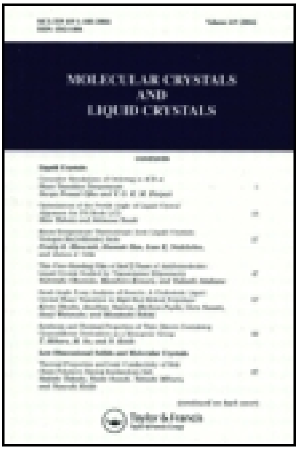

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Changes in the Electro-Optical Properties of a PDLC System by Monomer Substitution

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Changes in the Electro-Optical Properties of a PDLC System by Monomer Substitution

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This paper deals with the changes on switching fields and response times of a PDLC system when small percentages of the thermoplastic polymer are replaced by the same quantity of monomer. An improving of the electro-optical properties, i.e. a reduction in driving voltages and rise times, is obtained when about 10 weight % of polymer is replaced by monomers with a high solubility in liquid crystal droplets. Morphology changes are observed for substitutions larger than 20 weight %.

Keywords: PDLC; phase separation; liquid crystals

INTRODUCTION

Electro-optical properties of polymer dispersed liquid crystals (PDLC) have attracted the interest of many researchers in the last years.[1] Very active efforts have been given because PDLC are composite materials formed by liquid crystal droplets in a polymer matrix which can be electrically switched from an opaque state (OFF state) to a transparent one (ON state).[2] The use of PDLCs in display devices requires low driving voltages and rapid response times. Various factors affect the electro-optical properties of PDLC films: the chemical physical properties of components, the polymer-liquid crystal composition ratio, the film thickness, the shape and size of the droplets, the presence of additives as an adhesive, a colorant, a stabiliser etc..

Recent works[3-10] showed that such properties can be changed acting on the interfacial interactions between polymer wall and liquid crystal molecules in droplets. The interfacial properties have been modified by several methods such as mechanical stretchings, temperature changes, phase separation processes with an external field applied on samples, addition of plasticizers or monomers. Following this last method, Lackner et al.[6] added small amounts of monofunctional liquid crystal monomers to photopolymerizable mixtures of liquid crystal and monomers and obtained larger liquid crystal droplets in a less rigid polymer matrix. Kawatsuki et Ono[7] fabricated PDLCs by two-step phase separation method and changed the boundary conditions at the interface between liquid crystal and a thermoplastic polymer (PMMA) by photopolymerizing small amounts of added monomers. In the present work, we observed that PDLC films made with a thermoplastic polymer, show changes in their switching field and response time values when small percentages of the polymer matrix are just replaced by the same quantity of monomer.

A substantial decrease in switching fields and rise times is obtained when about 10 weight per cent of polymer is substituted.

EXPERIMENTAL

A PDLC model system was fabricated from dichloromethane solution of polymethylmethacrylate (PMMA from Aldrich, 40 weight %) and nematic liquid crystal TN10427 (from Rolich, 60 weight %). Phase separation was obtained by TIPS procedure.[1] NOA65 (Norland), tri(propylene glycol) diacrylate and trimethylolpropane triacrylate (both from Aldrich) were used as monomer substitutes of PMMA (0-20 weight %). All such monomers show a good solubility both in liquid crystal and PMMA. Mixtures were then casted in home made cells, whose thickness was about 15 μm. The cell walls had an indium thin oxide (ITO) conductive substrate in order to perform the electroptical characterisation. The electro-optical properties of films were measured using the optical line reported in a previous work.[11] The intensity of incident light measured with empty substrates was assumed as full scale intensity. The τ_{rise} and τ_{decay}, defined as the time required, respectively, to reach 90% and drop 10% of the maximum transmittance after the electric field is removed, was determined by applying a driving sine wave voltage of 200 Volts rms at a frequency of 1 kHz.

Scanning electron microscope (SEM) observations were performed on cross sections of PDLC with a Leica LEO 420 electron microscope.

RESULTS AND DISCUSSION

The PDLC model system presents a distribution of droplet radii ranging from less than 0.3 to more than 0.6 μm. SEM observations performed on all other samples show no drastic morphology differences between samples up to 10 weight % of monomer substitution. The droplet radius values are about 0.5 μm and comparable droplet densities are observed.

Slightly smaller droplets were observed for higher monomer concentration. Unstable fluid mixtures are obtained for monomer substitutions larger than 20 weight %.

Figure 1 shows the dependence of the transmittance on the applied voltage obtained trough PDLC films at different concentrations of monomer substitution.

The transmittance curve for the pure PMMA/TN10427 sample is reported in every graph as a reference. It can be observed that such sample does not reach the full ON state as it requires voltages higher than 250 Volts and shows a low slope due probably to the droplet size dispersion.

If small amounts of PMMA are replaced by whichever monomer we observed two main common characteristics:

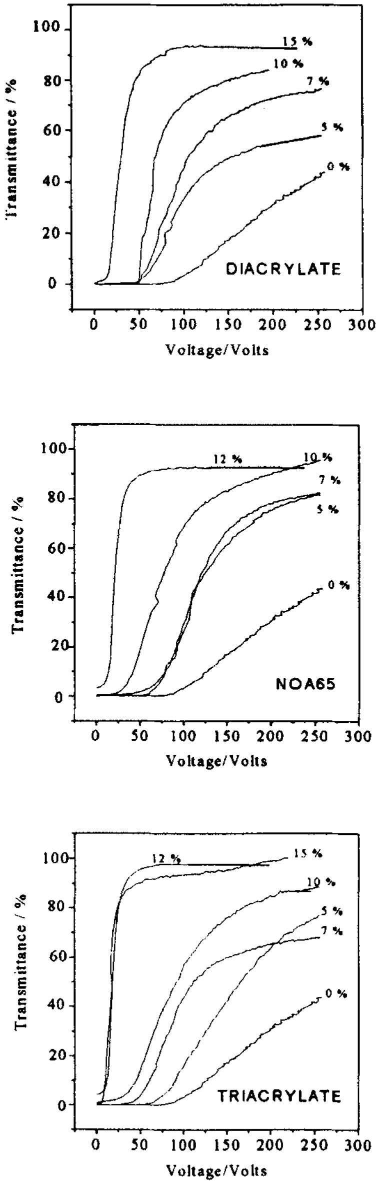

FIGURE 1 Voltage dependent transmittances trough PMMA/TN10427 films for different monomer substitutions of PMMA.

1. a strong reduction of the switching voltages,
2. an increase in the slope of transmittance versus voltage curves, i.e. a sharp threshold is present.

Both characteristics are monomer concentration dependent and are enhanced by the increase of monomer substitution. Such behaviour can be explained by a changed boundary condition between polymer matrix and liquid crystal in droplets, being the morphologies very similar.

Rise and decay time values for model PMMA/TN10427 cell are, respectively, about 4.2 ms and 1.4 ms in agreement with other data reported in literature for PMMA based PDLC.[10]

Figure 2 shows the electro-optical response of PDLCs as a function of monomer weight substitution. We observe a decrease of τ_{rise} and an increase of τ_{decay} as the concentration of monomer is increased up to 10 weight % followed by an inversion of such trend for higher concentrations. From a theoretical point of view the rise and decay times for a PDLC with a shape anisotropy, *l*, and a droplet radius, R, scales as[12]:

$$\tau_{rise} \approx \frac{\gamma}{\Delta\varepsilon E^2_{appl} - \frac{k(l^2-1)}{R^2}} \tag{1}$$

$$\tau_{decay} \approx \frac{R^2\gamma}{k(l^2-1)} \tag{2}$$

where E_{appl} is the applied electric field, while $\Delta\varepsilon$ is the dielectric anisotropy, k and γ are, respectively, the elastic constant and the rotational viscosity constant of liquid crystal in droplets in the one constant approximation. The experimental behavior is then, easily, explained by taking into account both the morphology analysis and the voltage dependent transmittance previously described.

Up to 10 weight % of monomer substitution, i.e. in the concentration range where no substantial morphology change is observed, the added monomer acts as a plasticizer of polymer giving rise to a softer matrix (i.e. an homogeneously dispersed droplet size distribution is obtained) and a lower anchoring force of liquid crystal molecules to polymer wall. For higher monomer concentration, τ_{rise} and τ_{decay} values are affected by the droplet size decrease (equations 1 and 2) due, in our opinion, to a better mutual solubility between polymer and liquid crystal.

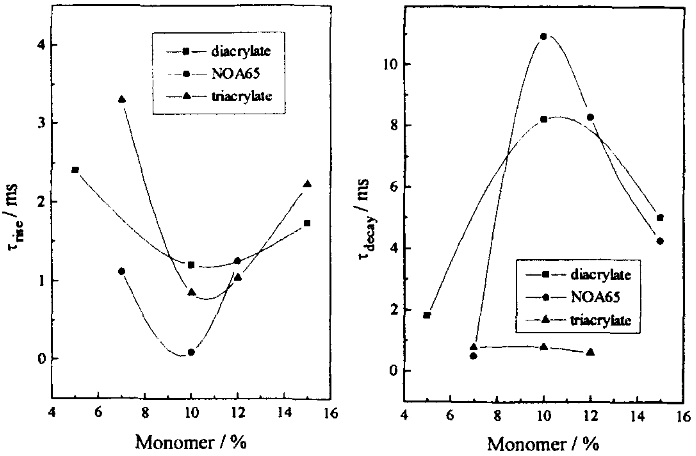

FIGURE 2 Rise (left) and decay (right) times for PDLC samples as a function of monomer substitution. Lines are just a guide to eyes.

CONCLUSIONS

We have shown that electro-optical properties of PDLCs can be improved by substituting small amounts of thermoplastic matrix with the same quantity of monomer as it determines a more homogeneously dispersed droplet size and a change of the interaction strength between polymer walls and liquid crystal molecules.

ACKNOWLEDGMENTS

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