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Cholesteric Polymer-Dispersed Light Shutters

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Cholesteric/polymer dispersed light shutters

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We report cholesteric/polymer dispersed (CPD) materials that switch from a reflecting, planar state to a relatively transparent, focal conic state. The reflective wavelength of the CPD materials can be continuously adjusted by varying the cholesteric pitch length. The electro-optic properties of these materials are similar to the recently reported polymer stabilized cholesteric materials; however, the polymer concentration is sufficient to provide a self-sustaining and self-adhering film, offering the potential of large area devices fabricated on flexible substrates.

Many of the earliest liquid crystal display technologies utilized the variable light scattering properties of cholesteric materials,[1] such as the cholesteric-nematic phase change mode.[2] Optical metastability and storage effects were also observed in the early 1970's for cholesteric mixtures having either positive or negative dielectric anisotropy and having homogeneous or homeotropic alignment.[3,4] None of these early cholesteric display devices was commercially developed because of material limitations, long response times and the commercial interest in twisted nematic displays developed about the same time.

Recently, Doane and Yang reported devices utilizing polymer stabilized cholesteric textures (PSCT), which can be electrically switched to a planar, reflecting state or to a focal conic, transparent state.[5–8] These materials are bright and optically multistable, making high resolution multiplexed displays feasible. The PSCT materials are formed from a solution of photocurable acrylate dissolved at a low concentration in a chiral nematic mixture. The solution is used to fill a cell having transparent conducting electrodes and a polyimide alignment layer. The solution is then photocured while an electric field is applied across the cell, stabilizing the focal conic texture. The resulting shutter can be switched from the planar to focal conic states by applying a higher or lower potential electric field, respectively. We report here on cholesteric/polymer dispersed (CPD) materials, which have electro-optic properties similar to PSCT materials but can be used to form self-adhering, self-sustaining films.

Two chiral components, CE2 and CB15 (EM Chemicals), were mixed in a 50:50 weight ratio. The chiral mixture was then added to the nematic host E48 (EM Chemicals). The concentration of the chiral components in the nematic host determines the pitch length and therefore the reflectivity of the resulting mixture (Fig. 1). Shutters of different colors can be easily fabricated by adjusting the amount of chiral component.

Table I lists the weight percent of the components used to make a CPD shutter. AU1033 is a hydroxy functionalized polymethylmethacrylate supplied by Rohm and Hass. The 1,6-diisocyanatohexane serves to slowly crosslink the AU1033 over time. The above materials were dissolved in toluene and the resulting solution poured on an indium tin oxide coated substrate. Ten micron polystyrene spheres were added to the mixture to control thickness. The sample was heated to 120 °C and the toluene allowed to evaporate. A second indium tin oxide coated glass substrate was heated at the same time. Once the toluene had completely evaporated, and with the temperature maintained at 120 °C, the second substrate was used to form a sandwich and 20 pounds per square inch of pressure was applied for 5 min, causing the substrates to contact the spacers. The resulting shutter was then cooled to room temperature.

The electro-optic response of the resulting shutters was measured using a customized electro-optics setup described in Ref. 6. Reflectivity measurements were made using a Perkin Elmer λ4B spectrophotometer equipped with an integrating sphere.

The reflectivity of a chiral nematic mixture composed of CE2/CB15/E48 in a weight ratio of 1:1:3 and of the resulting CPD are shown in Figs. 2(a) and 2(b), respectively. The chiral nematic mixture is in the planar state and has a reflectivity peak at 564 nm. Dispersing the mixture in

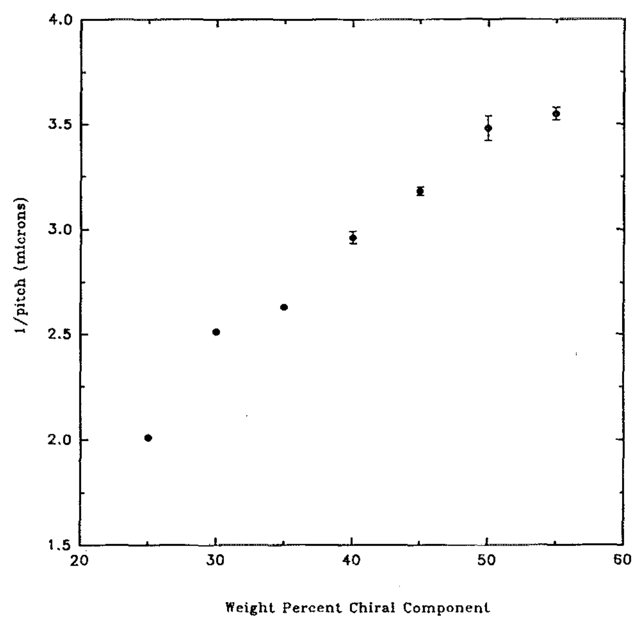

FIG. 1. Pitch length of CPD films in the planar state plotted as a function of the weight percent of the chiral component in the chiral nematic mixture. Each point is an average of three different samples. The standard deviation is indicated by the error bars. The chiral component consists of a 50:50 blend by weight of CE2 and CB15. E48 is the nematic host.

[a]Also at Motorola Corporation, 8000 W. Sunrise Blvd., Ft. Lauderdale, FL 33322.

TABLE I. Weight percent of components of PDC.

Component	Weight percent
AU1033	20
1,6-Diisocyanatohexane	5
Chiral nematic mixture	75

the AU1033 binder serves to lower the reflectivity peak for the planar state to 534 nm and change the shape of the curve. Also, cursory observation shows that the reflectivity wavelength of the CPD shutter changes much less with observation angle than does the original chiral nematic mixture. The lower wavelength reflectivity maximum for the CPD is the result of the AU1033 binder, which may induce either a distribution in the alignment of the pitch axis or shorten the pitch length of the chiral nematic. The domain structure of the dispersed system in the focal conic state scatters light uniformly over the visible portion of the spectrum, with the back scattered intensity gradually increasing at lower wavelengths.

The planar and focal conic states are both stable at zero applied field. The sample can be switched between the two states of application of voltage pulses of different amplitudes. Figure 3 shows the optical response as a function of time and applied voltage pulses for a 10 μm thick CPD shutter utilizing the above mixture. The reflectivity of the sample was measured at 540 nm. No measurements of the reflectivity wavelength were made during switching. The material is initially in the focal conic state and the reflectivity is at a minimum. A 130 V dc pulse of 20 ms duration was applied after 125 ms (point a), switching the cell to the planar reflecting state. Approximately 100 ms is required to switch from the focal conic to the planar state. The reflectivity of the planar state is constant until a second, 80 V pulse is applied after 1.25 s (point b), switching the shutter back to the focal conic state. Switching from the planar to focal conic state occurs in less than 10 ms.

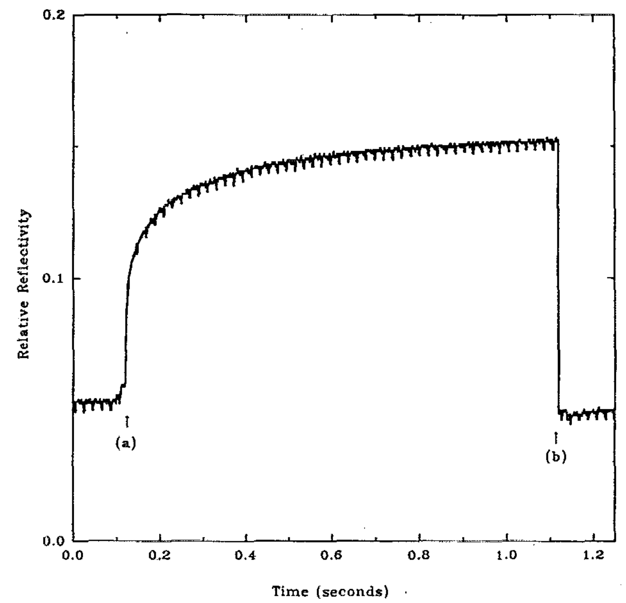

FIG. 3. The optical reflectivity of a CPD shutter plotted as a function of time. A 130 volt dc pulse of 20 ms duration is applied at point (a). An 80 V dc pulse of 20 ms duration is applied at point (b).

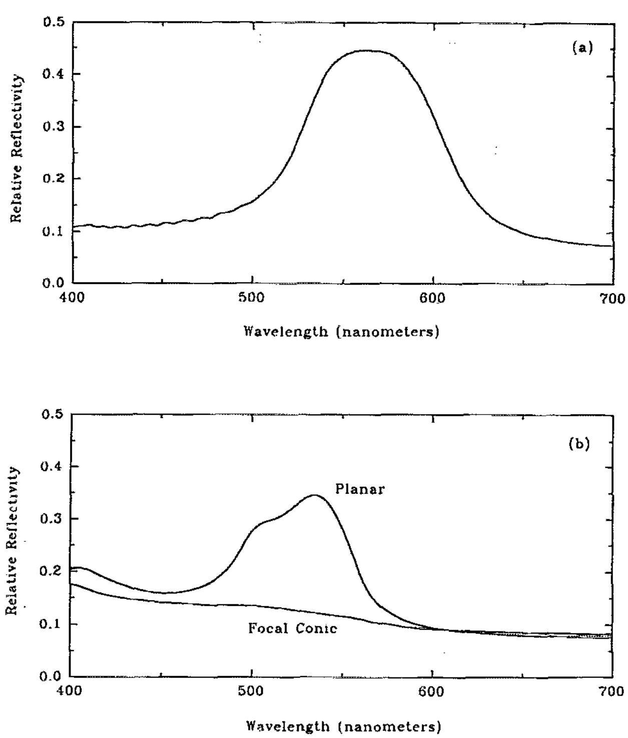

FIG. 2. Relative reflectivity plotted as a function of wavelength for (a) a chiral nematic mixture composed of CE2/CB15/E48 in a 1:1:3 weight ratio, and (b) a CPD shutter composed of the above chiral nematic mixture and the other components listed in Table I, in either the planar or focal conic state.

Figure 4 shows the bistability of the CPD mixture. A 20 ms dc voltage pulse of varying amplitude is placed across the sample and the optical reflectivity of the sample is measured 800 ms later. The measured optical reflectivity is plotted as a function of the applied voltage. Pulses of lower than 50 V have no effect on either the focal conic or planar state. Pulses between 50 and 80 V partially switch the planar to the focal conic state. The intermediate reflective states are also stable with time and the reflectivity wavelength is the same as the pure planar state. Microscopic observation of these states indicates that some domains of the material remain in the planar state while other domains are switched to the focal conic state. The reflectivity amplitude is determined by the relative proportion of these two domains. Pulses of 80 V completely switch the planar to the focal conic state. Voltage pulses between 80 and 110 V also produce mixed planar and focal conic domains.

Voltage pulses greater than 100 V are required to vary the reflectivity of the shutter in the focal conic state. As with shutters initially in the planar state, mixed domains are achieved for pulses between 110 and 120 V. Pulses greater than 120 V switch the shutter completely to the planar state. A flat black background maximizes the visual

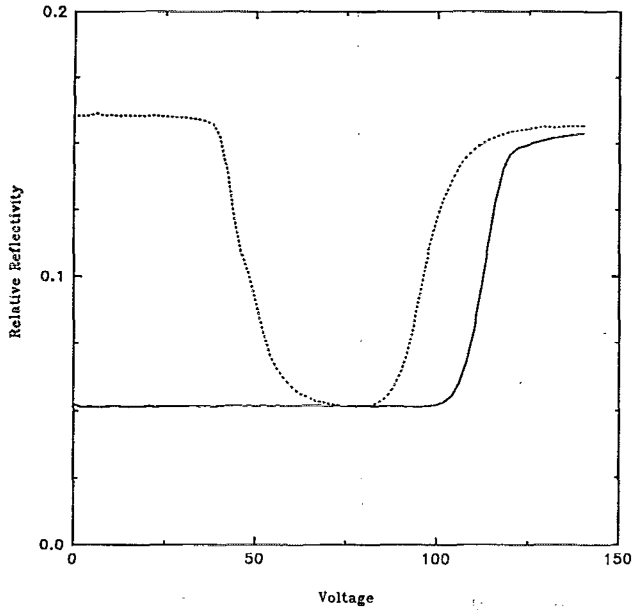

FIG. 4. Optical reflectivity of a CPD shutter initially in either the planar (dotted line) or focal conic (solid line) state plotted as a function of the voltage of an applied pulse. The voltage pulse is 20 ms in duration. The optical reflectivity is measured 800 ms after application of the pulse.

contrast of the CPD shutter by absorbing the transmitted light, leaving only the light reflected by the chiral nematic to be observed. The planar and focal conic states of the CPD materials are stable for long periods. Both states have been observed for months with no observed change in their texture or optical reflectivity. The CPD materials will be useful for high resolution, multiplexed, direct view displays. They form self-sustaining and self-sealing films, allowing easy fabrication of large area devices on glass or plastic substrates. Surface alignment techniques are not required, simplifying fabrication of devices.

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