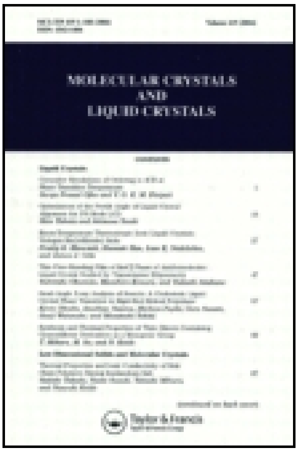

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Polarized Light Scattering and Off-State Transmission of Electron-Beam Cured Polymer Dispersed Liquid Crystals

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Polarized Light Scattering (LS) experiments are performed on thin Electron-Beam (EB) cured polymer precursor/liquid crystal (LC) films. The polarized component I_{vv} is obtained for irradiated blends of a low molecular weight aromatic polyester acrylate, additional monomers like tripropyleneglycoldiacrylate, and the nematic LC mixture of cyanoparaphenylene derivatives known under the tradename E7 (Merck). The whole composition range between the pure cured polymer precursor and E7 was covered by exposing the corresponding initial samples to constant EB-curing conditions. Only the light scattering of polymer/LC films with no external fields is considered here and the results are compared with additional measurements of the optical off-state transmission. The results obtained from LS and transmission experiments are in excellent agreement.

Keywords Light scattering, poly(acrylate), nematic liquid crystal

INTRODUCTION

Polymer Dispersed Liquid Crystals (PDLC) are made of nematic liquid crystal (LC) droplets dispersed in a solid polymer matrix[1-5]. In the normal mode situation, these systems scatter incident light strongly but become progressively transparent upon applying an external electric field with incresaing amplitude. The droplets are birefringent and possess an ordinary refractive index n_o and an extraordinary refractive index n_e while the host polymer is selected in such a way that its refractive index n_m matches closely n_o. In the off-state (no external field applied), the droplets are randomly distributed, any incident light is strongly scattered and the film appears opaque. In the presence of an external electric field applied the scattering is weak and the system becomes transparent. This switching capability from translucid to transparent is useful in the design of switchable windows and display systems.

Polymerization Induced Phase Separation (PIPS)[4-7] is initiated by EB exposure[6,7]. The precursor solution is made of a low molecular weight aromatic polyester in additional monomers like tripropyleneglycol-diacrylate together with the eutectic nematic LC mixture known as E7. The EB triggers the crosslinking-polymerization processes which take place simultaneously and lead to phase separation of the polymer and the LC. Compared with the traditional PIPS process by ultra-violet radiation, EB-curing yields a high conversion of monomers, fast reaction and does not require an additional initiator.

To perform LS measurements, the sample is illuminated with linearly polarized light, and the scattered intensity is examined after the light has passed through an analyzer whose axis is parallel to the polarization direction of the incident beam (polarized component I_{vv}).

The results are compared with the transmission of the films as a function of its composition in the absence of external electric field (off-state conditions).

EXPERIMENTAL PART

Materials

The LC mixture E7 was purchased from (Merck Eurolab, Darmstadt, Germany). Its refractive indices are n_o=1.5183 and n_e=1.7378[8]. The prepolymer chosen consists of an aromatic polyester acrylate (Rahn AG, Switzerland) diluted in additional monomers including Tripropyleneglycol-diacrylate (TPGDA) from UCB (Belgium). Refractive indices of cured prepolymer/LC blends at compositions below the phase separation were determined before[9]. It is found that under the curing conditions, nearly 20 weight percent (wt-%) of LC remain dissolved in the polymer matrix[7]. This leads to an increase of the refractive index of polymer as compared to the prepolymer cured without LC. The transparent cured film with 80 wt-% prepolymer / 20 wt-% LC has the refractive index n_p = 1.5269 (λ=632.8 nm)[9].

Sample preparation

(100-x) wt-% of the prepolymer (x=0, 13, 20, 24, 31, 49, 60, 70, 80, 90, 100) and x wt-% of the LCs are mixed together at room temperature. At each composition several samples are prepared to check for reproducibility of the results. The precursor mixture is put as thin layer of some μm thickness between a glass plate (Balzers, Liechtenstein) and a 50μm thick poly(ethyleneterephthalate) sheet (Renker, Germany), coated with a thin layer of indium/tin oxide (ITO).

Electron Beam Curing

The EB generator is an Electrocurtain Model CB 150 (Energy Sciences Inc., USA) with an operating high voltage of 175kV. The sample including reactive prepolymer/LC solution was placed in a sample tray and passed in an inert atmosphere under the accelerated electron curtain on a conveyor belt. A dose of 60kGy was reached with a beam current of 4mA and a conveyor speed of $0.22 m.s^{-1}$. These values are kept constant during the experiments but no temperature control was made during beam exposure.

Light scattering

The set-up of light scattering is illustrated in Figure 1. All the measurements were performed at room temperature. A He-Ne Laser

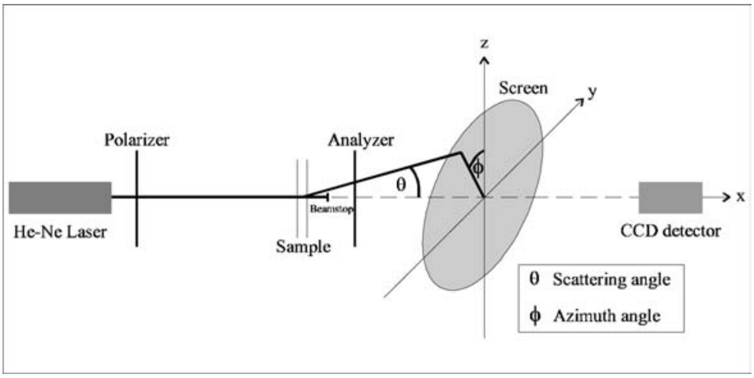

FIGURE 1 Experimental setup of the light scattering apparatus showing the scattering and azimuth angles.

(λ=632.8 nm) polarized perpendicular to the scattering plane was used to measure I_{VV} where the analyzer is kept parallel to the polarizer. The scattered beam was recorded by a CCD camera. A ϕ-independent circular intensity pattern was found allowing to get a radial average of the scattered intensity. Further experimental details can be found elsewhere[10-12].

Transmission

The optical transmission of the obtained cured polymer/LC films were measured at room temperature perpendicular to the film plane by using an unpolarized HeNe laser at a wavelength of λ=632.8nm. The collection angle of the transmitted intensity was about 2° and the obtained values were corrected to the transmission of the empty cell. Measurements were made on different places on each polymer/LC film allowing to average the obtained transmission values.

RESULTS AND DISCUSSION

In order to illustrate the changes in the scattered intensity with the LC concentration and show the correspondance between the scattering and

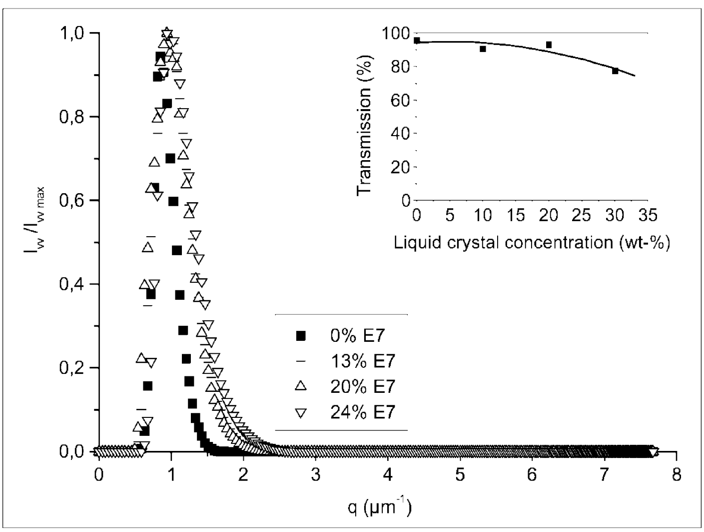

FIGURE 2a Variation of the scattering intensity I_{vv} $(q)/I_{vv}$ $(q=0)$ as a function of q for poly(acrylate)/E7 samples in the concentration range from 0 to 24 wt-% LC. The insert shows the corresponding transmission values.

the transmission of light, we choose to split the concentration scale of LC in three regions. From 0 (pure polymer) to 30 wt-% E7, the scattering is weak and the $I_{VV}(q)/I_{VV}(q\!=\!0)$ curves undergo a sharp drop near q=1μm^{-1}. This is clearly shown in Figure 2a where the insert exhibits the transmission in the off-state in this range of concentration.

Consistent with the weak scattering pattern, we have nearly a constant high degree of transparency of the film. For LC concentration varying from 30 wt-% to 80 wt-%, the curves indicate that the scattering of light by those films is dramatically enhanced consistent

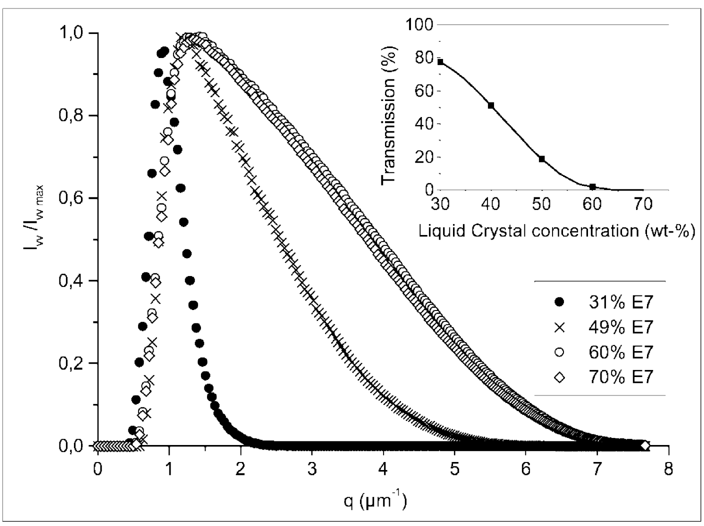

FIGURE 2b Variation of the scattering intensity I_{vv} $(q)/I_{vv}$ $(q\!=\!0)$ as a function of q for poly(acrylate)/E7 samples in the concentration range from 31 to 70 wt-% LC. The insert shows the corresponding transmission values.

with the transmittance curve which exhibits a rapid depression of light transmission from nearly 80% to zero (total opacity). These features are shown in Figure 2b and its insert. The last domain of LC concentration from 80 wt-% E7 to pure LC system is illustrated in Figure 2c. Here the curves $I_{VV}(q)/I_{VV}(q=0)$ drop rapidly with q but nevertheless, the scattering remains sensitively higher than in the case of Figure 2a. This behavior is consistent with the reverse tendancy of the transmittance curve inserted showing enhancement of transmission and reaching complete transparency at 100 wt-% E7.

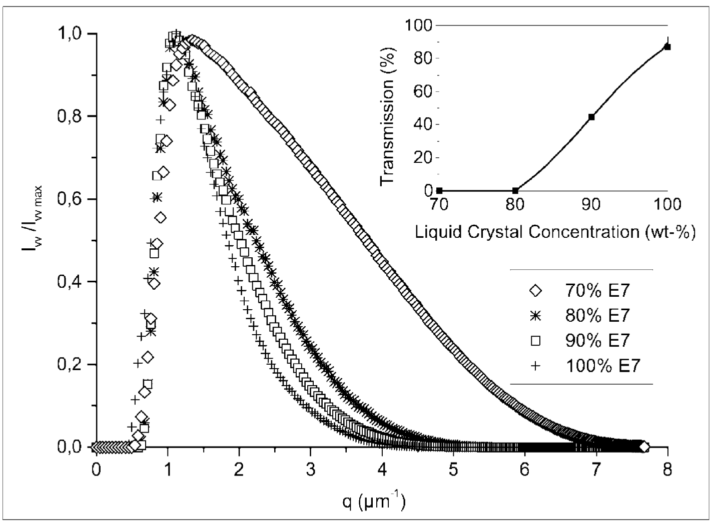

FIGURE 2c Variation of the scattering intensity I_{vv} $(q)/I_{vv}$ $(q=0)$ as a function of q for poly(acrylate)/E7 samples in the concentration range from 70 to 100 wt-% LC. The insert shows the corresponding transmission values.

CONCLUSIONS

LS measurements are performed using polymer/LC films of Polyacrylate/E7 prepared by electron beam radiation via a PIPS process. Comparison of the LS data with transmission in the off-state shows a complete consistency in the whole domain of LC concentration investigated. High transmission values were found for films with 0 to

31 wt-% E7 and these films show only weak scattering. In the concentration range between 31 and 70 wt-% E7, films scatter efficiently light leading to high values of $I_{VV}(q)/I_{VV}(q=0)$ at larger q and low transmission values. If the LC concentration is further increased from 70 wt-% E7 up to pure E7, the size of LC domains become larger than the wavelength of the incident Laser beam. As a consequence transmission values increase with LC concentration and the films scatter less the incoming light.

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