Finite Elements numerical analysis of the dynamic response of POLICRYPS gratings

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1. Background and proposed work

Recently an improved technique was introduced in order to realize permanent switchable liquid crystal (LC) volume gratings in polymer/LC composite mixtures. By ensuring that diffusion takes place faster than actual polymerization, researchers succeeded into fabricating grating structures in which well-defined polymer slices alternate with uniformly aligned slices of LC material. The new gratings, which are know as POLICRYPS (Polymer-Liquid-Crystal-Polymer-Slices) [1] or POLIPHEM (Polymer-Liquid-Crystal-Polymer-Holograms-Electrically-Manageable) [2] have the potential of very high diffraction efficiency with lower driving voltages compared to their H-PDLC counterparts [3]. Some initial works on electro-optical assessment of POLICRYPS gratings in the visible and infrared wavelengths have been reported [4][5] so far, but until now no robust model that accurately describes their switching mechanism has been presented.

In this communication, we present for the first time investigations into the switching dynamics of POLICRYPS-like geometries using numerical techniques based on finite elements analysis. We use software tools developed by the UCL modeling group (during European project MonLCD) [6] to build a 2D rectangular model of the LC slice sandwiched between two polymer slices. The liquid crystal 5CB and the polymer NOA61 (Norland) are considered in our calculations. Our model is extended to account for anchoring of the liquid crystal material at the interface with the vertical polymeric walls running normal to the grating vector. Both strong and weak vertical anchoring cases are considered. Starting from the Oseen-Frank expression of the elastic energy, the switching-on and switching-off times of the LC slices are calculated by numerically solving the corresponding energy dissipation equation.

2. Results

Our simulations clearly show that, for sufficiently thin liquid crystal slices, the effect of the boundary polymeric walls, on both the switching-on and the switching-off characteristics of the grating can be significant. The overall dynamic performance in this geometry is determined by the applied voltage, the thickness, the widths of the LC and the polymer slices, the elastic constants and the anchoring coefficient at the LC/polymer interface. Although tight confinement of a thin slab of LC material between polymer slices can slow down switching-on of the molecules, the elastic relaxation after removal of the field is much faster in the case of strong anchoring on the polymer walls. In this way, and unlike the typical behavior of Fréedericksz cells, switching-on and switching-off times can become similar for a given device. Switching-off time increases when a weak anchoring coefficient is assumed instead.

Furthermore, our simulations reveal that due to the particular confinement of the LC in between two vertical polymeric slices with a very different dielectric constant from that of the LC, an anomalous switching behavior can be predicted. Unlike conventional Fréedericksz cell, switching starts not from the mid-layer point of the cell but rather from two anti-symmetrical points close to the two glass boundaries.

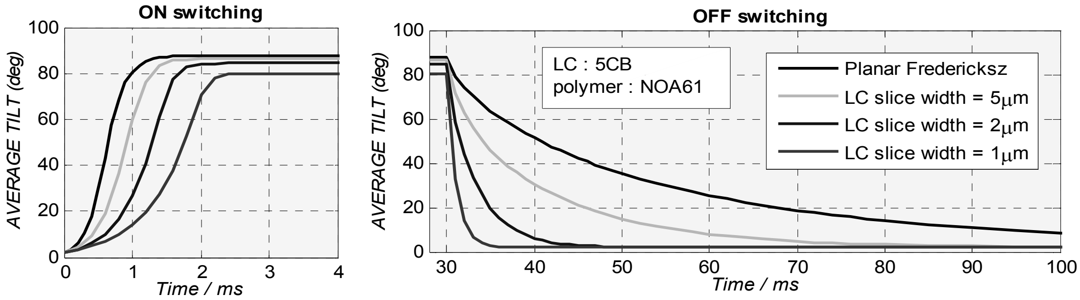

Fig. 1: Simulated effect of the vertical polymeric walls on the switching characteristics of a POLICRYPS device (Applied voltage=10volts, Thickness=5μm, periodicity=12μm). Relatively strong anchoring on the polymer/LC interface is assumed (Anchoring coefficient=50 Jm^{-2}). The black curve shows the response of a typical planar cell (i.e. without any polymeric walls)

3. Conclusions

We have used numerical methods to gain insight in the switching dynamics of POLICRYPS geometries. Our models set the framework for a detailed investigation of actual devices. By comparison with experimental results one can deduce important parameters such as anchoring coefficients on the LC/polymer interface, which in turn will be critical for further optimizing grating performance.

4. References

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