P-56: Aligning Liquid Crystals Using Self-Assembled Monolayers

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Abstract

Conventional method of liquid crystal (LC) alignment – rubbing of polyimide film with a cloth [1] – changes the topography of the layer and induces anisotropic orientation of polymer chains along the rubbing direction. Unfortunately, it also generates a lot of debris. Moreover, this method is incompatible with localized control over LC alignment.

Recently, anchoring of LC was demonstrated using low energy surfaces from self-assembled monolayers (SAMs) deposited from a liquid phase on gold and silica [2,3].

We applied Molecular Vapor Deposition (MVD™) technology for anchoring of MLC 6610 liquid crystal to ITO surface. Advantage of vapor-phase deposition in superior surface quality has been reported elsewhere [4]. Self-assembled monolayers of perfluorinated chlorosilanes and aminosilanes were used to build LC cell with symmetrical boundary condition and cell gap of 10 um. Anchoring energy of 4.2×10^{-4} J/m2 was obtained using capacity method for both types of SAMs. MLC 6610 showed 2.45 V threshold voltage. We observed a uniform vertical alignment of the cell without defects.

1. Introduction

Today the most common technique to align liquid crystals (LC) is to physically rub the polyimide film with a cloth [1]. This physical interaction changes the topography of the layer and induces an anisotropic orientation to the polymer chains. Unfortunately, rubbing process tends to generate a lot of debris. With small particles remaining on the surface, a cleaning operation is often required. Rubbing also tends to induce small scratches on the surface and can result in induced static charge. Moreover, this mechanical aligning technique is incompatible with the localized control over the LC.

Recently, anchoring of LC was demonstrated using low energy surfaces from self-assembled monolayers (SAMs) deposited from a liquid phase solution on gold and silica [2,3]. While solution-based techniques have been widely used, another challenge arises in manufacturing in that a liquid-phase process is highly susceptible to particulation and defects caused by the sensitivity of the reaction to the environmental humidity [4]. The use of solution-based films is currently limited by the quality, scalability, and reproducibility of the films and requires very elaborate and costly wet processing stations.

In this paper, organic SAM coatings were vapor deposited on single crystal Si wafers and ITO substrates. This was accomplished using a commercially available apparatus [5,6] specifically designed to provide a high degree of reaction control and superior film quality.

2. Experimental

We used a Molecular Vapor Deposition (MVD™) system [5,6] for the anchoring of MLC 6610 liquid crystals to an ITO surface. Fig. 1 shows the schematic of the vapor deposition set-up used in this study. The apparatus consists of a vapor deposition chamber that is pumped by a mechanical dry pump, special precursor delivery injectors, a remote plasma source, and a process automation controller. The typical base pressure of the reaction chamber is 10 mTorr with a chamber leak-up rate of less than 2 mTorr/min. The chamber walls and the delivery lines are heated above room temperature to eliminate condensation of the reactants and residual vapor contamination. The vapor delivery system allows for the precise dosage of precursors and catalytically vapors into the deposition chamber. The reaction pressure can be controlled within a relatively wide range depending on the initial vapor pressure of the precursor used in the reaction but is typically maintained in the range of 1 to 5 Torr.

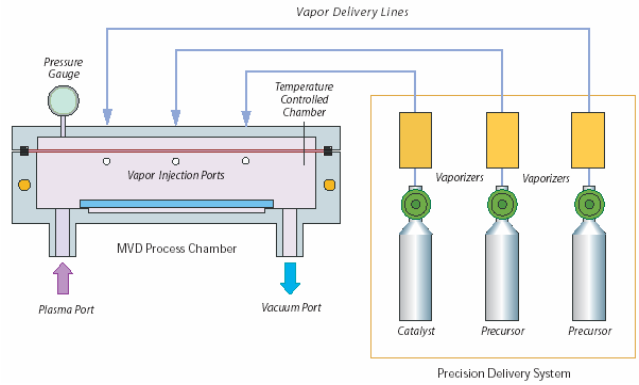

Fig.1 Schematic of the apparatus used in vapor deposition experiments.

A downstream O_2 RF plasma treatment is used for preparing the substrate surface prior to the monolayer deposition reaction. The chamber pressure during plasma treatment is about 0.5 Torr with the RF power in the range of 100 to 300 watts. In a typical implementation of the process, samples are placed in the deposition chamber and treated by the remote plasma prior to the application of the monolayer coating with no additional processing steps in between.

We have used 2 types of perfluorinated silane precursors, F1 and F4, having different attachment groups, to create ordered self-assembled pattern on Si wafers and ITO substrates. Samples were baked after deposition on a hotplate (110º C) for a half an hour. DI water contact angles were measured on Si(100) wafers using a Rame-Hart-100 goniometer equipped with DROP-image software. A Digital Instruments Nanoscope-III atomic force microscope was used in "tapping" mode to measure the roughness of the surfaces.

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3. Results and Discussion

Monolayer structures were shown to provide high quality liquid crystal alignment layers. We have investigated some physical properties of these monolayer structures. DI contact angles for both thin films on Si and ITO were above 110 deg, which indicates the formation of dense perfluorinated self-assembled monolayer on the substrate's surface. The thickness of the F1 film was 1.5 nm and the F4 film was 0.7 nm. Fig. 2 shows an AFM scan of the 2μm x 2μm area of the film. The RMS roughness value was approximately 0.26nm. The very thin monolayer structure was used to modify the properties of the surface. An ITO layer without any additional treatment normally has a planar alignment with a degenerate planar orientation. However with an ITO layer deposited on a monolayer structure, it was observed that the orientation of the LC changes from a random planar to the vertical alignment. Vertical alignment has no deviation from the vertical direction with the accuracy ±0.2 degree, which is provided by our method.

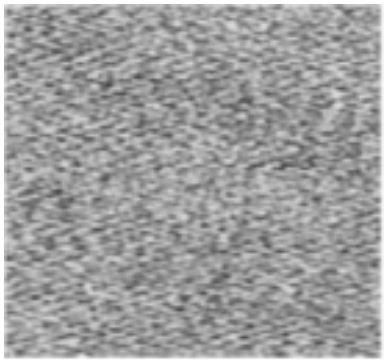

Fig. 2 AFM scan of F1 film

For the estimation of the anchoring properties of a monolayer structure, we used a capacitance method [7]. Liquid crystal cells with a cell gap of 10 μm and liquid material MLC 6610 were used. The dependence of capacity from applied voltage, used for anchoring energy measurements, is shown on Fig.3.

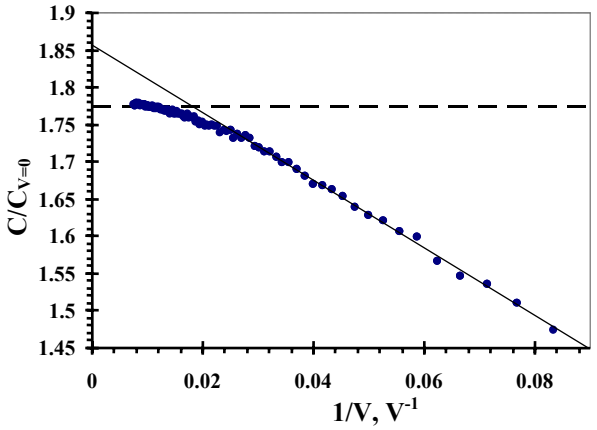

Fig. 3. Relative capacity vs applied voltage for F1 layer

A linear dependence was found for voltages from 10V to 30V. For the voltages around 100V, the dependence is close to the saturation. The anchoring energy value was estimated **W = 4.2x10^{-4} J/m^2** for both layers, F1 and F4, which is comparable with a W value for a polyimide (PI) layer in case vertical alignment. Schematically we show alignment LC material on surface of SAM alignment layer on Fig.4. High uniformity SAM layer has result that in cross polarizer LC display has uniform very dark state (fig.4)

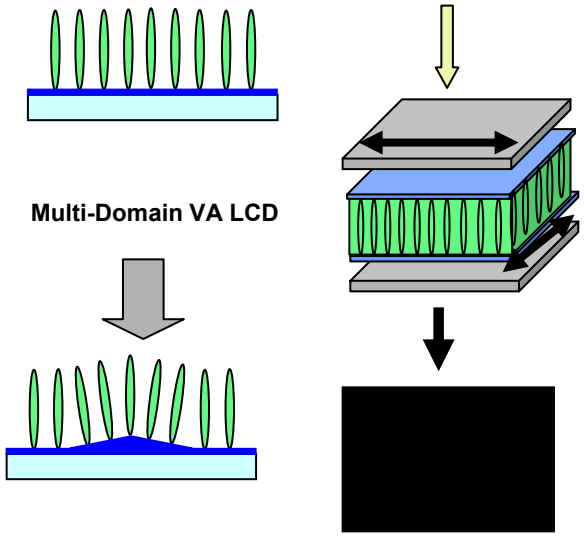

Fig. 4. Alignment of liquid crystal on surface of the SAM alignment layer.

4. Conclusions

Uniform, dense nano-films have been deposited using an innovative automated vapor phase deposition method referred to in this paper as MVD (Molecular Vapor Deposition). These nanofilms can be deposited on various materials, including ITO glass, used in LC fabrication. A uniform layer structure and strong anchoring energy with this type alignment technique can be recommended for multidomain VA-LCD.

5. Acknowledgements

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