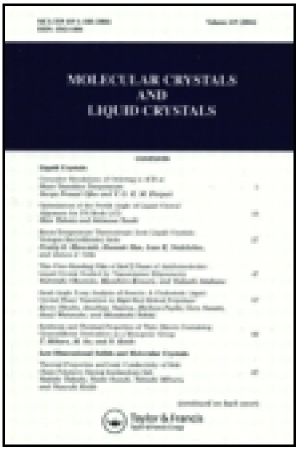

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SPATIAL LIGHT MODULATOR BY USING POLYMER CELL-WALL TYPE LIQUID CRYSTAL OPTICAL SHUTTER

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Abstract Polymer Cell-Wall Type Liquid Crystal (PCW-LC) light shutter has been developed. This is a kind of liquid crystal-polymer complexes (LCPCs), utilizing the light scattering of cholesteric focal conic texture. However, its abilities are superior to other LCPCs reported. As the cholesteric liquid crystal grains are covered with thin polymer films, the polymer content is very small, around 10 wt%. Consequently, the driving voltage is very low (Ca.5-6V). This type of LC light shutter has the great advantage of non-polarizer usage. Therefore, this type of light shutter can be useful for not only liquid crystal display devices but also other applications, for example, spatial light modulator (SLM). In this work, PCW-LC is introduced at first, and then the applications of PCW-LC light shutter to SLM is described. Non-polarizer usage makes it easier to combine it with the other component parts for producing a SLM.

INTRODUCTION

Many attempts have been reported to make Spatial Light Modulators using liquid crystal optical shutter [1]. However, a few have intended to utilize the advantage of non-polarizer usage. One of the reason may be due to difficulty to obtain a qualified light shutter without the usage of polarizers. The abilities of Polymer Cell-Wall Type Liquid Crystal (PCW-LC) light shutter which has been developed by us [2,3] are suitable for applications. This is a kind of liquid crystal-polymer complexes (LCPCs), using the light scattering of cholesteric liquid crystals [4]. As the cholesteric liquid crystals domains covered with thin polymer films, polymer content is very small, around 10 wt%. It is pointed out that the advantage of this PCW-LC light shutter is non-polarizer usage. Consequently, this type of light shutter can be useful for not only liquid crystal display devices but also other applications, especially spatial light modulator, because of non-polarizer usage, it becomes easier to combine other components to construct a spatial light modulator. In this work, the application of PCW-LC light shutter to a spatial light modulator will be introduced.

At first Polymer Cell-Wall Type Liquid Crystal (PCW-LC) light shutter will be introduced. Then, later the application of the light shutter to make a spatial light modulator will be.

POLYMER CELL-WALL TYPE LIQUID CRYSTAL (PCW-LC) SYSTEM

Recently polymer-dispersed liquid crystals (PDLCs) and liquid crystal-polymer complexes (LCPCs) are of great interest for display applications, since they have a lot of advantages, such as non-polarizer usage, easy fabrication and manufacture of large area display devices [5,6]. However, there remain problems in the threshold-voltage, response time and transmittance [7]. The Polymer Cell-Wall Type Liquid Crystal (PCW-LC) Optical Shutter has been developed by us [4] utilizing the tremendous light scattering of polydomain focal conic texture of cholesteric liquid crystals (ChLCs). Some attempts have been reported for developing an optical shutter using this property [8]. The time for polydomain texture reformation should be controlled to improve the quality. One way for this is to improve the cholesteric twisting power, and another is to introduce the polymer wall effects. First of all, the attempt that has been done to improve the turbidity and decay-time of LCPC films by controlling the cholesteric twisting power and the polymer wall effect will be introduced. We would rather call PCW-LCs mainly because the polymer thin films coat the cholesteric liquid crystal grains in our system [3,4]. The ratios of ChLC, NeLC [a cholesteric liquid crystal obtained by mixing ChLC+nematic liquid (NeLC)] and prepolymer were selected by comparing many experimental results [3,7]. A homogeneous solution of liquid crystal (LC) and prepolymer was firstly sandwiched between the two ITO-coated glass plates with a spacer of thickness (7.5μm-12.5μm), and then polymerized under UV light for 5-6min. The solution could become a two phase system. The polydomain ChLCs gradually appeared during the polymerization. Thus, the very small size particle-like LC grains covered with thin polymer films were formed within the cell. The thickness of the cell introduced here is 10μm.

The electro-optical properties of LCPC were investigated using OS-6411C Digital Storagescope (Iwatsu Co.Ltd.) with He-Ne lazer or white light as the light sources.

The Electro-Optical Properties of PCW-LC

It is well known that when a small amount of pure ChLCs is added to NeLCs, the mixed LCs will become ChLCs. As the nematic component 5-CB (4-cyano-4'-pentyl biphenyl) was used for all experiments reported here, because of quick response of orientational change of molecules to applied electric field. At first step, two cases were compared when cholesterol acetate and MC-15 (biphenyl type, Merck) were used as the cholesteric component. The best results obtained hitherto are shown in Figure 1 and Figure 2. As seen from the Figures, Case A gives (MC-15 being used as the cholesteric component) much better results than Case B (Cholesterol acetate being used as the cholesteric component). For example, the transmittance becomes maximum (68%) at V=9(V) in Case A, while in Case B it is observed at more than 12 V. Concerning response times τ_r and τ_d at 6V, for Case A they are a little bit longer than Case B. The components of the PCW-LCs are shown in Table 1.

TABLE 1 PCW-LC(C) Components and Properties

Components			Properties
Materials	Name	Contents	
NeLCs	4 cyano 4' pentyl biphenyl (5 CB)	90.55%	Volt=5-6 V
			τ_r=3-7 ms
ChLCs	Cholesteric (MC 15, Merck)	0.25%	τ_d=8-10 ms
SmC*LCs	ZLI4237 100 (Merck)	0.20%	T=75-78 (%)
Polymer	Poly (a kind of acrylate)	9.00%	Conts. ≒ 150

The Effects of Addition of Chiral Smectic LC for LC Optical Shutter

Electro-Optical properties of cholesteric LCs and polymer complexes are described above. It is interesting to know what happens when chiral smectic LC is added to the cholesteric LC systems. Chiral smectic LC are known to form also focal conic textures. Combination of the cholesteric focal conic texture and Smectic C* focal conic texture are interesting. It was found that the effect of additioning chiral smectic LCs on electro-optical properties are good, when the helical sense of smectic C* coincides with that of Cholesteric LCs [4]. As shown in Figure 3 (Case C), the additions of chiral smectic (ZLI4237) improve the Transmittance-Voltage properties, that is, the threshold voltages become lower and the transmittances at 6V increases very much (more than 75%).

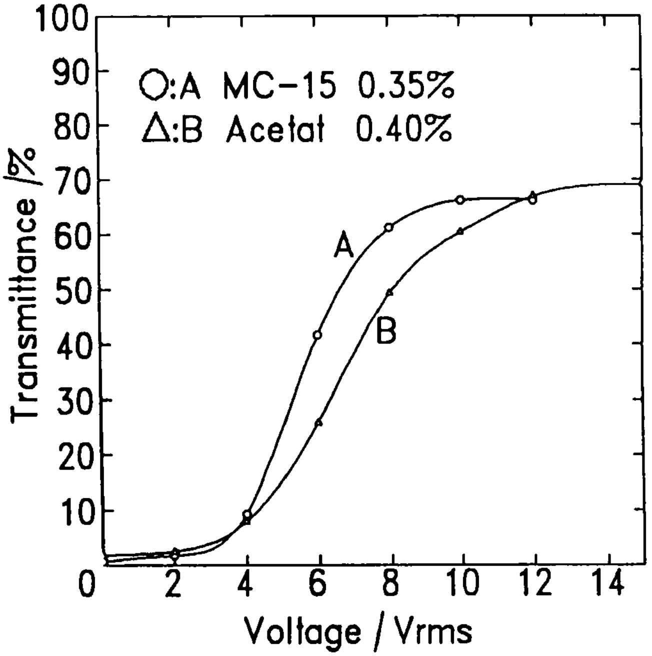

FIGURE 1 Changes of transmittance and response times of Case A and Case B against applied voltage at 500 Hz.

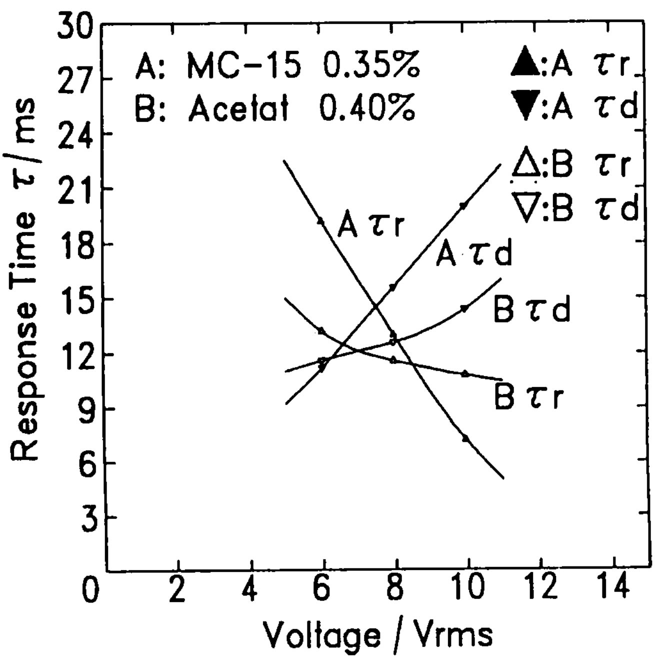

FIGURE 2 Comparison of response times for Case A with Case B at various applied voltage at 500 Hz.

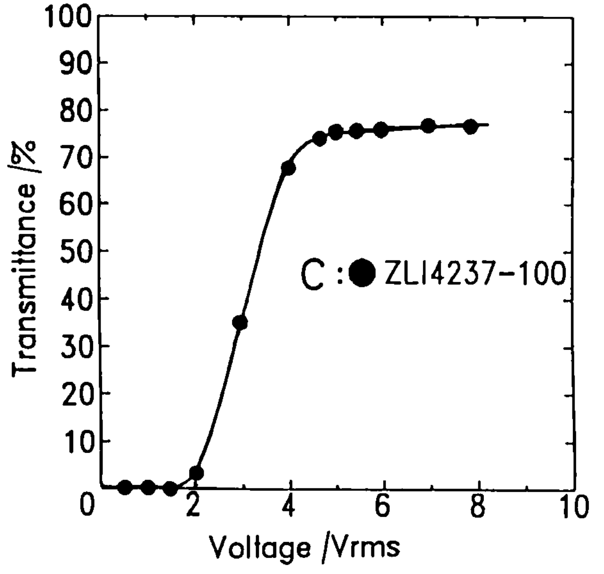

FIGURE 3 Changes of transmittance against applied voltage at 500 Hz for Case C.

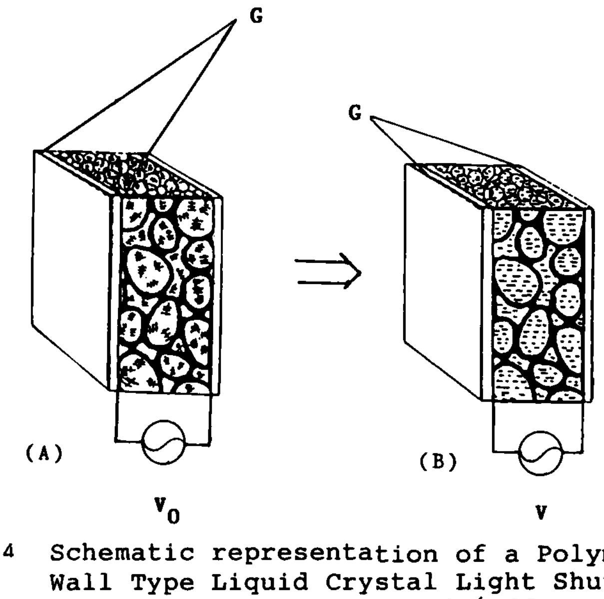

FIGURE 4 Schematic representation of a Polymer Cell-Wall Type Liquid Crystal Light Shutter.
(A):No voltage is applied (Off state).
(B):A voltage is applied (ON state).
G:ITO coated glass plates

As evidently shown in Figure 3, the LCPC film using combination of Cholesteric LC and Smectic C* has a very low driving voltage, very quick response time and also high contrast ratio for electro-optical application, as shown in Table 1. The electro-optical properties of LCPC are greatly affected by twisting power of cholesteric liquid crystals and polymer wall effect. It is clear that one can develop various kinds of LCPC films which have different driving voltage, response time and contrast ratio for light shutter and display applications by controlling polydomain textures of LCs and polymer wall effect in LCPC's films. Besides, it was found that the temperature during polymerization would greatly affect the turbidity of LCPC films after polymerization, which will be reported in near future. PCW-LC is a kind of LCPC. The schematic illustrations of PCW-LC light shutter is shown in Figure 4.

SPATIAL LIGHT MODULATOR

Construction of a Spatial Light Modulator

The construction of the spatial light modulator is as follows: transparent conductive glass plate + photo conductor plate + light absorber + dielectric mirror + PCW-LC + transparent conductive glass plate + anti-reflective coating. The schematic representation of a Polymer Cell-Wall Type Liquid Crystal Spatial Light Modulator is shown in Figure 5.

An Apparatus for the Testing of PCW-LC is Suitable for SLM

The essential parts of this SLM (Spatial Light Modulator) are the photo conductor and PCW-LC which are sandwiched by the two transparent conductive plates. An apparatus for the testing of PCW-LC for a SLM usage was constructed. The construction of the cell is: transparent conductive coated glass plate + photo conductive plate + PCW-LC + transparent conductive coated glass plate. Schematic diagram of the apparatus for testing is shown in Figure 6. When a light beam for writing light irradiates to photo conductor, the opening and closing of the light shutter of PCW-LC is controlled by the light intensitiy of writing light (LSW). The light beam from LS will pass through the PCW-LC cell when writing light intensity is strong enough. Here filtered monochromatic green light is used as writing light. When the light is irradiated on photo-conductive plate, the resistance of the photo conductive plate is reduced and the electric voltage is applied to PCW-LC. Then the optical shutter will be open, and

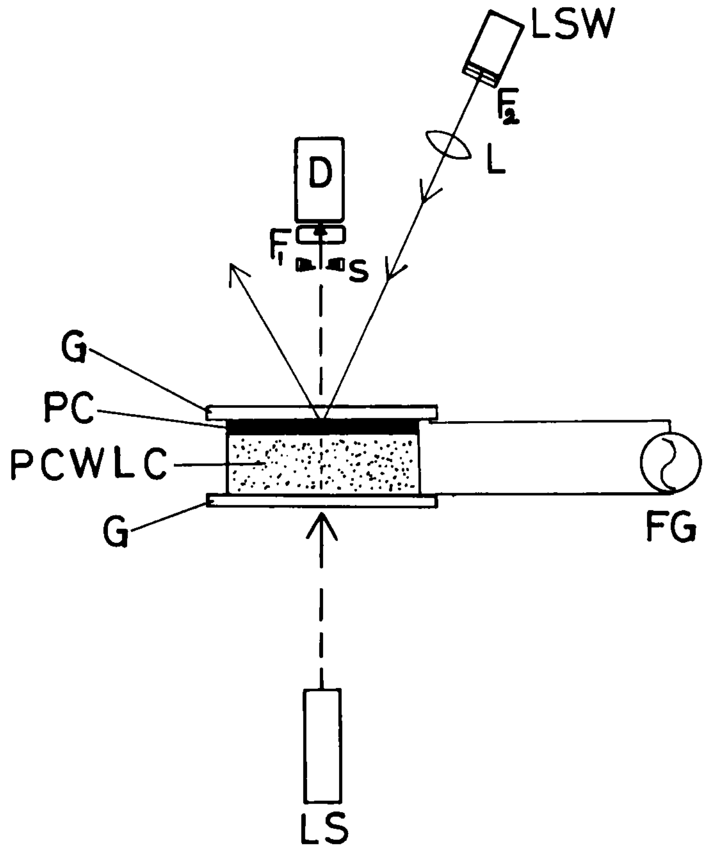

FIGURE 5 Schematic diagram of the apparatus for the testing of a SLM (Spatial Light Modulator) unit using Polymer Cell-Wall Type Liquid Crystal (PCW-LC) Light Shutter.

LS:Laser light source (He-Ne)
S:Slite
F_1 :Filter(6328A)
D:Detector for laser light intensities
LSW:Light source of condenced light for open shutter
F_2 :Filter to get monochromatic light
L:Lens
G:ITO coating glass plates
PC:Photoconductor
PCW-LC:Polymer cell-wall type liquid crystals
FG:Function generator.

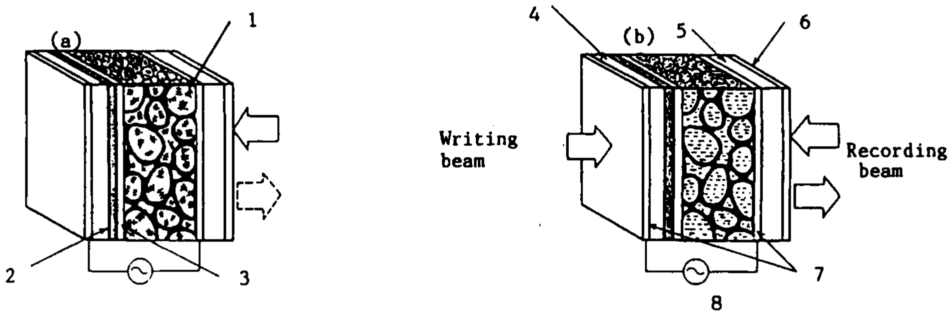

FIGURE 6 Schematic representation of a Polymer Cell-Wall Type Liquid Crystal Spatial Light Modulator.
1:Polymer cell-wall type liquid crystal
2:Light absorber
3:Dielectric mirror
4:Photoconductor
5:Glass plate
6:Antireflective coating
7:Transparent electrodes
8:Voltage source(Function generator).

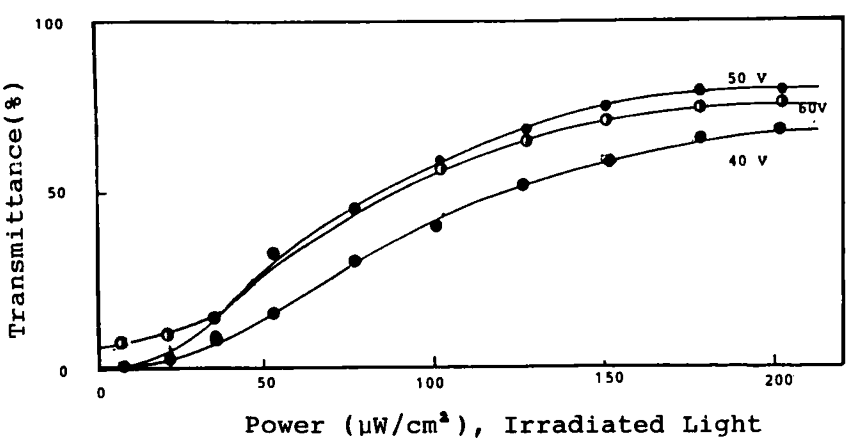

FIGURE 7 Transmittance against irradiated power

the reading light (LS) can pass through. The light intensity passing through the PCW-LC cell is controlled by writing light intensity.

RESULTS

Some examples of the relation between transmitted light intensity and irradiated light intensity are shown in Figure 7. As is seen from the Figure, the transmittance curve is best when applied 50 V. In this case, the thicknesses of photo-conductor BSO-crystal and PCW-LC are, respectively, 0.1mm and 10μm. Considering above the results, our SLM was tested as an image converter of moving image using monochromatic light (green) for projection (Recording beam) and the writing beam was projected onto photo conductor plate passing through 1.6 inch TV panel. The projection screen size was 24 inch. The moving image projected on the 24 inch screen seems rather good. The thinner the photo-conductor plate used, the better the distinction of the enlarged image projected.

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