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Ferronematics Phases: Exploring the Effects of Functionalized Hematite Anisotropic Nanoparticles in Liquid Crystal Order

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Liquid crystals (LCs) are materials that combine fluidity of liquids and anisotropic properties typical of solids. In particular, thermotropic LCs are commonly composed of anisotropic molecules called mesogens that exhibit long-range orientational order (nematic phase) depending on the temperature. This orientation gives rise to anisotropic physical properties (e.g., electrical conductivity or magnetic susceptibility). However, to observe magnetic effects in LCs, high intensity magnetic fields have to be applied because of their small anisotropic diamagnetic susceptibility. To enhance this effect, low concentrations of magnetic particles (MPs) can be suspended in the LC, creating a ferronematic phase. Particles of different magnetic behavior and morphologies have been used [1,2].
Here, we investigate hematite nanospindles (HNS), which exhibit weak ferromagnetism at ambient temperatures originated from a canted antiferromagnetic spin structure in their rhombohedral lattice. When cooled down below the Morin temperature (T_{Morin}), a spin reorientation to antiferromagnetic occurs. This transition depends on different factors such as crystalline properties, defects or dopants. It has been previously reported that T_{Morin} decreases with decreasing particle size, disappearing for particles smaller than 20 nm. However, we observed that in HNS the Morin transition can be suppressed in high aspect ratio spindles despite their high volume. High resolution transmission electron microscopy, X-ray diffractometry, (thermo)magnetometry, and Mössbauer spectroscopy provided closer insight into this unexpected behavior of the Morin transition [3].
To ensure compatibility and dispersion, HNS are functionalized with mesogenic ligands, enabling strong anchoring within the LC matrix. In our case, high aspect ratio HNS with a mesogen-functionalized polymer shell are introduced into a LC host. In the resulting ferronematic system, the functionalized HNS induce concentration-dependent changes in phase behavior, order parameter, and field induced transitions. These effects are attributed to magnetomechanical coupling in the ferromagnetic phase, where the magnetic moment of the functionalized HNS prefers to align with the nematic director 4.

1 K. Koch et al., Phys. Chem. Chem. Phys. 2020, 22, 2087-2097
[2] K. Koch et al., Phys. Chem. Chem. Phys. 2021, 23, 24557-24569
[3] J. Kopp et al., J. Phys. Chem. C 2025, 129 (48), 21508-21519
4 K. Koch et al., arXiv:2510.13513

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