NANOCOMPOSITES BASED ON NANOPARTICLES AND POLYMER MATRICES

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Recent advances in polymer science and nanotechnology have enabled the development of polymer-based nanocomposites with precisely engineered physicochemical properties, thereby expanding their potential in a wide range of biologically related applications. Polymer matrices integrated with inorganic nanomaterials—such as superparamagnetic iron oxide nanoparticles (SPIONs), carbon-based nanostructures, or organic photoactive agents—have gained significant interest as functional platforms in various fields, including targeted drug delivery, biosensing, tissue engineering, and bioseparation. Incorporation of nanoparticles into polymeric hybrids not only enhances physicochemical characteristics such as mechanical strength, thermal stability, and optical performance, but also introduces new modes of functionality critical for biological environments, including stimuli-responsiveness, biocompatibility, and selective molecular interactions. Among these nanofillers, SPIONs are particularly valuable due to their superparamagnetic behavior, enabling on-demand magnetic control over polymer composites. This feature facilitates magnetically guided drug transport, minimally invasive manipulation of biomaterials, and efficient magnetic bioseparation [1]. In contrast, carbon-based nanomaterials—such as graphene derivatives, carbon nanotubes, and carbon dots—provide high surface area, unique electronic properties, and versatile surface chemistry, supporting the design of polymer composites for biosensing, bioimaging, and controlled release systems. Their interactions with polymer chains can modulate, dispersion quality, and the overall features and functionality of the hybrid material [2]. These advanced polymer-based nanocomposites offer tunable interactions with biologically relevant molecules, including therapeutic compounds, biomacromolecules, and signaling agents. Their adjustable surface characteristics and responsiveness to external stimuli make them promising candidates for next-generation biomedical technologies, such as smart drug delivery platforms, enzymatic or cellular immobilization matrices, and dynamic scaffolds for regenerative medicine.

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