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A New Non-Rubbing Technique for Liquid Crystal Alignment

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Abstract

A new non-rubbing technique for uniform, planar alignment of liquid crystals has been developed. It involves a combination of chemisorption and UV-induced photo-dimerization. By varying chemical structure of the outermost part of the alignment layer, it has been possible to control the pretilt of the liquid crystal molecules at the surface ranging from 0 to 20 degrees. A feature of the process is that it is a room temperature process and applicable to a variety of substrates. Data on LCD cells fabricated using these alignment layers are presented.

Introduction

Flat panel liquid crystal displays (LCDs) require a uniformly planar orientation of the liquid crystal (LC) molecules at the surface. In addition, a finite pretilt angle of the LC molecule at the surface is required to prevent reverse tilt disclinations in twist cells. The pretilt angle is also important in order to avoid stripe domains in super twisted nematic LC displays (STN-LCD) and surface-stabilized ferroelectric liquid crystal displays (SSFLCs)[1-2]. Currently, a planar alignment with a pretilt of LC is being achieved in LCD industry by initially spin-coating the conducting glass substrate with polyimide followed by mechanical rubbing. This technique has some inherent problems like build up of dust and static charges during rubbing. These charges lead to failure of the devices, the problem being more severe for AMLCDs. Also, this alignment layer process is a high temperature process that can affect color filters. There is therefore a need for a non-rubbing low temperature LC alignment process.

Of late, there have been reports of non-rubbing processes. Essentially these new approaches can be classified into two types. In one case, the alignment is achieved using the cis-trans conformational change of the alignment layer molecule to achieve the LC alignment[3-6]. In the second case, the alignment layer is a polymer that is spin cast on the substrate followed by exposure to polarized UV radiation at normal incidence. This process leads to a photo-polymerized layer that in turn results in the alignment of the LC molecules[7-14]. One of the problems of the latter approach is that it tends to give a zero angle pretilt. Although there have been some recent reports of finite pretilt[12-14], in all cases variation of pretilt has been achieved by varying the processing conditions like the angle of incidence of the UV light, the baking time and temperature. In this article we present results on a new type of LC alignment technique which is distinctly different than all the previous approaches and which has many advantages that make it attractive for LCD fabrication.

The New Process

The first step of our LC alignment technique is a simple chemisorption process where a specific type of silane molecule is chemically bonded to the surface (Figure 1). This is followed by a single synthetic step wherein a photo-sensitive chromophore is attached to the silane. The third and final step of the process is UV-irradiation. The entire process[15] which is shown schematically in Figure 1, can be looked upon as a combination of chemisorption and photo-induced 'dimerization'.

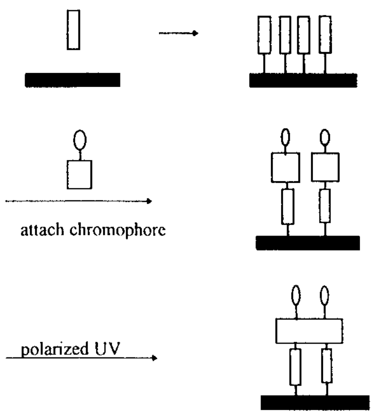

Fig. 1 Schematic of the steps involved in the new process

There are several important features of this new technique- it is a room temperature process, is applicable to a variety of surfaces like glass, ITO, passivated ITO or silicon, and is easy to scale-up relevant to LCD manufacturing. The efficacy of this alignment layer for LCDs is demonstrated by the results discussed in the next section.

Results and Discussion

a)Uniformity of Alignment and Contrast Ratio

The alignment layer obtained by this new process (hereafter referred to as the NRL process) yields extremely uniform alignment of both ZLI-type (fluorinated) and E-7 or E-63 type (cyanobiphenyl) of liquid crystals on a variety of substrates like glass, ITO, passivated ITO and silicon. Contrast ratios were measured in a completely automated measurement system. All experiments were performed in the normally white mode. Figure 2 shows a typical plot of the transmitted luminance as a function of voltage (60 Hz square wave) . From these plots, contrast ratios were calculated. Values ranging from 100-500 were obtained.

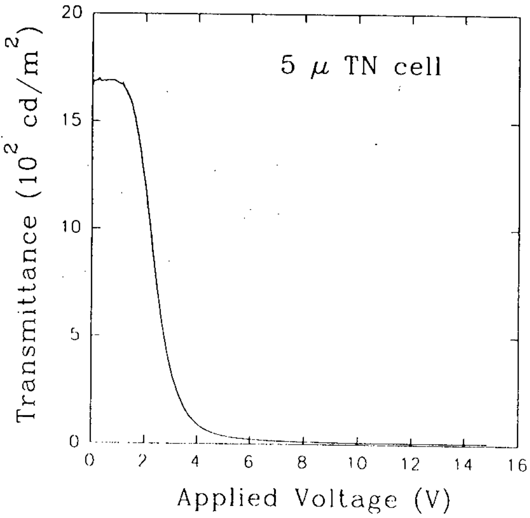

Fig. 2 Transmittance as a function of applied voltage for a TN cell treated with an alignment layer with 0.3 degree pretilt (Contrast ratio =216)

b)Response time

Typical rise and fall times of a TN device treated with the NRL alignment layer were determined. Characteristic electro-optic curves (Figure 3) show that rise time is about 5 ms while the fall time is about 15 ms. These switching times are very similar to those reported for rubbed alignment layers.

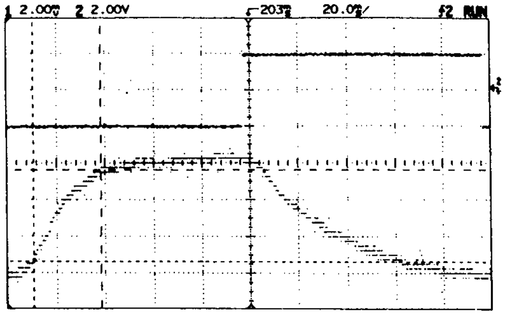

Fig. 3 Typical optical response curve for a 5 micron TN cell treated with an alignment layer

c)Pretilt Control

Preliminary experiments conducted using the NRL alignment layer yielded nearly zero degree pretilt. This result is in fact typical of most of the photo-polymerization based alignment layers. It has to be pointed out that the processing of the NRL alignment layer involves irradiation of substrates using polarized UV light at normal incidence. Although recent reports have indicated the possibility of pretilt by altering the angle of incidence, there are however problems associated with the stability of the pretilt as well as uniformity of pretilt. It is preferable to retain the normal incidence process. With this in view we have carried out a study by varying the chemical structure of the alignment layer keeping the process the same. This approach, which is unique to our technology, has resulted in fine control of the pretilt angle as shown in the following:

Variations of the alignment layer

The variation of the chemical structure of our alignment layer involved the synthesis of different types of chromophores (in all cases the underlying silane molecule being the same). The idea is to achieve a delicate balance of the dipolar, steric and Van der Waal's interaction at the interfacial region between the alignment layer and the first layer of liquid crystal molecules in contact with the alignment layer. This delicate tuning of the interactions viz-a-viz the chemical structure of the alignment layer enables us to obtain variations in pretilt for both ZLI and E-7 or E-63 types of liquid crystals.

Pretilts were measured by the standard crystal rotation method using planar cells that are at least 20 µm thick. Data showing pretilt angles in the range of 2 degrees to 20 degrees are given in Figures 4a and 4b. The solid curve is a fit of the raw data to a theoretical expression. Thus the feasibility of pretilt control using the new alignment technology is established.

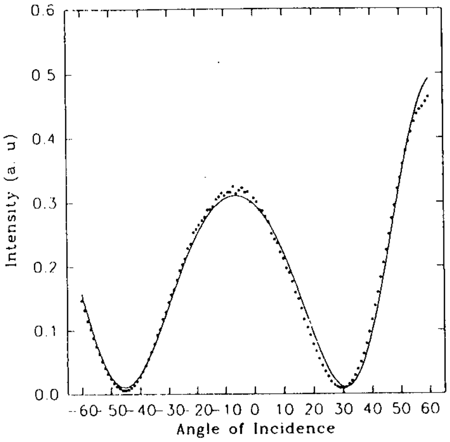

Fig 4a) Data and fit curves for a planar cell treated with an alignment layer (pretilt = 2.0 degrees)

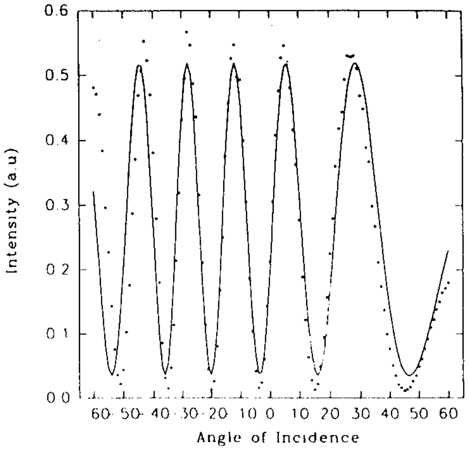

Fig 4b) Data and fit curves for a planar cell treated with a different alignment layer (pretilt = 20 degrees)

d)Pretilt stability

The stability of pretilt generated using the NRL alignment process was checked with respect to both temperature and time. A cell with pretilt of 2 degrees was subject to 120 degrees C for three hours. The pretilt was remeasured at room temperature. Figures 5a and 5b show pretilt curves before and after thermal treatment. A fit to the raw data gave identical values for the pretilt within the error limits of the measurement (± 0.3 deg).

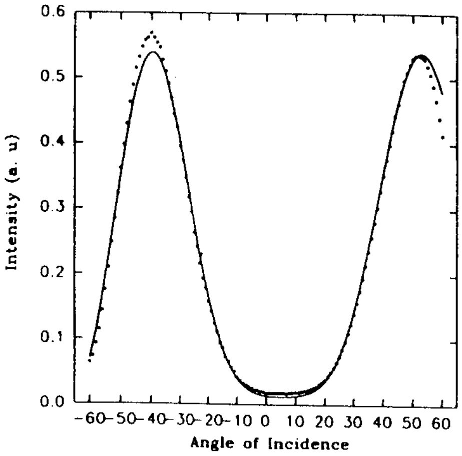

Fig 5a) Pretilt data for a planar cell with pretilt of 2.0 degrees

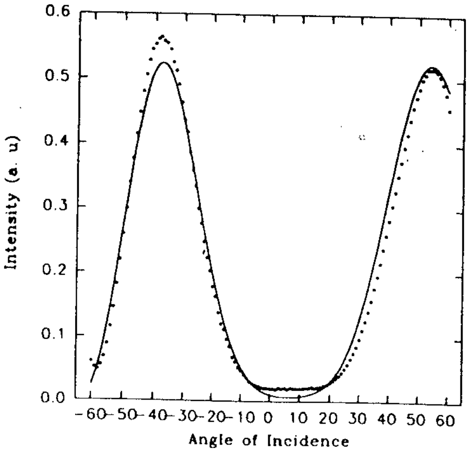

Fig5b) Pretilt data after thermal treatment. Pretilt remained the same.

Pretilt measured on this cell five weeks after the initial measurement gave the same value thereby demonstrating that the pretilt is temporally stable.

Summary

A new non-contact technique for uniform planar alignment of liquid crystals has been developed. Measurements of contrast ratios, response times and pretilt on planar and TN cells show that this new alignment technique yields display parameters comparable to that using rubbed polyimide. Other parameters of interest such as the voltage holding ratio and anchoring energy are being evaluated.

Acknowledgements

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