Stability of liquid crystal alignment to the electric field

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Abstract

We observed the destruction of the liquid crystal alignment with the repeating scan of strong DC electric field. The strong electric field seems to force the alignment to be scarred permanently and it accumulated with the repetition. In this report we connected alignment destruction behavior and electric field strength to obtain information on the alignment strength. And we compared the behavior between different alignment techniques.

1. Introduction

Usually we are using the electric field as the driving force to switch the liquid crystals (LC). With the appropriate range of field strength, LC responds safely and reversibly maintaining the ability to return to the original orientation. However, above the certain strength, LC expects to start losing the ability to return back to the original orientation and the alignment stability gets disturbed. At elaborated field strength the alignment must be destroyed completely. The destructing field strength and alignment ability may be related deeply.

Here we observed the change of the LC alignment ability for some alignment layers with polarizing optical microscope and capacitance measurement at the same time. We tried to match these results with the anchoring strength to understand the relation between the anchoring and the stability of LCs.

2. Experiment and Results

We prepared the planar alignment cells on the ITO glasses. Some of alignment layers were treated with conventional rubbing on the commercial polyimide (AL-3046) and the other did with photo-alignment on photo-reactive material. This material induces anisotropy with polarized UV-light by cyclo-addition of C-C bonds. Both surface treatments were acted sufficiently to ensure clear texture.

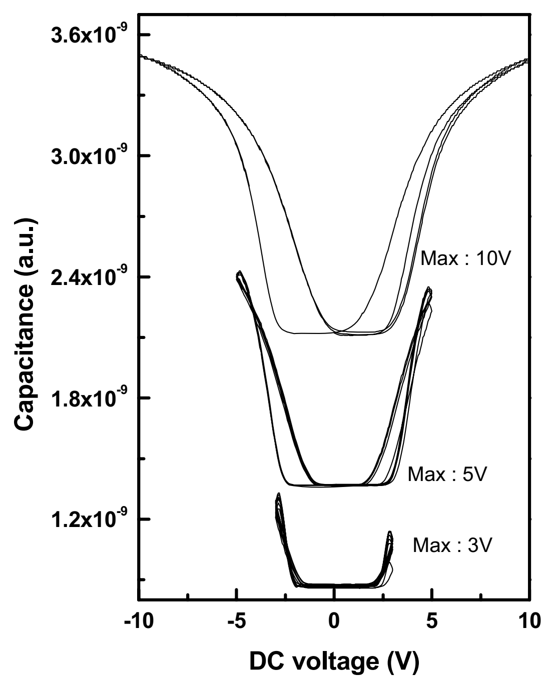

Figure 1. Change of capacitance with different maximum DC voltage. The alignment was realized by photo-alignment. Measuring signal was 0.1V, 1kHz and DC voltage was varied by 0.05V step.

The cell gap was several um, but with some variation at the edge. The overlapping area of electrode was several tens mm^2. LC was 4-n-pentyl-4'-cyanobiphenyl (5CB). All the measurement was carried out at room temperature.

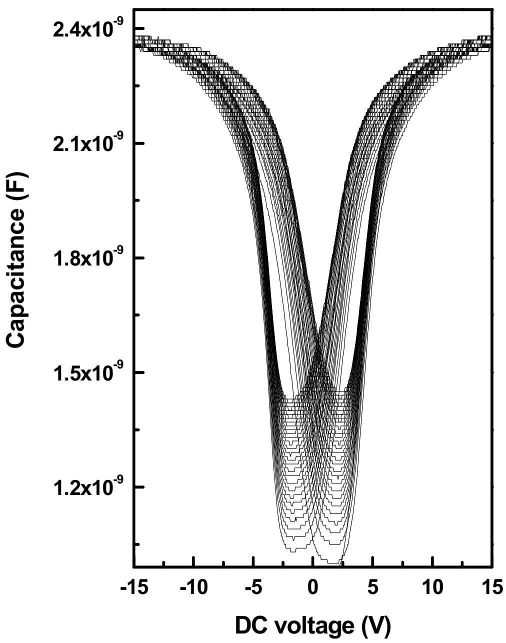

Figure 2. Permanent change of capacitance with applying DC voltage. The minimum capacitance was increased with repetition and it seems to be saturated. The maximum DC voltage was ±15V.

For the monitoring the change of the alignment, we used the typical experimental setup for residue DC voltage measurement. In other words, we measured the capacitance with small AC signal (1kHz, 0.1V) applying DC electric field. In this experiment we controlled the DC voltage up to ±40V. We observed the texture through a polarizing optical microscope simultaneously.

First, we investigated the LC cell, which alignment was realized by the photo-alignment. For the cycling electric field of appropriate range, the capacitance repeated almost the same graph with a certain hysteresis from the screening charges absorbed in the alignment layer as in Figure 1. In this case, up to ±10V, there was no base line change.

In most cases, the level of hysteresis is a very important parameter indicating reliability of LC devices [1,2]. For these experiments, the minimum value of capacitance did not change with the repetition.

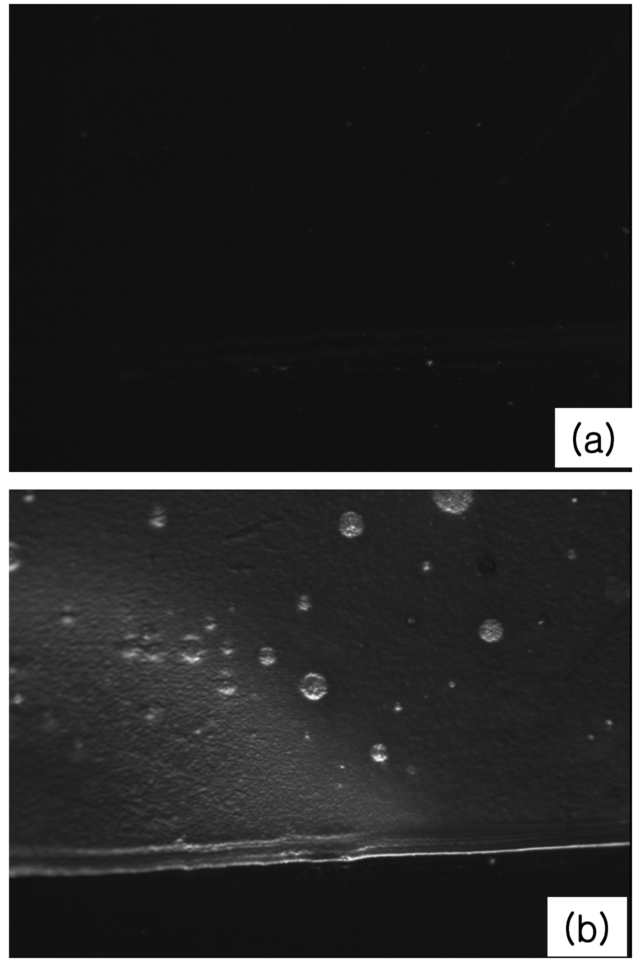

Figure 3. The change of texture with DC electric field. (a) The LC texture at the beginning of experiment. The textures on the electrode (upper area) and non-electrode (lower area) are the same. (b) The texture after certain time of experiment. The contrast between electrode and non-electrode is clear.

However, to the higher field, the minimum capacitance varied with cycling the DC voltage as Figure 2. The capacitance of zero electric field and minimum point was increased. The increased value did not relaxed back to the original minimum value even turning the DC voltage off. The texture has got brighter in proportion to the increased capacitance at

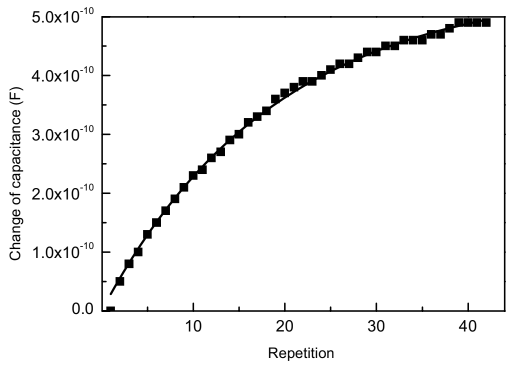

Figure 4. Changing minimum value of capacitance in DC voltage cycling. The y-axis value was shifted with the original capacitance as the reference. Dots indicated the experimental result and solid line did the fitted result.

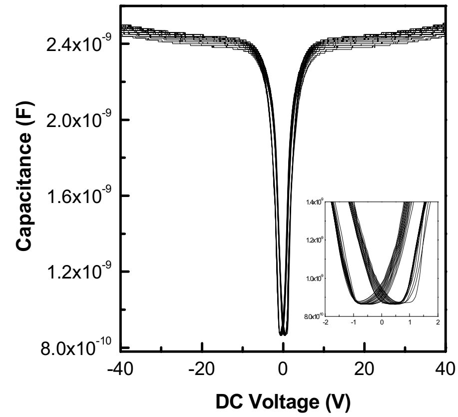

Figure 5. Stable behavior of capacitance. The alignment layer was a commercial polyimide and conventionally rubbed. Small graph in the box magnified the bottom part of large graph.

zero voltage or minimum capacitance. This indicated the destruction of LC alignment in polar and azimuthal orientation at the same time. Finally with higher field, the texture showed the destruction of the alignment with changing from uniform alignment to non-uniform one as Figure 3.

Increasing of the minimum capacitance with repetition plotted in the Figure 4. We would like to guess the anchoring energy using this result. As the electric field acts oppositely to the anchoring, we can easily expect the destruction rate of anchoring with each repetition is approximately equal to the ratio of electric energy to the anchoring strength. If the destruction is very tiny, we can assume that the destruction occurred with constant rate. With simple manipulation, we obtain the equation of capacitance change as $\Delta C(\mathrm{n}) = \Delta C_o(1-\exp(-\lambda \mathrm{n}))$, ΔC_o : maximum change of capacitance, n : number of the repetition, λ : destruction rate. The fitting with experiment was really great and resulted in $\Delta C_o = 5.5\times10^{-10}$ F and $\lambda = 0.05$.

From Fig. 3, the difference of capacitance between the planar alignment and homeotropic is about 1.4×10^{-10}F. If we consider the randomly oriented LC cell, we expect the capacitance to be increased crudely 0.7×10^{-10}F. That value is corresponds to the ΔC_o. Both from experiment and rough estimation show similar value.

As mentioned before,

$$\lambda \approx electric\ energy / anchoring\ energy$$
$$\approx 0.5\Delta\varepsilon \mathrm{E}^2 l / \mathrm{W}_o$$

($\Delta\varepsilon$: dielectric anisotropy, E : electric field strength, l : thickness of surface layer (Here we assumed it is comparable with molecular length.), W_o : anchoring strength).

From the data of 5CB and experimental conditions ($\Delta\varepsilon \approx 7\times10^{-11}$F/m , $K_{22} \approx 2\times10^{-12}$N , $\mathrm{E} \approx 2$V/um , $l \approx 1nm$), we obtained $W_o \approx 3\times10^{-6}$ J/m^2 (extrapolation length ≈700nm), indicating rather weak anchoring as usually known (3,4).

Finally we observed the capacitance of the conventionally rubbed cell, which alignment layer is a commercial polyimide and rubbed sufficiently. As shown in the Fig. 5, even though the electric field is much stronger than photo-aligned cell, there is little change with the repeating DC scanning. It is rather contrast result with the behavior of the photo-aligned cells. It seems that this reflects the different strength of anchoring with different alignment technique and alignment layer.

We can connect the alignment stability and anchoring as above argument. However, to clarify the result, we must carefully examine several aspects of the experiment ; the influence of the ions in the cell, connection of polar and azimuthal anchoring, etc.

3. Conclusions

Observing the capacitance behavior and optical microscope image with DC voltage scanning, we can connect the destruction of alignment with anchoring strength. The anchoring strength of photo-alignment layer was reasonable value of $3x10^{-6}$ J/m^2.

However, to make sure the relation, we need to examine more seriously in several aspects.

4. Acknowledgements

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5. References

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