Photoaligning and Photopatterning Technology:

Applications in Displays and Photonics

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ABSTRACT

The advantages of LC photoalignment technology in comparison with common "rubbing" alignment methods tend to the continuation of the research in this field. Almost all the criteria of perfect LC alignment are met in case of azo-dye layers. Nowadays azo-dye alignment materials can be already used in LCD manufacturing, e.g. for the alignment of monomers in LCP films for new generations of photonics and optics devices. Recently the new application of photoaligned technology for the tunable LC lenses with a variable focal distance was proposed. New optically rewritable (ORW) liquid crystal display and photonics devices with a light controllable structure may include LC E-paper screens, LC lenses with a variable focal distance etc.
Fast ferroelectric liquid crystal devices (FLCD) are achieved through the application of nano-scale photo aligning (PA) layers in FLC cells. The novel photoaligned FLC devices may include field sequential color (FSC) FLC with a high resolution, high brightness, low power consumption and extended color gamut to be used for PCs, PDAs, switchable goggles, and new generation of switchable 2D/3D LCD TVs, as well as photonics elements.

Keywords: liquid crystal, photoalignment, photopatterning, display, photonics, lenses, optically rewritable devices, highly efficient polarizers, fast ferroelectric LCD.

1. Introduction

Commercial photoalignment materials are now readily available. Many new applications, in addition to the alignment of LCD, have been proposed and demonstrated. In particular, the application of photoalignment to active optical elements in optical signal processing and communications is currently a hot topic in photonics research [1].
Photoalignment possesses obvious advantages in comparison with the usually "rubbing" treatment of the substrates of liquid crystal display (LCD) cells. Possible benefits for using these techniques include new advanced applications in displays and photonics, fiber communications, optical data processing, holography and other fields, where the traditional rubbing LC alignment is not possible due to the sophisticated geometry of LC cell and/or high spatial resolution of the processing system. New optical elements for LC technology, such as highly efficient polarizers based on polarization grating and patterned phase retarders, optical lenses with voltage controllable focal distance, optically rewritable devices etc. can be also successfully made by photoalignment and photopatterning technology.
Photo-alignment possesses obvious advantages in comparison with the usually "rubbing" treatment of the substrates of liquid crystal display (LCD) cells. Possible benefits for using this technique in display and photonics LC devices include [1]:
(i) new advanced applications of LC in fiber communications, optical data processing, holography and other fields, where the traditional rubbing LC alignment is not possible due to the sophisticated geometry of LC cell and/or high spatial resolution of the processing system;
(ii) ability for efficient LC alignment on curved and flexible substrates;
(iii) manufacturing of new optical elements for LC technology, such as patterned polarizers and phase retarders, LC E-paper, fast ferroelectric LC devices etc.
The photoaligning materials developed by us are enable [1,2]: (i) high order parameter more than 0.8; (ii) excellent alignment quality of nematic and ferroelectric LC materials in various modes; (iii) temperature and UV stability due to

Emerging Liquid Crystal Technologies XI, edited by Liang-Chy Chien, Dick J. Broer,
Hirotsugu Kikuchi, Nelson V. Tabiryan, Proc. of SPIE Vol. 9769, 97690J

the polymerization and cross-linking effect in dye layers; (iv) perfect adhesion and anchoring energy comparable with rubbed polyimide (PI) layers; (vi) excellent sensitivity with a minimum exposure energy; (vii) ability to align LC materials in curved surfaces and photonic holes.
Here we will demonstrate several applications of LCD photoalignment and photopatterning technology, such as LC E-paper, optical lenses, highly efficient polarizers, fast ferroelectric devices.

2. Optically Rewritable LCD

Optical rewritable technology (ORW) [1,2] is a modified method of azo-dye photoalignment that possesses traditional high azimuthal anchoring energy, up to $2x10^{-4}J/m^2$, and has a unique feature of reversible in-plane aligning direction reorientation, i.e. rotation perpendicular to the polarization of an incident light. An ORW LC cell consists of two substrates with different aligning materials (Fig.1).

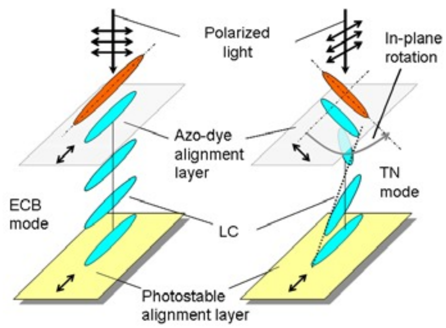

Figure 1. Operation principle of LC ORW cell [1,2].

One aligning material is optically passive and keeps aligning direction on one substrate. The other aligning material is optically active and can change its alignment direction being exposed with polarized light through the substrate. In comparison with electrically controlled plastic display ORW can be significantly thinner and requires no ITO photolithography and etching on plastic substrate because no electrodes are needed. Switching and continuous grey scale of 5 bits or more are achieved by control of aligning direction of photoaligning azo-dye layer, which is insoluble in liquid crystal (Fig.2) [3].

Figure 2. Left: 5 bit gray level image on LC E-paper [3].
Several methods to generate grayscale images on ORW e-paper have been proposed: (i) exposition of the photo-alignment layer with different amount of time or exposure energy, which strongly depends on the thermal treatment of the cell; (ii) division of one pixel to several black or white parts to get gray levels, which reduces the spatial resolution of the image; (iii) light polarization rotation for each pixel.
We fabricated the prototype of this polarization rotator (optical scheme shown in Fig. 3) and characterized its performance to rotate the polarization by controlling the voltage. The substrates of VAN LC cell were spin coated by vertical polyimide PIA8520 and assembled in electrically controlled birefringence (ECB) mode. The VAN cell gap was 8μm with liquid crystal NA0175, its effective refractive index anisotropy measured was Δn=0.045 at the wavelength of 450nm. For the QWP, we coated PI 3744 on the substrate first, and after hard bake it was coated again by 22%

UCL017A at 4000 RPM for 30 seconds. Afterwards, for polymerization, the substrate has been exposed by UV light for 5 minutes. A 450nm 10mW laser, function generator (500Hz, square waveform), photo-detector and motorized analyzer were used to measure the polarization state of the output light. The continuous change of the writing polarization plane is shown in Fig. 3, the red line is theoretical calculation of the rotation angle using the retardation of the VAN LC cell, which was measured by the previous setup.

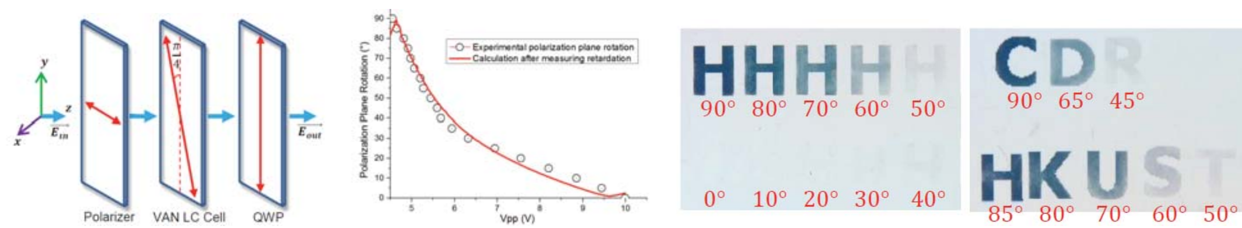

Fig. 3 From left to right: Optical scheme of the polarization rotator; Polarization plane rotation vs voltage; ORW gray levels by using polarization rotator.

It shows not only a sufficiently large step voltage for different gray levels, but also gives a possibility of continuous twist angle of liquid crystal in the ORW e-paper. We used this polarization rotator with different voltage as the mask and exposed the ORW e-paper cell through the mask by 450nm LED array. ORW gray levels are also shown in Fig. 3. The approximate twist angle of each character is marked in red, which was controlled by selecting polarization plane of the polarization rotator.

ORW is very tolerable to the cell gap variation as even 50% changing of the cell gap will not cause noticeable change in LC transmission value, while achromatic switching of all ORW grey levels can be obtained [1,2]. Every transmission level is stable and visualizes information with zero power consumption for a long time. Optical rewritable LC alignment is a good base for new types of LC displays, especially on plastic substrates, when no ITO films and electrodes are needed [1,2]. Recently 3D E-paper was obtained by writing two images in one E-paper, providing 3D effect (Fig.4) [4].

Figure 4. 3D images on E-paper for the left (a) and right (b) eyes of the observer [4].

No backlight is required as reflective type polarizer is used as the bottom substrate. The image is truly stable, can be written to any grey level with the saturation and rewritten a large number of times with a high reproducibility of properties. The overall reflection is about 30%, while the aspect ratio is 1. The unique property of being cell-gap non sensitive allows to maintain proper performance even when the device is bent. The ORW E-paper potential applications are light printable rewritable paper, labels and plastic card displays.

3. Low Voltage Driving Tunable Liquid Crystal Lens using Photoalignment Method

Lenses with an electrically tunable focal length and/or are positionable focus are of broad interest for a number of applications. Because there are no moving parts in such a lens, they can be more reliable and able to withstand mechanical shock. Such tunable lenses can be applied in adaptive binocular glasses, autofocus cameras, LED light steering applications, 2D/3D switchable liquid crystal displays (LCDs) [1,2].

Many photonic devices required lenses with variable focal distance. A zoom lens system usually consists of a group of lenses, the separation distances between which are mechanically adjusted. Mechanical adjusting processes are, as a rule, complicated and bulky. That is the reason for developing a new type of tunable lenses that are compact, lightweight, low-cost, and efficient. Such lenses are highly desirable and urgently needed for purposes of adaptive optics, optoelectronics, machine vision, stereo displays and eyeglasses applications. Due to the property to be controlled with an external electrical field LC cells are especially attractive for tunable lenses.

A tunable lens can be based on a planar uniform cell gap and is controlled with a uniform electrical field [2,5]. The needed gradient profile is achieved due to non-uniform surface conditions, in particular, spatial distribution of the anchoring energy. The LC lens was composed of LC material sandwiched between two transparent flat substrates. Similar to convention LC cells for displays, the inner sides of the substrates was covered with transparent electrodes and alignment layers. Specific of the LC lenses to be considered is that the anchoring energy of the alignment layers is not a constant over the surface and is characterized with some spatial distribution. The simplest case to achieve the distribution of the anchoring energy is the use of photoalightment technique [1,5].

If the anchoring energy is non-uniform along the axis x parallel to LC cell surface (Fig.5), the lens profile will be created even for uniform driving voltage V over LC cell [2,5]. The optimal values of d and V to achieve a maximal possible optical power can be found for a strong anchoring energy (e.g. $3\cdot10^{-4}$J/m^2) and weak anchoring energy (e.g. $5\cdot10^{-6}$J/m^2) taking LC material E7 from Merck ($k_{11}=12\cdot10^{-12}$N; $k_{33}=19.5\cdot10^{-12}$N; $\varepsilon_{\perp}=5.1$; $\varepsilon_{\parallel}=19.6$; $n_{\perp}=1.5237$, $n_{\parallel}=1.75$) [5]. This material is good for LC lens, because of the high birefringence. Fig.5 contains results for both positive and negative lenses due to the nonuniform distribution of the anchoring energy [2,5].

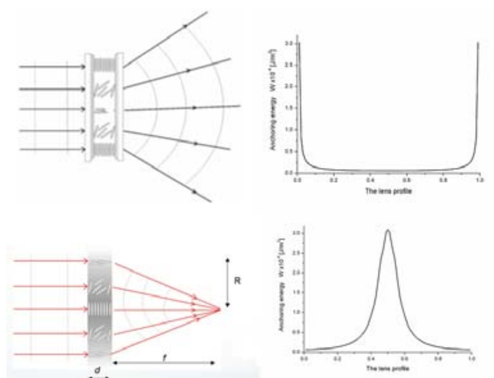

Figure 5. Tunable lenses (left) developed by a non-uniform distribution of LC anchoring energy [2,5]. Initial LC alignment is homogeneous. Top: diverging lens; bottom-converging lens.

Spatially varying the LC pretilt angle can be a good alternative to achieve low power consuming tunable LC lenses [2, 6]. The pretilt angle of the LC alignment is an important parameter to define the characteristic of LC devices. A tunable LC lens based on the approach of controlling the pretilt angle profile by means of the irradiance doses of a photoalignment (PA) layer was reported [6]. Such a PA layer provides precise control on the pretilt angle over a wide range of the pretilt angles, i.e., 1°–89°, which provides a great potential for applications not only in the tunable LC lens but also for other photonics and display devices. The PA material CPL024 (DIC, Japan) was used, which is a cross-linking polymer, providing a broad range of pretilt angles (1°–89°) depending on the irradiance doses. The pretilt angle profile for the CPL024 at different irradiance has been studied by making a 10-μm thick-antiparallel LC cell with several distinct areas having different irradiance (Fig. 6). The fabrication process includes the following steps. First, the CPL024 powder was dissolved in solvent cyclohexanone with a concentration of 0.5% wt⁄wt. Then, the solution was spin-coated on ITO glass substrates and thereafter exposed by UV light, of the wavelength 328 nm, at a plane inclined obliquely at an angle of 45°. This oblique exposure defines the azimuthal direction φ (defined in Fig. 6) of the alignment layer which is critically important to generate such a regular pretilt angle profile; otherwise it will be random. The fabrication process flow is shown in the top insertion of Fig. 6 [6].

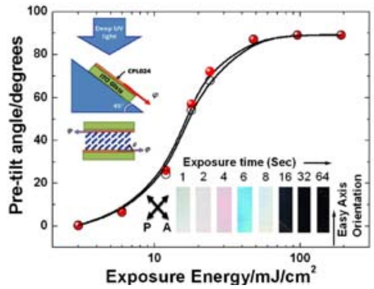

Figure 6 Pretilt angle dependence on the exposure energy (solid circles) [6]. Open legends represent the same experimental results repeated after several hours of photographing and thermal exposure. The top insertion shows the simple fabrication procedure to make the LC cell to analyze different PA parameters, whereas the bottom insertion shows the photograph of the prepared LC cell under the crossed polarizers for distinct areas with different irradiance and pretilt angles.

Thereafter, the crystal rotating method was used to measure the pretilt angles for different areas with different irradiance; its dependence is shown in Fig. 6. The pretilt angle increases with an increase in irradiance. The inset at the bottom right of Fig. 6 represents the photos for the LC cell with different pretilt angles achieved at different irradiance, which confirms the good alignment quality with different pretilt angles [6]. The pretilt angle depends on the irradiance. Therefore, spatially variable UV irradiance patterns can be employed to achieve any desired pattern. The same approach has been used to fabricate the LC tunable lens (Fig. 7) [6]. The schematics of the experimental setup and cell structure are shown in Figs. 7(a) and 7(b), respectively.

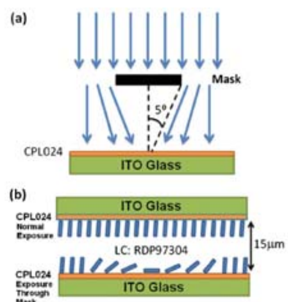

Figure 7 (a) Exposure setup to achieve spatially variable light intensity on the exposing plane. (b) The fabricated LC lens structure [6].

To generate the spatially variable UV irradiance, a mask with circular structure of radius R was placed at a distance D from the substrate (Fig.7). The light intensity exposed on the substrate was distributed in circular symmetry with the smallest intensity at the center and the largest at the border of the circle. Therefore, after being exposed through this irradiance pattern, the pretilt angle defined on the substrate will be spatially variable with the smallest pretilt angle (1°) at the center and increasing gradually to the largest pretilt angle (89°) at the border. In the next step, the LC cell was assembled with the prepared substrates in an antiparallel azimuthal arrangement. The cell gap was maintained at 15 µm, and a nematic LC RDP97304 (DIC, Japan) with $\Delta n = 0.27$ was filled into the LC cell. The fabricated tunable LC lens structure is shown in Fig. 7. The microscopic photographs of the LC lens at different voltage and the retardation parameter profiles for the fabricated circular LC lens at different voltages are shown are shown in Fig. 8, wherein the length of the marker is 700 µm.

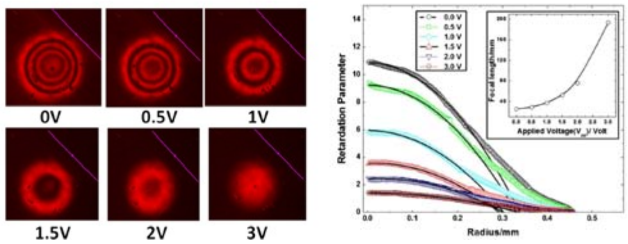

Figure 8 Left: Optical microphotographs of the circular LC lens at different applied voltages that have been clicked in red light. The marker size is 700 μm [6]; Right: Retardation parameter profile dependence along the radius of the LC lens at different voltages. The open legends show the experimental retardation parameter profile, while the solid lines represent the best parabolic fitting. The inset shows the voltage dependence of the focal length of the same lens

All of these retardation parameter profiles show parabolic character that is also the best case for any lens design. The solid lines in Fig. 8 (right) represent the best fit of the parabola approximation to the experimental retardation profile (open legends). It is clear that the retardation parameter profiles fit very well with the parabola approximation, which confirms the working concept of the designed LC lens. The voltage dependence of the lens focal distance f is shown in the inset on Fig. 8 (right). Only 3 V is enough to tune f from 2.5 to 20 cm, which can be decreased further by optimizing the LC parameters and cell gap of the lens. Furthermore, given the easy fabrication procedure in association with low operating voltages, such devices could find applications in many modern optical and photonic devices. The proposed approach can also be employed to fabricate the bistable LC displays, photonic elements e.g., beam steering devices, diffraction gratings, etc. In spite of having several advantages, further research is required to improve the lens profile, which could include use of certain grayscale masks or control of exposing environments, but these are simple technological issues that can be resolved by further improvement in the technology.

The principle of the polarizer free lens liquid crystal display is shown in Fig. 9 [2]. If a pixel is not activated, LCD cell is transparent as shown in Fig. 9 (up) . If the pixel is activated, it is not transparent as shown and form on the eye retina a grey spot in the place determined by the geometrical position of the pixel with respect to the eye (Fig. 9). The lack of the image on the pixel can be done by creating either divergent or convergent lens in accordance with the ray tracing picture shown on Fig. 9. Fig. 9 is a schematic sectional view of the ray tracing from an object located outside in the case when the pixel acts as a short focus convergent lens. In this case, the rays coming from the object pass the pixel and do not reach the eye. The rays coming from outside reaches the eye. The eye sees the pixel as a spot, brightness of which is equal to average brightness of surrounding environment (Fig. 9).

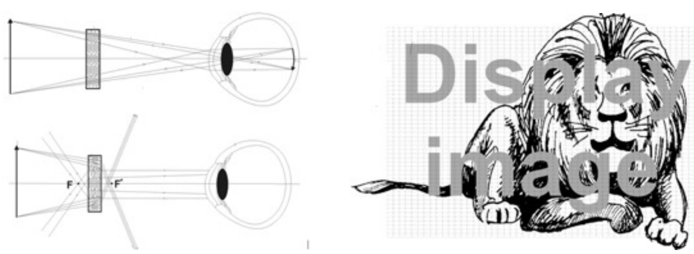

Figure 9. Left: Up: A schematic sectional view of the rays tracing from an object that is seen through a display when optical power of pixels is zero and formation of the image of this object on the retina; Down: A schematic sectional view of the rays tracing from an object that is not seen through a pixel when optical power of pixel is big and positive: the pixel acts as convergent lens. The same effect is observed, when pixel is big and negative: the pixel acts as divergent lens [2]. Right: A schematic view of the image seen by observer.

Fig. 9 (right) shows also a schematic sectional view of the lens non-polarizer display with background (lion picture). The brightness of the image (display image) is equal to the average brightness of the background (lion picture). Thus a lens non-polarizer liquid crystal display containing an array of pixels was proposed [2]. Each pixel contains at least one layer of liquid crystal with two electrodes; alignment layers setting orientations of the molecules of said liquid crystal near its boundaries and covering substrates, wherein the pixels are lenses with controlled optical power. A lens can be created by a non-uniform distribution of the LC anchoring energy, non-uniform electric field or non-uniform thickness of the LC or alignment layer. Double lens construction is also possible. Photoalignment technology can give a unique opportunity to get a non-uniform LC alignment either by non-uniform exposure or non-uniform thickness of the alignment layer. The polarizers are not necessary for this kind of LCD. Random azimuthal distribution of the LC molecules is also possible.

4. Nanoscopic Optically Engineered Polymeric Thin Film Polarizer

The concept to fabricate the polarizer with optical efficiency ~100 % is based on the nanoscopic manipulations of the liquid crystal polymer (LCP) director to form a diffraction grating with complex 2D alignment patterns, in order to diffract incident non-polarized light into two distinguished circularly polarized beams and separate them spatially at an extremely short distance [7]. The proposed structure is an assembly of the two specially nanoscopically engineered films, first the 4 domain 2 dimensional (D) polarization grating (PG) and second the 2 domain 2D quarter wave plate (QWP). The non-polarized light after passing through the spatially nanoscopically engineered patterned PG diffracts into left hand circular polarized (LHC) and right hand circular polarized (RHC) beams corresponding to the -1st and +1st diffraction orders with diffraction efficiency ~100 % (Fig. 10). The two distinguished circular polarized light diffracted from the 4 domains film are separated spontaneously and collected separately at specific QWP domain (Fig.10). Thereafter the specially designed QWP converts the two distinguished circularly polarized lights in to the linearly polarized light. Unlike the simple PG, the proposed structure provides advantages for uniformity and compactness that could secure application in modern photonic devices.

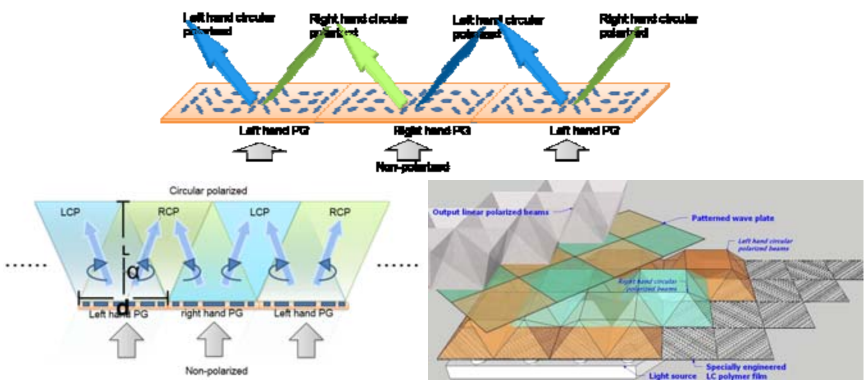

Figure 10. Top: Polarization grating (PG) separating the non-polarized light after passing through the spatially nanoscopically engineered patterned PG diffracts into left hand circular polarized (LHC) and right hand circular polarized (RHC) beams corresponding to the -1st and +1st diffraction orders with diffraction efficiency ~100 %. The two diffraction orders are propagating in different directions corresponding to the diffraction angles defined by equation $\Lambda Sin\theta_m = m\lambda$, where Λ represents the grating pitch, λ-light wavelength, θ_m represents the diffraction angle of the m_{th} order, and $m = \pm 1$ for PG. Bottom from left to right: conversion of the circular polarized light to linear polarized light by a patterned QWP.

The novelty of the concept, which lies in the 4-domain 2D patterned PG, offers a real experimental challenge to fabricate the nanoscopically defined alignment. Most common alignment technologies including the micro rubbing suffer from experimental limitations to design 2D patterned PG with small pitch ~ 2μm without any serious defect and misalignment of different domains. Small PG pitch, domain size and the defect line in between the two domains are critical parameters that decide the optical quality of the system. Photoalignment (PA) technology provides a high resolution nano scale alignment domains, which is the essential requirement in the fabrication of the proposed 4-domain 2D patterned PG (Fig.10).

The LCPs are a group of optical anisotropic materials with LC phases that could be aligned to desired directions and polymerized. Thus the nanoscopically defined easy axis of the local molecular orientations can be arranged and fixed afterwards to make a solid optical film. The chemical structure of a typical LCP material (RMM 257), which has been used in the present study, is shown in Fig. 11 [7].

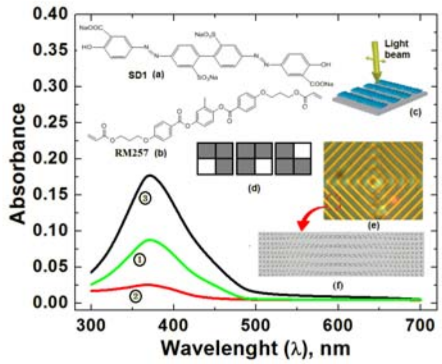

Figure 11| The material and process. a, SD1 ①before the light exposure, ②after irradiation in a direction parallel to linearly polarized light; and ③after exposure in a direction perpendicular to linearly polarized light. **b,** LCP material used **c,** molecular alignment of the SD1 molecule after being exposed by the blue light. **d,** shows the amplitude mask used for the fabrication of 4-domian 2D patterned PG structure. **e,** optical microphotograph of the 4-domian 2D patterned PG with 2μm of pitch, whereas **f,** represents the arrangement of the LCP director profile for one pitch length of the PG.

Thus the fabricated LCP film, with 4-domain 2D patterned PG, functions as a diffracting element to diffract non-polarized incident light into LHC and RHC beams corresponding to the -1st and +1st diffraction orders. The theoretical maximum efficiency i.e. 100% can be achieved by precisely controlling the nano scale alignment pattern and the film thickness with optical retardation equal to half of the light wavelength λ/2. The measured diffraction efficiency of the ±1st orders in the present case ~99.3 % [7]. The PG with 2μm pitch with diffraction efficiency ~100% can be obtained only if the LCP director rotation of 180° within 2μm pitch is continuous and therefore the director of the LCP molecules should be rotated, uniformly (Fig. 11(e)), along the grating vector with an angular resolution of 0.9° per 10nm distance that has been achieved [7].
To improve the angular performance, it was found that a lens array attached to the front side of the LCP layer with each lens exactly mapped over the entire line of the grating domains in the LCP film could solve the problem (Fig. 12) [7]. For a lens array having f/1.8, acceptance angle of ±13º has been recorded within which the efficiency of the proposed thin film polarizer remains above 95%. (Fig. 12b).

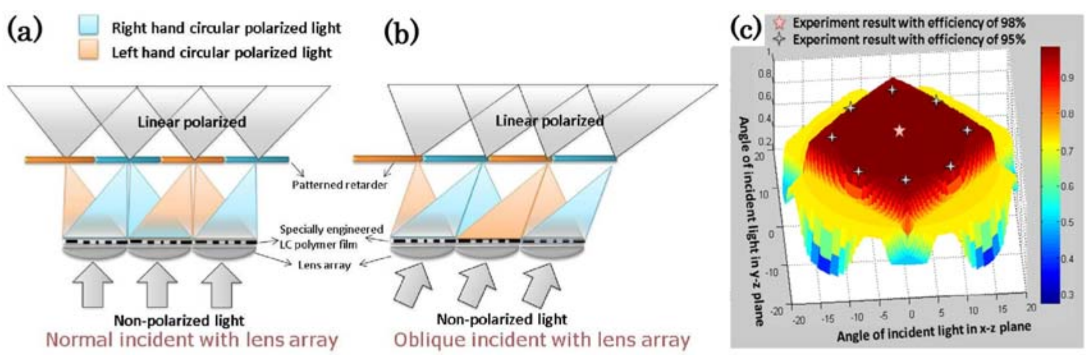

Figure 12| Angular dependence of the out-put light with lens array. **a,** the schematic of the normally incident light passing through the lens array and thin film polarizer. **b,** the schematic of the obliquely incident light passing through the lens array and thin film polarizer. **c,** represents the angular dependence of the polarizing efficiency for different light incidence angle.

The novelty of the concept lies in the 4-domain 2D patterned PG which has been achieved by the nanoscopic PA technology. Experimentally measured extinction ratio of the converted impinging light, from the proposed thin film polarizer, is ~ 130:1 with efficiency >98% with incident acceptance angle 0-13º from normal, which can be further improved. The thin film polarizer with ~100% polarization conversion efficiency, uniformity and compactness offer perfect solution to overcome the theoretical limits of the conventional thin film polarizers and therefore it could secure application in modern photonic and optoelectronic devices. One of the most important applications is LCD's, where the overall efficiency can be increased up to 2-3 times than the existing devices that will surely improve the energy consumption statistics of the existing LCD's. However, certain parameters have to be optimized before it could be applied for the real applications. Moreover it is critically important to improve the wavelength dependence of the system that can be done by multilayer structure. Although, such films could immediately find application in LED's, LED LCD backlight or other photonic devices where only narrow wavelength light band is needed.

5. Fast Ferroelectric LCD

FLCD is the fastest LC mode, which can work with both fast responses time and low driving voltages and is highly suitable for field sequential (FSC) applications [2]. Fast switching ferroelectric liquid crystal (FLC) displays (FLCD) is a good candidate for the new generation of field sequential color (FSC) LCD, which proved to be better in response time, than usually used nematic LC. The best FLC parameters can be obtained on the basis of electrically suppressed helix (ESH) mode [2,8].
Recently a reflective display cell which is suitable for projection displays based on electrically suppressed helix ferroelectric liquid crystal (ESHFLC) with fast response time, which is quite suitable for field sequential display was proposed [8]. The pulse width modulation (PWM) technique is used to control the residual light and thus provide several gray levels. This display cell can give 10 bit gray level colors. For the reflective cell, the upper layer was a reflective mirror (aluminum layer with 100nm thickness) coated with photoaligned azodye SD1 (0.5% in DMF) and exposed with the polarized light with 350nm to align the ferroelectric liquid crystal in a direction perpendicular to that. The bottom layer but with ITO substrate was treated the same way. Afterwards, the cell was assembled anti-parallel with 0.75µm spacer to set the half wave condition. After fabrication, the cell was filled with FLC4004FD (DIC, Japan)).
The frame frequency of 240 Hz seems to be enough to avoid color break up problem in FSCDs. For the driving scheme, the pulse width modulation (PWM) was used [8]. The frame rate was set at 240Hz which gave around 4.61ms of the frame time. During each frame, red, green and blue LEDs were sequentially turned on for 1.39ms. When positive voltage was given to FLC cell, the cell was bright otherwise, it was in the dark state. The driving scheme is shown below as Fig. 13. To achieve a high number of colors the reflective FLC cell was driven at the maximum frequency of around 5 KHz in ESH mode [8].

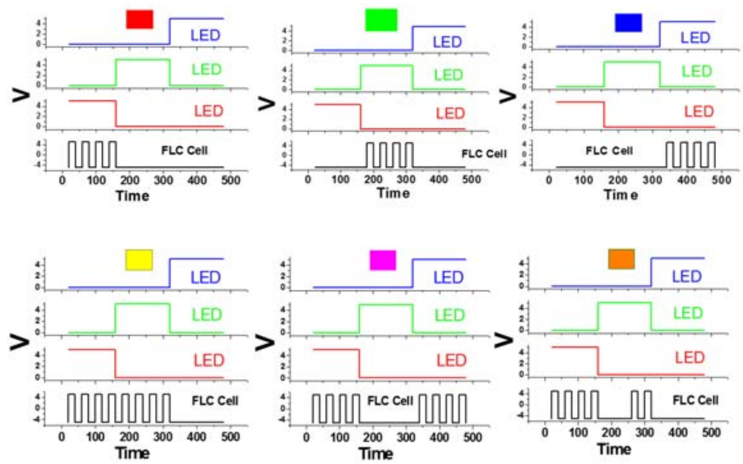

Figure 13. PWM driving scheme for field sequential color reflective ESH FLC display [8].

The electrooptical (EO) performance of reflective cell at the electric field of 3 V, and the frequency of 5 KHz was set to achieve a high number of colors. The response time dependence of driving frequency under different driving voltage is shown in Fig 14. Even with small driven voltage, reflective FLC cell still maintains enough contrast ratio (CR) for display CR>10000:1.

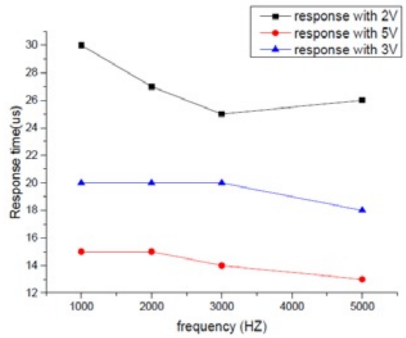

Fig. 14. Response time dependence of driving frequency under different driving voltage [8].

The response time of reflective FLC cell driven at 5 KHz and with the electric field of 5V was about 14μs. Such a fast response time enables us to drive the FLC cell even at very high driving frequency *f* = 5 kHz (Fig. 14).

Novel photoaligned FLC devices may include FSC FLC with a high resolution, low power consumption and extended color gamut, which can be used in the screens of portable PCs, mobile phones, PDAs. The switchable goggles and lenses based on new FLC prototypes can be efficiently applied in the new generations of switchable 2D/3D LCD TV. FSC FLC microdisplays, which is now one of the most advanced technologies for pico-projectors can be also made on the basis of new materials and electrooptical modes in FLC [2]. The photoalignment technology enables to solve the key problems usually faced in FLCD applications, such as (i) quality of FLC alignment on sufficiently large surface area; (ii) appropriate adjustable anchoring energy and pretilt angle; (iii) low losses in the alignment layers due to their small thickness etc [2,8].

The further the development of novel photoaligned fast FSC FLCD is aimed at: (i) further fundamental study of the new appropriate electrooptical modes used for switching; (ii) further understanding of physical mechanisms of FLC interaction with a photoaligned surface of different photosensitive nature to produce a stable alignment with a controllable anchoring energy and pretilt angle over sufficiently large surface area; (iii) development of new fast responded FLC materials with fast switching and a sufficient number of switchable gray levels (V-shape switching); (iv) implementation of the working prototypes of novel FSC FLC displays; (v) investigations of regimes of operation to allow to use efficient addressing of FLCD.

6. Conclusion

Photoalignment and photopatterning technology is a very promising direction in LC display and photonics devices due to the: (i) reliable and simple fabrication; (ii) high resolution; (iii) multi-functional applications, including highly efficient polarizers, optical lenses with voltage controllable focal distance, optically rewritable E-paper, fast ferroelectric LCD etc.; (iv) possibility to use glass and plastic substrates [1]. We demonstrated several recent examples of the applications in this technology is LC display and photonics devices. New photovoltaic, optoelectronic and photonic devices based on highly ordered thin organic layers may also be possible. Examples of such applications are single molecules organic light emitted (OLED) films, solar cells, optical data storage and holographic memory devices. The novel and highly ordered layer structures of organic molecules may exhibit certain physical properties, which are similar to the aligned LC layers [1].

7. Reference

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