Alignment of ferroelectric liquid crystal on surface SiO_2 films on oblique ion beam deposition

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ABSTRACT

Investigation of alignment properties of SiO_2 thin films produced by oblique ion beam deposition on substrate surface is presented. Suitable uniform alignment properties of the ferroelectric liquid crystals can be received on the alignment layer prepared by this method. Large deposition angle from 80º to 70 º can be used for thin SiO_2 layer deposition (from 10 to 20 nm). Linear design of the ion beam sputtering source gives a possibility to work with large size substrates.

1. INTRODUCTION

Ferroelectric liquid crystals (FLC) have a tremendous potential for production of fast switching electro-optical devices for display and other application. Basic problem for FLC is quality and stability of alignment in different types of devices. Best result can be received for non-contact technology of liquid crystal alignment such as oblique evaporation [1,2], ion beam treatment [3,4] or photoalignment [5] techniques. From the other side the new generations of LCDs operate with large-area substrates (1870 x 2200 mm^2 for the production lines of 7th generation) that create difficulties with the alignment uniformity for large substrate sizes.

Ion beam technique with linear source theoretically has no limitation for oblique sputtering deposition of alignment layer on large-size substrates. Thin SiO_2 layers guarantee a high speed deposition process and ion beam technology provides an excellent quality of dielectric layers. In previous papers this technique was used for alignment of nematic liquid crystals [6,7,8]. A linear source has some specific features in a formation of a thin alignment layer and a mechanism of formation of alignment properties is also slightly different. In this paper the results of investigation of anisotropy properties of the thin SiO_2 layer using 2D Fourier transform analysis of the AFM pictures are presented. The results of investigation of the alignment of FLC materials on the SiO_2 films produced by the ion-beam deposition for LC devices are also shown.

2. EXPERIMENTAL

2.1 Sputtering deposition setup

The scheme of the sputtering source and deposition geometries is presented in Fig. 1. It is based on the anode-layer ion source with the racetrack shape of the discharge area. It generates two sheet-like fluxes of Ar+ ions focused on the surface of a lengthy target with the dimensions of 60 x 500 mm^2. The incidence angle of ions onto the target, determined from the target's normal, is about 60°, which allows to obtain the maximal efficiency of sputtering at the same power consumption. The ion-source aperture limits the flux of sputtered material providing its partial collimation. The SiO_2 films were deposited on the substrates by sputtering the vitreous quartz target by the argon-ion beam. To neutralize the charges generated on the non-conducting surface of the target under the action of the ion beam, the thermoionic compensator made of wolfram filament located near the target was used. In the majority of experiments, the parameters for the sputtering of the target material were maintained to be constant. The thickness of the SiO_2 coatings was changed by the deposition time and measured by the quartz-crystal controller. Glass plates from Asahi Co., containing ITO electrode layers were used as substrates. Size of the experimental cells was 20 x 15-mm^2 and experimental display 45x45 mm^2 with active area 35x35 mm^2. Before SiO_2 deposition, the ITO surface was cleaned with an anode-layer ion source.

2.2 Properties of the thin SiO_2 layers

Alignment layer is deposited on surface with roughness. It can be transparent electrode (ITO film), reflective layer (Al film), clean glass or Si. Every surface has its own roughness, which can vary from 1nm to 20 nm and usually is 2 – 7 nm for ITO layers. It is evident that thin SiO_2 with thickness 10 – 20 nm cannot completely change profile surface and can only modify it. AFM picture (Fig. 2) shows a profile of clean ITO (70 nm) layer and SiO_2 layer with a thickness of 10 nm that was deposited on ITO under angle of 75° degree to normal from linear ion-beam source. Fig.2 does not show any periodic structure on this image. Roughness of ITO layer was 2.14 nm and after deposition of SiO_2 layer decreases and goes to 1.92nm. We cannot see any significant changes in surface profile, which can be responsible for LC alignment. However, such SiO_2 layer can orient LC molecules [5,6]. For alignment of liquid crystals a profile must have anisotropic properties of roughness picks or periodic structure in one direction.

For investigation of the periodic properties we used 2D Fourier transform of the AFM picture (Fig.3). Every point on this plot is responsible for some periodic structure in direction from the point on 2D Fourier transform plot to the center of plot. If relief has a pure sinusoidal profile, only two points can be found on this plot located symmetrically with respect to the center. We can see that 2D Fourier plot is symmetrical around the center (the dark line corresponds on the one hand to the orientation of linear source but on the other hand to scanning direction of AFM microscope). After deposition of SiO_2 layers of different thickness (5,10, 20 and 40 nm), we cannot find any changes in 2D Fourier function. The alignment effect of sputtered SiO_2 layers cannot be explained by formation of some periodic structure and can be the result of ITO layer peaks relief modification. Azimuthal anchoring energy in this case must be small and pretilt angle is zero for planar aligned LC [6,7].

The situation changes if we use the ion-beam etching process. We used ion-beam etching for pretilt angle generation as a second treatment process in perpendicular direction to the plane of SiO_2 deposition during the first process. After ion-beam treatment we can find series of the peaks in direction of the treatment process at the surface (Fig. 4).

FLC materials are aligned in a perpendicular direction to the deposition plane without any pretilt angle. The second process can be used for a generation of a pretilt angle: ion-beam etching in perpendicular direction.

2.3 FLC alignment

FLC cells with antiparallel alignment of SiO_2 layers on both substrates (symmetric configuration) were assembled for alignment tests. The cell gap was formed by 2 µm spacers. Ferroelectric material FELIX 017-100 from Clariant was used. The test cells were filled with liquid crystal in an isotropic state and in a low vacuum condition. After filling the cells were slowly cooled with a speed of 2-4℃ degree per minute.

After cooling uniform alignment of ferroelectric liquid crystal was found in the cells. Direction orientation of molecules was perpendicular of the deposition direction. Moreover zig-zig defects appear in cells. For elimination of zig-zag defects low frequency (10Hz) a.c. electrical field with amplitude 10V/µm was used. After electrical treatment uniform alignment with good bistability was obtained (Fig.5). These results have a good correlation with the data of super thin SiO layer [2] that exhibit a common mechanism of orientation on thin silicon oxide oblique deposited films.

3. DISCUSSION AND CONCLUSION

The sputtering deposition of SiO_2 is a promising technique for the alignment of ferroelectric liquid crystal materials. It provides uniform alignment with a high contrast ratio (more than 100:1) in a bistable switching. Fig. 8 provides an electrooptical response in a bistable mode for 5V amplitude and 1 ms duration driving signal. In a binary mode the switching time for the same voltage 5V was 150 µs. Two types of alignment chevron (before) and bookshelf (after electrical treatment) were received. Optimization of technological parameters and angle deposition was performed on test cells.

Acknowledgements

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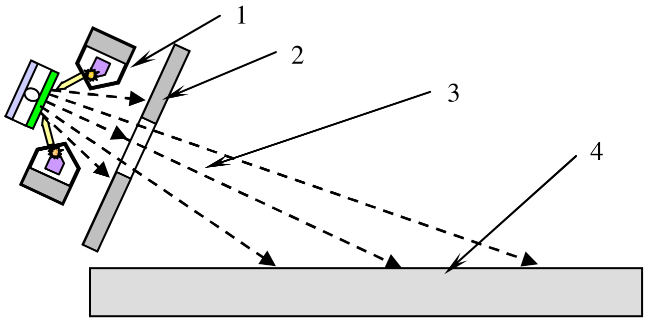

Fig. 1 Scheme of sputtering system
Sputtering source and sputtering-deposition geometries. 1 — parts of sputtering source, 2 – diaphragm, 3– ion beam; 4 – moving platform with substrates.

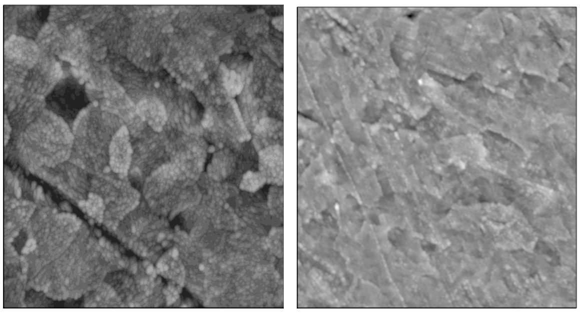

Fig. 2 AFM picture
Clean ITO, size area 1.5x1.5 µm (left) and 10 nm SiO_2 on ITO size area 3x3 µm (right)

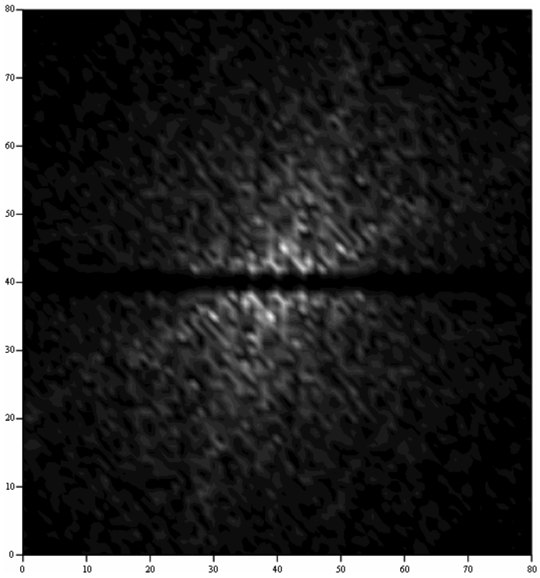

Fig. 3 2D Fourier function
for AFM picture 10 nm SiO_2 on ITO

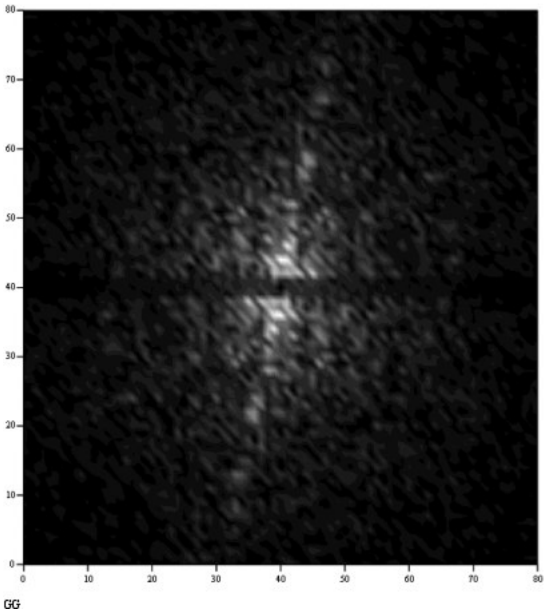

Fig. 4 2D Fourier function
for AFM picture 10 nm SiO_2 on ITO and ion-beam treatment.

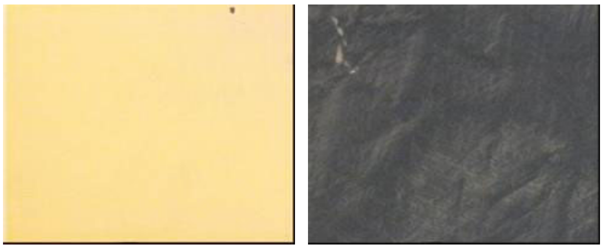

Fig. 5 FLC alignment on SiO2 alignment layer
Bright (left) and dark (right) states.

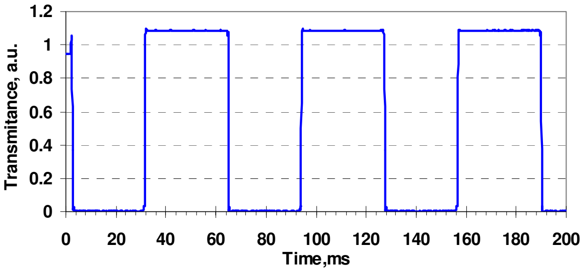

Fig. 6 Electro-optical response
FLC on SiO2 alignment layer in bistable mode