Enhanced flexoelectric switching made from self-assembly of smectic liquid crystal and triallyl dopant

Tong-Kun Lim and Ji-Hoon Lee*

Department of Physics, Korea University, Seoul 136-713, Korea
Phone: 82-2-3290-3094, E-mail: tongklim@korea.ac.kr

Abstract

Here we report an enhanced flexoelectric switching in a self-assembled system of smectic liquid crystal and some specific dopant. The assembled unit block seemed to have electric dipole and as a result induces large flexoelectric polarization due to its asymmetric shape and shows fast switching to the electric field. The unit blocks are oriented in a helical fashion in the cell with large gap (~5 ㎛) and shows selective reflection property. In the thin cell (~2 ㎛), the unit blocks are aligned homeotropically on the bare ITO substrate with no surface treatment and shows fast decaying time.

1. Introduction

Flexoelectric effect of liquid crystal (LC) has been drawn much attention in the viewpoint of the application display system because it can switch LC molecules with fast response time. Previous researches on the flexoelectric effect in LC were reported in the hybrid aligned nematic (HAN) state or cholesteric state. However, the magnitude of flexoelectric polarization (P_f) in those works is too small (typically less than 1 nC/cm^2) for the application in the liquid crystal display device.

In this research, we report large enhancement in flexoelectric effect in the material composed of linear-shaped smectic LC and some specific shaped dopant. As the electric field is turned on, the LC and the dopant molecules are self-assembled and makes a unit block which has strong electric dipole moment. The assembled unit block has asymmetric shape hence it can induce a splay distortion and makes flexoelectric polarization.

2. Results

We used 4-octyl-4'-cyanibiphenyl (8CB) and some specific shaped dopant. By measuring the small angle X-ray scattering spectrum and DSC thermogram, it was shown that the mixed compound shows nematic phase at 25 ℃.

The orientation of optic axis of the doped 8CB is shown in figure 1. Firstly, it is noted that the optic axis (OA) rotates in the opposite direction to the opposite sign of the electric field. Secondly, the rotation angle of OA is almost linear when the strength of the electric field is low (less than 0.5 V/㎛). These measurements imply that the doped 8CB shows polarity-sensitive switching behavior.

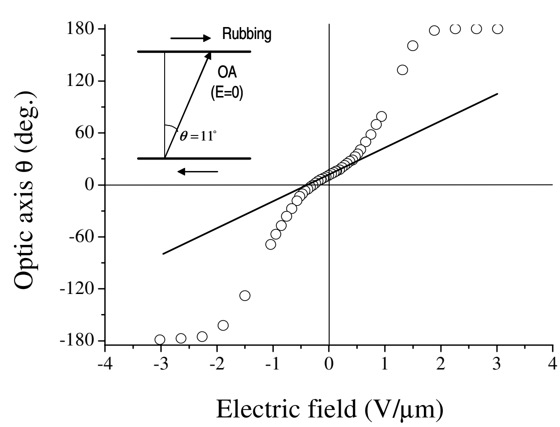

Figure 1. Optic axis of the doped 8CB cell as a function of electric field. Cell gap is 5.0 ㎛. Data was taken at 25℃.

The rising time of the doped 8CB cell is shown in figure 2. Similar to the case of general material showing flexoelectric switching behavior, this sample shows linear response to the electric field above threshold voltage. Rising time of doped 8CB at 10 V/㎛ is 5.5 ㎲ which is twice times faster than the theoretical rising time of pure 8CB (11 ㎲) which has dielectric switching behavior.

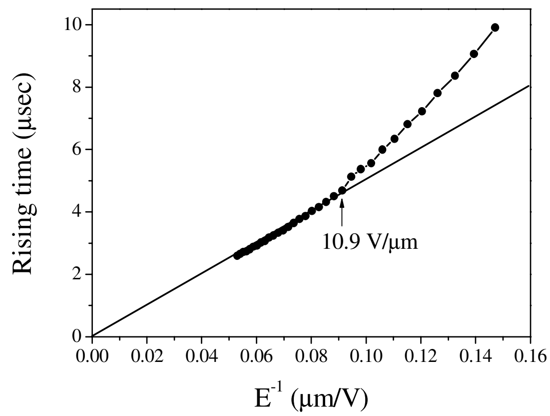

Figure 2. Rising time of the doped 8CB cell as a function of the inverse of electric field. Cell gap is 5.0 ㎛. Data was taken at 25℃.

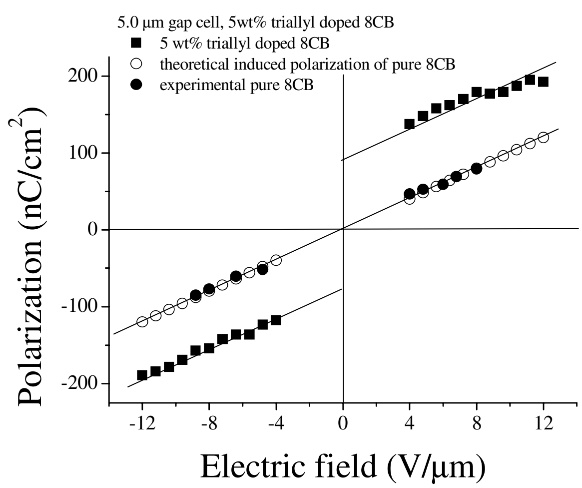

Figure 3. Polarization of the doped 8CB and pure 8CB cell. Cell gap is 5.0 ㎛. Data was taken at 25℃.

Figure 3 shows the polarization of the doped 8CB and pure 8CB cell measured by a switching current method. The polarization of doped 8CB cell is 80 nC/cm^2 larger than the pure 8CB cell independent of the applied field strength. This difference is thought to be contributed from the flexoelectric polarization. The magnitude of this polarization measured from the doped 8CB cell is much larger (roughly 150 times) than the reported one of pure 8OCB molecule (0.22 nC/cm^2) which has similar chemical structure with 8CB.

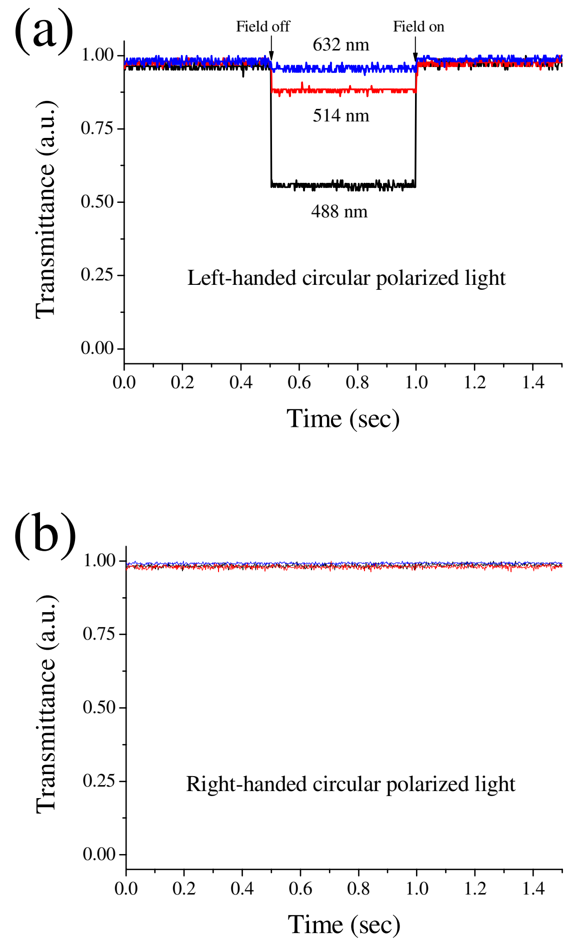

Figure 4. Transmittance of the doped 8CB cell to the left-handed (a) and right-handed circularly polarized light (b) with 488 ㎚, 514 ㎚, 632 ㎚ wavelength. Cell gap is 5.0 ㎛. Data was taken at 25℃.

Figure 4 is the transmittance data which shows the selective reflection of the doped 8CB cell to the left-handed circularly polarized light (a). There is no selective reflection for the right-handed circularly polarized light for only different wavelength (b). At the field off state, the doped cell shows the strongest reflection to the light with 488 ㎚ wavelength [Fig. 3 (a)]. However it does not reflect the circularly polarized light with opposite handedness. From these wavelength and handedness selective reflection property, it can be thought that the doped 8CB has helical structure at field off state. As the electric field is applied, the selective reflection property does not appear. Therefore it seems that the helical structure of doped 8CB is destroyed as the field is turn on. The formation of helical structure is seemed to be due to reorientation process of the assembled unit block to reduce the electrostatic energy of them.

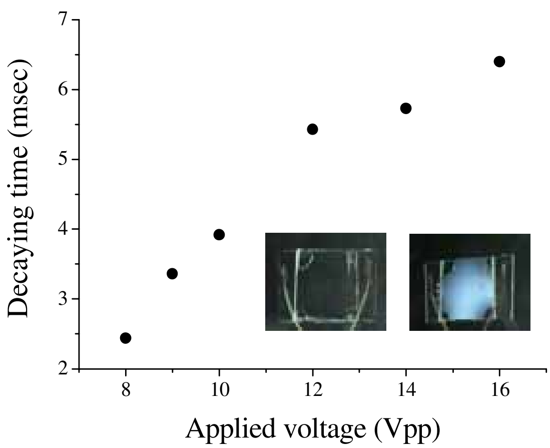

Figure 5. Decaying time of the doped 8CB cell without any surface treatment. Inset shows the transmitting state of the cell between crossed polarizers to the normally incident and obliquely incident light. Cell gap is 2.0 ㎛.

The doped 8CB was found to align homeotropically on the bare ITO substrate with no surface treatment [see the inset of figure 4]. By applying an electric field parallel to the substrate plate, the optic axis could be aligned parallel to the substrate. Then, as the electric field off, the cell showed very fast decaying time (less than 6.5 msec) as shown in figure 4.

3. Conclusion

We have shown that large enhancement in flexoelectric switching using a self-assembly of smectic LC and dopant. In a larger gap cell, this assembled unit block shows wavelength and handedness selective reflection property due to its helical structure. On the other hand, it aligns homeotropically on the bare ITO substrate in the thin cell. It could be switched using in-plane electric field with fast response time. This novel LC material is expected to be applied in various type of display application device.

4. Acknowledgements

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5. References

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