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# Engineering Dynamic Magnetic Response of Multicore Nanoparticles: Shape-Induced Enhancement of Low-Frequency Losses

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Multicore magnetic nanoparticles –where multiple single-domain cores are embedded in a non-magnetic matrix –offer a versatile platform for tuning magnetic response through internal architecture. While spherical multicores have been extensively studied, the role of overall particle shape, particularly elongation, on dynamic susceptibility remains largely unexplored. Here we investigate ellipsoidal multicore particles with aspect ratios ranging from sphere to highly elongated shapes, focusing on how shape modulates relaxation spectra and dissipative properties.

Using Brownian dynamics simulations with explicit internal and rotational relaxation, combined with a spectral reconstruction method based on non-negative least squares fitting of autocorrelation functions, we resolve multiple relaxation modes across a wide frequency range. A modified mean-field theory accounting for demagnetisation effects is developed to interpret static susceptibility.

Our results reveal a qualitative transition with increasing dipolar coupling strength. For weak interactions, elongation merely shifts the Brownian peak to lower frequencies without altering the spectral shape. However, for stronger inter-core dipolar coupling, elongation profoundly enhances internal magnetic correlations. Analysis of angular distributions shows that core magnetic moments increasingly align along the long ellipsoid axis as elongation grows. This alignment, promoted by reduced demagnetisation along the major axis, leads to spectral broadening, emergence of multiple relaxation modes, and a marked redistribution of dissipation towards lower frequencies –with the dominant loss peak shifting by up to two orders of magnitude compared to spheres. The most striking consequence is the reshaping of specific loss power. For strongly elongated particles with moderate anisotropy and strong dipolar interactions, low-frequency losses improve by more than an order of magnitude relative to spherical multicores, while high-frequency performance remains unaffected. These findings are particularly relevant for magnetic hyperthermia, where clinical constraints limit accessible frequencies. Ellipsoidal multicores enable concentration of dissipative power within this window, offering a design pathway for more effective cancer thermotherapy.

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