Electric field induced undulations in cholesteric elastomers

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We investigate the macroscopic properties of cholesteric side-chain liquid single crystal elastomers (SCLSCEs) when exposed to a static homogeneous external electric field. The external electric field direction is oriented parallel to the axis of the cholesteric helix. As a major result, we obtain, besides a Fredericks-like instability, the possibility of an undulatory instability at a certain electric threshold field amplitude.

Cholesteric side-chain liquid crystalline elastomers are synthesized by chemically crosslinking polymer chains to which mesogenic units are attached as side groups [1]. Through specific routes of synthesis monodomains of the cholesteric director orientation can be obtained. This is possible for example by anisotropic deswelling of the materials during the crosslinking process or by prior surface alignment [2,3]. The resulting monodomain materials are called cholesteric SCLSCEs.

We study a geometry that corresponds to the one used to observe the Fredericks transition in low molecular weight (LMW) nematic liquid crystals. Consequently, the cholesteric SCLSCE is confined between a top and a bottom plate, where the cholesteric helical axis is oriented perpendicularly to the plate surfaces. The director is assumed to be strongly anchored at the plate surfaces, and the electric field is oriented parallel to the helical axis (splay geometry). We consider a laterally infinitely extended system and assume that the cholesteric SCLSCE behaves like a perfect electric insulator.

To investigate this geometry, we use a macroscopic continuum model proposed by de Gennes. In this model, relative rotations between the director orientation and the network of crosslinked polymer backbones play a central role [4]. Similar to the LMW Fredericks transition, we find the existence of a critical electric threshold field, above which the director starts to reorient. The anchoring of the director at the sample boundaries and the helical twisting of the director orientation oppose the director reorientation. In the case of cholesteric SCLSCEs, however, also the anchoring of the director within the crosslinked polymer network significantly adds to this effect.

One possible instability we have found is of the Fredericks-type [5]. This means that the reorientation of the director field occurs spatially homogeneously in the directions perpendicular to the cholesteric helical

axis. Since the director orientation is coupled to the elastic deformational degrees of freedom via relative rotations, this effect is accompanied by strain deformations of the material. The latter also occur spatially homogeneously in the directions perpendicular to the cholesteric helical axis.

Besides, however, we have identified another, qualitatively different type of instability [5]. This instability is characterized by spatial undulations of the director orientation and the associated strain deformations. The undulations occur in a direction perpendicular to the cholesteric helical axis.

The appearance of an undulatory instability at threshold has already been observed for other liquid crystalline polymeric systems [6]. In the latter case, however, special values of the Frank constants were found to favor the undulations. This is qualitatively different from our case, where relative rotations between the director orientation and the crosslinked polymer network underlie the emergence of the undulations at onset.

Finally, we show that the undulatory instability is preferred over the Fredericks-type instability at the threshold field amplitude only for a limited range of material parameters. As we will explain, this is related to another result of our analysis. Namely, for special values of the material parameters we find from the linearized model that a reorientation of the director may occur without involving strain deformations of the elastomers.

Related results have also been obtained from the analysis of the macroscopic behavior of nematic SCLSCEs [7,8].

References:

(1) H. Finkelmann, H.-J. Kock, G. Rehage *Makromol. Chem., Rapid Commun.* **1981**, *2*, 317.
(2) S. T. Kim, H. Finkelmann *Macromol. Rapid Commun.* **2001**, *22*, 429.
(3) A. Komp, J. Rühe, H. Finkelmann *Macromol. Rapid Commun.* **2005**, *26*, 813.
(4) P. G. de Gennes, in *Liquid Crystals of One- and Two-Dimensional Order*, edited by W. Helfrich, G. Heppke (Berlin, Springer, 1980) pp. 231 ff.
(5) A. M. Menzel, H. R. Brand *Phys. Rev. E* **2007**, *75*, 011707.
(6) F. Lonberg, R. B. Meyer *Phys. Rev. Lett.* **1985**, *55*, 718.
(7) O. Müller, H. R. Brand *Eur. Phys. J. E* **2005**, *17*, 53.
(8) A. M. Menzel, H. R. Brand *Eur. Phys. J. E* **2008**, *26*, 235.