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Proceeding Paper

Spectral Properties of Tunable Privacy Window Films Made of Polymer-Dispersed Liquid Crystals †

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Featured Application: **Tunable privacy window operating in a wide spectral range.**

Abstract: Modern applications of polymer-dispersed liquid crystals (PDLC) made of liquid crystal droplets dispersed in polymer matrices continue to grow. They include privacy and smart windows, flexible diffusers, advanced displays, energy storage and energy harvesting devices, to name a few. An electrically controlled switching between opaque and transparent states of PDLC films enables their numerous applications. An applied electric field reorients an average director of a liquid crystal droplet resulting in a gradual transition from an opaque to a transparent state. A fully transparent state is observed if the refractive index matching is achieved. As a rule, electro-optical characterization of polymer dispersed liquid crystals is performed using a laser. As a result, basic physical parameters such as switching times, contrast ratio, and transmittance are obtained for a single wavelength of light. Even though the spectral dependence of electro-optical properties of PDLC films was mentioned in several papers, systematic studies reporting the dependence of contrast ratio, transmittance, and switching curves of PDLC films on the wavelength of light are still missing. In this paper, electrically controlled spectral properties of PDLC films are reported. The obtained dependence of the contrast ratio and transmittance on the wavelength of light can be used for the optimization of electro-optical performance of polymer-dispersed liquid crystals.

Keywords: privacy window; polymer-dispersed liquid crystals; spectral properties; electro-optics

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1. Introduction

By mixing liquid crystals with polymers advanced composite materials with new functionalities can be achieved [1]. Polymer-dispersed liquid crystals (PDLC) made of liquid crystal droplets dispersed in polymer matrices are an important class of such materials. Modern applications of PDLC continue to grow. In addition to conventional privacy windows, they include flexible diffusers, advanced displays, energy storage and energy harvesting devices, to name a few [2,3].

Recent demands for smart windows revitalized the field of polymer-dispersed liquid crystals [4–6]. In general, an electrically controlled switching between opaque and transparent states of PDLC films enables their numerous applications. An applied electric field reorients an average orientation of liquid crystalline molecules within a droplet resulting in a gradual transition from an opaque to a transparent state [4–6]. As a rule, electro-optical characterization of polymer-dispersed liquid crystals is caried out using a monochromatic light source. From perspectives of smart windows applications, it is critical to study the dependence of electro-optical response of PDLC samples on the wavelength of light [7–10]. In this report, we present the results of systematic studies of spectrally dependent electro-optics of polymer-dispersed liquid crystals.

2. Materials and Methods

Polymer-dispersed liquid crystals were produced by mixing nematic liquid crystals (E44) and UV-curing adhesives (NOA65) [11]. Basic physical parameters of nematic liquid crystals E44 (from British Drug House (BDH) Chemicals) can be found in paper [12] and some optical and viscoelastic properties of NOA65 are provided by its manufacturer [13]. The mixture sandwiched between two indium-tin oxide (ITO) glass substrates was exposed to a UV irradiation. The UV light initiates the polymerization-induced phase separation leading to the formation of polymer-dispersed liquid crystals.

Optical characterization was carried out using a polarizing microscope equipped with a digital camera and a heating stage. A standard electro-optical characterization of polymer-dispersed liquid crystals includes a laser, PDLC sample, source of electric field (the combination of a waveform generator and amplifier), and light detector (photodiode) [4,14]. In this case, an intensity of light passing through a PDLC sample can be measured by a photodiode as a function of the applied voltage. In this paper, in addition to a standard electro-optical setup, a modified experimental arrangement was used. More specifically, a photodiode was replaced with a fiber optic spectrometer, and a laser was replaced with a wideband light source, in a similar way as it was done in paper [10]. As a result, voltage-dependent spectral properties of PDLC samples were measured.

3. Results and Discussion

Electro-optical performance of PDLC samples can be affected by many factors including its thickness, and wavelength of light [4–6]. In this report we prepared samples of varying composition and thickness. By applying an external electric field across a sample, an opaque state could be switched into transparent one as shown in Figure 1.

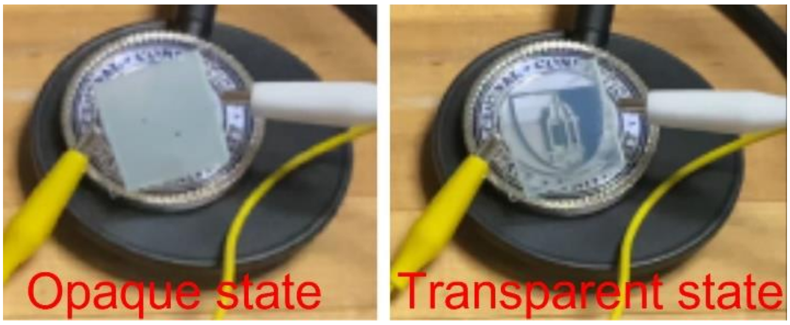

Figure 1. Opaque and transparent states of the produced PDLC samples made of nematic E44 and NOA 65 (50%:50% mass ratio).

To study the effect of the wavelength of light on electro-optical performance of PDLC samples electro-optical response of PDLC samples (transmittance versus applied voltage) was measured at several wavelengths of light. Figures 2 and 3 show electro-optical curves measured for two types of PDLC samples at several wavelengths of light (400 nm, 500 nm, 600 nm, 700 nm, and 800 nm). Figures 2 and 3 are characterized by similar features. The transmittance of light increases as wavelength of light gets longer. In addition, the voltage required to switch a sample from opaque state to a transparent one decreases as the wavelength increases.

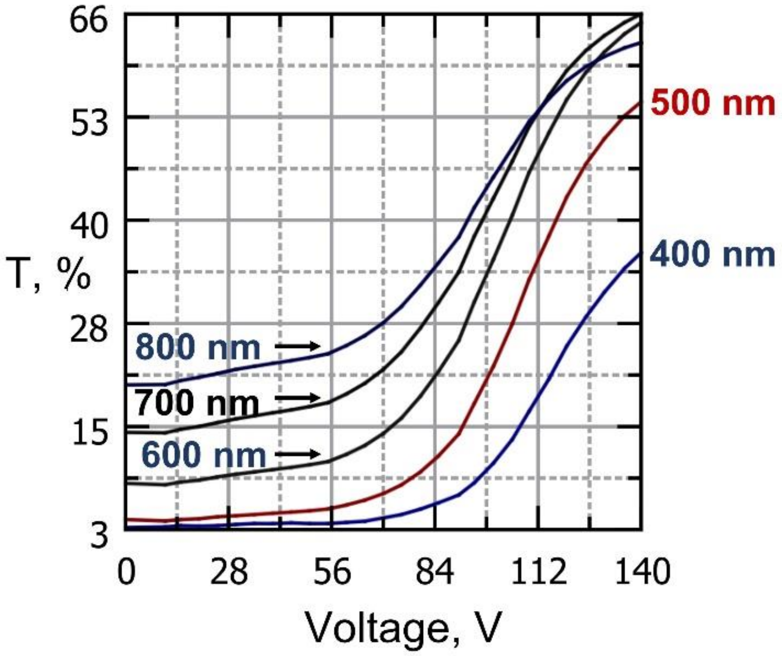

Figure 2. Electro-optical curves (transmittance vs. applied voltage) of PDLC sample made of nematic E44 and NOA 65 (50%:50% mass ratio). The thickness of PDLC film is 28 μm.

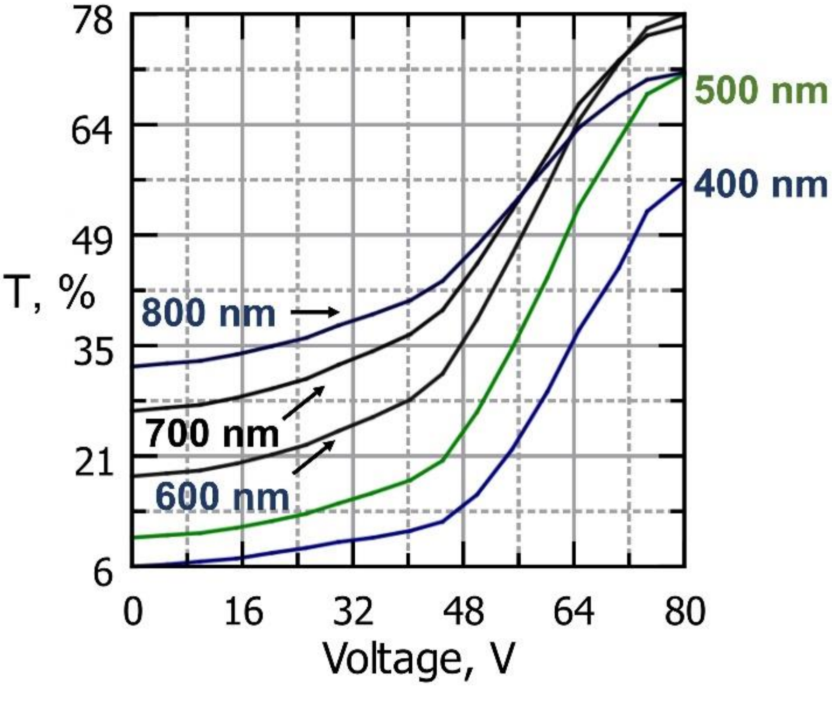

Figure 3. Electro-optical curves (transmittance vs. applied voltage) of PDLC sample made of nematic E44 and NOA 65 (60%:40% mass ratio). The thickness of PDLC film is 15 μm.

Figures 2 and 3 were used to find a contrast ratio of the studied PDLC samples shown in Figure 4.

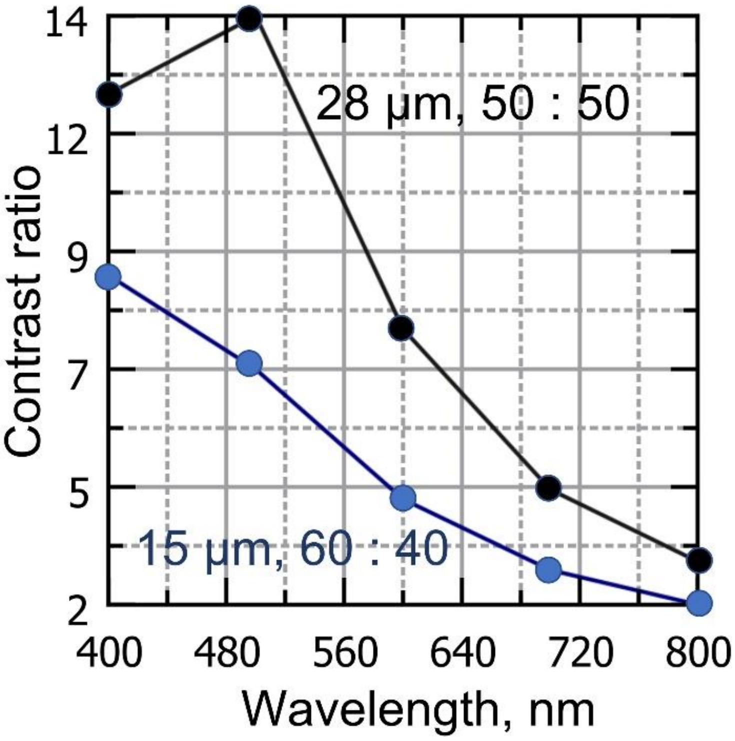

Figure 4. Spectral dependence of the contrast ratio of the studied PDLC sample made of nematic E44 and NOA 65.

As can be seen from Figure 4, the contrast ratio of the studied PDLC samples strongly depends on wavelength of light. A 50%:50% PDLC sample exhibits non-monotonous dependence of the contrast ratio on the wavelength of light. At the same time, a contrast ratio of a 60%:40% PDLC sample decreases monotonically as the light wavelength gets longer (Figure 4).

4. Conclusions

Our results (Figures 2–4) indicate that performance of a PDLC sample as a privacy window is strongly affected by the wavelength of light. The contrast ratio increases as the cell thickness goes up. Interestingly, the dependence of the contrast ratio on the wavelength of light can be both monotonic and non-monotonic depending on the composition and thickness of the PDLC samples (Figure 4). Additional studies are needed to shed light on relationships between the morphology of the samples and the observed dependence of the contrast ratio on the wavelength of light.

The obtained experimental results shown in Figures 2–4 can be used to tailor the performance of polymer-dispersed liquid crystals to the chosen electro-optical application such as smart windows.

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