118

Magneto-Plasmonic Nano-Objects with Tunable Domain Architectures –Experiments and Simulations

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The integration of magnetic and plasmonic functionalities into single hybrid nanostructures enables multifunctional nanoscale behavior. We report a modular synthesis of anisotropic Pt–$[CoFe_2O_4]_n$ (CF-��) nanostructures with tunable domain number and geometry. By controlling precursor composition, surfactant concentration, and seed-to-precursor ratio, we achieve precise spatial arrangement of $CoFe_2O_4$ cuboids on Pt nanocubes (Figure 1), enabling direct correlation between architecture and magnetic properties—such as saturation magnetization, remanence, and interdomain coupling. A heteroepitaxial interface with minimal lattice mismatch ensures consistent, anisotropic growth. These hybrid nanostructures exhibit programmable magnetic responses governed by geometric design.
For example, in trigonal-pyramidal CF-3 particles with C_3 symmetry, the magnetization axes of individual $CoFe_2O_4$ cuboids converge to a 54.74° (magic angle) misalignment between the preferred magnetic and geometrix axis. Micromagnetic simulations (MuMax3) reveal 38 individual magnetic configurations. In the ground state (minimizing net magnetization), two cuboids are magnetized in antiparallel arrangement, with the third pointing in orthogonal. Under external fields (>30 mT), all domains align parallel, maximizing magnetization. At intermediate fields (~10 mT), a metastable state with 2.25 effective domains emerges. The angle between geometric and net magnetization remains the magic angle (54.74°), indicating robust symmetry-driven behavior. The simulation results are compared with experimental observations.

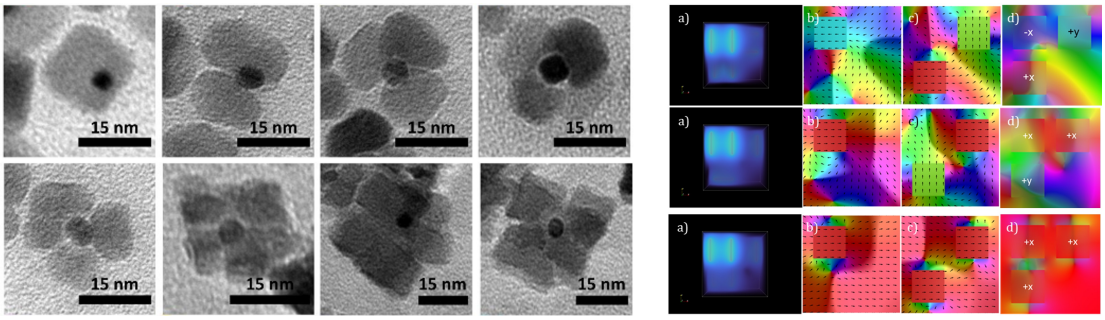

Figure 3: (left) TEM images of CF-z nanoparticles with z = 1 to z = 8 CFO moieties; (right) MuMax3 simulation results of the (1st column) demagnetization and (2nd-4th column) magnetization fields passing through (2nd) the front cube, (3rd) the back cubes, and (last) the full volume of a single CF-3 particle in the lowest energy state; (upper) B = 0; (middle) B = 10 mT; (lower) B = 75 mT.

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