Frederiks transition in ferroic liquid crystal suspension

V.Yu. Reshetnyak, I.P. Pinkevych, S. Shelestiuk, V. Zadorozhnii

National Taras Shevchenko University of Kyiv, Volodymyrska Str., 64, Kyiv, 01601, Ukraine

T. J. Sluckin

University of Southampton Highfield, Southampton SO17 1BJ, United Kingdom

Liquid crystal colloids display a richer set of properties than conventional colloidal systems [1]. Of these, ferroelectric and ferromagnetic liquid crystal colloids have been the subject of considerable recent work [2-9]. The colloidal particles are so small that the suspensions seem optically identical to pure liquid crystal, but nevertheless the electric and magnetic field response is strongly enhanced, even at low colloidal concentrations.
Using continuum and statistical mechanical theories, we study the switching properties in a nematic liquid crystal cell doped with ferromagnetic particles subject to homeotropic boundary conditions at the cell and particle walls [8]. An external magnetic field normal to the cell plane is also imposed. At low fields we find thresholdless switching of the nematic director, consistent with experimental data. At higher fields, there are three regimes, depending on the strength of the anchoring interaction between the director and the ferroparticle orientation. For low anchoring strengths, there is an inverse Frederiks effect, and the nematic reorientation reduces and then disappears continuously at a critical magnetic field. At intermediate fields, the degree of reorientation reduces at high fields but remains finite. For high fields, however, the director switching saturates.
We also construct a theoretical model of the dielectric properties of a ferroelectric LC nanosuspension, using a generalized Maxwell-Garnett picture. The theory supposes that the suspension may as a first approximation be considered as a complex homogeneous dielectric ceramic, thus neglecting positional correlations of the colloidal particles. The suspension then consists of an anisotropic matrix with a very low concentration (<1% by volume) of impurity particles. The impurity particles possess both shape and dielectric anisotropy, as well as a permanent electric polarization and strong liquid-crystal director anchoring on the particle surface. We calculate the effect of doping a liquid crystal with ferroelectric impurities on the Frederiks transition. The theory takes account of inclusion shape, dielectric susceptibility, and local field effects. We neglect the possibility of dielectric particle chaining, which appears experimentally not to occur in general. Our calculations [9] suggest, in qualitative agreement with experiment, that doping a nematic liquid crystal with ferroelectric particles, even at very low particle concentration, can in some cases significantly shift the electric Frederiks threshold field.
Acknowledgement: *This work was partly supported by EOARD Grant 078001.*

References

[1] H. Stark, Phys. Rep. **351**, 387,(2001).
[2] Yu. Reznikov *et al.*, Appl. Phys. Lett. **82**, 1917 (2003).
[3] F. Li et al., Phys. Rev. Lett, **97**, 147801 (2006).
[4] G. Cook *et al.*, Optics Express **16**, 4015 (2008).
[5] L.M. Lopatina and J.V. Selinger, Phys. Rev. Lett. **102**, 197802 (2009).
[6] Martin Čopič *et al.*, Phys. Rev. E **76**, 011702 (2007).
[7] A. Mikulko *et al.*, EPL, 8**7**, 27009 (2009).
[8] V.I. Zadorozhnii *et al.*, SIAM J.Appl.Math, **68**, 1688 (2008).
[9] S. Shelestiuk *et al.*, Phys. Rev. E **83**, 041705 (2011).