HIGH-DOSE GAMMA IRRADIATION EFFECTS ON HDPE/SiO_2 NANOCOMPOSITE FILMS: STRUCTURE, CRYSTALLINITY, AND INTERFACIAL BEHAVIOR

A.A. Nabiyev[1,2], O.I. Ivankov[2], A.H.A. Elmekawy[2,3,4] and A.I. Kuklin[2]

[1] *Ministry of Science and Education Republic of Azerbaijan, Institute of Physics, Baku, Azerbaijan*
[2] *International Intergovernmental Organization, Joint Institute for Nuclear Research, Dubna, Russia*
[3] *Experimental Nuclear Physics Department, Nuclear Research Center, Egyptian Atomic Energy Authority, Cairo, Egypt*
[4] *Cyclotron Facility, Nuclear Research Center, Egyptian Atomic Energy Authority, Cairo, Egypt*

E-mail: asifnebi@gmail.com

The presence of nano-SiO_2 particles in a polymer matrix can influence the behavior of the polymer under ionizing radiation by altering radical formation, recombination dynamics, and structural efficiency. In particular, the addition of inorganic nanoparticles such as silicon dioxide (SiO_2) can improve the crystallinity, thermal stability, and mechanical strength of the polymer matrix. These types of nanocomposites have potential applications in electronics, coatings, optics, and space technologies [1–5]. In this study, HDPE nanocomposites reinforced with nano-SiO_2 particles were fabricated and exposed to high-dose gamma irradiation. The objective of this work is to analyze changes in structural integrity, crystallinity, defect formation, radiation resistance, nanoparticle dispersion, and interfacial interactions within these nanocomposites, as well as to assess their long-term suitability for use in radiation-intensive environments.

Here we presented the effects of gamma radiation on the structural and thermal characteristics of high-density polyethylene nanocomposite films. These thin films consist of a combination of high-density polyethylene (HDPE) and nano-SiO_2 particles prepared by hydrostatic thermal pressing a mixture of HDPE powder and nano-SiO_2 in various volume concentrations (ω = 1%, 5%, 10%, and 20%). Radiation-induced defects and microstructural changes in HDPE nanocomposite films containing embedded nano-SiO_2 particles were investigated under high-dose gamma irradiation (100–500 kGy). DBAS analysis revealed that SiO_2 nanoparticles effectively suppress radiation-induced defect formation and positronium formation across most doses through void-filling and interfacial positron trapping mechanisms [6]. Defect evolution showed a transition from chain scission-dominated behavior (increasing defects up to 300 kGy) to crosslinking dominance at 500 kGy, with SiO_2 significantly mitigating both processes. However, at the critical dose of 300 kGy, where crystallinity (66.2%) and structural reorganization peak, anomalous defect behavior was observed for 1% and 20% SiO_2 loadings, attributed to insufficient structural constraint and interfacial stress concentration, respectively. Electron momentum distribution (EMD) analysis confirmed carbonyl group (C=O) formation during oxidative degradation. Optimal radiation resistance was achieved with 5–10 vol% SiO_2 at doses up to 300 kGy, in consistent with SAXS and WAXS findings, where the lamellar long period and crystallite thickness decreased, indicating a more ordered structural arrangement, while at 500 kGy chain scission and oxidative degradation became dominant.

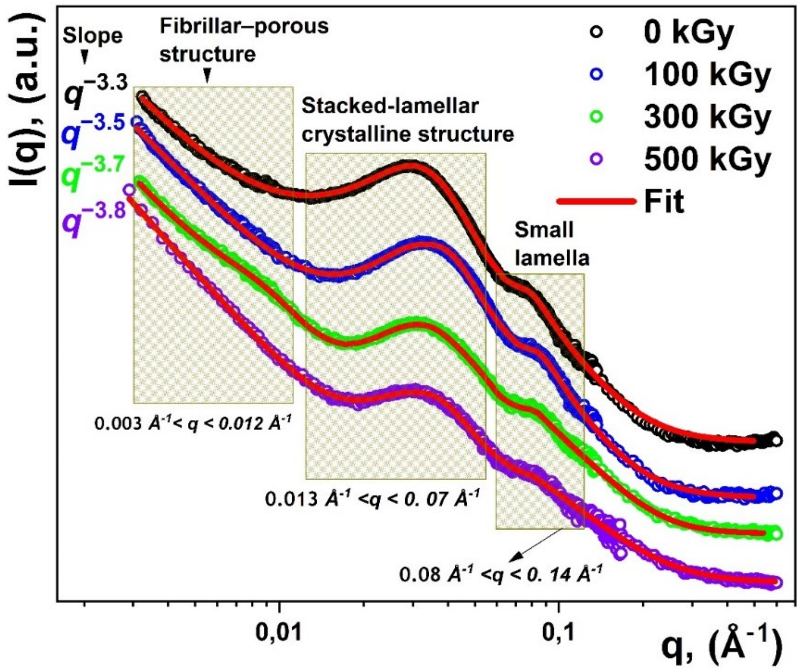

Fig. 1. Small-angle X-ray scattering plots of high dose gamma-ray irradiated pure HDPE films

These results provide fundamental insights into radiation resistance mechanisms and support the design of HDPE/SiO_2 nanocomposites for use in high-dose radiation environments.

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