# Structural and Magnetic Divergence in Ferrite-Silica Nanocomposites: A Comparative Study of Core-Shell and Matrix-Embedded Architectures

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Magnetic spinel ferrite nanoparticles (MSFNPs) of formula $MFe_2O_4$ ($M = Ni, Co, Zn$) are promising for magnetic hyperthermia in cancer treatment [1]. We compare two synthesis architectures, where MSFNPs are embedded in silica to increase their biocompatibility and chemical stability. The core-shell structures were obtained via microemulsion [2], and the matrix-embedded nanoparticles were synthesized by a wet-chemical route [3]. We investigate how these configurations influence the structural and magnetic evolution during annealing at different temperatures ($T_A$).

Structural characterization via diffraction and microscopic methods was complemented by synchrotron X-ray absorption to resolve chemical gradients at the ferrite-silica interface. Results show that $T_A$ drives the transition from disordered metal-silicates to crystalline ferrites. However, the magnetic dynamics diverge; AC/DC magnetometry reveals that matrix-embedded samples exhibit more pronounced cluster-spin-glass behavior for $T_A \leq 870°\mathrm{C}$ due to enhanced interfacial frustration.

$^{57}Fe$ Mössbauer spectrometry at 77 K shows a distribution of spin expectation values $\langle S_z \rangle$, reflecting synthesis-dependent cation distributions and spin-canting. While the core-shell architecture better preserves magnetic order, the matrix-embedded route allows for finer tuning of collective relaxation by annealing. These findings enable deterministic design of nanocomposites for optimized hyperthermia efficiency.

## References:

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