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Preparation of novel in-situ layered B_4C and PbO reinforced solution casted layered polymer composites (SCLPC) for augmenting the gamma irradiation shielding capability

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Highlights

- The fabrication route is novel in-situ layered molding and curing route.
- Two distinct layers of B_4C and PbO were formed and is confirmed through microscopy.
- The prepared composite was subjected thermal and gamma radiation shielding studies.
- The composite was able to portray shielding with an efficiency of nearly 45% at low doses.

Abstract

The present article deals with the preparation of novel in-situ layered B_4C and PbO reinforced solution casted layered polymer composites (SCLPC) for irradiation shielding applications. Two distinct layers of B_4C and PbO were formed inherently in the sample owing to the difference in density of the reinforcements in the epoxy matrix. The formed layers were distinct and the interface was continuous as well. Further, the as-prepared in-situ layered sample was subjected to XRD and FTIR to confirm the particle reinforcements and chemical stability respectively. The gamma irradiation shielding studies revealed the superior efficiency in shielding of gamma irradiation at lower energy doses making it more suitable for gamma ray shielding applications.

Introduction

Radiation shielding plays a major role in safeguarding the environment from the harmful radioactive sources employed in various sectors such as power plants, medical and transportation [1]. Ionizing radiation that includes gamma, X-ray and neutron radiation possess serious threat when not shielded effectively. Various materials are widely used for shielding radioactive radiation, among which, lead is widely used nowadays. However, the usage of lead increases the threat due to toxicity and heavy weight. Although, it is well known that material with high density acts as an effective shielding material, researchers find the difficulty in using lead based shielding due to sustainability issues [2]. To address this issue, focus has turned towards the development of polymeric shielding material with the matrix reinforced with a promising filler material.

Numerous researches suggest the utilization of polymer matrices such as high-density polyethylene, Nylon, Polystyrene and epoxy [3]. However, as a result, epoxy and was found to be more promising in terms of shielding characteristics. Various particles such as bismuth oxide, cadmium, gadolinium oxide was filled with polymer matrices and were studied for radiation shielding properties. Research suggests the potential ability of Boron Carbide and its suitability in various sectors like military industry, abrasive and cutting tool industries, nuclear industries for neutron absorption and etc. [4]. The wide characteristics like high melting point, wear resistance, perfect geometry, good rigidity and mechanical properties, high resistance to chemical mixtures, neutron absorbing capability, ease of availability and low cost led the researchers to consider Boron carbide as an effective engineering material. However, it should be taken into account that the utilization of boron carbide for radiation shielding comes with the cost of irradiation after-effect damages i.e., it is more prone to radiation damages after multiple cycles [5]. Hence, it is highly imperative to have a addition reinforcement to reduce the after effects of irradaiation. Studies reveal polymer filled with lead oxide particles was studied for the γ-ray shielding characteristics and reported the suitability for shielding when filled with greater particle concentrations. Further, studies on PbO, PbO_2 and Pb_3O_4 filled isophthalic resin reveal the better attenuation and shielding efficiency of PbO samples [6]. Moreover, studies reveal the performance of bulk and nano PbO particles with HDPE polymer matrix and reported the better radiation shielding of nano PbO particles. However, the difference between both the bulk and nano-PbO stands less than 1% [7] On the other hand, there is almost a

void in gamma irradiation studies on boron carbide filled epoxy laminates. Nevertheless, works on layered polymeric laminates for irradiation shielding is limited due to the poor mechanical property and inability to maintain uniform adhesion between the layers. This work reports the gamma radiation shielding properties of in-situ layered B_4C–PbO dispersed Solution Casted Layered Polymer Composites (SCLPC) fabricated through molding and curing route [8].

Section snippets

Materials and methods

The matrix used for this work epoxy LY556 and its corresponding hardener H596 were procured from Herenba Resins Pvt. Ltd. Chennai. The Boron carbide (10μm) and lead oxide particles (10μm) were commercially procured from Neena Metal Mart, New Delhi and Alpha Chemica, Mumbai respectively. The procured particles were analyzed and confirmed through SEM equipped with EDS and are portrayed in Fig. 1a and Fig. 1b.

The samples were prepared through molding and curing route as illustrated in Fig. 1c.…

Results & discussions

Fig. 3a shows the XRD pattern of the powdered as-prepared sample. The pattern reveals the presence of B_4C and PbO particles in the matrix. The peaks corresponding to PbO particles were in accordance with the JCPDS card 01-078-1665,88–1589, and 85–1739 confirming the occurrence of lead oxide particles. Further, the peaks corresponding to the B_4C are at 2θ values at 30.18°, 37.67°,52.69°,55.34°,64.32° and are in accordance with JCPDS card 75–0424 [10] and also in accordance with work by Matlab N. …

Conclusions

In this present study in-situ layer formation of B_4C and PbO particle reinforced epoxy composite was fabricated for irradiation shielding applications through novel molding and curing route. The results are summarized as below:

i. The fabrication route adopted was a novel route which formulated the distinct layers with an aid of density of the reinforced particles.…

ii. The X-Ray diffraction pattern confirmed the presence of particle reinforcement with matrix and the FTIR spectra of the as-prepared…

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CRediT authorship contribution statement

S. Vignesh: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **J.T. Winowlin Jappes:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **S. Nagaveena:** Validation, Software, Resources, Investigation, Formal analysis. **R. Krishna Sharma:** Writing – review & editing, Investigation, Formal analysis, Data curation. **M. Adam Khan:** Validation, Resources,…

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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