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Rapid-Response Renewable Biopolymer Detector for Neutron & Gamma Radiation in Dosimetry and Reactor Flux Mapping

PLA-based biopolymer detectors distinguish gamma vs neutron doses in 1–40 kGy ranges for low-cost dosimetry and nuclear flux mapping.

Researchers at Purdue have developed a low-cost, readily deployable solid state, biopolymer polylactic acid (PLA)-based dosimeter capable of measuring and individually identifying gamma and neutron radiation components as well as conducting neutron-gamma dosimetry in the industrially relevant range of 1-40 kGy. The technology is based on correlating the dissolution of the small (0.2 g; $0.1/sample) irradiated PLA beads in a heated acetone bath at select temperatures. Existing systems to characterize gamma/neutron radiation components range from the millions of dollars for large, bulky spectrometers, $1-10k for portable radiation sensors, and $10-100 for personal dosimeters. Furthermore, neutron-specific radiation detection/dosimeters are far more complex and require specialty materials to manufacture.

The researchers discovered that at a given temperature for a bath of acetone (~40 â€“ 54 Â°C), the ratio of the mass loss to dissolution (MLD) of the PLA beads to the initial mass of the PLA beads was correlated with accumulated gamma and neutron radiation dose. Furthermore, the type of radiation can be determined by measuring the MLD at different temperatures for the bath of acetone and comparing MLD for combined radiation sources and neutron-only sources. Because gamma irradiation directly interacts with the electron clouds of molecules, while neutrons can only interact with the four orders-of-magnitude smaller nucleus, the effect of gamma photons upon the PLA bead's structure should be different than the effect due to neutrons at the same radiation dose. This means that a lower acetone bath temperature will be needed for mass dissolution of gamma-irradiated PLA beads than equivalently dosed neutron-irradiated or combined neutron-gamma irradiated PLA beads, allowing one to distinguish irradiation purely due to gamma radiation from neutron-irradiated samples.

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Chemicals & Advanced Materials/Materials Processing & Manufacturing Technologies

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Technology Validation:

To validate the accuracy of their method in the case of purely gamma-radiation, the researchers placed the PLA samples in the center of a GammaCellTM Co-60 irradiator. Gamma doses were evaluated by multiplying the time-averaged dose rate over the irradiation duration by the irradiation time, to get a range of accumulated gamma doses from 1-100 kGy. The MLD of the Co-60 irradiated samples was measured by immersing the PLA samples into a pre-heated bath of acetone at 50 Celsius for 20 minutes, after which the remaining undissolved PLA was dried and weighed to find the mass lost upon dissolution. The researchers found that there was a strong correlation between MLD and total dose ($R^2 = 0.9815$).

To evaluate the ability of the method to distinguish between gamma and neutron radiation, the researchers placed PLA beads into Purdue University's 8-kW pool-type (PUR-1) research nuclear reactor. The PLA beads were exposed to total radiation doses of ~9-40 kGy at different locations in PUR-1, of which the gamma:neutron ratio varied from ~2:1 for total doses 20 kGy, and 1:1 for doses >20 kGy. The MLD of samples from PUR-1 were measured at acetone bath temperatures of 40.5 and 45.5 Celsius, along with equivalently dosed PLA samples from the purely gamma Co-60 irradiator. It was discovered that at an acetone bath temperature of ~40.5 Celsius, samples that had only been gamma irradiated (from the Co-60 irradiator) were able to dissolve significantly, while equivalently dosed 1:1 gamma and neutron irradiated samples did not dissolve significantly. Only after the acetone bath temperature had been increased to 45.5 Celsius did the PUR-1 neutron and gamma-irradiated samples start to dissolve. At acetone bath temperatures >50 Celsius, a linear trend was observed between MLD and radiation dose, regardless of the source (gamma, neutron, etc). Considering that gamma ray interactions have a general commonality of interaction with atoms as with e-beams, the technique is expected to be extendable to e-beam irradiation facilities as well.

Advantages:

- Can discriminate between purely gamma irradiation and gamma/neutron irradiation

- Measures accumulated gamma and neutron radiation dose

- Biodegradable/environmentally friendly

- Simple

- Rapid

- Accurate

- Low cost

- Nonpowered

- Lightweight

- Solid state

Applications:

- Food Irradiation/Packaging Sterilization

- Medical Device Sterilization, Radiation Cancer Therapy

- Dosimetry in high radiation fields for Medical/Nuclear Reactor systems

- Nuclear Power Reactor Energy/Safety, Irradiators, Accelerator Systems

- Nuclear Reactor neutron and gamma flux-power mapping

TRL: 5

Intellectual Property:

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