Advanced EMI Shielding with Quantum Dots and 2D Nanomaterial Enhanced Dual-Polymer Fiber Films

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An ultra-thin, lightweight, and highly flexible nanocomposite film is developed by synergistically integrating iron oxide quantum dots (FeQDs) and graphene nanoplatelets (GNPs) using the advanced electrospinning technique, specifically targeting electromagnetic interference (EMI) shielding applications. To enhance the electrical conductivity of the resulting thin film, a dual-faceted strategy is employed: utilizing a hybrid polymer system as the matrix and constructing a QDs/2D nanomaterial-integrated multilayer network within the film's architecture. This intricate design approach facilitates a robust investigation into the fiber-based thin films' structural, chemical properties, electrical conductivity, and EMI shielding capabilities, including characterization and simulation methodologies.Findings reveal that the electrospun fibers of 10GNP-1QDs exhibit an average diameter of ~613 ± 192 nm, presenting a significantly higher surface roughness than the pristine PAN fibers. This morphological variance is attributed to the intricate particle-polymer interactions. Raman spectroscopy analysis confirms the successful incorporation of GNPs and FeQDs into the fiber matrix, as evidenced by slight shifts in peak positions, indicative of atomic and molecular interactions between the composite's organic and inorganic constituents. Electrical conductivity measurements underscore a remarkable figure of 350,000 S/m, a characteristic partially ascribed to GNPs and FeQDs' facilitative role in enhancing the polymer matrix's conductive pathways. The magnetic SE within the frequency range of 250 to 1000 MHz spans between 30 to 35 dB, surpassing the performance of all other thin films, including control samples fabricated through coating and casting methodologies. This enhanced performance is linked to the improved electron mobility afforded by FeQDs. Additionally, within the low-frequency range of 0 to 1 MHz, the film exhibits an SE ranging from 40 to 50 dB, markedly outperforming Al and Cu films of equivalent thickness. Notably, within the high-frequency X-band spectrum of 8 to 12 GHz, the SE reaches levels up to 170 dB, ~30 dB higher than that of Al and Cu films. Furthermore, across the far-field frequency range of 100 MHz to 12 GHz, the film demonstrates an SE between 65 to 100 dB. The predominant shielding mechanisms contributing to these outcomes include absorption, multi-reflection,

reflection, hysteresis loss, and polarization loss, collectively ensuring the nanocomposite's superior performance in EMI shielding applications. This exploration significantly advances the field by demonstrating the exceptional capabilities of 1D/2D nanomaterial-integrated thin films across a wide frequency spectrum, setting a new benchmark for developing next-generation EMI shielding materials.