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A Variable Tilt Smectic A Electro-Optic Effect Giving Stored Colours

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A VARIABLE TILT SMECTIC A ELECTRO-OPTIC EFFECT GIVING STORED COLOURS

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Abstract A smectic A phase was aligned with a uniformly high tilt such that it appeared coloured between crossed polarisers. By applying an electric field the tilt angle of the structure increased progressively giving a Newton Spectrum series of colours. The colours remain on removal of the drive voltage.

In 1971 Tani[1] reported on an electrically induced scattering texture in the smectic A (S_A) phase of N-p-cyanobenzylidene-p-n-octyloxyaniline. In 1974-75, Hareng et al showed that the focal-conic[2] and planar[3] textures of the S_A phase of 4-cyano-4'-n-octylbiphenyl (8CB) could be re-oriented into a homeotropic texture using an electric field. Dazai[4] has recently described three electro-optic effects in S_A phases; two of the effects were exhibited by Schiff's bases of positive dielectric anisotropy. One of these effects was a planar-to-hometropic transition and the other was a scattering effect. The present letter describes a new electro-optic effect in the S_A phase of a material of positive dielectric anisotropy (8CB).

Initially the S_A phase is aligned in a thin cell such that the structure of the phase has a uniform tilt of 68° from the glass surface (22° from the homeotropic position). When viewed in transmission between crossed polarisers, the cell appears coloured and is at maximum brightness when the direction of tilt is at 45° to each polarisation direction. On the application of an a.c. electric field the tilt angle increases until it eventually reaches 88° and the cell then appears black.

The S_A phase was aligned by evaporating SiO at a glancing angle of 5^o onto flat indium-tin oxide coated glass, and then dipping the SiO coated electrodes into a dilute solution of hexadecyl trimethyl ammonium bromide in methanol and allowing them to dry. The SiO evaporation directions were placed parallel but opposite when the cell was assembled, with a mylar spacing between the electrodes. Cell thicknesses as measured capacitively were 20 μm. To obtain an even colour the thickness of the cell had to be very uniform.

The cells were filled with 8CB and the tilt angle, measured conoscopically,[5] was 68^o over the entire cell (3 cm square) and remained the same in the S_A phase after repeated heating to the nematic or isotropic phases and then cooling. It was not clear whether the tilt was due to the molecules tilting in the smectic layers and the layers being parallel to the glass (i.e. pseudo S_C) or whether the molecules were normal to the layers and the layers were tilted. First indications are that the former seems likely, but further work is in progress to confirm this.

When a gradually increasing a.c. electric field was applied to the cell the tilt angle of the structure, as observed by its conoscopic figure, gradually increased up to 88^o (Fig. 1). At frequencies below 800 Hz the conoscopic figure could not be followed as it became very diffuse, this was probably due to the start of some electro-hydrodynamic instability within the structure. However, at higher frequencies the conoscopic figure remained very sharp on application of the electric field.

The initial colour of a 20 μm thick cell was brown-yellow when observed normal to the glass surface. The retardation for a 20 μm thick cell containing a liquid crystal aligned at 68^o from the glass surfaces and of birefringence $n_o = 1.52, n_e = 1.675$ (values[6] for 8CB) can be calculated to be 450 nm, which is brown-yellow. Figure 1 shows the sequence of colours found (and calculated) for the tilt angles associated with a cell of 20 μm thickness as the voltage is increased.

By altering the thickness of the cell the initial colour can be altered. Thicker cells will start at a higher order colour in the Newton spectrum, and on application of an electric field can be stepped through a wider range of colours, e.g. a 29.5 μm thick cell appears sky blue and upon applying an electric field the tilt alters and the colour changes to yellow.

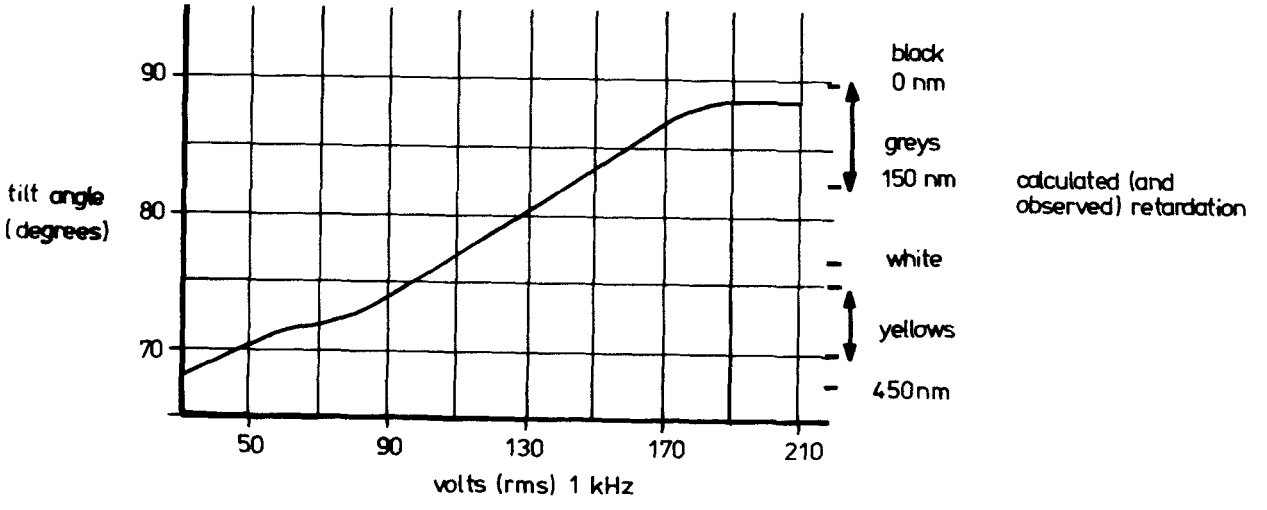

Fig. 1 Applied voltage versus molecular tilt angle (deg) for a 20 μm cell with the associated retardation colours.

It should be possible to obtain a different starting tilt, and therefore a different starting point in the Newton spectrum, by using a different surface treatment, though this has not yet been accomplished. Once established, the tilt is stored until either a higher field is applied (to increase the tilt) or the cell is heated to the nematic phase and then cooled (to obtain the original 68° tilt).

The 20 μm cell appears black to the eye at about 140-150V, which corresponds to a tilt of between 80° and 85° when the calculated retardation corresponds to grey. The maximum tilt obtained was 88°, this was probably due to the molecules in the smectic layers adjacent to the glass surfaces still retaining the surface orientation angle, the measured tilt being an average of the bulk smectic tilt and that of the molecules at the surface.

As far as we are aware this is the first example of an electro-optic effect in smectic liquid crystals that uses a controlled molecular tilt. It is the first electro-optic effect in liquid crystals that enables strong colours, originating in the birefringence of a material, to be electrically produced in the material, and then stored without being sustained by an electric or magnetic field.

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