Multifunctional Graphene-Based Plasmonic Nanoplatforms for Enhanced Sensing and Imaging

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Graphene-based plasmonic nanostructures have emerged as powerful platforms for advanced biosensing, multimodal imaging, and photothermal therapy due to their synergistic optical and physicochemical properties [1]. In this work, we present a series of multifunctional graphene–metal hybrid nanosystems engineered for enhanced molecular detection and biomedical applications.

Graphene oxide decorated with in situ synthesized gold nanoparticles was employed as a surface-enhanced Raman spectroscopy (SERS) platform to investigate DNA strand organization and hybridization behavior at the nanoscale [2]. The results demonstrate that the SERS response strongly depends on strand length, grafting strategy, and spatial positioning within plasmonic hot-spots, enabling insight into molecular orientation and local electromagnetic field distribution.

To extend functionality toward theranostic applications, hybrid graphene–polymer–gold bipyramid nanocomposites were developed, combining covalent and supramolecular assembly strategies. These nanosystems exhibit efficient near-infrared light-to-heat conversion and effective intracellular localization, demonstrating their potential for simultaneous bioimaging and photothermal therapy in melanoma cells [3].

Additionally, biopolymer-assisted reduced graphene oxide and polymer-passivated graphene oxide nanoflakes were fabricated as biocompatible, label-free optical contrast agents [4]. Enhanced Raman and photoluminescence properties enabled their application in confocal Raman imaging, super-resolution microscopy, and two-photon fluorescence lifetime imaging within tissue-like environments.

Overall, the rational integration of graphene derivatives, plasmonic nanostructures, and functional polymers provides tunable optical performance, controlled electromagnetic enhancement, and excellent biocompatibility. These multifunctional nanoplatforms hold significant promise for next-generation sensing, imaging, and nanotheranostic strategies.

References

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