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Kinetic Control of Iron Oxide Nanostructure and Its Impact on Magnetic Heating Performance

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Magnetic iron oxide nanoparticles are promising components of multifunctional nanomedicines designed for targeted drug delivery and remote activation under alternating magnetic fields. In particular, their ability to generate heat or mechanical effects under magnetic excitation makes them attractive for overcoming biological barriers such as dense extracellular matrices in solid tumors. These properties are strongly dependent on nanoparticle morphology, which governs magnetic interactions and energy dissipation mechanisms.
Considering all of the above, a polyol-based synthesis of iron oxide nanostructures was investigated with the objective of obtaining anisotropic architectures known for their high magnetic heating efficiency. The study revealed a pronounced sensitivity of the reaction pathway to thermal and gas-phase conditions, enabling morphology control through kinetic parameters without altering precursor composition. By tuning the heating profile and reaction environment, a transition from anisotropic nanowires (Fig. 1 (a)) to nanorods and nanoflowers (Fig. 1 (b)) was achieved. Transmission electron microscopy confirmed this morphology evolution, while AC magnetometry demonstrated a strong dependence of magnetic heating performance on structure. Nanoflowers exhibited specific absorption rate (SAR) values up to 220 $W \cdot g^{-1}$ at 280 kHz and 24.0 kA/m (Fig. 1 (d)), whereas high-aspect ratio anisotropic structures showed significantly reduced SAR at a maximum of 22 $W \cdot g^{-1}$ (Fig. 1 (c)). These results highlight the importance of kinetic control in tailoring iron oxide nanostructures for magnetic field-responsive applications. Such control over morphology and magnetic response is a key step toward the rational design of nanocomposite systems for remotely triggered drug delivery in challenging pathological environments.

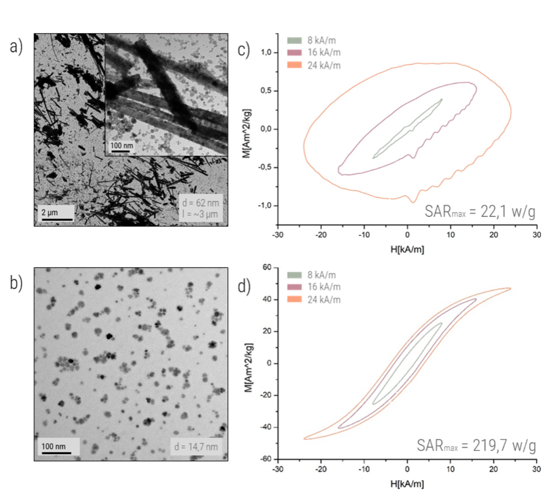

Figure 1: TEM images of: a) iron oxide nanowires, b) iron oxide nanoflowers; magnetometry measurements of: c) iron oxide nanowires d) iron oxide nanoflowers.

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