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Evaluation of Surface and Flexoelectric Polarizations in Nematic Liquid Crystal using Short Pulse Laser Irradiation

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Nematic liquid crystals are uniaxial media with a preferable direction of molecular axes $\boldsymbol{n}$ called the director. The states of the director $\boldsymbol{n}$ and $-\boldsymbol{n}$ are indistinguishable (no polar axis) and the nematic phase does not show spontaneous polarization. At the interface with a glass or free surface exposed to air, the mirror symmetry is broken and the surface polarization $\boldsymbol{m}_{surf}$ arises. A macroscopic polarization may also be induced in the bulk of a nematic by a bend or splay distortion of the director field. A commonly used term for that polarization is flexoelectric one and its general form satisfying symmetry requirements

$$\boldsymbol{P}_f = e_1\boldsymbol{n}(\nabla\cdot\boldsymbol{n}) - e_3(\boldsymbol{n}\times(\nabla\times\boldsymbol{n}))$$

consists of two terms with correspondent flexoelectric coefficients e_1 and e_3 related to the splay and bend distortions. From the microscopic point of view, dense packing of dipolar banana- or pear shape molecules in a bent or splayed structure inevitably creates a dipole moment in a unit space.

Despite the fact, that the concept of the surface and flexoelectric polarization is discussed for many years, the quantitative data are very scarce. Only rough estimations of $\boldsymbol{m}_{surf}$ at room temperature have been done from observations of surface instabilities. The situation with the sign of $\boldsymbol{m}_{surf}$ is also controversial. The temperature dependence of the surface polarization has never been measured, therefore it is difficult to estimate the contribution of the nematic order into the magnitude of the polarization.

In this study, for the first time, the temperature dependence of the "nematic part" of the surface polarization[1] has been measured for both the planar and homeotropic orientation of a nematic liquid crystal at a solid substrate. A conventional liquid crystal 5CB, pure and doped with

a bis-azo-dye, was used in cells with controlled asymmetry for light absorption. The measurements have been made by a pyroelectric technique using a short pulses of a YAG laser (at both the fundamental and second harmonic) to create a temperature increment. The latter, in turn, was measured independently by a novel time-resolved "optical thermometer" technique monitoring temperature dependent birefringence by a He-Ne laser beam. The surface polarization ($\boldsymbol{m}_{surf}$) was shown to have different signs for the two orientations: for the homeotropic orientation by a clean ITO surface $\boldsymbol{m}_{surf}$ is directed from 5CB to the substrate; for the planar orientation by a rubbed polyimide layer $\boldsymbol{m}_{surf}$ is directed from the substrate into the liquid crystal. The bis-azo-dye somewhat increases $\boldsymbol{m}_{surf}$ at the homeotropic interface and reduces it at the planar one. The temperature dependence of the surface polarization is rather steep just below the isotropic-nematic transition and becomes fairly flat with decreasing temperature. It seems to be not correlated with the order parameter behaviour[2] and reminds more the jump-like behavior of the second order nonlinear susceptibility[3]. The $\boldsymbol{m}_{surf}$ magnitude at room temperature ranges from -4 to +2 pC/m.

The same technique has been used for the measurement of the flexoelectric polarization[4] in hybrid cells. The value of the sum of the flexoelectric coefficients (e_1+e_3) found for 5CB is negative and about -13pC/m at room temperature.

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