Photochemically Induced Alignment of Liquid Crystals on a Polymer Surface

Cam Tran

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Cam Yen Tran
Wilson Magnet High School

Advisor: Kenneth L. Marshall

University of Rochester
Laboratory for Laser Energetics
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1. Abstract

In the past, the accepted procedure of aligning liquid crystals on a polymer surface has been mechanical buffing, which is an inherently dirty process. In recent years, much research has been performed to discover a non-contacting way to photochemically align liquid crystals using linearly polarized light. The term "photobuffing" has been coined to describe this process. The goal of this research is to make liquid crystal alignment using the photobuffing technique as high quality as the alignment produced by the standard mechanical buffing technique. Using the linearly photopolymerizeable polymer Staralign™ 2100 CP, which is manufactured by Vantico, and the nematic liquid crystal Merck E7, which is manufactured by EM Industries Inc., photobuffing experiments were performed in order to evaluate the capability of the photoalignment process. At this point, the quality of photoalignment does match that of the alignment due to mechanical buffing on a macroscopic scale, but because of the presence of light scattering features on the surface of the substrates, the quality of photoalignment on a microscopic scale is less than that of alignment produced by the mechanical buffing technique. Further research will need to be done before the photobuffing technique can be applied to laser and photonics applications.

2. Introduction

Liquid crystal alignment on polymer surfaces can be used for various device applications and thus it is a very important process in many fields of research and development. Mechanical buffing, also known as the rubbing technique, has been the standard procedure for aligning liquid crystals on polymer surfaces.[1-8] The coated substrate is moved back and forth underneath a buffing wheel covered in a velvet cloth. This cloth scratches the surface of the substrate and forces the polymers on the surface to align. Although mechanical buffing has been used for many years, this technique is inherently flawed in that it is a very dirty process. The buffing wheel embeds dirt particles on the surfaces with which it comes into contact and causes an electrostatic charging that attracts even more particles. It is also a time-consuming trial and error process in which the buffing wheel must be adjusted to a height where it barely touches the surface of the substrate. Photochemically induced alignment, or "photobuffing," is a technique that could potentially replace mechanical buffing as the standard technique of alignment. It is a non-contacting way of aligning liquid crystals in which the only thing that comes into contact with the polymer surface is light, which does not leave any particulate matter at all. This could save a great deal of time and money in manufacturing liquid crystal devices and could potentially change the way that all LC devices are assembled.

3. Experimental[9]

Glass substrates were cut from glass cover slides and ITO substrates were obtained. They were then cleaned in the ultrasonic bath, hand-scrubbed using Texwipe® MiracleWipes™ and deionized water, dried off with a nitrogen air gun, and heated at 110°C for 90 minutes in order to remove any left over solvent. Approximately 2 ml of the linearly photopolymerizeable polymer Staralign™ 2100 CP was placed on the spin coater and a crystallization dish was placed over it in order to trap the vapors and saturate the surrounding air with the solvent. Each substrate was then flooded with Staralign™ 2100 CP, left to sit for 30 seconds, and spun at 3000 RPM for 60 seconds. The substrates were then hard baked at 130°C for 10 minutes. They were allowed to cool off for about 5 minutes and were then placed inside of a polarizer box equipped with an Oriel dichroic polarizer. The polarizer box was placed into a Rayonet chamber and the substrate was exposed to vertically polarized 300 nm UV-light for 10 minutes.[10] When each substrate was removed from the polarizer box, a mark was made on the upper right hand edge of the substrate. Each time an ITO cell was assembled, two substrates were obtained and were glued together anti-parallel to one another with the mark serving as an indicator to the orientation of the substrate. UV-epoxy containing 22 μm spacers, a cell assembly mount, and a mercury vapor lamp were used to assemble the cells. The cells were left underneath the mercury vapor lamp for 60 seconds to harden the UV-epoxy. The glass cells were assembled in the same fashion using the same materials, except, instead of the cell assembly mount, the cells were put together manually. After the cells were assembled, they were filled vertically with the nematic liquid crystal Merck E7. The cells were then sealed with 5-minute epoxy and left to dry. After the cells dried off, they were cleaned with acetone and labeled.

A few photobuffing experiments were performed using a Nissan 610 polyimide in order to see if the polyimide would photochemically align. First the ITO substrate was flooded with a polyimide solvent, left to sit for 30 seconds, and spun at 3500 RPM for 60 seconds. Each substrate was then flooded with a polyimide solution made out of a 1:2.5 ratio of polyimide solute to polyimide solvent, left to sit for 60 seconds, spun at 3500 RPM for 120 seconds, soft baked at 80°C for 10 minutes, and then hard baked at 250°C for 60 minutes. The irradiation and assembly procedures were the same as for the Staralign material.

4. Results

The initial results of this experiment were very poor, but at this point in time, the quality of photoalignment matches that of the mechanical buffing technique on a macroscopic scale only. As can be seen in Figure 1 and Figure 2, the quality of alignment of the photobuffing and mechanical buffing technique are almost equal to one another. The photobuffed cells show good contrast, which means that there is a well-defined transition between polarization states and that

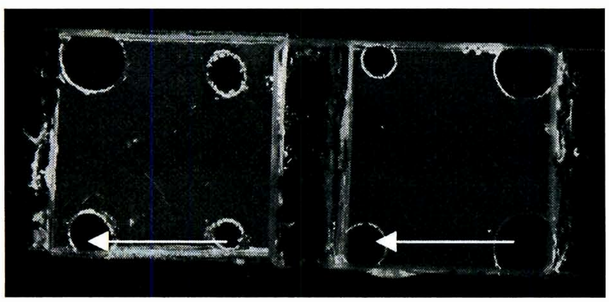

Figure 1: Photobuffed cell (left) and mechanically buffed cell (right) aligned with one of the axes of the crossed polarizers.

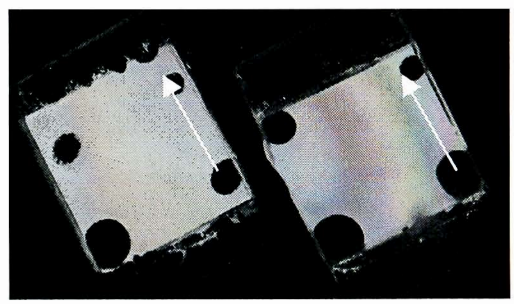

Figure 2: Photobuffed cell (left) and mechanically buffed cell (right) tilted 45° to one of the axes of the crossed polarizers.

the liquid crystals are aligned. (White arrows indicate direction of polarization or rub direction depending on the cell being observed.) The various colors seen in the cells in Figure 2 indicate that there is a disparity in the thickness of the cell gap across the cells. Other than this problem, the quality of the cells is very high and macroscopically, the buffed and photobuffed cells are identical. Microscopically, there are still some defects with the photobuffed cells that need to be fixed. The presence of light scattering features, such as ridges in the polymer coating, prevents the microscopic quality of photoalignment to equal that of mechanical buffing. As can be seen in the following pictures, the mechanically buffed cell is relatively smooth. Other than a few specs of dust and the scratches caused from rubbing the surface with the velvet buffing cloth, the buffed cell has no major defects on its surface as can be seen in Figure 3 below. The photobuffed cell, on the other hand, has microscopic ridges on the surface that disrupts the alignment in those areas as can be seen in Figure 4.

Figure 3: Microscopic surface of a rubbed polyimide cell.

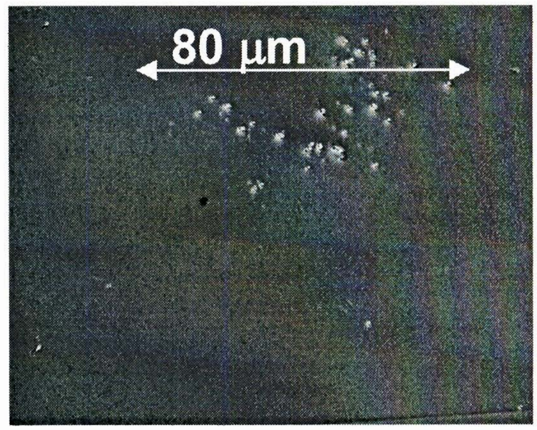

Figure 4: Microscopic surface of a photobuffed Staralign cell.

5. Discussion and Conclusions

The photobuffed cells were of poor quality due to the rapid evaporation of the Staralign solvent. In certain areas of the cells, the solvent was evaporating too quickly and so ridges of the solvent formed from the uneven evaporation. In order to make the solvent less volatile, a small amount of the solvent was placed on the spin coater and then the spin coater was covered in a crystallization dish. This would allow for the solvent to saturate the surrounding air, which would prevent the solvent later placed on the substrates themselves from evaporating too quickly. This resulted in a much smoother surface as opposed to the types of surfaces seen in Figure 4 above.

In any case, alignment can be obtained photochemically. The quality of alignment of the nematic liquid crystals produced by the photobuffing technique was equal to that of the alignment produced by the rubbing technique macroscopically. At this point, the process can be used for low power applications that do not require the cells to be perfectly aligned. Microscopically, there are more defects that must be removed before the photobuffing process can be used for photonics and laser applications.

6. Future Studies

More research will need to be performed in order to achieve the same high level of alignment on a microscopic scale. Experiments will also be performed using other liquid crystals, including smectic, chiral, and cholesteric liquid crystals, in order to ensure that the process can be used for a wide range of applications.

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