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A study of microencapsulated chiral nematics in the presence of electric fields

M. K. Evans, C. W. Rapley*, D. W. Wilcock, T. H. Sheldrake

School of Engineering and Applied Technology, University of Sunderland, Sunderland SR1 3SD, U.K.

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1. Introduction

Thermochromic liquid crystals have been used for the visualisation and measurement of heat transfer and temperature distributions since the late 1960s. The dawn of this rapidly exploited technology followed shortly after a review of liquid crystal materials [1, 2] where it was noted that a number of possible applications could arise from the ability of liquid crystal substances to register minute fluctuations in the local temperature, mechanical stress and electromagnetic radiation.

Much work followed this period in the examination of the effect of electric fields on unencapsulated liquid crystals. Among which, Gerritsma and Van Zanten [3] showed that there was an electric field induced transition from the cholesteric mesophase to the nematic mesophase. During these tests it was noted that if the helical axes of the liquid crystals were parallel to the applied electric field, a periodic distortion in the planar texture occurred. At higher fields the helical axes were seen to rotate through 90° before the cholesteric to nematic transition occurred. Such transitions are easily detectable with the naked eye. The selectively reflected colours, characteristic of the cholesteric mesophase, would diminish in terms of saturation level as the focal conic structure was adopted. Untwisting of the helices would result in varying colour play properties being observed, until either the pitch of the helices was unsuitable for reflecting wavelengths of visible light [4] or, the molecules of the liquid crystal had adopted the structure of the nematic mesophase.

Since this period, liquid crystals have been used in a variety of heat transfer studies: typical of which are Hippensteele et al. [5] and Ireland and Jones [6]. However, it should be noted that less emphasis has been placed on examining the properties of liquid crystals in recent studies, and as such heat transfer studies have been bound by examinations of unencapsulated rather than microencapsulated materials which are commonly in use today. Instead, techniques have been developed to help process the observed isochromes into desired temperature, and heat transfer coefficient, distributions [7, 8].

It is the aim of this work to examine the effect of an electric field on microencapsulated chiral nematics. From this it should be possible to identify whether electric fields have a significant effect on these liquid crystals and, if this is so, to what extent. In the present study a circular cylinder, coated with microencapsulated chiral nematic liquid crystals, was placed in electric fields up to 15 kV per meter parallel to the coated surface and up to 30 kV per meter perpendicular to this surface coating. Transitions to the nematic phase and variations in the colour play of the liquid crystal coating were investigated under these conditions.

2. Experimental apparatus and procedure

A circular cylinder was chosen for observational reasons; the curvature allows colours to be observed at positions almost perpendicular to the surface. In an additional test, a 6 mm thick ABS slab was coated with microencapsulated chiral nematics and placed in a 150 kV per meter electric field, perpendicular to the surface coating, to again check for the cholesteric–nematic transition.

All test objects used in this investigation were sprayed with three layers of microencapsulated chiral nematic

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* Corresponding author.

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liquid crystal in a polyvinyl alcohol binder; a black substratum was applied beforehand to reduce the reflection coefficient of the test objects, and thus provide improved colour display. The ratio of capsules to binder was 1:1 by volume, as supplied by Thermographic Measurements Ltd, U.K. This ink required dilution with demineralised water to transform it into a form suitable for spraying. The estimated total thickness of the sprayed layers was about 25 microns. The colour play response gave a red start at approximately 27°C with a 1°C bandwidth.

The experimental apparatus, shown in Fig. 1, allowed for an electric field, of variable magnitude, to be applied either parallel or perpendicular to the surface of a test object. The electrodes were not fixed in place, and were adjusted to accommodate the test object under consideration. As noted in the literature [9, 10], observation and illumination angles are of significant importance. To accommodate this, slits were cut into the electrodes so that an area of the test surface could be suitably observed.

It should perhaps be noted at this point that the test conducted had to ensure the continuous presence of the cholesteric mesophase in the region of the observation. If the temperature of this area was allowed to fall below that of the visible start, the liquid crystal helices untwist naturally into a smectic structure [11]. It is known that this often preferred effect will provide a tightly formed alignment of the liquid crystal molecules. Such an effect would clearly influence the results expected in this work, and as such were avoided. The general procedure adopted was as follows.

First of all, a general calibration of the liquid crystal's colour play response was obtained in the absence of an electric field. This was performed so that comparisons could be made throughout the test. With the test object in the desired orientation to the electrodes, and an embedded thermocouple in the field of view, the test object was heated using a 250 W combined heat/illumination source; the source had a daylight spectrum with adjustment of its output controlled by a sliding shutter; natural convection was considered sufficient for the liquid crystal coating to be affected. With the shutter fully open, the object under test was heated until a blue colour was observed at the thermocouple's position. The desired electric field was applied and relevant observations were recorded. Using the appropriate colour filters, the heat supply was carefully reduced until the green colour was observed, followed by the yellow and then the red. The applied electric field was present for at least 600 s, in total, for each test performed.

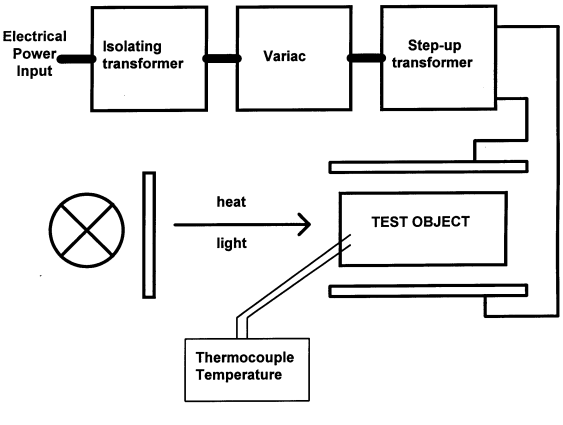

Fig. 1. Experimental set-up.

Problems were encountered with heating of the test object due to close proximity of the electrodes and object surface. This was eliminated by ensuring a minimum of 2 mm separation between the electrodes and the test object's surface.

3. Results and discussion

Experimental results obtained with the electric field parallel and then perpendicular to the liquid crystal coated surface are presented in the following. It should be noted that these results reflect somewhat consistent observations obtained through repeating this test five times. In addition, even though there are no results presented for after an electric field was applied, this was considered; a calibration was undertaken 300 s after the electric field had been removed, to check for any hysteresis effects, but no such effect was found.

The results are mainly presented in the form of a calibration which was conducted using two monochrome filters. One being yellow (589 nm ± 10 nm) and the other being green (530 nm ± 10 nm). This allowed the red start to be identified, (without any filter), and by elimination using the yellow filter's response. Using a similar approach, the blue start could also be identified by use of the green filter. From this approach the red, yellow, green and blue start colours were calibrated against the temperature of a T-type thermocouple embedded in the surface over which the liquid crystal coating was applied.

The colour play response for fields up to 2.4 kV per meter, applied parallel to the liquid crystal coated surface is shown in Fig. 2. The results, obtained whilst the electric field was present, have been represented as a single calibration curve as any deviations in the measurements were too small, and inconsistent, to be of significance. This was found to be the case after the electric field had been removed, and liquid crystal coating recalibrated, as shown in Fig. 2 also. A comparison of the colour saturation levels before, during and after the electric field was present showed no observable change. This was considered for variations in the saturation level both overall, and from region to region, of the coated surface. This suggests that the electric field has no significant influence

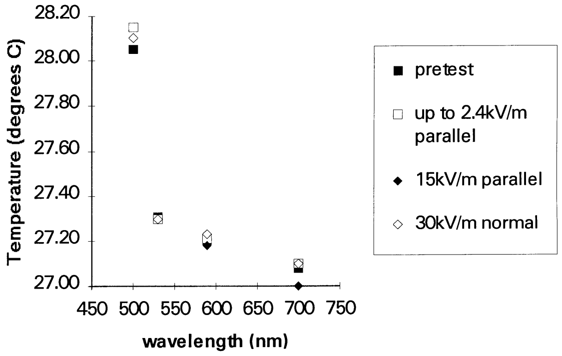

Fig. 2. Comparison of colour play properties for electric fields applied both perpendicular and parallel to a liquid crystal coating with that of a pre-test calibration.

on the twist, or orientation, of the liquid crystals with the field applied parallel to the surface.

Results of a further test conducted at 15 kV m^{-1} is also presented in Fig. 2. Again the colours obtained, both before and during the electric field was present, were consistent in their saturation levels as compared with an untreated sample.

The colour play response for fields of up to 30 kV m^{-1}, applied perpendicular to the liquid crystal coated surface, is also given in Fig. 2. The results in this figure are presented for each test situation of before and during the electric field being applied. No variation in colour saturation levels nor evidence of the helices untwisting, as seen by Gerritsma and Van Zanten [3], was observed during the test. It is believed that the liquid crystals used by these authors were similar to the electro-optically active type [12, 13] as employed in liquid crystal displays (LCDs). It is therefore the opinion of the authors of the present work that either the microcapsule stabilises the liquid crystal and/or the chiral nematics, considered in this work, are much more tightly twisted.

Finally examination of the ABS slab, both before and during the electric field being applied, for an electric field of 150 kV m^{-1} perpendicular to the surface gave no observable indication that a transition from the cholesteric to the nematic mesophase had occurred.

4. Conclusions

A study of microencapsulated chiral nematics in the presence of electric fields has been carried out and gave no observable change in the characteristic optical properties. Electric fields of up to 150 kV m^{-1} perpendicular and up to 15 kV m^{-1} parallel to a surface of microencapsulated liquid crystals are found to have no effect on the colour play response. As such, this type of liquid crystal appears to be unsuitable for detecting fluctuations in electric fields, but will be suitable for work such as heat transfer measurement in the presence of such fields. And finally, the expected transition from the cholesteric to the nematic mesophase for fields as high as 150 kV m^{-1} does not occur with this type of liquid crystal.

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