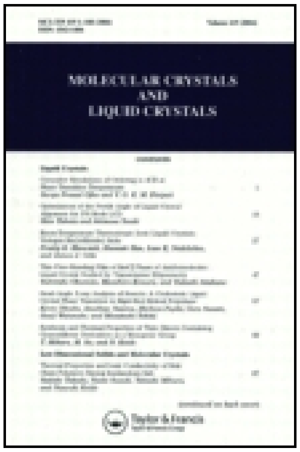

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Measurement of the Polarization Field in Pdlc with Memory State

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MEASUREMENT OF THE POLARIZATION FIELD IN PDLC WITH MEMORY STATE.

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Abstract A memory state can be induced in PDLC films through the application of a strong D.C. voltage. This memory state is due to the onset of an internal polarization field, which keeps the film in a high transparent state. This polarization field remains in the film from hours to weeks, depending on the temperature at which the external polarizing field is applied. We have found the way to measure such an internal field by observing the electrooptical response of the film, under a low frequency driving voltage. Due to the presence of the polarization field the light transmission obtained during the positive half period of the driving voltage is not equal to that observed in the negative half period. The polarization field corresponds to the D.C. bias voltage which is needed to equalize the light transmission in the two half periods. The time dependence of the polarization field has been determined.

INTRODUCTION

Memory effects of light transmission in polymer dispersed liquid crystals (PDLC) films have been observed since 1991 and mainly investigated by Yamaguchi and Sato. These authors report in an early paper[1] that PDLC, made by UV curable polymer, show a residual transparency after removal of the on-state A.C. applied voltage. This residual transparency was found strongly dependent on the applied on-state voltage. The presence of an electrooptical hysteresis was also observed. Successively the same authors were able to optimize the transparence of the memory state by introducing a procedure according to which a relatively high A.C. voltage was applied to the PDLC film while cooling it down from the isotropic temperature of the liquid crystal to room temperature (PTF operation)[2,3]. The angular dependence of the light transmission of PDLC in memory state has also been investigated[4].

In this paper we report a new type of memory state of PDLC film obtained by polarizing the film for some minutes by a strong D.C. electric field (pre-charging process). After leaving the PDLC cell under the effect of such a D.C. field a permanent internal polarization field could be detected. The permanence time of this internal field was found strongly dependent on the temperature of the pre-charging process, the value of the pre-charging field and the time elapsed.

The observation of the electrooptical response of pre-charged PDLC samples, under the application of low frequency driving voltages, allowed the measurement of the internal polarization field.

EXPERIMENTS AND DISCUSSION

Materials

PDLC samples have been prepared using the TIPS[5] procedure. As a thermoplastic matrix we used PMMA (poly (methyl methacrylate)) from Aldrich and the dispersed liquid crystal was the E49 nematic mixture from Merck. The two components were in the weight ratio of PMMA/E49 = 1/1. The sample was sandwiched between two ITO (Indium Tin Oxide) coated glass plates, heated to about 120 °C and then cooled to room temperature to induce phase separation with droplet sizes of 1-2 microns.

Several samples were prepared with this mixture, the thickness of which was about 40 microns.

We will show in detail the results obtained from the above mixture, but our investigation has been extended to other PDLCs, made also by PIPS[6], using a variety of polymer matrices and liquid crystals. The observed effects were similar in all the analyzed samples, so we can assert that the phenomena here described are common to any type of PDLC film.

Light Transmission

The first experiment we discuss is that concerning the measurement of the light transmission of a PDLC cell to which a D.C. field of 10 Volts/micron was applied, as a function of time. All the measurements were made at room temperature (20 °C). Results are shown in Fig.1.

Line a) is the transmission observed while the field remained continuously applied to the sample; line b) is the transmission observed once the field was removed.

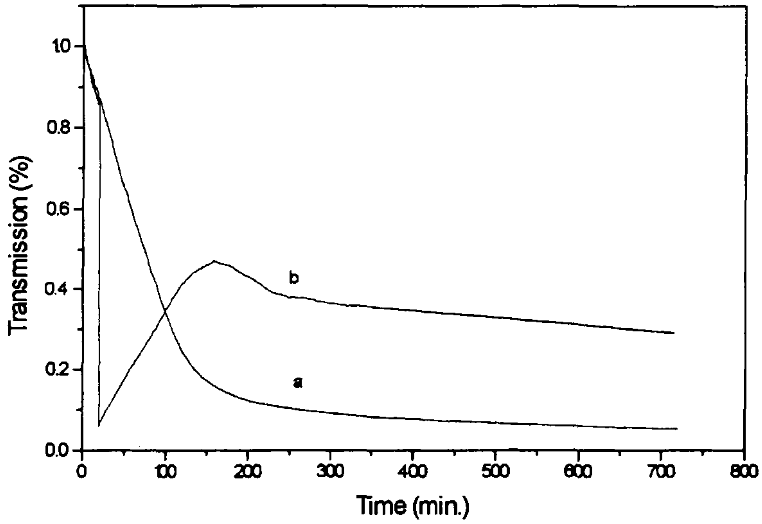

FIGURE 1 Line a) is a light transmission of a PDLC under a D.C. field of 10 Volts/micron; line b) is a light transmission after removing the external field, both as a function of time.

A simple explanation of the gradual decreasing of the light transmission during the application of the D.C. field (line a) can be given in term of the gradual increasing of an internal polarization field, due to ion accumulation and/or dipole orientation at the droplets interface. This field will oppose the external one, in such a way that the total field acting on the liquid crystal droplets will gradually decrease.

Once the external field is removed (line b), only the polarization field acts on the droplets, bringing up the light transmission. Of course the polarization field will slowly disappear, due to the remixing of ions and/or random dipole orientation, and this will result in a decline of the light transmission.

We have got an indication that the polarization field is due to charge accumulation at the droplet interface, following the dielectric constant of polymer/liquid crystal films where the concentration of the liquid crystal is gradually increased. The results are illustrated in Fig.2. Here the normalized variation ((Cp'-Cp)/Cp, being Cp and Cp' the dielectric constant before and after the pre-charging process respectively) of the dielectric constant of the films, is reported. Up to the 25% of liquid crystal no liquid crystal droplets are present, being this component completely dissolved in the polymer matrix and it can be seen that no polarization field appears in the sample. Only when the liquid crystal droplets become visible, the dielectric constant starts to be sensitive to the pre-charging process.

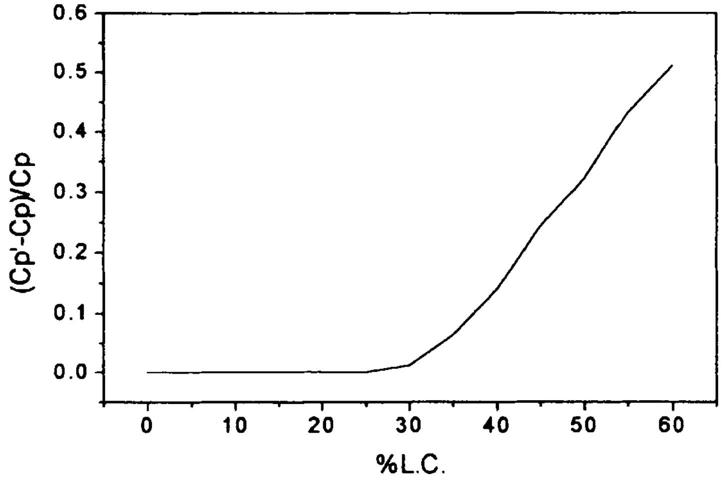

FIGURE 2 Normalized variation of the dielectric constant of a PDLC film, due the polarization of the material by a 10 Volts/micron D.C. field.

Of course this sensitivity enlarges with the increasing of the number of droplets. So we can conclude that the phenomenon appears only if droplets do exist and since it was never observed in such an extent in pure liquid crystals, it must be associated with the polymer/liquid crystal interface.

The polarization field depends strongly on the temperature at which the pre-charging process is carried out. This can be deduced by observing Fig.3, where the light transmission observed in samples pre-charged at different temperatures is reported as a function of the time elapsed after removal of the external field.

From the inset it is clear that samples have a similar behaviour whatever is the pre-charged temperature (we must recall that samples may slighty differ for their thickness).

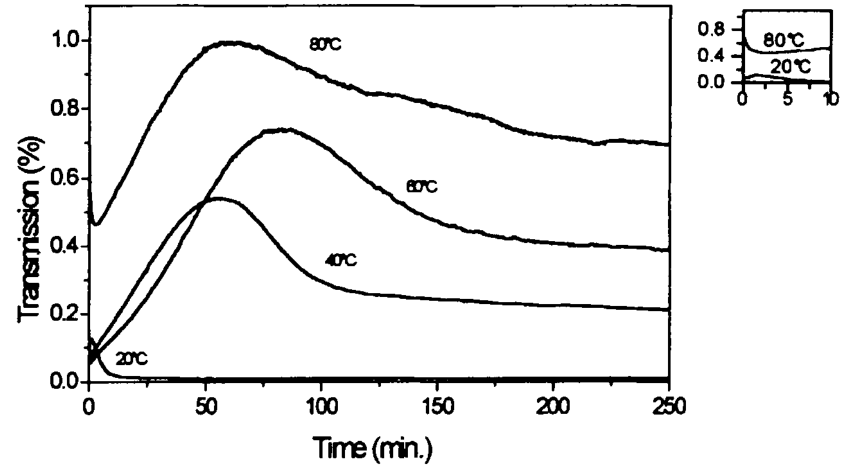

FIGURE 3 Light transmission measured at room temperature, against time, of a PDLC film pre-charged at different temperatures.

It must be first underlined that the light transmission increases with increasing of the pre-charging temperatures, but another unexpected phenomenon appears. Taking off the external field one would expect a gradual decreasing of the light transmission: this is not the case, since for every pre-charging temperature a maximum comes in view.

It is not easy to find an explanation for the above observation. One possibility is to hypothesize that during the pre-charging process the droplets become deformed and that such a deformation relaxes influencing the optical character of the scatterers. Studies are in progress to elucidate this particularly interesting effect.

Measurement of the internal polarization field

When a PDLC film is driven by an A.C. low frequency field the light transmission is modulated according to Fig.4a. Peaks of equal intensity are observed in the optical transmission at both the positive and negative maxima of the driving field half-periods. We have observed that this is not the case when the PDLC film is previously charged by a strong D.C. field. In such a case the light transmission behaves as it is shown in Fig.4b. During the negative half period of the driving field, the film shows much less optical transmission than that recorded during the positive one.

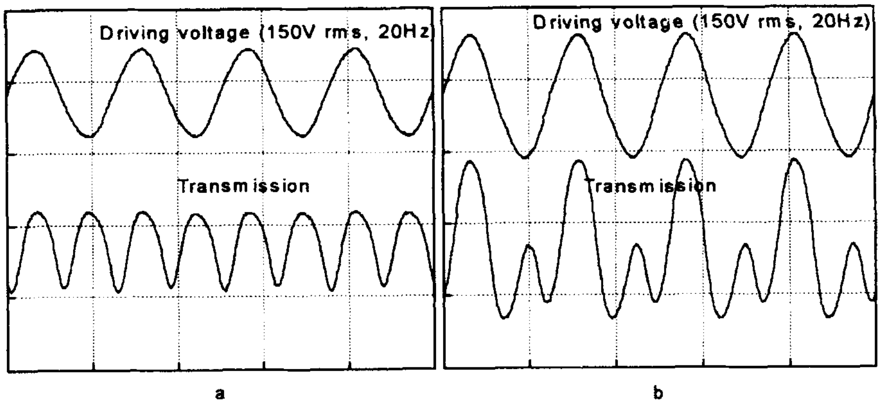

FIGURE 4 Electrooptical A.C. response of a PDLC: a) not pre-charged PDLC; b) pre-charged PDLC.

This is of course due to the fact that in the first case the internal polarization field opposes the driving field, while in the second case the polarization field and the driving field add up, being in the same direction.

Starting from the above observation, two different methods can be used to measure the internal field generated by the pre-charging process.

-The driving field can be chosen in such a way that during the negative half-period the peak in the optical transmission is completely suppressed, as it is illustrated in Fig.5.

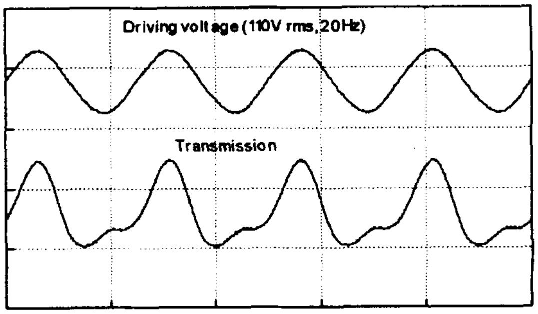

FIGURE 5 Typical electrooptical response of a pre-charged PDLC film. In this case the polarization field is cancelled by the negative peak value of the driving voltage.

In this condition the peak value of the driving field is equal to the internal polarization field present at that time.

-On the other hand a D.C. bias field can be added up to the driving field in order to bring to the same value the optical transmission peaks measured during the positive and negative half periods of the A.C. driving field. In this condition the bias field counteracts exactly the inner polarization field. Such bias value is equal to the internal polarization field present at that time. This second opportunity is illustrated in Fig.6.

We have applied the above two procedures to measure the polarization field and we have observed that both give the same results, in the limit of the experimental errors.

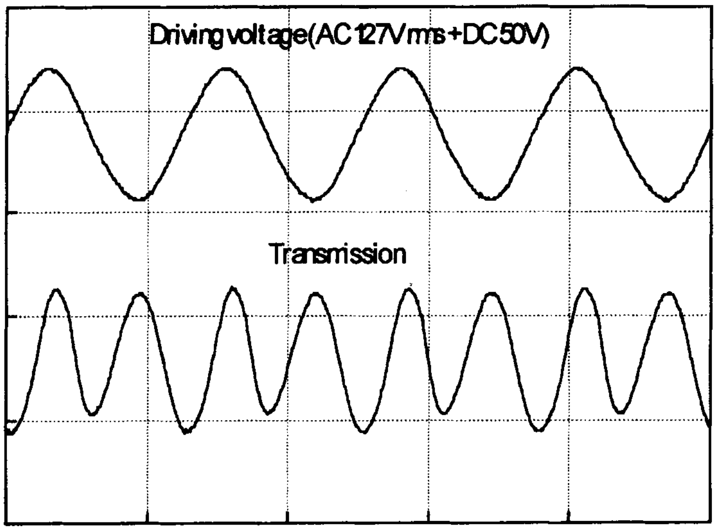

FIGURE 6 Typical electrooptical response of a pre-charged PDLC film: a D.C. bias which cancels the polarization field is added to the driving voltage.

As the internal polarization field decreases with time (because ions remix and/or dipoles reorient), the driving peak field (first procedure) or the D.C. bias value (second procedure) must be again matched.

The values of the polarization field measured as a function of the time elapsed after pre-charging with the D.C. field and as a function of the pre-charging temperature are reported in Fig.7.

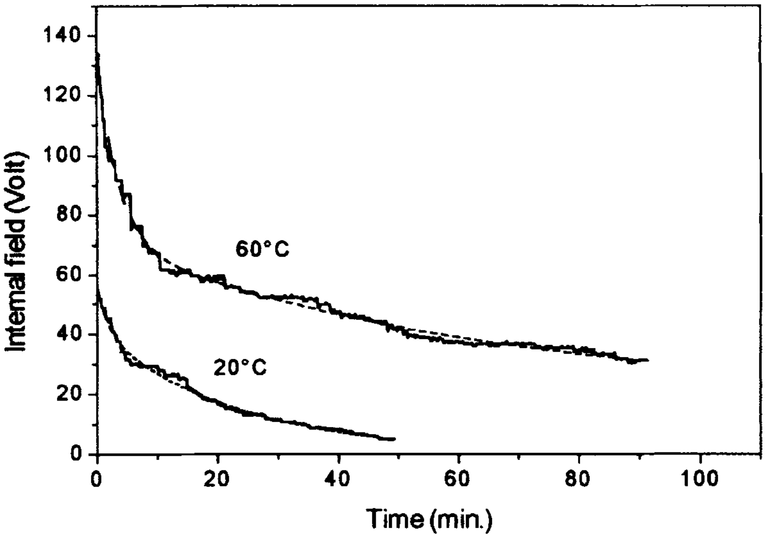

FIGURE 7 Internal polarization field generated into a PDLC film by pre-charging with a D.C. field of 10 Volts/micron at different temperatures, — experimental; ---- calculated (see text).

In the same figure a theoretical fit of the experimental data obtained according to the equation:

$$E = E_0 + a \exp(-t/T_1) + b \exp(-t/T_2) \qquad (1)$$

is reported. In the case of the curve obtained for a pre-charging temperature of 20 ^{0}C the fitting parameters were:

$E_0 = 0.347$; $a = 14.87$; $b = 41.14$; $T_1 = 1.69$; $T_2 = 22.83$

while in the other case, where the temperature was 60 ^{0}C, the values of the above parameters resulted to be:

$E_0 = 19.73$; $a = 62.11$; $b = 52.24$; $T_1 = 3.36$; $T_2 = 60.07$

T_1 and T_2 can be interpreted as the relaxation times of two different polarizing mechanisms. While a and b can be associated to the two relative weigths of these mechanisms. Of course these mechanisms can be associated with dipole orientation and ion migration. The relative incidence of the two mechanisms depends strongly on the charging temperature: when this increases the weigth of the slow relaxing mechanisms also increases. It does not seem feasible, at the moment, to assign the two observed relaxation times to each one of the above mentioned mechanisms. Dielectric relaxation studies are in progress to solve this problem.

CONCLUSION

A slow relaxing strong polarization field can be induced in PDLC films pre-charged with a 10 Volt/micron D.C. field. Two mechanisms of polarization such as dipole orientation and ion migration have been evidentiated. The polarization field has been measured, by means of electrooptical methods, as a function of the time elapsed from the pre-charging process and a temperature. The fitting of the field decay allows the determination of two characteristic times of the polarization decay.

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