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Radiation Attenuation Coefficient Assessment of PDMS/B_4C Composite Sheets

Fatemeh Bonakdari[1], Ebrahim Ahmadi[1], Simin Janitabar Darzi[2]*, Zahra Rafiei-Sarmazdeh[2], Mojtaba Kakai[2], Shahryar Malekie[3], Armin Mosayebi[3], Rouhollah Habibzadeh sbo[2]

[1]Department of chemistry, Faculty of Science, Zanjan University, 45371-38791, Zanjan, Iran
[2]Nuclear FuelCycle Research School, Nuclear Scienceand Technology Research Institute, P.O. Box: 11365-8486, Tehran, Iran, * *Email: sjanitabar@aeoi.org.ir*
[3] Radiation Application Research School, Nuclear Scienceand Technology Research Institute, Iran

Abstract

Materials containing boron element are effective in thermal neutron absorption and flexible composite of silicone rubber and B4C is an interesting candidate material for neutron shielding material.However, regarding to the lack of gamma ray attenuation effects reported about this material, the fabrication of different thickness sheets of polydimethylsiloxane/B_4C composite with different boron carbide contents was done via physical mixing method. In this study, B_4C incorporated to polydimethylsiloxane rubber matrix via ball milling pocedure and then was vulcanized to form homogeneusly sheet. After that, its characterization tests were performed by means of FTIR and SEM analyses. Silicone rubber composited with B_4C just shows a little gamma absorption capability. The dosimetry results and visual appearance of the prepared sheets show that the sheet contents 7% B_4C and thickness of 10.5 mm is the best candidate for gamma ray attenuation among the different studied sheets in this research.

Keywords: B_4C, PDMS, Composite, Shielding effect

Introduction

Boron carbide is one of the advanced ceramic materials that is being used in many industries such as nuclear, military, and aerospace industry due to its high melting point temperature, high resistance to corrosion and relatively low density and thermal expansion. However, the most significant specification of boron carbide is its high cross section for neutron absorption [1].

Base materials of shielding products are polymer resins such as silicone resin or a vinyl chloride resin. When a radiation-shielding substance such as B_4C is blended in a polymer matrix, it confers the properties of the radiation-shielding character on the produced polymer composite, owing to its outstanding process ability. However, problems arising during the compounding process may affect the thickness, strength, and flexibility of the material, resulting in mass-production problems. Mechanical properties of the radiation-shielding proposed materials like B4C/polymer composites are very important in a point of view of commercialization.

in order to reach good mechanical capability, recent publications in the literature propose the use of smaller particle size filer or even nanoparticles embedded in a polymeric matrix for radiation shielding purposes [2].

One of the methods for producing ceramic nanopowders is ball milling. For obtaining low-sized particles and homogeneously distributed powder particles are exposed to collisions by milling balls and chamber. This method is a very popular method for refining additives and microstructure homogeneity not only micro-composites but also nanocomposites.

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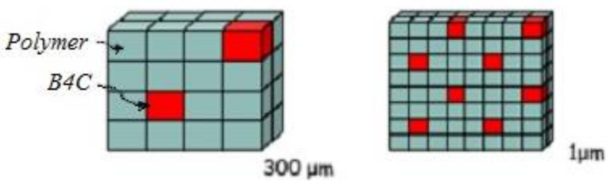

Fig. 1. Imaginary diagram for size-dependent boron compounds embedded in polymer matrix

In this work probable gamma shielding properties of PDMS/B_4C Rubber composite sheets was studied for first time.

Experimental

Micro scale B_4C was grinded using ball mill machine. Then grinded B_4C was characterized by means of XRD analysis. The prepared powder was mixed by 21.78, 21.34, 20.9, 20.46, 19.8, 18.7 gr of PDMS polymer to produce composites with 1, 3, 5, 7, 10 and 15 percent of B_4C. The prepared composite mixture was analyzed by means of FTIR spectroscopy (only FTIR of 5% sample is presented in this paper). Composite films were then prepared by hot pressing at 190 degrees centigrade. It was predicted that a uniform dispersion of nanoparticles throughout the polymer bulk were prepared in all contents of B_4C.

The prepared sheets were exposed to gamma ray Radiated from the ^{60}Co gamma source.

Results and discussion
Characterization of materials

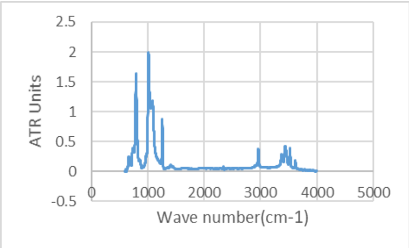

Fig. 1. FTIR analysis of B_4C/PDMS composite before hot press.

Fig.1 presents the FTIR analysis of B_4C/PDMS composite before hot press. As shown in the FTIR curve, stretching vibration of Si-O-C is observed at 1080 cm^{-1} and C-H in the area of 2840-3000 cm^{-1}.

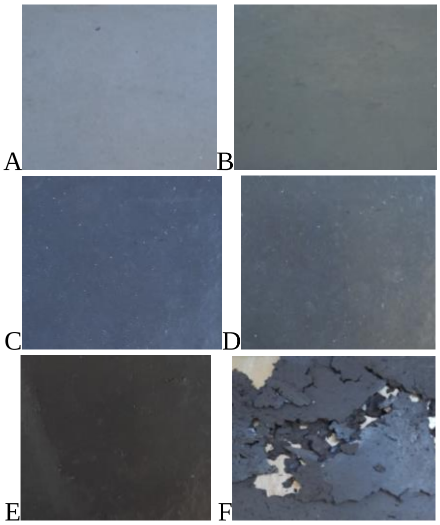

Fig. 2 camera image of hot pressed B_4C/PDMS with 1, 3, 5, 7, 10 and 15 percent of B_4C (A, B, C, D, E, F).

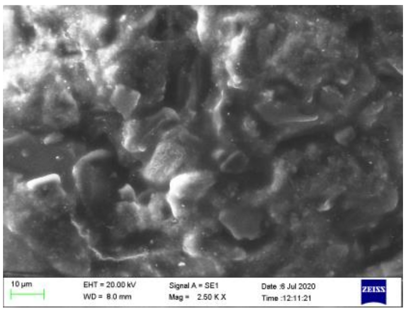

Fig.3 SEM image of hot pressed B_4C/PDMS (15%).

Fig. 2 presents the photo of composites films after hot press procedure. According to the photos the composite films with B_4C content more than 10% have not suitable visual and mechanical properties for preparing shielding sheets. As the sheet contained 15% B_4C was an easily tearing sheet, we left that sheet and the experiments were continued on other sheets. Fig.3 shows SEM image of hot pressed composite contained 15 % of B_4C. As shown in the Fig. 3, the surface of prepared sheet is not homogenous .So it is not surprising that it could be tearing easily. At the next stage, the sheets with 1, 3, 5, 7 and 10 percents of B_4C were exposed to gamma ray. Table 1 shows the result of irradiation tests. The data presented in the table shows that gamma attenuation is weak in the sheets composed of polydimethylsiloxane and B_4C.However, among the different prepared sheets, the best attenuation could be achieved by a sheet contents 7% B_4C and thickness of 10.5 mm or a sheet contents 10% B_4C and thickness of 5 mm. The results revealed that the more thickness of sheets and the more contents of B_4C provide the better attenuation condition for B_4C/PDMS shielding materials.

Table 1. The attenuation assessment of composite sheets

B4C content	thickness	I_0	I_{av}
COM 1%	2 mm	0.56	0.51
	3.5 mm	0.56	0.49
	5 mm	0.56	0.47
	10.5 mm	0.56	0.45
COM 3%	2 mm	0.56	0.48
	3.5 mm	0.56	0.46
	5 mm	0.56	0.44
	10.5 mm	0.56	0.40
COM 5%	2 mm	0.56	0.46
	3.5 mm	0.56	0.43
	5 mm	0.56	0.41
	10.5 mm	0.56	0.39
COM 7%	2 mm	0.56	0.43
	3.5 mm	0.56	0.40
	5 mm	0.56	0.38
	10.5 mm	0.56	0.37
COM 10%	2 mm	0.56	0.42
	3.5 mm	0.56	0.40
	5.5 mm	0.56	0.35

Conclusions

In this work, different thickness sheets of B4C/PDMS composite with different boron carbide contents was prepared via physical mixing method followed by hot press. Visual investigation shows that prepared sheets containing less than 15% B_4C are suitable for shielding tests and attenuation coefficient assessment of composite sheets revealed that the more contents of B_4C, as well as more thickness sheets resulting the better attenuation condition for B_4C/PDMS shielding materials.

References

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