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Note on « new electromechanical effect in chiral smectic C* liquid crystals »

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Résumé. — Nous montrons que les résultats récents concernant le couplage électromécanique des C* peuvent s'expliquer par les équations dynamiques que nous avons écrites. Nous montrons que le couplage observé est un couplage dynamique réversible entre les variations de polarisation dans les couches et les gradients de vitesse. Ce type de couplage réversible caractérise les systèmes à symétrie pseudo-vectorielle (l'hélice). Il disparaît en phase C non chirale.

Abstract. — We show how the recent experimental results concerning an electromechanical coupling in smectic C* can be obtained from the macroscopic dynamic equations derived by the authors. We point out that the coupling observed is a reversible dynamic cross coupling between the change in the polarization inside the layers and velocity gradients. This type of reversible cross coupling is unique to systems which possess a pseudoscalar quantity (e.g. a helix) and does not exist in nonchiral smectic C.

In a recent Letter [1] the observation of a velocity change in the plane of the layers of a smectic C* sample due to an alternating electric field (also applied in the layer plane) was reported. It was pointed out in reference [1] that the effect observed is not contained in the continuum description of the C* phase given by the present authors [2] and it was suggested that the effect is a dissipative one.

The purpose of the present note is twofold. First of all we show that the experimental results can be explained by the macroscopic dynamics given in reference [2]. Secondly we point out that the effect observed is a *reversible* dynamic cross coupling between the velocity gradients and the external field.

To show how the observations can be described in the framework of the macroscopic dynamics for smectic C*, we use the same notation as in reference [2]. As has been shown in [2] the changes

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in the polarization $\delta\mathbf{P}$ (or the electric field associated with it) are not independent from the displacement of the helix U_c but related to U_c via equation (3.9) of reference [2] — with z parallel to the layer normal

$$(\hat{\mathbf{P}}_0 \times \delta\mathbf{P})_z = q_0 U_z^c \quad (1)$$

for in-plane changes of $\mathbf{P}_0$. Differentiating equation (1) w.r.t. time we have

$$(\hat{\mathbf{P}}_0 \times \delta\dot{\mathbf{P}})_z = q_0 \dot{U}_z^c \quad (2)$$

Now we can make use of the dynamic equation for U_c (Eq. (2.6) of Ref. [2]) :

$$\dot{U}_i^c + X_i^c = 0 \quad (3)$$

with X_i^c the quasicurrent associated with the helix displacement U_i^c .

By inspection of the experimental results reported in reference [1] it follows immediately that we are seeking a dynamic cross coupling between the electric field and velocity gradients since there is no static effect. Combining equations (2.18) and (3.13) of [2] we have for the reversible part of the quasicurrent

$$X_i^{cR} = -\rho_i \rho_j V_j + V_j \nabla_j U_i^c - q_0 \tau_{ijk} \nabla_j V_k \quad (4)$$

with

$$\tau_{ijk} = \tau_1 \rho_i \rho_j \rho_k + \tau_2 \varepsilon_{ijk} + \tau_3 \rho_i \delta_{jk}^r + \tau_4 \rho_j \delta_{ik}^r + \tau_5 \rho_k \delta_{ij}^r. \quad (5)$$

Inspecting the combination of (2.14) and (3.11) of [2] we see that the dissipative part of the quasicurrent X_i^c does not couple to velocity gradients. This follows also immediately from time reversal symmetry.

If we assume that the changes of $\mathbf{P}$ and thus $\mathbf{E}$ are restricted to the plane of the layers we read off from equation (5) that the contributions proportional to τ_4 and τ_5 have to vanish in the geometry studied [1] since both, $\mathbf{P}_0$ and $\delta\mathbf{P}$ are in the plane of the layers.

From the experimental results we also infer that there is no velocity component parallel to the layer normal; therefore the term proportional to τ_1 in equation (5) also does not contribute.

Combining equations (2)-(5), taking into account the analysis just described and linearizing equation (4) we have

$$(\hat{\mathbf{P}}_0 \times \delta\dot{\mathbf{P}})_z = q_0^2 (\tau_2 \varepsilon_{zjk} \nabla_j V_k + \tau_3 \delta_{jk}^r \nabla_j V_k). \quad (6)$$

From the description of the experimental results it is not completely clear whether τ_2 alone or a linear combination of τ_2 and τ_3 has been measured since the authors [1] only state, that the bottom plate is fixed whereas the top plate is allowed to move in the direction of the spring. From the fact that the bottom plate is fixed we conclude that τ_2 definitely contributes since a shear is involved.

Equation (6) does not show explicitly the dependence of the new effect on q_0^2 , since τ_2 and τ_3 are still (unknown) functions of q_0^2 in the description of [2].

In any case we read off immediately from (6) that $\omega \delta P$ is directly proportional to the velocity gradient and this result coincides with the experimental observations.

Thus we find that the effect observed is due to a *reversible, dynamic* cross coupling between the applied electric a.c. field and velocity gradients. That for higher frequencies a different behaviour is found experimentally could be e.g. due to retardation effects.

It seems worth noticing that the new electromechanical effect cannot be explained by the dissipative effects (including couplings to the electric field) already described in reference [2].

In conclusion we have shown how the recent experimental observations of an electromechanic coupling in smectic C* can be described in the framework of a macroscopic dynamics [2] and we have pointed out that this is a reversible dynamic cross coupling and not a dissipative one as previously suggested [1].

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