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Gamma Attenuation Behavior of h-BN and h-BN-TiB_2 Composites

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Hexagonal boron nitride (h-BN) and hexagonal boron nitride-titanium diboride (h-BN-TiB_2) composites are advanced materials for high-tech applications. They were investigated against gamma radioisotope sources Cs-137 and Co-60 which have gamma peaks 0.662 MeV for Cs-137, and 1.17 and 1.33 MeV for Co-60. Materials have been produced at 1800 °C temperature in argon atmosphere without pressure during 2 h time. Linear and mass attenuation coefficients were calculated for the materials. Gamma transmission technique was used in the experiments. The experimental investigated mass attenuation coefficients of the materials for Cs-137 and Co-60 gamma radioisotope sources were compared with XCOM computer code. For h-BN-TiB_2 composites the ratio of TiB_2 in the composites is 55% by weight. So gamma attenuation effects of adding TiB_2 to h-BN were discussed. It could be said that adding TiB_2 to h-BN increases the linear gamma attenuation of the samples.

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1. Introduction

Hexagonal boron nitride has important properties such as high temperature resistance, thermal shock resistance, high thermal conductivity, poor wettability [1]. h-BN has many application fields in some industries which include automotive, glass, high temperature applications, cosmetic and steel industry [2, 3]. There are also some applications in nuclear technology such as in neutron detectors and neutron shielding applications [4]. There are some studies related with h-BN which commonly were studied on neutron properties [5].

In this study, we investigated h-BN and h-BN-TiB_2 composites on their gamma attenuation behaviors. Gamma transmission technique was used in the experiments. Cs-137 and Co-60 gamma radioisotopes were used as radiation sources. The linear and mass attenuation coefficients of the materials were carried out. The effects of reinforcing TiB_2 on h-BN materials were investigated.

2. Experimental

Gamma transmission technique is based on the geometry where source, material and detector components are put on the same axis [6]. The transmittance of gamma radiation could be calculated from the formula [7]:

$$I = I_0 \mathrm{e}^{-\mu x}, \tag{1}$$

where I and I_0 represent transmitted and incident gamma radiation intensity, respectively. μ is the linear attenuation coefficient of the sample at a specific gamma ray and x is the thickness of the sample.

Then the results of gamma radiation intensities which were measured with/without sample were evaluated and interpreted. General view of gamma transmission technique and information of experimental set up geometry could be seen in Fig. 1.

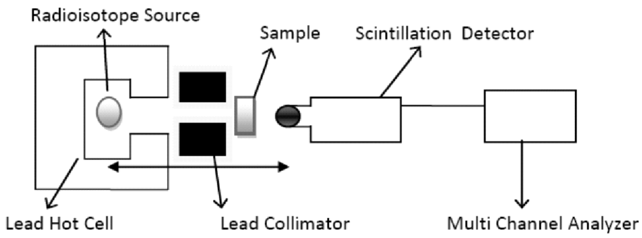

Fig. 1. Schematic view of gamma transmission technique and studied geometry.

The source was set away to detector at 10 cm distance for Cs-137 and 14 cm for Co-60 gamma radioisotopes and a collimator which hole diameter is 0.7 cm and length is 5 cm was set in front of the source.

Cs-137 and Co-60 gamma radioisotopes were used in the experiments as gamma sources where their half lives are 30.1 and 5.23 years, respectively [6]. Cs-137 gamma source has single energy peak at 0.662 MeV and the activity of 8.9 μCi. Co-60 gamma source has two main energy peaks at 1.17 and 1.33 MeV which has been assumed the average energy peak as 1.25 MeV [8]. The activity of studied Co-60 gamma radioisotope is 14.1 μCi. PM1401K model scintillation detector and multichannel analyzer was used in the experiments.

h-BN and h-BN-TiB_2 samples were sintered at 1800 °C under nitrogen atmosphere without pressure for 2 h.

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h-BN-TiB_2 materials which include 55% TiB_2 by weight have 5×5 cm^2 area at different thicknesses. h-BN samples have cylindrical shape at 5 cm diameter and 1 cm thickness. The densities of h-BN and h-BN-TiB_2 are 1.5 and 2.214 g/cm^3, respectively.

In the experiments, firstly background radiation was measured to reduce it from the all other measurements to indicate net intensities. Then I and I_0 gamma intensities for different sample thicknesses were measured by 600 s accumulation time. Afterwards relative intensity values (I/I_0) were calculated for all sample thicknesses. Finally relative intensity–thickness graphs were drawn for all materials and their gamma attenuation properties were evaluated.

3. Results and discussion

First, the results for Cs-137 gamma source were carried out. Experimental results of h-BN and h-BN-TiB_2 composites for Cs-137 and Co-60 gamma radiation were given in Table I.

TABLE I

Experimental results for h-BN and h-BN-TiB_2 against Cs-137 and Co-60 gamma source.

Material (code)	Thickness [cm]	1. count	2. count	3. count	Av. count	Std. deviation	Relative count	R. std. deviation (±)
Cs-137								
h-BN	0	3044	3046	3058	3049	8	1.0000	0.0050
	0.6896	2826	2830	2822	2826	4	0.9268	0.0036
	1.3792	2620	2622	2625	2622	3	0.8600	0.0030
	2.0688	2432	2423	2429	2428	5	0.7962	0.0035
	2.7584	2285	2286	2291	2287	3	0.7501	0.0029
h-BN-TiB_2	0	3010	3013	3025	3016	8	1.0000	0.0053
	0.2348	2916	2920	2920	2919	2	0.9677	0.0033
	0.6761	2690	2688	2696	2691	4	0.8924	0.0037
	1.8768	2256	2257	2258	2257	1	0.7483	0.0023
	2.5529	2022	2020	2023	2022	2	0.6703	0.0023
	2.7877	1943	1951	1956	1950	7	0.6466	0.0039
Co-60								
h-BN	0	2995	3014	2992	3000	12	1.0000	0.0080
	0.6896	2870	2861	2868	2866	5	0.9553	0.0054
	1.3792	2705	2706	2717	2709	7	0.9030	0.0058
	2.0688	2568	2554	2538	2553	15	0.8510	0.0084
	2.7584	2437	2422	2447	2435	13	0.8117	0.0074
h-BN-TiB_2	0	2995	3014	2992	3000	12	1.0000	0.0080
	0.2348	2950	2936	2936	2941	8	0.9801	0.0066
	0.6761	2777	2775	2765	2772	6	0.9240	0.0058
	1.8768	2405	2406	2419	2410	8	0.8032	0.0058
	2.5529	2205	2212	2224	2214	10	0.7378	0.0061
	2.7877	2166	2175	2184	2175	9	0.7249	0.0059

TABLE III

Mass attenuation of h-BN and h-BN-TiB_2 for Cs-137 and Co-60 gamma sources.

Material	Mass attenuation coefficient [10^{-2} cm^2/g]					
	Cs-137			Co-60		
	Experimental	XCOM	Difference [%]	Experimental	XCOM	Difference [%]
h-BN	7.153	7.470	4.24	5.047	5.507	8.36
h-BN-TiB_2	7.069	7.338	3.67	5.280	5.398	2.19

By using the values from Table I the relative intensity--material thickness graphs were drawn for h-BN and h-BN-TiB_2, in case of Cs-137 and Co-60 gamma radioisotopes have been used separately. The graphs were shown in Fig. 2.

It could be seen from Fig. 2 that h-BN-TiB_2 composite has bigger gamma attenuation effect than h-BN for both Cs-137 and Co-60 gamma radioisotope sources. The linear attenuation coefficients of the samples were carried out by using Origin program and given in Table II.

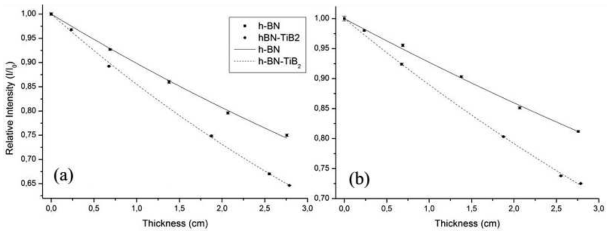

Fig. 2. Cs-137 (a) and Co-60 (b) gamma attenuation of h-BN and h-BN-TiB_2.

TABLE II

Linear gamma attenuation of h-BN and h-BN-TiB_2 for Cs-137 and Co-60 gamma sources.

Material	Linear attenuation coefficient [cm^{-1}]			
	Cs-137	Std. error	Co-60	Std. error
h-BN	0.1073	0.0014	0.0757	0.0012
h-BN-TiB_2	0.1565	0.0013	0.1169	0.0012

In addition, experimental mass attenuation coefficients (μ/ρ) of the samples were calculated and compared with theoretical values which were taken from XCOM computer code [9]. The results were given in Table III.

For all the samples, the experimental and theoretical mass attenuation coefficients are close to each other. The difference percentages of the results for h-BN and h-BN--TiB_2 are between 2.19 and 8.36%.

Finally the half value layers (HVL), which mean the material thickness to reduce initial radiation intensity to its half, of the samples were calculated by using the formula [10]:

$$\mathrm{HVL} = \frac{0.693}{\mu}, \tag{2}$$

where μ is the linear attenuation coefficient of the sample at specific gamma rays. HVLs of the materials for Cs-137 and Co-60 gamma radiation were listed in Table IV.

TABLE IV

HVLs of h-BN and h-BN-TiB_2 against Cs-137 and Co-60 gamma radiation.

Material	Cs-137		Co-60	
	HVL [cm]	Std. deviation	HVL [cm]	Std. deviation
h-BN	6.460	0.084	9.157	0.145
h-BN-TiB_2	4.429	0.037	5.929	0.061

As seen in Table IV, h-BN-TiB_2 has smaller HVL than pure h-BN for both Cs-137 and Co-60 gamma radiation. Adding TiB_2 to h-BN decreased HVL nearly 33% for both Cs-137 and Co-60 gamma sources.

4. Conclusion

The linear and mass attenuation coefficients of hexagonal boron nitride and h-BN-TiB_2 materials were carried out against Cs-137 and Co-60 gamma radiation. h-BN-TiB_2 has the bigger linear attenuation coefficients than pure h-BN. In addition the HVLs of both pure h-BN and h-BN-TiB_2 against Cs-137 are 6.46 and 4.429 cm, respectively. Furthermore against Co-60 HVLs of h-BN and h-BN-TiB_2 are 9.157 and 5.929, respectively. So it means that the h-BN-TiB_2 composites have approximately 33% smaller HVL according to h-BN samples for gamma radiation. Therefore adding TiB_2 to h-BN decreased the HVL of h-BN against Cs-137 and Co-60. In conclusion, beside the good neutron shielding properties of h-BN and h-BN-TiB_2 composites their gamma attenuation properties also could be taken into account if gamma shielding needs for the system.

References

[1] C. Steinborn, M. Hermann, U. Keitel, A. Schöneker, J. Rathel, D. Rafaja, J. Eichler, *J. Europ. Ceram. Soc.* **33**, 1225 (2013).

[2] H.O. Pierson, *Handbook of Refractory Carbides and Nitrides; Properties, Characteristics, Processing and Applications*, Noyes Publications, New Jersey 1996.

[3] J. Eichler, C. Lesniak, *J. Europ. Ceram. Soc.* **28**, 1105 (2008).

[4] J. Li, R. Dahal, S. Majety, J.Y. Lin, H.X. Jiang, *Nucl. Instrum. Methods Phys. Res. A* **654**, 417 (2011).

[5] B. Ertug, in: "Powder Preparation, Properties and Industrial Applications of Hexagonal Boron Nitride", *Sintering Applications*, Intech Publications, 2013, p. 33.

[6] B. Buyuk, A.B. Tugrul, A.C. Akarsu, A.O. Addemir, *Acta Phys. Pol. A* **121**, 135 (2012).

[7] G.F. Knoll, *Radiation Detection and Measurement*, University of Michigan, Ann Arbor 2002.

[8] S. Croft, *Ann. Nucl. En.* **33**, 466 (2006).

[9] M.J. Berger, J.H. Hubbell, S.M. Seltzer, J. Chang, J.S. Coursey, R. Sukumar, D.S. Zucker, K. Olsen, "XCOM: photon crossection database", `http://www.nist.gov/pml/data/xcom/index.cfm`, USA.

[10] *Handbook of Radioactivity Analysis*, Ed. M.F. L'Annunziata, 2nd ed, Elsevier Sci., USA Waltham 2003.