Controlling biaxiality in liquid crystal phases of colloidal goethite

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Board-like colloidal particles of the mineral goethite (α-FeOOH) constitute one of the few known experimental realizations [1] of biaxial nematic liquid crystals. Above a volume fraction of around 0.1, some goethite particles – characterized by their length $L >$ width $W >$ thickness $T$ – not only spontaneously orient their $L$-axis but their $W$- and $T$-axes as well, giving biaxial phases for specific particle dimensions close to the condition $(L/W) \approx (W/T)$. Applying a magnetic field along the main director of the biaxial nematic phase leads to a clear decrease in biaxiality with increasing magnetic field strength [2] as observed by synchrotron small-angle x-ray scattering (SAXS). Above a certain magnetic field strength (depending on the volume fraction) the biaxiality is completely suppressed and the biaxial nematic phase transforms into an ordinary uniaxial nematic phase (figure). Interacting with a permanent magnetic moment along the $L$-axis the magnetic field substantially narrows the orientation distribution and releases more space for the particles to rotate freely along this axis, increasing the orientational entropy. This is confirmed by theory [2] and it implies that for more plate-like particles $(L/W < W/T)$, which initially would only display nematic ordering of the $T$-axis, the rare biaxial phase could be induced by applying a magnetic field with a carefully chosen field strength – an easily tuned parameter.

(top) SAXS patterns of a nematic goethite dispersion with their main ($L$-)axis oriented along the beam: an increasing magnetic field $B$ along the beam gives a complete transformation from a biaxial to a uniaxial nematic phase; (bottom) schematic particle configurations and typical correlation distances (arrows)

We will also discuss the addition of small silica spheres to goethite dispersions, where theory predicts that the addition of depletants could widen the range of biaxiality. The mechanism behind this widening is an increased tendency of particles to align their $T$-axis because of the larger overlap volume of depletion layers in this configuration.

References:

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