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BORON FILLED POLYETHYLENE SHIELDING CERAMIC-METAL APPLIED FOR COMPOSITE SHIELDING TO NUCLEAR RADIATION

Introduction

Concerns of mixed neutron and gamma radiations are common in most nuclear applications. This is a result of neutrons' interactions with materials, which can lead to the generation of secondary gamma-rays.

Shielding material. Among them, UHMWPE composites (B_4C-W/UHMWPE) synergistically reinforced by boron carbide (B_4C) particles and tungsten (W) particles have received particular attention.

Radiation induced from Nuclear Reactor

Radiation is energy that arises from a source, traverses space, and has the potential to penetrate a variety of materials. According to its ability to ionize matter, radiation is divided into two distinct groups. Ionizing radiation comes in two forms: (1) and (2) [1].

Nonionizing radiation, the energy required to liberate electrons from atoms and form ions is absent from electromagnetic waves, such as X-rays and gamma rays (alpha, beta, and neutrons) [2].

Choosing the Right Radiation Shielding factors

Radiation Protection is an important field across a wide range of industries from healthcare and medical imaging to nuclear energy, nuclear medicine and non-destructive testing. ALARA (As Low as Reasonably Achievable) is a principle that strives to minimize the exposure of ionizing radiation to people and the environment while considering economics, technology and social factors [3].

Table 1

Several types of commercial polyethylene materials' attenuation coefficients [5]

Materials	Coefficient, Σ (cm^{-1})
Low density polyethylene	0.146
High density polyethylene	0.321
Linear of low density polyethylene	0.147

Table 2

Coefficient of attenuation of the HDPE/B4C combination [8]

Materials	B_0	B_7	B_{15}	B_{24}
Attenuation Coefficient, Σ (cm^{-1})	0.33	3.65	3.98	4.46
Relaxation Length (cm)	3.03	0.27	0.25	0.22

Why Boron and Heavy metals Efficient in neutron Shielding

To minimize the dose of gamma radiation caused by neutron capture interactions, neutron shielding may also include high atomic weight elements or layers of higher atomic weight shielding material (n, γ)[6].

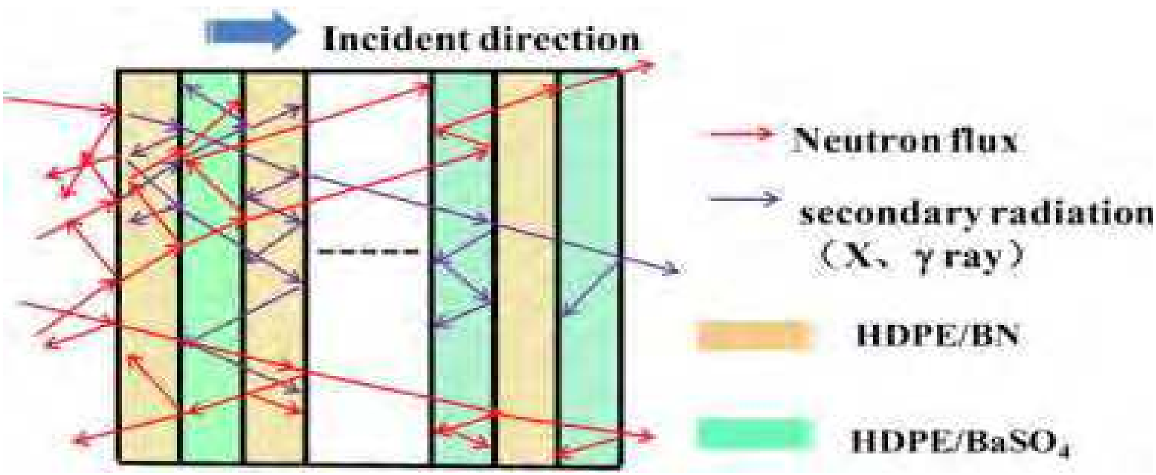

Fig. 1. The alternating multi-layered distribution structure of the composite (one layer was high density polyethylene (HDPE)/boron nitride (BN), and another layer was HDPE/barium sulfate (BaSO4) [3]

Several polymer composites are used as neutron shielding materials for this purpose

The 2.2 MeV energy of the released -rays. These -rays can affect the physical characteristics of the polyethylene and, in some circumstances, may also serve as a somewhat undesirable source of radiation exposure [4].

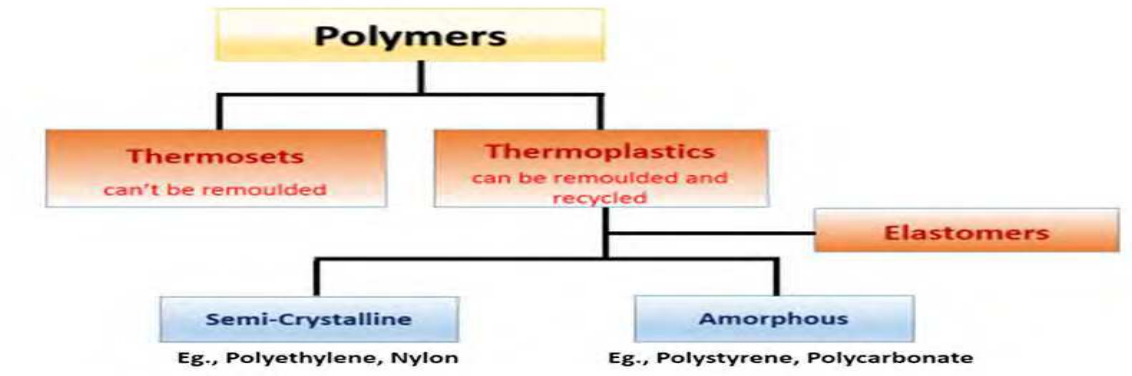

Fig. 2. Upon temperature change, polymers are classified into semi-crystalline and amorphous thermosets and thermoplastics

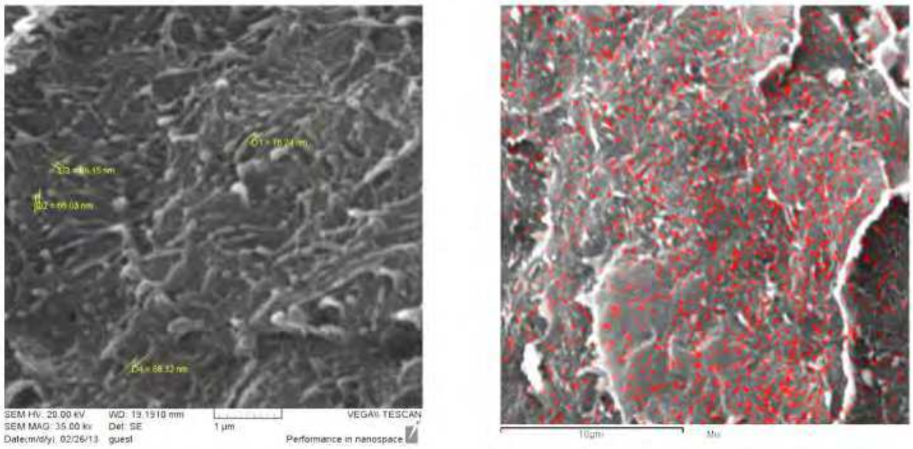

Fig. 3. SEM images of boron carbide Nano-composites, a) the magnified image to show the size of Nano-particles with 1 µm [9]

Fig. 4. Following recycling, polymer composite materials utilization in a variety of applications, such as radiation protection materials [8]

Several polymer composite types are used as materials for neutron shielding

High purity polyethylene (HDPE) is used to thermalize fast neutrons, primarily for experimentation where it is desirable to produce a thermal neutron flux from a higher energy field. HP Polyethylene has minimal impurities that might absorb thermal neutrons [7].

Pure Polyethylene can be easily machined into complex shielding form factors and is available in virtually any shape or configuration. This material is often used in applications involving reactor physics, activation analysis, isotopic neutron sources and specially fabricated neutron casks [8].

Polyethylene due to its high hydrogen content, is a well-known material for shielding purposes. The atomic number one element, hydrogen, has the greatest energy loss per mass. Since hydrogen has a shorter mean free path for ions than other materials, heavier ions fragment more easily, resulting in a smaller dose being delivered.

Polyethylene has an extremely high molecular weight (UHMWPE) is a linear polyolefin containing a CH_2CH_2 repeating unit. Long chains with a molecular mass of 2 106-6 106 g mol-1 comprise up the long chains of medical-grade UHMWPE, which is a semi-crystalline polymer with a set of ordered areas contained in a disordered amorphous phase [5].

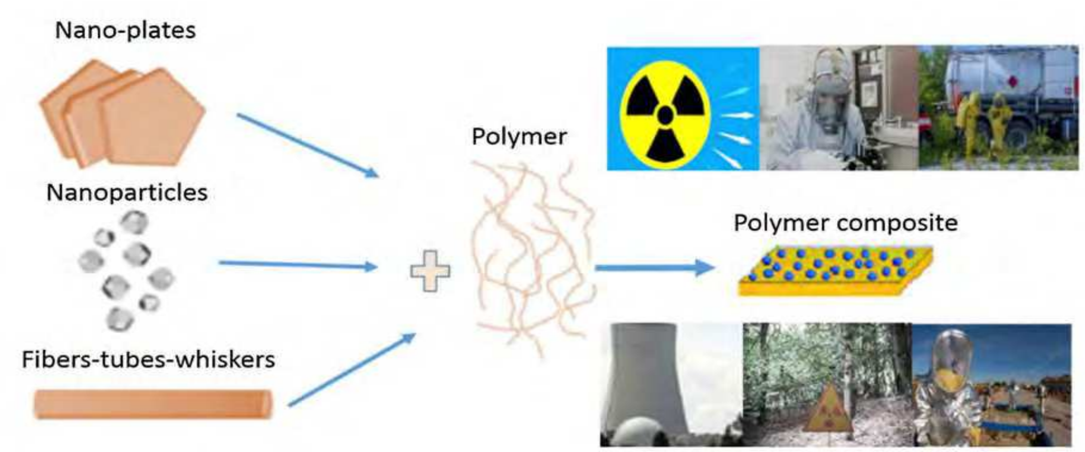

Fig. 5. To create polymer composites, a variety of Nano plates, nanoparticles, fibers, and tubes can be included into the polymer matrix. [9]

Conclusion

Boron atom has the largest thermal neutron absorption cross-sectional area in common substances (second only to Pu, Sm and Gd), and B_4C is cheap; W has a large atomic number, which can effectively shield γ rays, and is non-toxic and harmless; UHMWPE has a very high atomic number.

High Hydrogen atom content can significantly moderate fast neutrons, and is resistant to impact, wear and acid and alkali corrosion. Therefore, the B_4C-W/UHMWPE composite material not only has excellent composite shielding effect on high-energy rays, but also has good impact resistance, wear resistance, acid and alkali corrosion resistance and other advantages.

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