.338
A_4	170	-7.138	0.99893	0.349-0.351

IV. CONCLUSION

In this study, the effect of Ag addition on the mechanical properties such as microhardness, elastic modulus, elastic stiffness coefficient, brittleness index and yield strength of Bi-2212 ceramic composites has been investigated. Results show that Ag addition has a positive effect on the mechanical properties of Bi-2212 samples. The experimental results of the microhardness measurements has been also analyzed using Meyer's law. The Vickers microhardness, yield strength and elastic parameters of samples were improved with increasing Ag addition. These enhancement are believed to be due to the presence of Ag particles that can encourage compressive stresses in the superconducting matrix and resist crack propagation by pinning the propagating cracks, and it is associated to the formation of liquid phase during the hot pressing process and the reinforcement of the weak links by Ag, as reported in previous works [2,9-13].

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