Hysteretic behavior in polymer stabilized ferroelectric liquid crystal

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Abstract

We have found that the hysteretic behavior of a polymer stabilized ferroelectric liquid crystal system coincides with Blinov et. al's model qualitatively. The hysteresis inversion frequency could be promoted up to 7000 Hz by connecting external capacitor and resistor in serial. In addition, the influence of temperature and the amplitude of the applied field on hysteresis-free switching of the cell could be minimized.

1. Introduction

In 1990's, ferroelectric liquid crystal (FLC) materials (T3 mixutre, Inui mixture) which does not show any hysteresis at wide temperature range were reported in Japan [1-3]. Then various models to interpret the mechanism of hysteresis-free switching (V-shape switching) were reported extensively [4-6]. Recently, Blinov et. al has suggested that the hysteresis-free switching is only an apparent phenomenon, not a real effect, which were caused by the coincidence of the impedence of LC with specific applied electric field condition [7-8].

In this research, we have examined whether the polymer stabilized ferroelectric liquid crystal (PSFLC) switching behavior as well as the pure FLC system follows Blinov et. al's model. Then we have connected external capacitor or resistor outside of the LC cell and examined the optimized condition which has desirable high hysteresis inversion frequency (w_{inv}) and minimum dependence on the temperature and the amplitude of the operating electric field during the V-shape switching.

2. Experiment

Commercially available FLC Felix 018-100 was used as host material and UV-curable prepolymer NOA63 (Norland products) with thiol and ene constituents was used as monomer. The polyimide was spun on the ITO coated glass and rubbed in antiparallel directions. The LC and polymer were mixed and injected via capillary action at 110 ℃. The samples were polymerized at 25 ℃ (SmC* phase) with irradiation of 40 ㎽ high pressure Hg lamp for 10 min. Temperature was controlled in an accuracy of 0.1 ℃ using hot state. Spontaneous polarization (P_S) was determined by measuring the current response to the triangular voltage as previously suggested [10]. Cone mode viscosity was calculated from the spontaneous polarization data using eq. (1) [11],

$$g = P_S t / \sin^2 q \qquad (1)$$

where P_S is a normalized spontaneous polarization, t is a normalized rising time, q is a tilt angle and g is a normalized viscosity of the LC c vector rotating around the cone axis. The capacitance and resistance of the sample were measured with LCR meter with 1 V bias voltage at 1 kHz frequency.

3. Results and Discussion

Figure 1 shows the hysteretic behavior of transmittance of the pure FLC cell and PSFLC cell controlled by a triangular shaped electric field. Both cell showed hysteresis-free switching at specific frequency, voltage and temperature and the cell showed hysteresis loop as one of the condition was varied. Even the cell with 40 wt% polymer also showed same behavior. From these results, the PSFLC cell as well as the pure FLC cell follow the model suggested by Blinov et al. in the qualitative aspects.

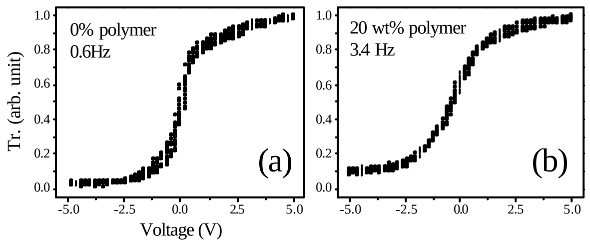


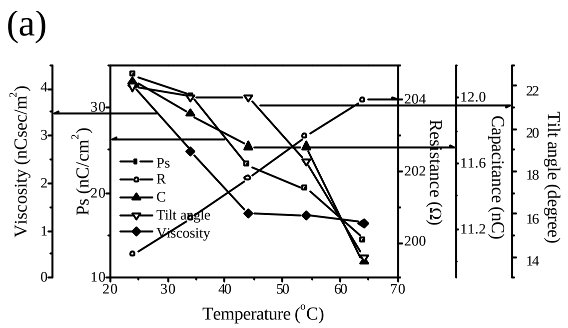
Fig 1: Transmittance of the pure FLC (a) and the PSFLC (b) cell controlled by a triangular voltage.

Next, we have measured each parameter that determines the hysteresis inversion frequency as suggested in eq. 2, and then examined the hysteretic behavior of PSFLC coincide with the Blinov et al.'s model in the quantitative aspects

$$w_{inv} \approx \sqrt{\frac{1}{xR_{LC}(C_{LC}+C_P)}}$$

$$x = \frac{1}{4P_s^2 e_0 g q^2} \qquad (2)$$

For the estimation of inversion frequency one need parameters such as tilt angle, spontaneous polarization of the FLC as well as the viscosity, resistance and capacitance of the cell. These are measured as a function of temperature and were used to estimate the inversion frequency. The inversion frequency does not coincide with the normalized value which was directly measured. It is thought that there may be an unknown parameter or mechanism of hysteretic behavior in PSFLC.



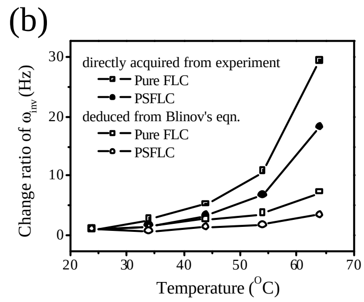


Fig. 2: Ps, resistance, capacitance, tilt angle, normalized viscosity of the PSFLC cell at different temperature (a). Comparison of inversion frequency directly acquired from experiments with the evaluated value from Eq. 1 (b).

For the display application, the hysteretic inversion frequency should be larger 100 Hz and the influence of the temperature also should be minimized. To accomplish these conditions, we have connected external capacitor or resistor in serial or parallel to the PSFLC cell and examined the effects of them [Fig. 3].

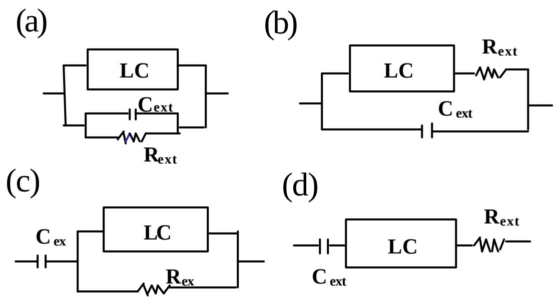


Fig. 3 Equivalent circuit of the PSFLC cell with external capacitor and resistor in serial or parallel direction.

The inversion frequency of hysteresis results acquired from the cell configuration suggested in figure 3 is shown in figure 4. For the case of external capacitor connected in parallel direction, the inversion frequency is less than 100 Hz and the influence of temperature dependence is strong. On the other hand, the case of serially connected capacitor shows desirable high inversion frequency and the influence of temperature is less than the former case. From these results, it can be shown that the capacitor should be connected in serial direction to show high inversion frequency and low influence of temperature.

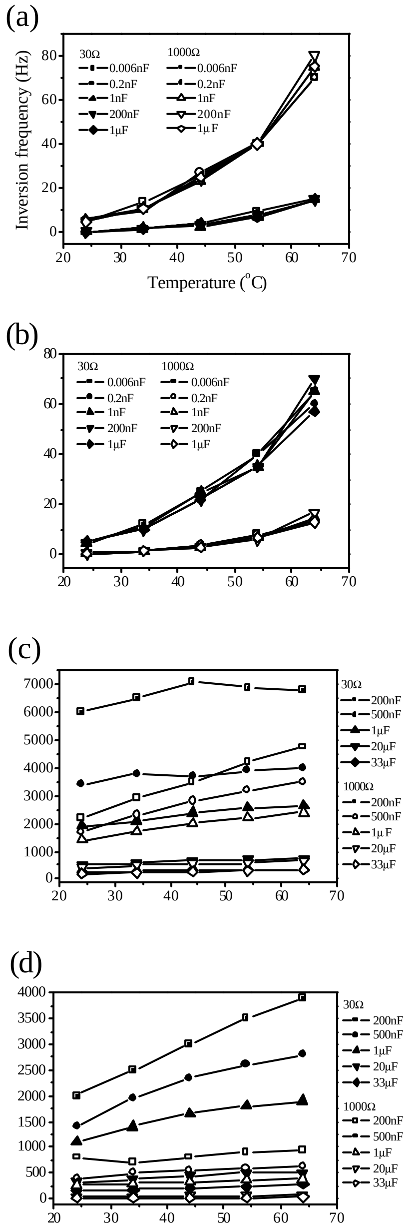


Fig. 4 Hysteresis inversion frequency under the cell configuration suggested in figure 3 at different temperatures.

Next, we have examined the normalized hysteresis inversion frequency to see the temperature dependence of the inversion frequency. The ratio ($w_{inv,64°C} / w_{inv,24°C}$) is plotted in the Fig. 5. The variation in inversion frequency for a serial capacitor connection [Fig. 5 (c), (d)] was 10 times lower than that of the circuit with the parallel capacitor connection [Fig. 5 (a), (b)]. Therefore the external capacitor should be connected in serial in order to have lager w_{inv} and less variation against temperature.

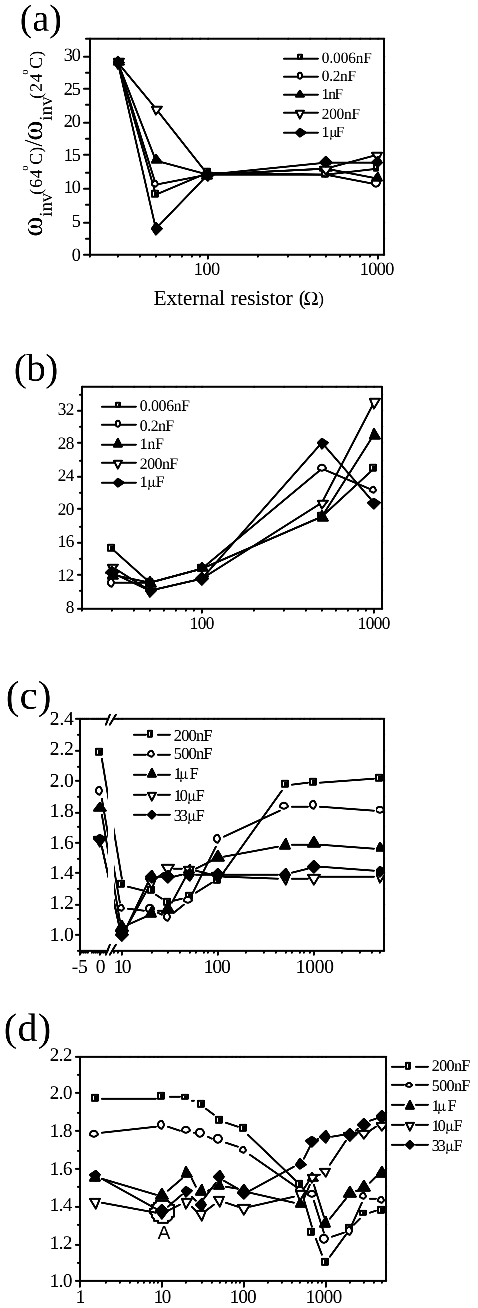


Fig. 5: Ratio of inversion frequency change of the cell with temperature variance

4. Conclusion

We have found that the hysteretic behavior of PSFLC as well as pure FLC coincides with the model suggested by Blinov et. al. The hysteresis-free switching appeared only at some specific frequency and shows temperature dependent behaviors. We promoted the hysteresis inversion frequency up to 7000 Hz and also minimize the influence of temperature on the hysteresis-free switching of the cell by connecting external capacitor and resistor.

5. References

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