Synthesis of magnetoplasmonic nanoparticles with anisotropic shape

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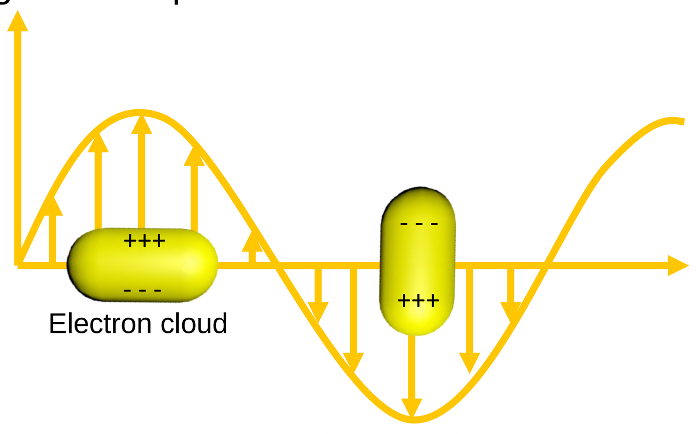
Introduction

The synthesis and application of anisotropic nanoparticles have attracted considerable attention due to their unique properties and potential applications in areas such as catalysis, sensing, and photonics. Among these, gold nanoparticles are particularly notable for their tunable optical properties, which are highly dependent on their shape and size. To exploit these characteristics for applications requiring precise control over nanoparticle orientation and optical behavior, we developed a method to synthesize anisotropic gold nanoparticles..

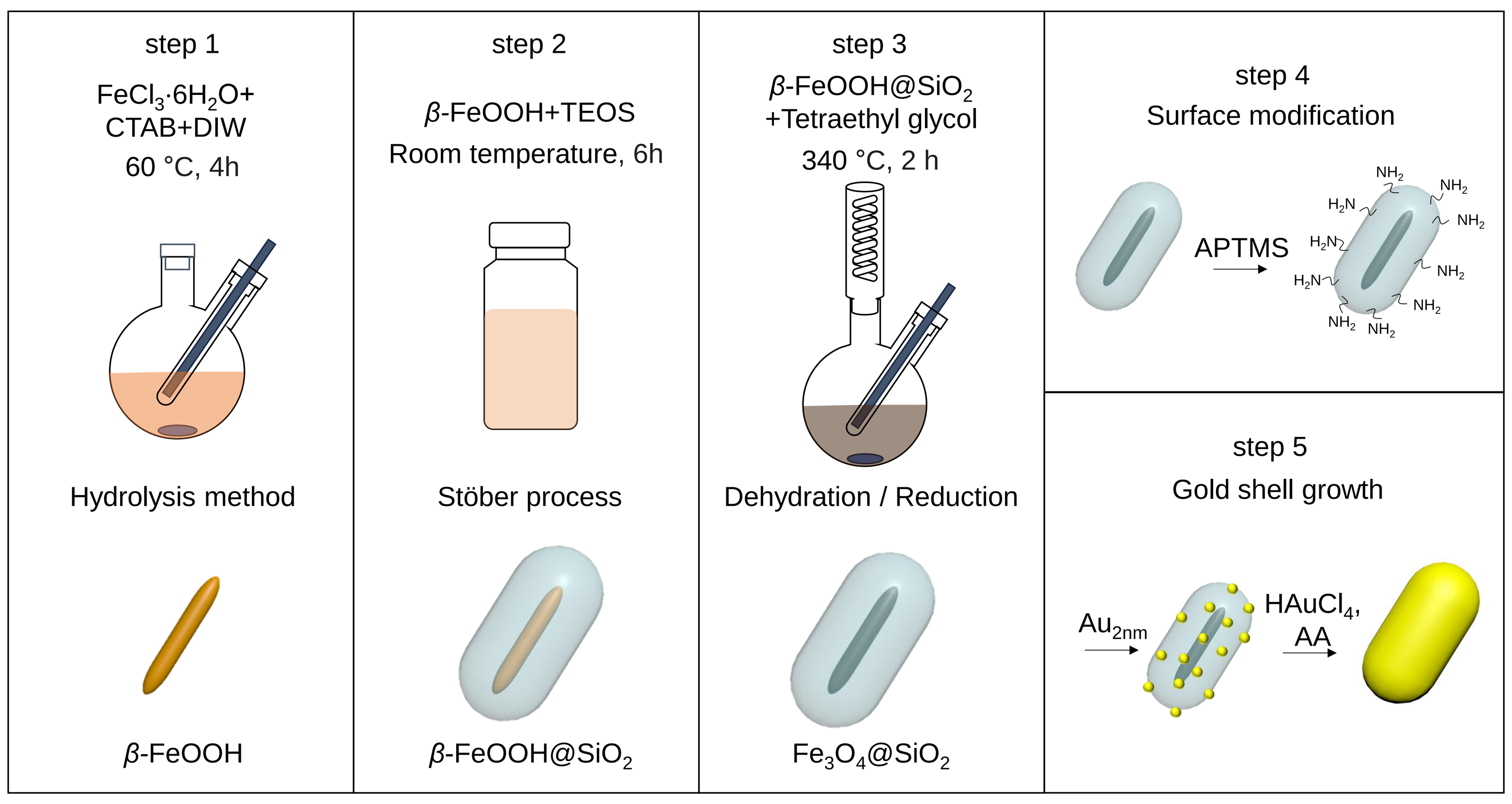
In this study, we initially synthesized rod-shaped β-FeOOH nanorods, which were reduced to form Fe_3O_4, known for its superparamagnetic properties. The anisotropic shape of these nanorods is advantageous as it allows for enhanced magnetic responsiveness when subjected to external fields. These nanorods demonstrate significant magnetic properties and can be aligned using external magnetic fields. This alignment capability opens new possibilities for the precise manipulation of these nanorods in various technological applications.



To further enhance their functionality, the Fe_3O_4 nanorods were coated with a gold layer, resulting in a structure that combines the magnetic tunability of Fe_3O_4 with the plasmonic properties of gold. This approach not only preserves the anisotropic shape of the nanorods but also enables potential adjustments to their optical properties under the influence of external magnetic fields.

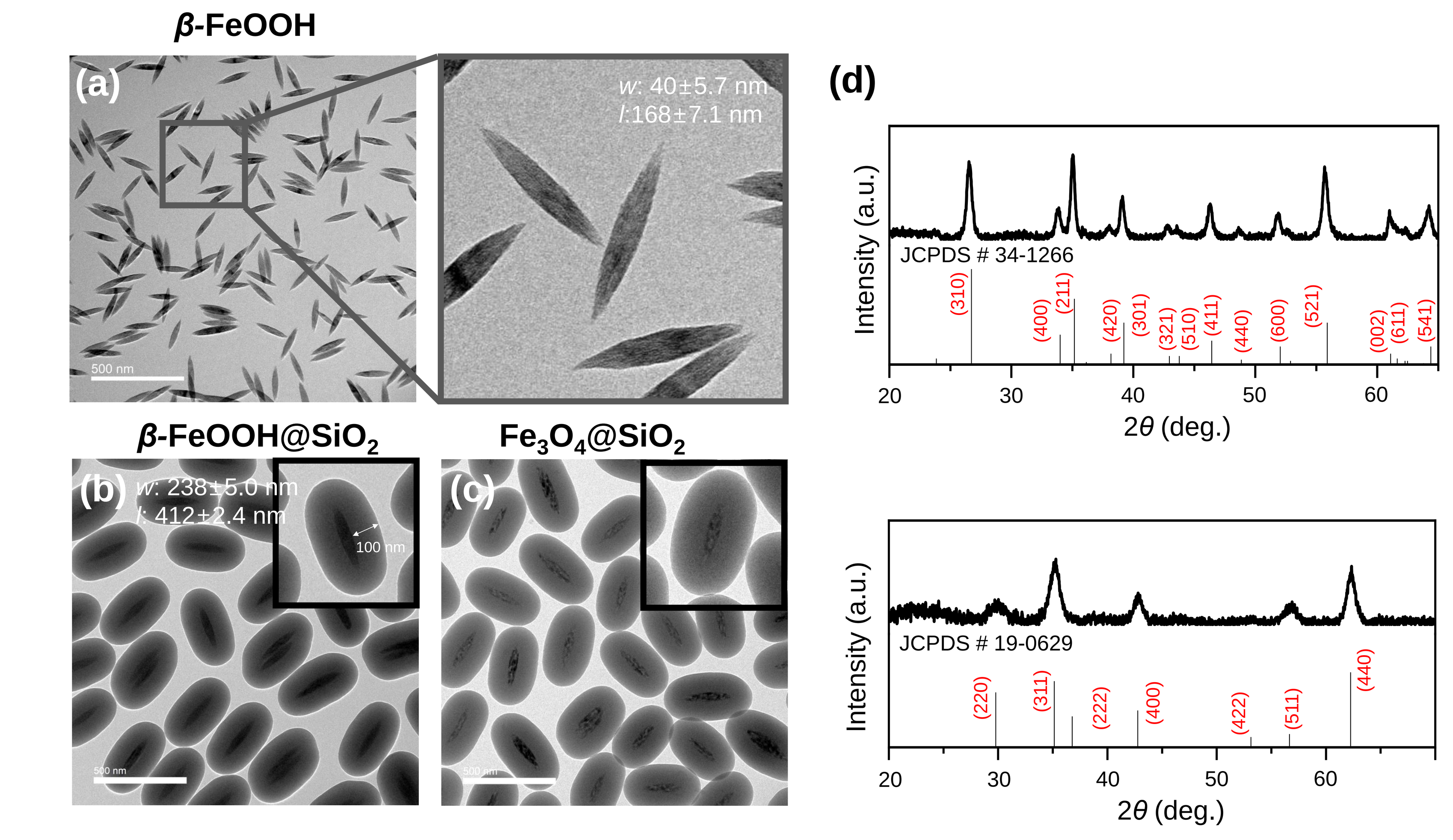
Experimental Methods

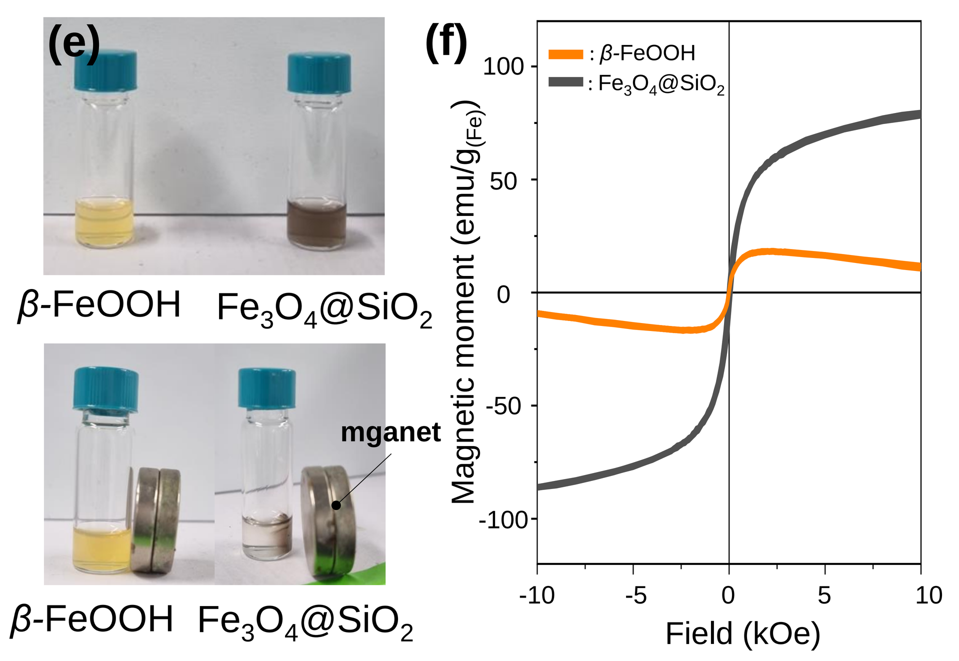
Synthesis scheme



Results

I. Synthesis of magnetic ellipsoidal nanoparticles





(g)

	β-FeOOH	$Fe_3O_4@SiO_2$
Fe (ppm)	26.91	1.287
metal %	51.16	2.74

	β-FeOOH	$Fe_3O_4@SiO_2$
M_s (emu/g $_{Fe}$)	7	81
H_c (Oe)	0	50

Figure 1. TEM images of **(a)** β-FeOOH nanorods, **(b)** β-FeOOH nanorods after silica coating, **(c)** $Fe_3O_4@SiO_2$, **(d)** Crystal structure analysis of β-FeOOH and Fe_3O_4 **(e)** Comparison of β-FeOOH and Fe_3O_4 nanorods magnetism by external magnet **(f)** Magnetic properties analysis of β-FeOOH and Fe_3O_4 **(g)** ICP

II. Alignment of the anisotropic nanoellipsoids depending on the field direction

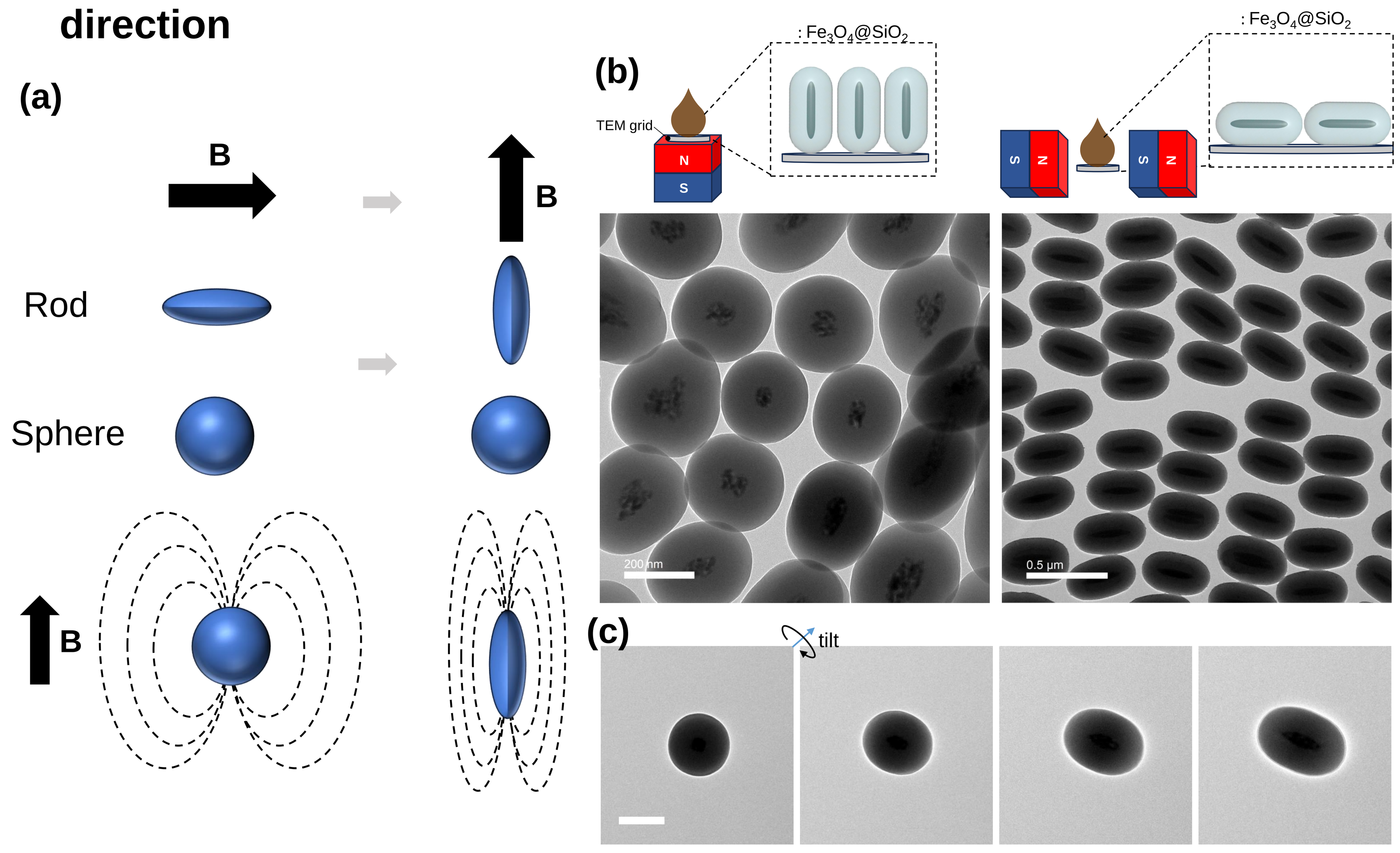
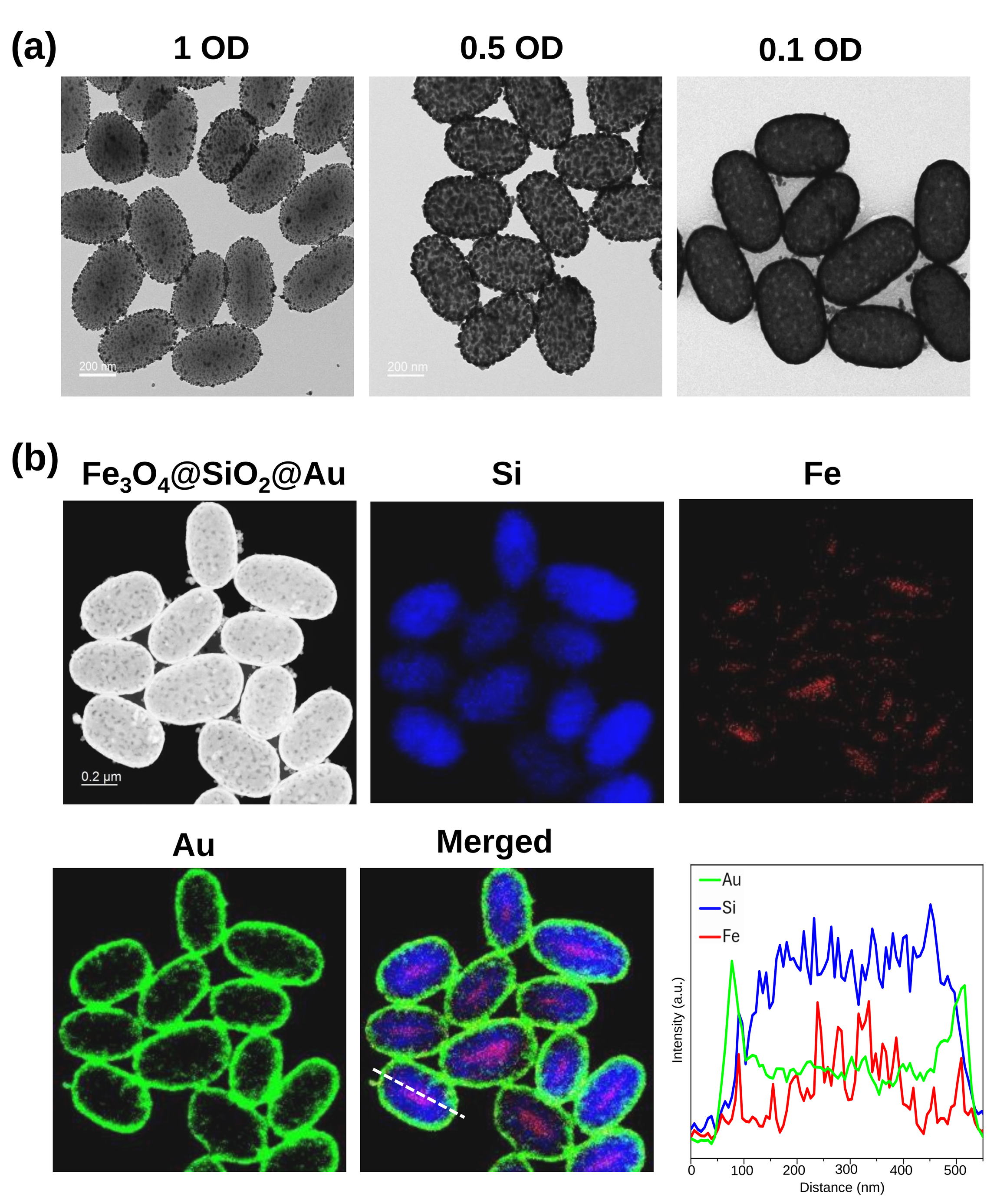
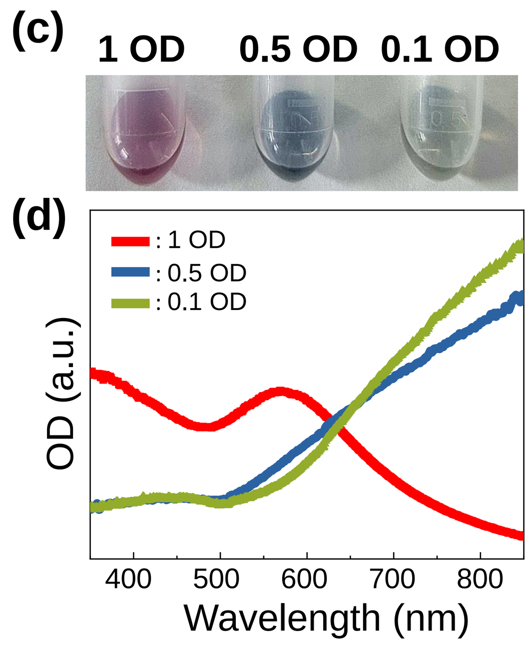


Figure 2. (a) schematic illustration of magnetic particles rotation **(b)** schematic illustration and TEM images of alignment of $Fe_3O_4@SiO_2$ by external magnetic field

III. Magnetoplasmonic nanoparticles with anisotropic shape





IV. Future study

magnetically controlled angle-dependent plasmonic property

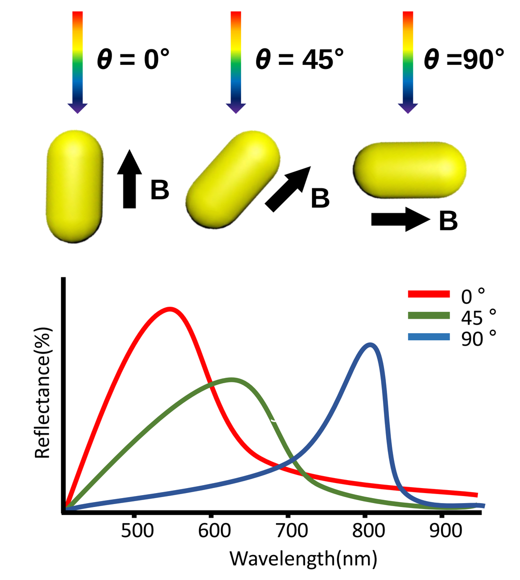


Figure 3. TEM images of **(a)** $Fe_3O_4@SiO_2@Au$ **(b)** EDS elemental analysis images of $Fe_3O_4@SiO_2@Au$ **(c)** plasmonic color variation of $Fe_3O_4@SiO_2@Au$ **(d)** UV-Vis Spectra of $Fe_3O_4@SiO_2@Au$

Figure 4. Future study: Reflection spectra of photonic structures under magnetic fields with varying directions with respect to the direction of light

Conclusion & Further Study

In this study, we successfully synthesized $Fe_3O_4@Au$ core-shell nanorods starting from β-FeOOH nanorods, which were first coated with silica and subsequently reduced to Fe_3O_4. After the reduction, a uniform Au coating was applied, resulting in $Fe_3O_4@Au$ nanorods with both magnetic and plasmonic properties. The magnetic properties of Fe_3O_4 nanorods were compared to those of the original β-FeOOH nanorods, showing significant enhancements in magnetic responsiveness. This magnetic property was further exploited by aligning the $Fe_3O_4@Au$ nanorods using an external magnetic field, which highlighted the anisotropic characteristics of the nanorods.

For future studies, it would be valuable to explore the dynamic plasmonic tuning capabilities of the $Fe_3O_4@Au$ nanorods under varying magnetic field strengths and directions, as demonstrated in related work on magnetic/plasmonic nanocomposites. Additionally, investigating the use of these nanorods in magnetic-field-direction sensing could open new avenues for applying these materials in advanced technologies. Integrating these nanocomposites into polymer matrices or other substrates could also lead to the development of new functional devices with real-time tunable optical properties.

Reference

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