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THE EFFECT OF GAMMA RADIATION DOSES ON MECHANICAL PROPERTIES OF Bi- 2212 SUPERCONDUCTOR

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ABSTRACT

The effect of gamma irradiation on mechanical properties of $Bi_2Sr_2CaCu_2O_8$ (Bi-2212) superconductor ceramics was studied by exposing the superconductor with five different gamma radiation doses of 10 kGray, 20 kGray, 30 kGray, 40 kGray and 50 kGray respectively. The Bi- 2212 samples were prepared via the conventional solid-state reaction method. The samples were characterized using the X-Ray Diffractometer (XRD). The XRD patterns for the non-irradiated and irradiated samples showed well-defined peaks of which could be indexed on the basis of a Bi-2212 phase structure. Small dose of gamma radiation enhanced the mechanical properties of the materials. The phase purity, lattice parameter, surface morphology and degree of crystallinity for the non-irradiated and irradiated samples were also compared and analyzed.

Keywords: Bi-2212 superconductor; gamma irradiation; phase structure; mechanical strength

INTRODUCTION

The ability of superconductor to conduct current with zero resistance resulted in the materials to have huge potential in industrial applications. High temperature superconductor (HTSC) ceramics $Bi_2Sr_2CaCu_2O_8$ or Bi-2212 has advantages over other HTSC due to its phase stability and high transition temperature, T_c. The bismuth compounds (BSCCO) exhibit an interesting property of being micaceous; that is, they are like mica [1]. The crystal lattice shears easily along the bismuth oxide planes, and this allows BSCCO to be deformed and shaped with less difficulty than the other ceramic superconductors. Irradiation is practically used in industry to create defects in the microstructure that promotes better flux pinning center and improve their electrical and mechanical properties [2-5]. A higher critical current density, J_c is vital for the practical applications of superconductors [6]. However, irradiation is also known to affect the other superconducting properties, such as T_c of the superconducting materials [7].

To ensure the superconducting properties are sustainable, the mechanical properties need to be enhanced as the conduction depends on the grain boundaries, grain alignment and chemistry deviation. According to Albiss et al. [8] gamma-irradiation generates some defects, improves the grain boundaries, and decreases the number of weak link junctions between the grains and eventually improved the critical current density, J_c. By observing the changes of phase structure and mechanical strength of Bi-2212 superconductor before and after irradiation with variation doses of gamma radiation, the mechanical properties of this ceramic material can be evaluated. In this study, the effect of gamma radiation doses on the phase formation and mechanical strength of Bi-2212 superconductor ceramics material were observed and analyzed.

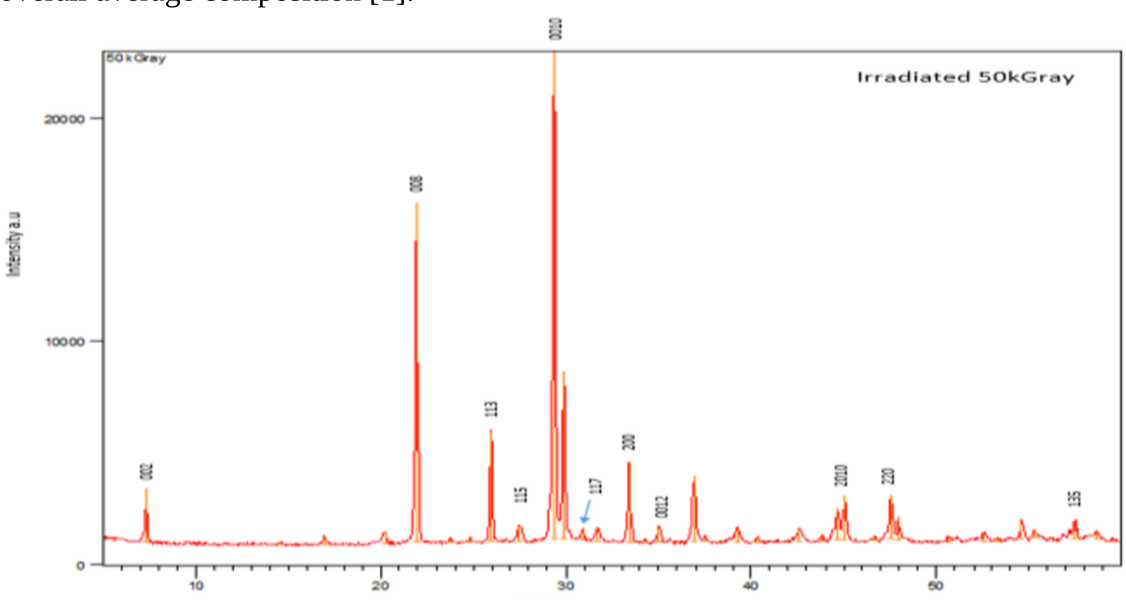
EXPERIMENTAL

Conventional solid-state reaction method was used for the sample preparation of Bi-2212 superconductor. The precursor's oxide powder was thoroughly mixed and grounded in agate mortar. The samples were pelletized and then sintered to achieve Bi-2212 phase. After the initial grounding process, the compound went through annealing process at temperature of 800˚C for 12 hours. The blackish powder was grounded for about 30 minutes and pelletized under 7 tons or 70 000 psi. The pellets were sintered by partial-melt temperature where the samples were heated at maximum heat of 865˚C for 6 minutes, annealed at 840 ˚C for 48 hours and then furnace-cooled to room temperature. Partial-melt process of Bi-2212 is known to significantly improve the microstructure of Bi-2212 phase superconductor since it produced the required texture of the Bi- 2212 superconductor compounds [9]. The samples were then irradiated by gamma ray using JS10000 (IR-219) irradiator with five different doses level of 10 kGray, 20 kGray, 30 kGray, 40 kGray and 50 kGray, respectively. The irradiation was conducted at SINAGAMA Plant, Malaysian Nuclear Agency. Structural investigations of non-irradiated and irradiated samples were conducted using a Bruker D8 Advanced X-Ray Diffractometer (XRD) to confirm their phase formation. Compression test on the samples were done at room temperature using the Instron Material Testing System where the mechanical properties of the Bi-2212 superconductor ceramics was investigated.

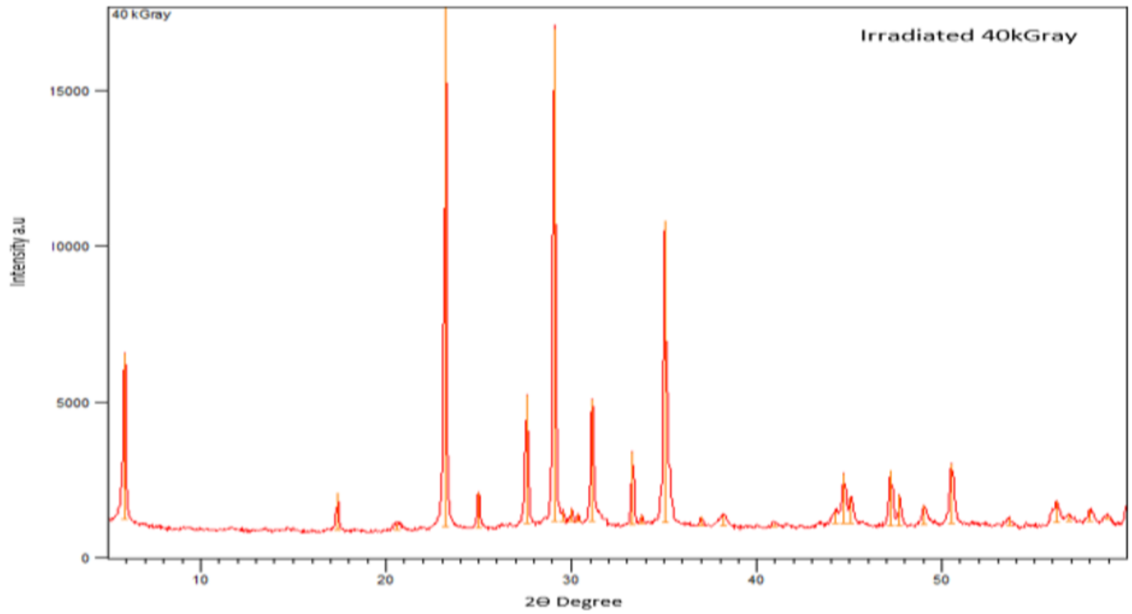
RESULTS AND DISCUSSION

The XRD patterns for both non-irradiated and irradiated samples show well-defined peaks of which could be indexed on the basis of a Bi-2212 phase structure. The (0010) peak clearly indicates the changes over the five different gamma irradiation doses. For non-irradiated sample as shown in Fig. 1 (f), it drawn sharper and well-defined (0010) peak compared to the gamma-irradiated sample with 10 kGray doses in Fig. 1 (e). The increasing of intensities of peaks as shown in Fig. 1 (e) to (c) are observed for samples subjected with doses of 10 kGray to 30 kGray. The XRD patterns that are observed as small amount of dose is increased indicate the increasing of volume fraction as well as degree of crystallinity of Bi-2212 phase. As the doses increased to 40 kGray in Fig. 1 (b), the intensity of the peak is reduced, which indicates the decreased in volume fraction and the degree of crystallinity of the Bi-2212 phase. This indicates that gamma ray irradiation reduced the volume fraction of Bi-2212 phase and diminished the crystal growth in the superconductor ceramics [9].

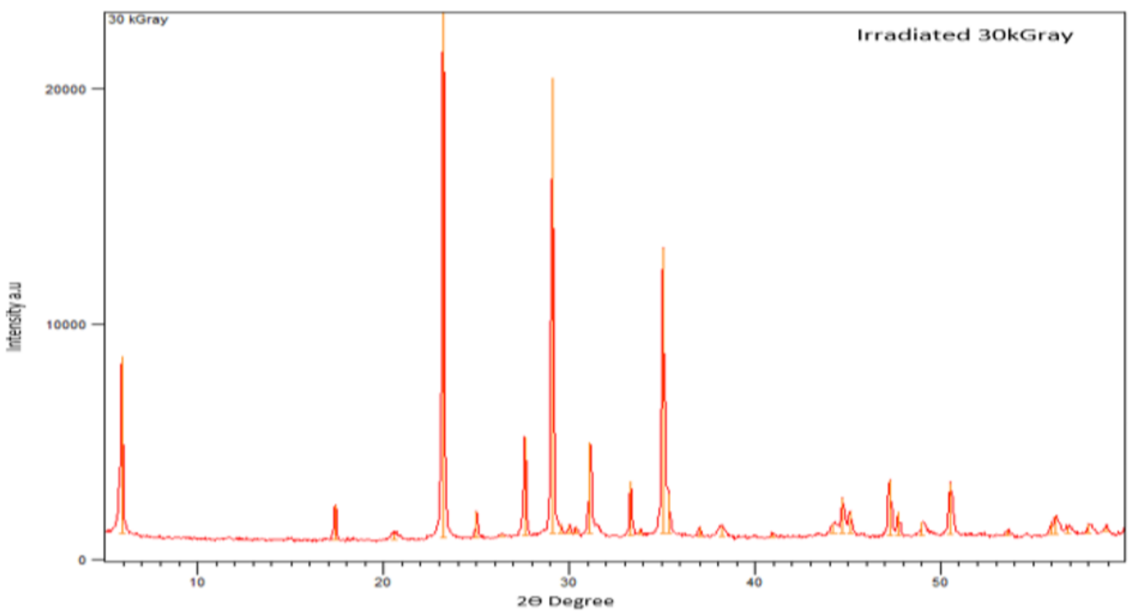
Nevertheless, the opposite is happening as the dose is increased to 50 kGray as shown in Fig. 1 (a). The intensity of (0010) peak is slightly higher than the intensity of (0010) peak at 30 kGray dose in Fig. 1 (c). This indicates that the volume fraction and the degree of crystallinity of Bi-2212 phase structure increased. On the other hand, there is possibility that irradiation could has damaging effect on the bonds in the Cu-O planes of the superconducting region and decreases the number of holes in the lattice [10, 11]. A few peaks of unknown phases and other impurities are also observed. The presence of unidentified peaks is most probably due to inappropriate heat treatment during the sintering process which resulted in unidentified secondary phases [10]. From the observation, there are two types of diffraction peaks position pattern of Bi-2212 phase. The first type is as shown in Fig. 1 (b), (c) and (f), and the second type is as shown in Fig. 1 (a), (d) and (e). Theses indicate that some changes in lattice parameters within the resolution of XRD may have occurred. The changes are probably due to inhomogeneity of mixing the powder during sample preparation. If the powders are not homogeneously mixed, the local composition at any point may be unrepresentative, and so the final local phase assemblage will be dictated by the local starting composition rather than the overall average composition [1].



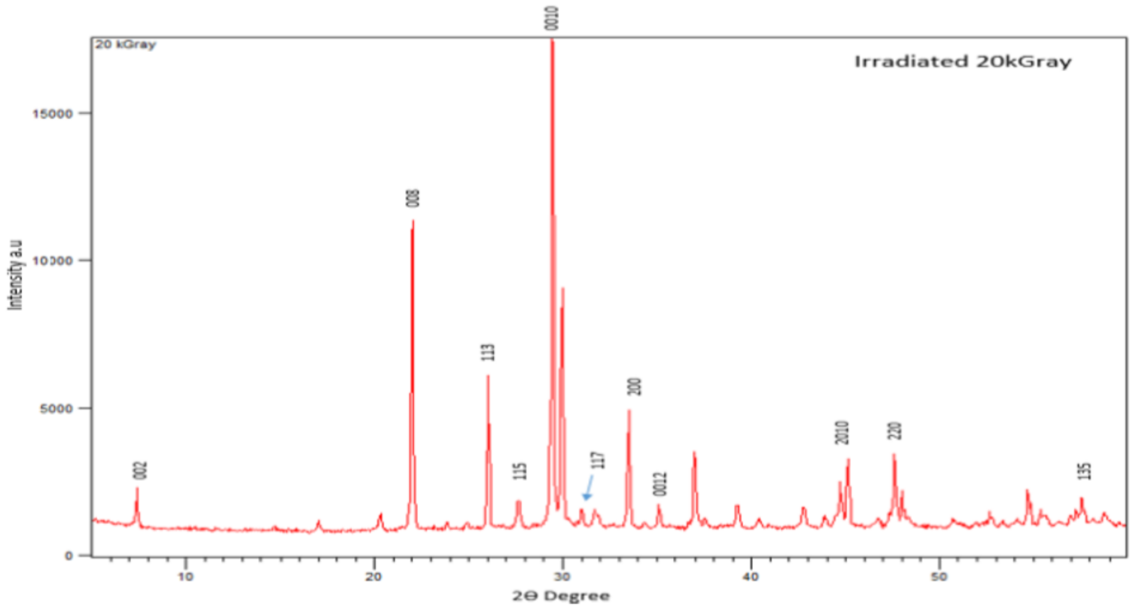
(a)


40 kGray
Irradiated 40kGray
Intensity a.u
15000
10000
5000
0
10
20
30
40
50
2θ Degree

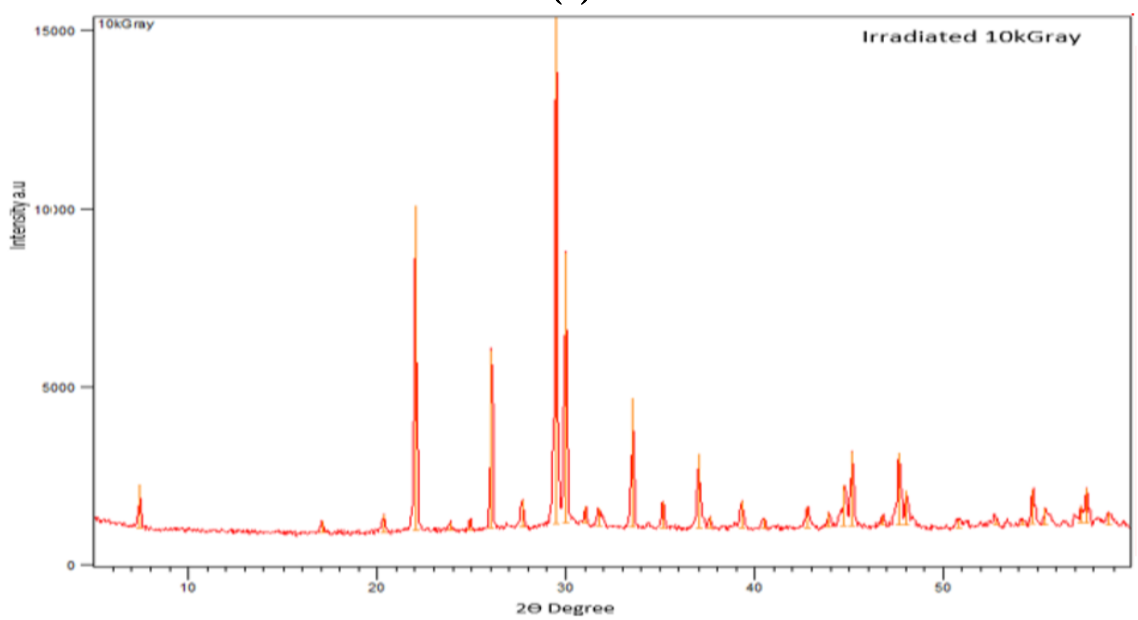
(b)


30 kGray
Irradiated 30kGray
Intensity a.u
20000
10000
0
10
20
30
40
50
2θ Degree

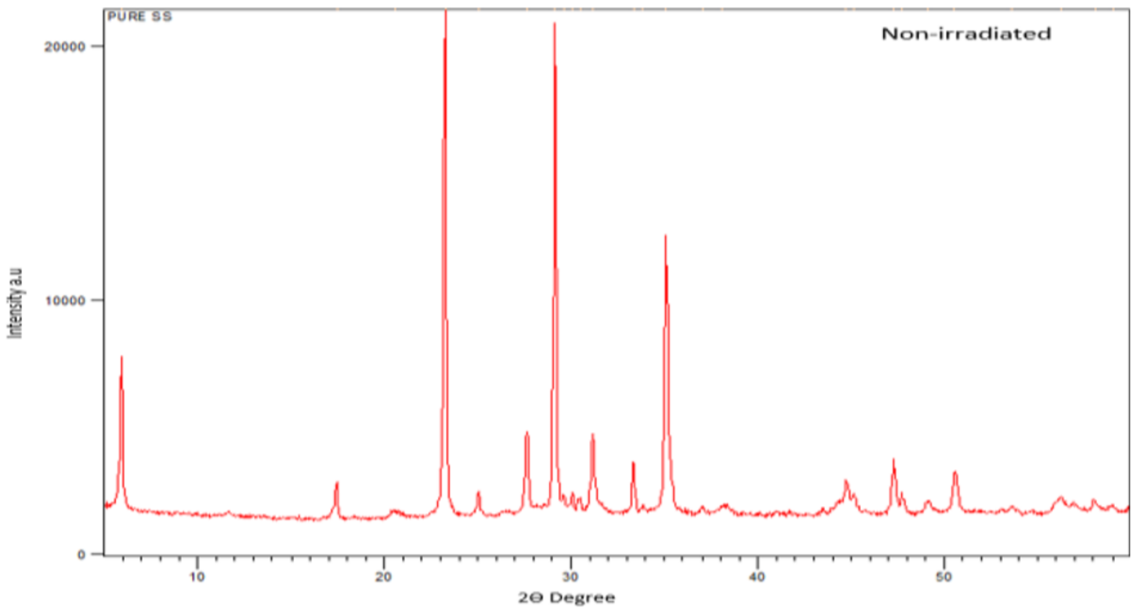
(c)


20 kGray
Irradiated 20kGray
Intensity a.u
2Θ Degree
0010
008
113
200
2010
220
002
115
117
0012
135
0
5000
10000
15000
10
20
30
40
50

(d)


10kGray
Irradiated 10kGray
Intensity a.u
2Θ Degree
0
5000
10000
15000
10
20
30
40
50

(e)



(f)

Figure 1: XRD Patterns of Bi-2212 Superconductor Samples with Gamma Irradiation Doses of (a) 50 kGray; (b) 40 kGray; (c) 30 kGray; (d) 20 kGray; (e) 10 kGray; and (f) non-irradiated

Table 1 shows the compressive strength of both non-irradiated and irradiated samples at room temperature. The compressive strength is increased as the non-irradiated sample is subjected to gamma irradiation dosage of 10 kGray. As the dose is increased to 20 kGray, the compressive strength decreased. The increasing of compressive strength occurred for doses between 20 kGray to 40 kGray. Nevertheless, the compressive strength decreases as the doses is increased up to 50 kGray. For higher dosages samples, the results showed disorientation of grain size that led to reduction in mechanical strength. Local changes in geometry of a stressed material can lead to concentrations of stress. Increasing in porosity and disorientation of grains in irradiated samples leads to reduction in mechanical strength of Bi-2212 superconductor [9]. It was also found that the strength of porous ceramics increases with the decreasing of porosity [12, 13]. This information is very useful since the mechanical properties such as stiffness, strength and toughness at room temperature are able to predict such behaviors at cryogenic temperature [12].

Table 1: Compressive Strength of Non-irradiated and Irradiated Bi-2212 Superconductor Samples

Sample	Compressive Strength [MPa]
Non-irradiated	163.64
Irradiated 10 kGray	167.56
Irradiated 20 kGray	165.21
Irradiated 30 kGray	238.92
Irradiated 40 kGray	253.32
Irradiated 50 kGray	244.35

CONCLUSION

Gamma irradiation has considerable effects on the mechanical properties of Bi-2212 superconductor. Changes occurred in lattice parameter, surface morphology, volume fraction and degree of crystallinity of Bi-2212 superconductor phase structure as the superconductor is subjected to small increment of gamma radiation doses. Even though there is slightly decreased of compressive strength occurred at some level of doses in the gamma irradiated samples, in general the mechanical strength of Bi-2212 superconductor compound increased when subjected to gamma irradiation of less than 50 kGray. Better mechanical properties are needed to achieve a sustainable Bi-2212 superconductor ceramics that can be used for development and fabrication of Bi-2212 superconductor wires and tapes.

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