Nanoparticle doping in nematic liquid crystals

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Doping nematic liquid crystals with nanometer-sized particles is a very topical subject in liquid crystal research and of increasing interest. During the last decade it has been shown that adding small amounts of functionalized nanoparticles to a nematic liquid crystal can change the alignment, induce topological defects or significantly alter the electro-optic response of the host. Our recent work aims to better understand the origins of these effects in nematic nanocomposites. A distinction between different degrees of surface coverage of nanoparticles at the confining substrates is introduced. This allows sorting many reported yet sometimes unexplained experimental observations into bulk or surface dominated effects and facilitates the understanding of interactions between host molecules and dopants.

The frequently observed nanoparticle-induced homeotropic alignment is caused by particles residing at the interfaces and superimposing the effect of the initial alignment layers, as revealed by confocal fluorescence microscopy on dispersions containing fluorescent CdSe quantum dots. Appearing birefringent stripe patterns are relics from the isotropic / nematic phase transition, the defect lines are either pinned to the substrate interfaces or to macroscopic agglomerates of nanoparticles as a source of stabilization. By combining polarizing optical microscopy and high-resolution fluorescence confocal polarizing microscopy, these birefringent stripes were identified to be twist declination lines.[1]

The reverse switching of dispersions containing alkylthiol-capped gold nanoparticles requires also homeotropic alignment caused by a strong surface coverage of particles. Additionally, nanoparticles in the bulk increase the conductivity of the sample and facilitate the formation of electrodynamic instabilities. Within a certain frequency range, external electric fields cause birefringent convection rolls and therefore induce a switching from an initial dark state to a bright state between crossed polarizers[2]. This reverse switching phenomenon represents a new example of instabilities in (+,-) nematic liquid crystals.

By employing numerical fitting routines on experimental results for dispersions containing functionalized gold nanoparticles it is shown that particles residing at the interfaces affect the surface tilt angle as well as the polar anchoring energy. We found that an intermediate degree of surface coverage does not necessarily induce homeotropic alignment, but still influences the boundary conditions of the nematic host molecules and therefore alters the electro-optical response of the dispersion[3].

An example for negligible surface coverage is given by dispersions of gold nanoparticles featuring a stabilized ligand shell via silanization conjugation[4]. These particles show a superior miscibility and stability in the nematic host and no effect of particles on the alignment layers is found. Dispersions feature a decrease of threshold \( V_{th} \) and an increase of dielectric anisotropy \( \Delta \varepsilon \) compared to the undoped nematic host. Therefore they give a good example for improved electro-optical properties due to nanoparticle doping.

References:

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