Functionalized Magnetite-Gold Nanoparticles for Enhanced Biosensing and Targeted Therapeutic Applications in Neurodegenerative Diseases

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The development of multifunctional magnetic nanoparticles holds significant promise for advancing biomedical applications such as biosensing, targeted drug delivery, and magnetic hyperthermia. In this work, we report the successful synthesis and functionalization of magnetite/gold core/shell nanoparticles (Fe_3O_4/Au) designed for high sensitivity in biosensing and controlled therapeutic release. The Fe_3O_4 core provides magnetic responsiveness, while the gold shell enhances biocompatibility and enables functionalization with biomolecules. The nanoparticles were synthesized using a wet-chemical method, followed by gold shell growth through a seed-mediated process. Structural and morphological characterization via X-ray diffraction, transmission electron microscopy, and dynamic light scattering confirmed the formation of uniform core–shell structures with an average size of ~50 nm. Magnetic measurements revealed superparamagnetic behavior with a saturation magnetization of ~45 A m^2/kg, ensuring effective magnetic targeting and hyperthermia potential.

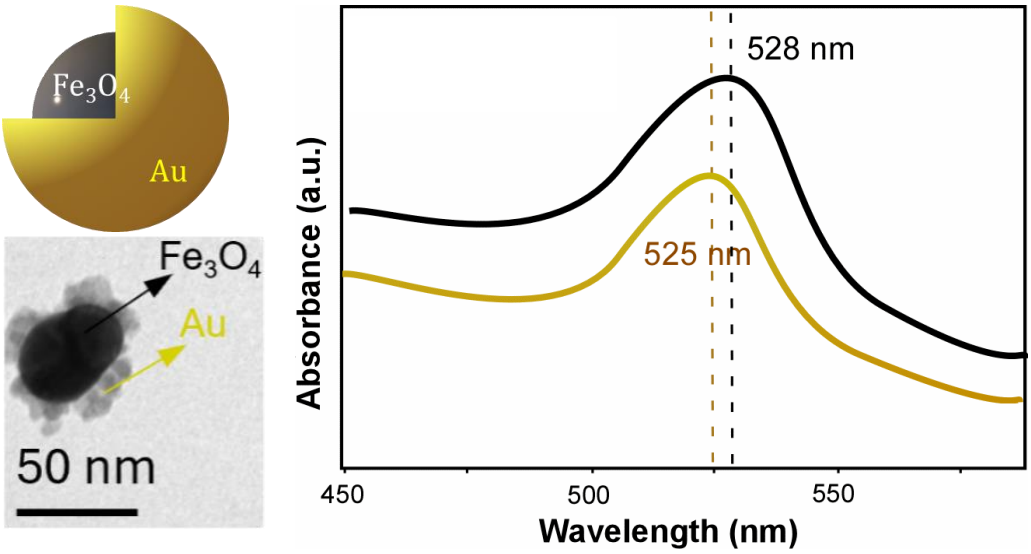

Figure 1. Left: Top: Schematic of core-shell formulation, Bottom: TEM image of Fe_3O_4/Au formulation Right: UV–vis–NIR absorption spectra between 450 nm and 600 nm of Fe_3O_4/Au nanoparticles (bottom-yellow curve) and Fe_3O_4/Au nanoparticles conjugated with aptamers (top-black curve). The plasmonic resonance of initial specimen occurs at 525 nm, while upon conjugation with aptamers, the resonance shifts to 528 nm, indicating successful conjugation and a change in the local environment around the gold nanoparticles.

Functionalization with thrombin-binding aptamers was achieved through gold-thiol chemistry, resulting in stable nanoparticle conjugates. Biosensing performance was assessed using a colorimetric assay, demonstrating a limit of detection in the nanomolar range, highlighting the enhanced sensitivity due to the gold shell's plasmonic properties (Figure 1-Right). Next steps, include immobilization of AD aptamers on Fe_3O_4/Au to eventually bind to AD blood biomarkers like Aβ40, Aβ42, and p-Tau with good selectivity, specificity, fast response, and low limits of detection (LOD), across different stages of Alzheimer's disease.

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