The Structural Analysis of PVDF/WS_2 Polymer Nanocomposite films by TEM and Small-Angle X-Ray Scattering method

***A.A. Nabiyev*[1,2], *O.I. Ivankov*[2], *A.H.A. Elmekawy*[2,3]**

[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*

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In recent years, there has been growing interest by academics, scientific community, and industry in the development of polymer composites containing organic, inorganic, or hybrid fillers. This interest is primarily due to the potential to enhance thermal, mechanical, and dynamic-mechanical properties through interfacial interactions between the polymer matrix and the filler [1, 2]. The polyvinylidene fluoride (PVDF) polymer matrix is tough, flexible, and easy to process into films, allowing for the creation of lightweight, bendable, and wearable shields. The high surface area of WS_2 nanosheets enhances the formation of a conductive network at low loadings, making the shield efficient and lightweight. Based on the search results and current scientific literature, the application of PVDF+%WS_2 nanocomposite films for radiation protection is an emerging and promising area of research, though not as well established as their use in energy harvesting. These composites show potential primarily for shielding against electromagnetic (EM) radiation and, to a lesser extent, ionizing radiation.

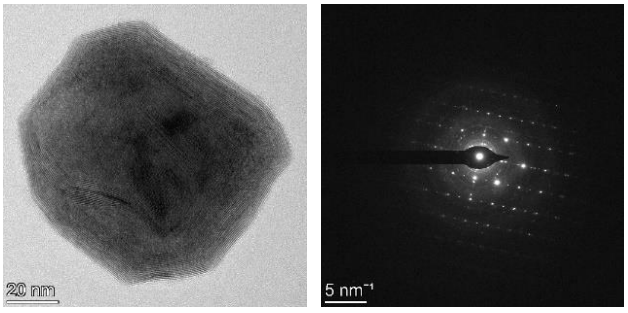

Figure 1. TEM micrograph and electron diffractogram of WS_2 nanosheets

In the current work a polymeric matrix samples of pure PVDF and PVDF/WS_2 composite films irradiated with different gamma-ray doses (100, 300, 500 and 700 kGy) were analyzed using small-angle and wide-angle X-ray scattering. The SAXS/WAXS measurements were carried out at the Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research (JINR), Dubna, Russia [3]. SAXS experiments showed WS_2 nanosheets mainly distributed in polyvinylidene fluoride matrix as aggregates system [4]. WS_2 disperses well in the range of 0.1-0.5%, and an average distance of ~9-10 nm between particles is observed within the PVDF matrix. As the concentration increases, surface roughness increases (2.05 → 2.30). 0.5% is the optimal concentration: This sample exhibits both an ordered structure (inter-particle distance ~9.2 nm) and favorable surface roughness (D_S≈2.30) for interfacial activity. The percolation threshold is crossed between 0.5% and 10%. At 10%, the "broad peak" disappears, and a dual-level fractal structure forms instead. This indicates that WS_2 has undergone strong aggregation with (D_S≈2.92) indicating much roughness than that of pure WS_2 (D_S≈2.68), it is expected that PVDF chains nucleate on the WS_2 surfaces, creating additional roughness.

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2. Nabiyev A.A., Mustafayev I.I. et al. Post-γ-irradiation effects in nano-SiO_2 particle reinforced high-density polyethylene composite films: Structure–property relationships, thermal stability and degradation // Polymer Composites. 2025. V. 46. P. S44-S62.

3. Nabiyev A.A., Ivankov O.I. et al. High-dose gamma irradiation effects on HDPE/SiO_2 nanocomposite films: Structure, crystallinity, defects, radiation endurance, dispersion, and interfacial behavior // Polymer Degradation and Stability. 2026. V. 245. P. 111851.