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Field-Controlled Self-Diffusion in Ferrogranular Mixtures

Author: Oksana Bilous[1]

Co-authors: Kirill A. Okrugin[1]; Ali Lakkis[2]; Matthias Biersack [2]; Reinhard Richter[2]; Sofia Kantorovich[1]

[1] *University of Vienna, Faculty of Physics, Kolingasse 14-16, Vienna, Austria*

[1] *University of Bayreuth, Experimental Physics, Universitätsstrasse 30, Bayreuth, Germany*

Ferrogranular mixtures exhibit a rich interplay between structure and transport that can be tuned by external magnetic fields. Combining extensive Langevin dynamics simulations of a quasi-two-dimensional Stockmayer fluid mixed with repulsive non-polar particles [3] and corresponding mm-scale experiments[1], we show that an out-of-plane magnetic induction and particle area fraction jointly control hierarchical relaxation, dipolar–susceptibility coupling, and a two-length-scale anomaly [2]. The field aligns dipoles perpendicular to the layer, inducing strong in-plane repulsion that dismantles large aggregates, while higher area fractions stabilise compact clusters through enhanced crowding. Single magnetic particles and glass beads diffuse nearly normally across all concentrations, yet cluster-bound particles display persistent subdiffusion accompanied by pronounced non-Gaussian statistics. Most strikingly, at high induction and area fraction the non-magnetic species itself acquires strongly non-Gaussian dynamics –a clear signature of field-induced dynamical freezing, or "magnetic cooling". The quantitative agreement between simulation and experiment [1,3] provides a predictive framework for designing responsive ferrogranular materials with tailored transport properties.

Keywords: dipolar–susceptibility coupling, two-length-scale anomaly, Langevin dynamics.

References

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