Photopatterning of Liquid Crystal Alignment Cells

Ariel White

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Ariel White
Eastridge High School

Advisor: Kenneth L. Marshall

University of Rochester
Laboratory for Laser Energetics
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1. Abstract

Recently, "photobuffing" has emerged as a clean and efficient means of aligning liquid crystals on a polymer surface without contacting it. This process may also be used in combination with a photoresist mask to create cells with patterned directional alignment. Photopatterning has been used to create cells with multiple, separate alignment domains. When made with indium-tin oxide (ITO)-coated substrates and exposed to a voltage, the conductive coating can induce a change in the alignment of the liquid crystal material, making the cells electrically switchable. This feature could have useful applications in both passive and electrically addressable multi-domain liquid crystal devices, including tunable liquid crystal gratings and passive distributed polarization rotators.

2. Introduction

For many years, the accepted process for aligning liquid crystals was the mechanical buffing, or "rubbing" technique. In this process, a coated substrate is contacted by a cloth-covered buffing wheel, which is believed to scratch the coating and cause alignment[1], or to pull on the polymer molecules, creating a "preferential alignment" along the direction of rubbing[2]. However, this procedure has had the drawbacks of leaving the substrate with many particles and static charges on it. Rubbing has also limited the creation of multi-domain devices for optics or photonics, as it was difficult to achieve distinct boundaries without disclinations at the edges.

The process of "photobuffing" has recently emerged as a cleaner alternative to the rubbing method of aligning liquid crystals[3]. It also makes possible the use of a mask and polarized UV light source to perform "photopatterning" on substrates coated with an LPP (linearly photopolymerizeable polymer). The polymer, exposed to UV light, then forms chains, along which the liquid crystal molecules align themselves[4,5]. When multiple patterned substrates are combined to produce cells, various optical effects may be achieved[6].

3. Experimental Data[7-10]

ITO-coated substrates were obtained pre-cut to size, while uncoated glass substrates were cut from glass microscope slides. All substrates were cleaned in an ultrasonic bath, then scrubbed with Texwipe® Miraclewipes™ and deionized water. They were then dried with a nitrogen air gun and left for 90 minutes on a hotplate at 110° C. After cooling, they were placed on a spin coater and flooded with the LPP coating solution (Rolic ROP-203/2CP.) After 30 seconds, they were spun at 3000 rpm for 60 seconds and then baked on a hotplate for 10 minutes at 130° C. A Newport rotating stage measuring 8.5 cm square calibrated in 1-degree increments was modified to hold a chrome photo-mask with 1-mm wide stripes against a glass or ITO substrate coated with the LPP material (Fig. 1). Spacers ranging from 3 to 12 μm were placed on the

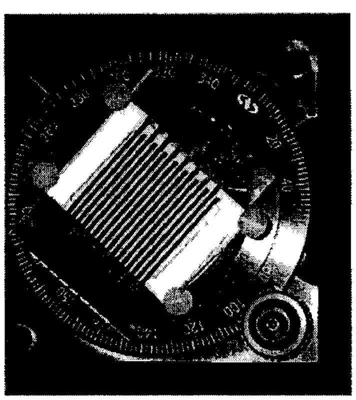

Figure 1 :Rotating stage used to expose substrates.

corners of the substrate to create a gap between the substrate and the mask. To hold the stage in place and avoid exposing the coating to other light during the exposure process, the stage was placed inside a box 110 cm x 90 cm x 125 cm at a distance of 2.5 cm from the end of the light source setup. A 100-watt xenon light source was used to expose the samples. It was placed behind a polarizer made of 14 fused quartz microscope slides arranged at Brewster's angle. All cleaning, coating, and cell assembly took place in a class 1000 clean room.

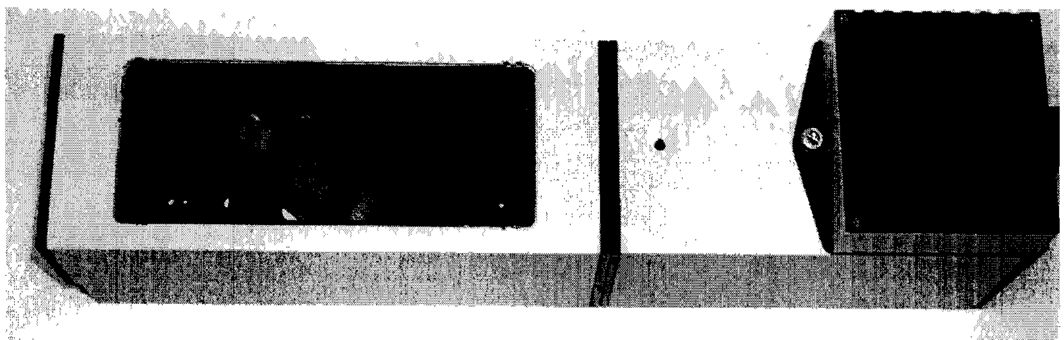

Figure 2: Setup with light source at right and view of brewster's angle polarizer at left.

One set of cells was produced by exposing the first substrate, with no mask, for 8 minutes at 0° rotation. The second substrate was exposed at 0° rotation for 4 minutes with the striped mask over it, then the mask was removed and the substrate was rotated 45° for another 4 minutes of exposure. Cells were made with both thin glass and ITO substrates. Glass cells were assembled by hand, while ITO cells were assembled with a cell assembly mount. In both cases, the two substrates were assembled into cells with the initial direction of 0° rotational exposure of each substrate set 180° away from that of the other. The cells were assembled with 22.1 μm UV epoxy, and cured with a 100W mercury vapor lamp for 90 seconds. The cells were then filled with the nematic liquid crystal E7 by Merck.

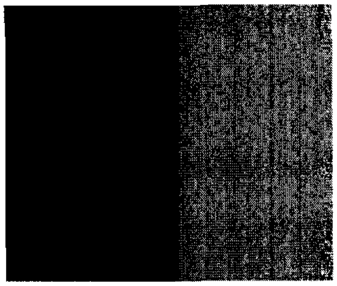

Figure 3: boundary between two adjacent alignment domains, viewed at 100x magnification.

These cells are composed of 1-mm wide alignment domains in the shape of alternating stripes. They show good contrast and alignment, and are comparable in quality to mechanically buffed cells on a macroscopic scale. The boundaries between domains are quite clear (fig. 3). These devices are also switchable when a voltage of 0-15 volts is applied across them, and demonstrate clear and gradual transition between alignment stages.

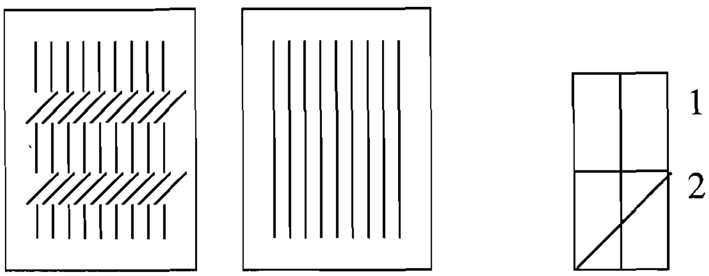

Figure 4: A diagram representing, at left, the patterned and uniformly exposed substrates used to produce a 2-domain cell, and at right, a representation of the alignment created in the two repeating domains of this cell; in domain 1, uniform untwisted alignment, and in 2, 45- degree twist.

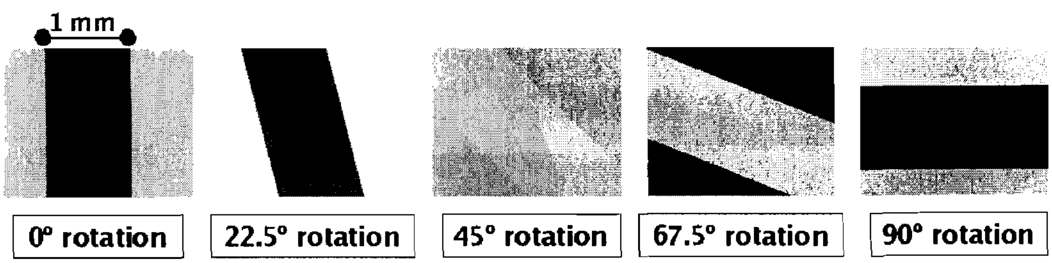

Figure 5: 2-domain cell rotated under crossed polarizers to show contrast.

Cells with four repeating alignment domains were also created. Two patterned substrates were created with 1-mm stripes of alignment at a 45° orientation to one another. The cell was then assembled with the stripes at right angles to one another at a thickness of 22.1 μm. These cells were first filled with E7, and displayed some evidence of what was thought to be reverse twist along the boundaries between domains, in which certain regions of "twisted nematic" areas of the cell twist the opposite direction from the rest of the cell. A mixture of E7 and .002% CB15, a reverse twist agent, was then used to fill another cell, and did not entirely correct the situation. It is still not clear what causes these regions of disclination, or flaws in the alignment of the cell. However, decreasing the thickness of the cell somewhat while still including some reverse twist agent when filling the cell may prevent these regions of reverse twist.

The alignment domains in these cells alternate between having 45° and 90° twist between the substrates, as illustrated in figure 6. Although they demonstrate disclinations along some boundaries when voltage is applied across the cell, within the individual alignment domains the contrast is good and the switching action is uniform. The cells display some surface flaws as well as the boundary disclinations. However, the previous process of buffing (using the rubbing technique on a coated substrate) through a mask that only allowed the buffing wheel to contact certain areas of the coating while moving in one direction, then moving the mask and buffing in another direction, tended to create regions of alignment separated by unaligned regions, as well as leaving the static charges and particles discussed in the introduction. The devices produced by photopatterning (figure 7) do not have the gaps between domains that were present in comparable devices produced by mechanical buffing[11].

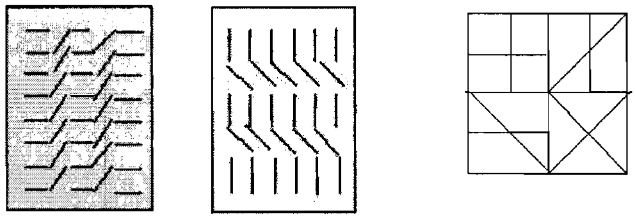

Figure 6:At left, diagrams of alignment directions on the two substrates of a 4-domain cell. At right is a diagram of the twist created in the pattern of four repeating alignment domains when the cell is assembled with the two substrates shown at left: clockwise from top left, 90°, 45°, 90°, and 45° of twist are visible.

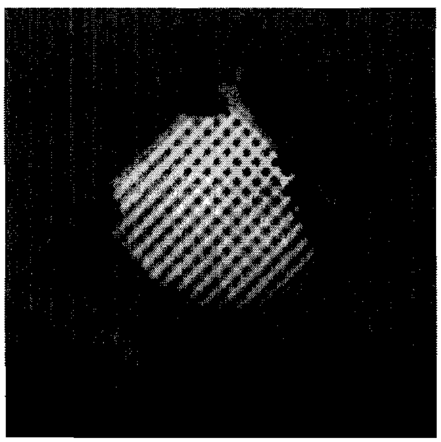

Figure 7: A cell produced with a pattern of four repeating alignment domains

Both sets of cells demonstrate the possibilities of photopatterning, but more investigation must be done into the causes of surface flaws and boundary disclinations in twisted cells, particularly if they are to be used in electrically-addressable devices. Thinner cells should be made to investigate whether this will eliminate regions of reverse twist. Photo-masks with smaller patterns must also be used if useful devices, such as tunable gratings, are to be produced with this process. Larger devices should be attempted, and devices should be produced in a cleaner environment to prevent coating flaws. However, the process of photopatterning is clearly a useful one for producing multidomain liquid crystal devices intended to alter the polarization of light in a controlled manner.

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