Magnetite-Gold Hybrid Nanoparticles for Dual-Modality Biosensing and Targeted Therapy in Neurodegenerative Disorders

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Abstract:

The integration of magnetic and plasmonic functionalities into a single nanoscale platform opens new frontiers in biomedical diagnostics and therapeutics. In this study, we present the synthesis and surface engineering of Fe_3O_4/Au core–shell nanoparticles designed for dual functionality: magnetic responsiveness and enhanced biosensing performance. Magnetite (Fe_3O_4) cores were synthesized via a wet-chemical co-precipitation route, followed by gold shell formation through a seed-mediated growth process, resulting in uniform nanoparticles with an average size of ~50 nm, as confirmed by XRD, TEM, and DLS analyses.
The core–shell structure exhibits superparamagnetic behavior with a saturation magnetization of ~45 A·m²/kg, suitable for magnetic targeting and hyperthermia. The gold shell improves biocompatibility and enables robust biofunctionalization via thiol chemistry. Conjugation with thrombin-binding aptamers was successfully achieved, yielding stable nanoconjugates. A colorimetric biosensing assay demonstrated detection sensitivity in the nanomolar range, attributed to the gold shell's plasmonic enhancement (Figure 1, Right).

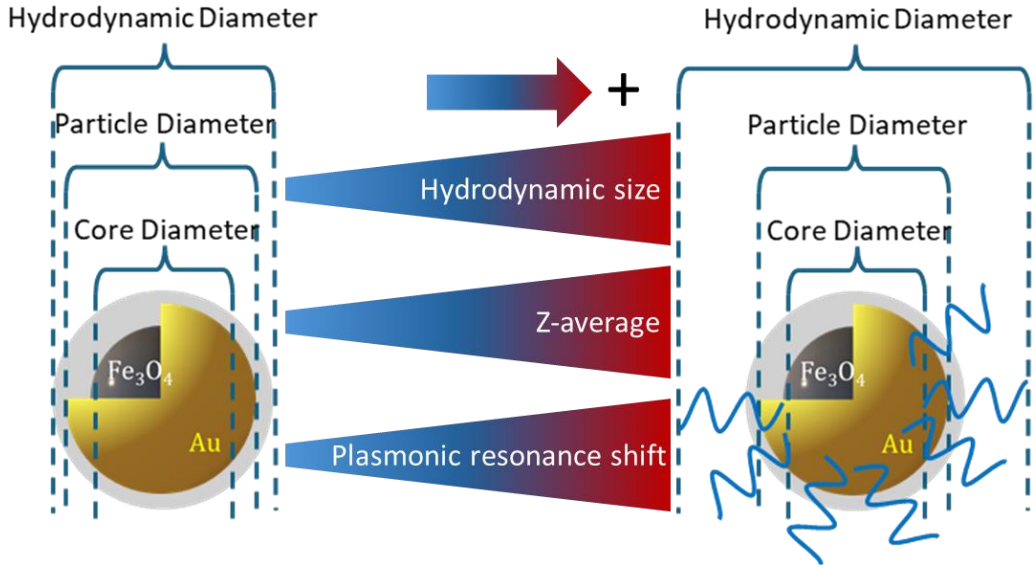

Figure 1: Schematic representation of Fe_3O_4/Au core–shell nanoparticles before (left) and after (right) functionalization with aptamers. Functionalization results in an increase in hydrodynamic size and Z-average, along with a redshift in plasmonic resonance, indicating successful conjugation and enhanced biosensing capabilities.

Future directions include immobilizing Alzheimer's-specific aptamers on the nanoparticle surface to selectively capture key blood biomarkers (Aβ40, Aβ42, p-Tau), enabling rapid and low limits of detection (LOD) across disease stages. These multifunctional nanoplatforms hold promise for next-generation point-of-care diagnostics and magnetically modulated therapeutic strategies.

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