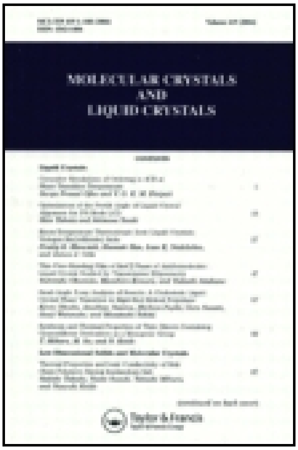

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POLARIZATION STUDIES ON STRETCHED POLYMER DISPERSED FERROELECTRIC LIQUID CRYSTAL FILMS

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Polarization Studies on Stretched Polymer Dispersed Ferroelectric Liquid Crystal Films

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We obtained polymer dispersed ferroelectric liquid crystal films using a new ferroelectric liquid crystal code name S9MHL and PMMA. The elongation of the liquid crystal droplets appeared, caused by hot stretching and pressing the films. We studied the dependence of the polarization upon temperature, frequency and amplitude of the applied electric field for different liquid crystal concentrations. The highest switching time in the range of tens of microseconds has been reached.

Keywords: PDFLC; ferroelectric liquid crystals; polarization; polymers; mechanical stretching

INTRODUCTION

In the last decade, the interest in polymer dispersed liquid crystal (PDLC) composite films has been constantly growing, due to their advantages as compared to the liquid crystal devices. PDLC films can

be self-supported and flexible since the polymer matrix is plasticized by the dissolved LC molecules. Neither surface treatments nor sealing of the cells are necessary, and they work without polarizers. The use of ferroelectric liquid crystals (FLC) dispersed in the polymer matrix [1,2] promises inherent memory properties as well as significantly faster dynamics of electrooptic response than can be achieved with standard nematics.

The first aim of our work was to prepare PDFLC cells containing SmC* phase in form of ellipsoidal droplets with homogeneous alignment. The unidirectional alignment of the droplets in a PDFLC film can be produced by several methods: polymerization of the matrix in the presence of a strong longitudinal electric or magnetic field, shearing deformation, stretching of the film [3,4]. Stretching is very effective, providing a high degree of droplet ordering and anisotropy of the polymer matrix. In our paper we used the hot stretching and pressing of the PDFLC film, in order to induce a high value of the polarization.

The second aim of our work was to study the dependence of the polarization upon temperature, frequency and amplitude of the applied electric field for different FLC concentrations. Optical transmission through the sample was measured.

EXPERIMENTAL

For this study we use a new ferroelectric liquid crystalline mixture with the code name S9MHL [5,6]. This mixture has the phase sequence: (-14°C) K-SmC*; (64°C) SmC*-SmA; (83°C) SmA- N*; (108°C) N*-I. The spontaneous polarization Ps is 82 nC/cm^2 at saturation below 30°C Tilt angle grows from 0 at SmA-SmC* transition to about 30 degree at saturation [6].

We used the SIPS (solvent induced evaporation phase separation) method to obtain PDLC films.

FLC was mixed with the polymethyl methacrylate in three ratios of 25%, 30% and 35% by weight and chlorophorm was added in a 6:1 b.w. ratio, to dissolve completely the components and to obtain a homogeneous solution which was spread onto a glass substrate. After the evaporation of the solvent at room temperature, the film was removed from the substrate.

To create geometrical anisotropy, the films have been stretched and pressed. By stretching the films unidirectional, the radial symmetry of the droplets is destroyed, and they become elongated. In the stretching process, the polymer matrix also becomes anisotropic. The polymer chains are more straightened out and aligned along the stretching direction. The degree of the film elongation, p, defined as the ratio between the local film length in the deformed and in the non-deformed states, was p=2. The film was stretched when the liquid crystal was in its isotropic phase - hot stretching.

An elongation of the LC droplets induces preferred direction of the director **n** inside the droplets for tangential anchoring conditions thus the orientation of the LC becomes the same for all droplets. The size of the droplets was ranged between 1÷5μm. The stretched films have been pressed and stuck between ITO covered glass plates, using epoxy glue. The measured cell gap of the obtained samples was of 40-50 μm.

The investigation of the ferroelectric properties of liquid crystals can be carried out by the Sawyer-Tower method, which gives a display of the hysteresis loop on an oscilloscope [7]. The polarization is determined by measuring the value obtained by extrapolation of the linear part of the loop. Nevertheless, this method is unsuitable for samples exhibiting higher conductivity. As shown by Diamant et al [8], a conductive sample exhibits a loop with rounded edges, which makes impossible to accurately determine the correct value of the polarization. The method initiated by Diamant et al. surmounted these difficulties.
Using a specially built apparatus, hysteresis meter [9], we applied on the sample a.c. electrical signals of different frequencies and amplitudes. For compensating the conductivity and the non-ferroelectric capacitance of the sample we used the experimental set-up shown in Figure 1.
If U_y is the voltage value needed to reach compensations, then:

$$U_y = k\,P_s\,S/\,C_0 \qquad (1)$$

where P_s is the spontaneous polarization, S is the surface area of the sample, C_0 a fixed capacitance, which should be adjusted in steps in such a way as to stop the saturation of the differential amplifier when the signals E_1 or E_2 are increased, and k is a constant.

The measurements have been performed in the following conditions:
a) The electric field was increased until saturation was achieved; if this is done slowly, breakdown can be avoided.

b) The free capacitance of the sample should be independent of the applied voltage; otherwise corrections have to be introduced.

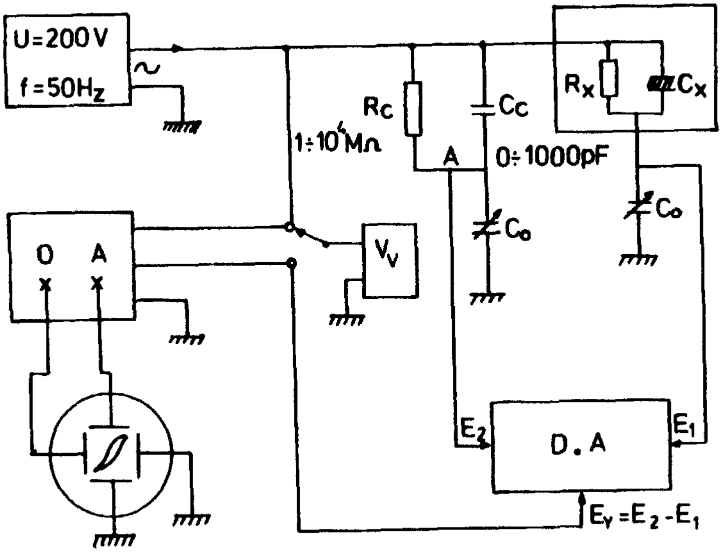

FIGURE 1. Bridge for measurements of ferroelectric hysteresis. OA- output amplifier, DA=differential amplifier, V_v – peak voltmeter. Voltage range 0-200V, C_0 =100nF, C_x = sample, $R_x = 10^4$-$10^{10}\Omega$.

c) The frequency of the applied voltage was filtered in order to eliminate distortions due to the higher harmonics.

d) In order to measure the temperature dependence of the polarization, the PDFLC cell was introduced in an oven, with controlled heating and cooling; the precision of the temperature control was: ±0.01°C.

RESULTS AND DISCUSSIONS

Using the described method, we measured the polarization dependence on temperature, applied electric field amplitude and its frequency.

In Figure 2 the dependence of the saturation polarization as a function of temperature is presented. When increasing the temperature starting from room temperature, the polarization decreases, reaching a minimum, when approaching the transition from SmC* to SmA [10]. Increasing further the temperature, the polarization also increases due to role of the stretched PMMA in the generation of the polarization, which is due to the great space charge existent in the PMMA [11]; this charge reaches a maximum at 125°C [11] and finally tends to vanish for higher temperatures.

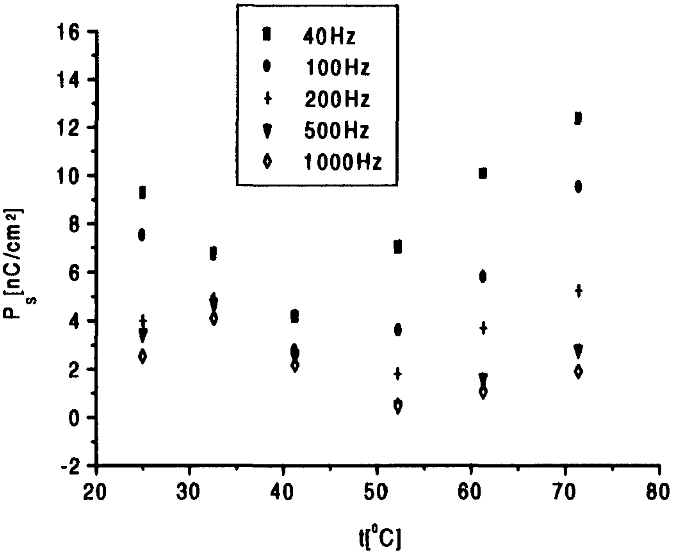

FIGURE 2. Dependence of the saturation polarization on temperature for S9MHL/PMMA 35% sample, at 100 V_{rms}.

In Figure 3 the dependence of the saturation polarization on the amplitude of the applied voltage is shown. We limited the maximum value of the applied voltage at 100V_{rms} to avoid the heating effects of the sample, which result in hysteresis loop distortions. A linear increase of the polarization with the voltage is noticed.

In Figure 4 the polarization dependencies on frequency at different temperatures are shown. Considering the dependence of the

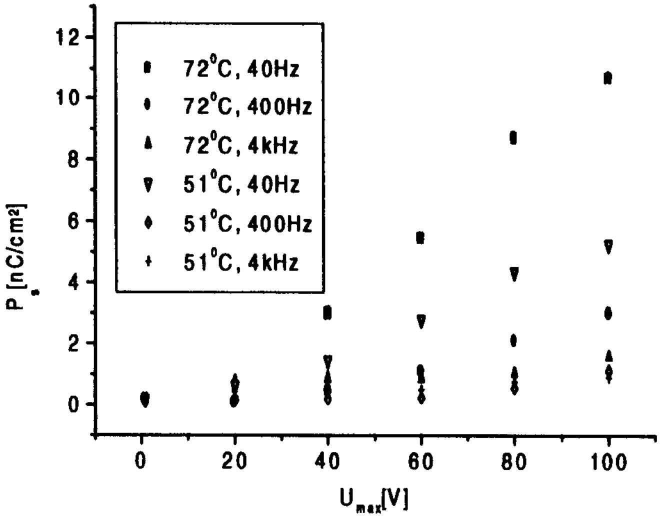

FIGURE 3. Dependence of the saturation polarization on the applied voltage, for S9MHL/PMMA 35%.

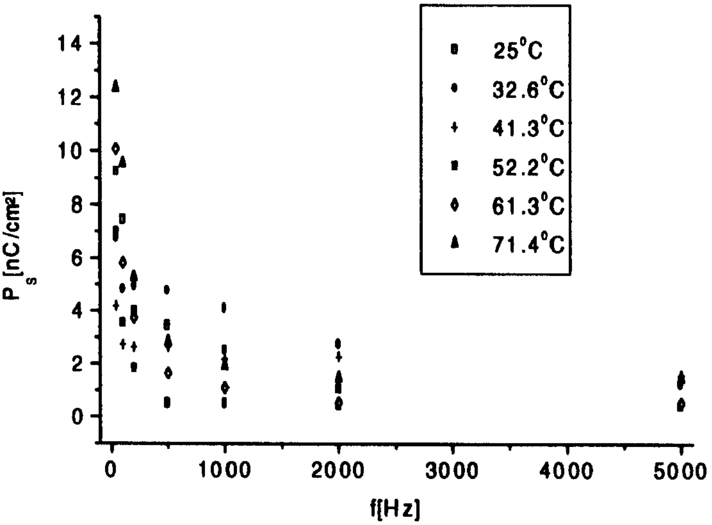

FIGURE 4. Saturation polarization versus frequency.

polarization on the applied electric field in the form: $P = \varepsilon_0 E (\varepsilon_r - 1)$, we define the cut-off frequency as the frequency where the modulus of ε_r becomes one. From Figure 4 this frequency is in the range of MHz, which leads to switching times of the order of tens of microseconds.

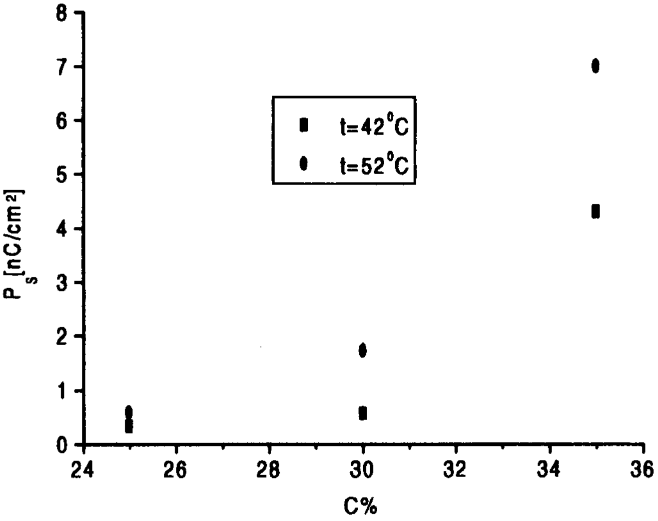

FIGURE 5. Polarization dependence on FLC concentration at 40Hz.

In Figure 5 we represented the dependence of the polarization on the FLC concentration for two different temperatures, both corresponding to the SmC* phase at the same frequency of 40 Hz. As it was expected, an increase of the polarization with the FLC concentration was obtained.

We focused our studies also on the variation of the optical transmission with the applied voltage, at different temperatures corresponding to all LC mesophases. At all temperatures we observed a switching between the ON and OFF states, around a voltage of 50V d.c., the contrast being higher for the temperature corresponding to the nematic phase.

CONCLUSIONS

In PDFLC the saturation polarization is much lower than in the pure FLC, in spite of stretching of the polymer matrix.

The polarization decreases with the temperature but because of the PMMA stretching a higher value was obtained even in the SmA and N* temperature range, corresponding to the beginning of the PMMA glass transition.

The polarization increases linearly with the voltage and decreases exponentially with the frequency. The frequency dependence of the saturation polarization leads to relaxation times of tens of microseconds, comparable with the values of the optical switching time.

As expected, the polarization of the PDFLC samples increases with the FLC concentration.

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