Size-Dependent Structural and Optical Behavior of ZnO/MWCNT Nanocomposites toward Optoelectronic Applications

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In this study, nanocomposites based on zinc oxide (ZnO) nanoparticles of different sizes and acid-functionalized multi-walled carbon nanotubes (F-MWCNTs) were synthesized, and their structural and optical properties were systematically investigated. The ZnO/MWCNT nanocomposite films were prepared by a solution-mixing approach using various MWCNT mass fractions. Surface morphology and structural characteristics were examined by atomic force microscopy (AFM) and X-ray diffraction (XRD). AFM analysis revealed that although both small- and large-sized ZnO nanoparticles exhibit a certain degree of agglomeration, their primary particle sizes remain within the nanoscale range, ensuring a high specific surface area. XRD results confirmed the preservation of the wurtzite crystal structure of ZnO, while the appearance of a characteristic carbon-related diffraction peak indicated the successful incorporation of MWCNTs into the nanocomposites. Fourier transform infrared (FTIR) spectroscopy revealed the presence of oxygen-containing functional groups and ZnO–MWCNT interfacial interactions, confirming effective functionalization and composite formation. Optical properties were investigated using UV–Vis absorption and photoluminescence (PL) spectroscopy. The UV–Vis spectra showed that the fundamental absorption features of ZnO were retained in the nanocomposites, accompanied by a pronounced enhancement in absorption intensity. PL measurements demonstrated that, depending on ZnO particle size and MWCNT loading, either luminescence quenching or emission enhancement occurred, reflecting differences in interfacial charge-transfer efficiency and electron–hole recombination behavior.