DEVELOPMENT OF GAMMA-RAY AND NEUTRON RADIATION SHIELDING USING GEOPOLYMER-PARTICULATE COMPOSITES

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Geopolymers are hydrated, inorganic aluminosilicate polymers that can be used as matrix binders to accommodate various filler phases or reinforcements [1]. By selecting dispersant materials with a high probability of interaction with ionizing radiation, geopolymers can be optimized for radiation shielding. Geopolymer composites promise highly versatile and configurable products that can take advantage of the thixotropic properties of geopolymer resin. Processing differences would allow for the production of composites with a tunable viscosity, providing a highly versatile shielding solution [1,2]. High-viscosity composites could be pasted onto vertical surfaces or ceilings to be cured, akin to plaster. Tuning the processing could be done to match the workability of high-density concrete. Geopolymer radiation shielding offers a path forward for replacing high-density concrete in high radiation environments, such as nuclear reactors, reducing the carbon release during the construction of nuclear facilities.

In this work, the gamma-ray and neutron shielding ability of potassium-based geopolymer composites were investigated. This was done using tungsten, chosen for its high photoelectric absorption probability, and boron nitride, chosen for its large cross section for low-energy neutron capture, as attenuating dispersants. Tungsten powder was mixed with a 1 K_2O · 1 Al_2O_3 · 4 SiO_2 · 11 H_2O geopolymer to produce a composite for attenuating gamma radiation. Different sizes of tungsten powders were incorporated, submicron average particle size (APS) and 30-micron APS, using various processes to maximize the homogeneity of the powder dispersion throughout the geopolymer matrix. Neutron shielding properties were also tested using a composite of the 1 K_2O · 1 Al_2O_3 · 4 SiO_2 · 11 H_2O geopolymer with submicron APS boron nitride powder.
X-ray diffraction (XRD) and scanning electron microscopy (SEM) were used to determine the homogeneity of the powder dispersion. SEM imaging showed the 30-micron APS tungsten powder settling to the bottom of the sample before a saturation amount was exceeded and the dispersion was homogeneous. The submicron APS tungsten powder agglomerated easily and required mixing into the potassium water glass to disperse with minimal agglomeration. This was confirmed as XRD showed a decrease in intensity of the tungsten powder peaks in submicron APS samples without significant agglomeration.

The shielding ability of the geopolymers was quantified using 137Cs-662-keV gamma-rays and fission neutrons measured using NaI(Tl) and organic scintillation detectors, respectively. The mass attenuation coefficient, the attenuation coefficient normalized by the density of the material, of the geopolymer composite with 75 wt.% 30-micron APS tungsten was comparable to lead. The geopolymer loaded with 12 wt.% boron nitride attenuated fission neutrons approximately six times more than lead. These experimental results proved promising geopolymer composite ionizing radiation shielding ability with tungsten and boron nitride dispersants. Combined with the thixotropic properties of geopolymers, their demonstrated radiation shielding efficiency can open new application avenues in the nuclear power and security industry.

References

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