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Response Time Improvement for Liquid Crystal / Polymer Composite Films Using Dual Frequency Addressable Liquid Crystals

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We report a significant improvement in decay time for liquid crystal / polymer (LC/P) composite films, using dual frequency addressable liquid crystals. LC/P composite film consists of a mixture of a photoactive monomer, an oligomer and a dual frequency addressable liquid crystal. The decay time for this LC/P composite film applied 50 V of 10 kHz is about 10 times faster than the passive decay time. It is also found that the response times for the LC/P composite films are controlled by superimposing the high frequency bias voltage on the low frequency voltage.

Nematic liquid crystals, which are dispersed or networked in a polymer matrix, give electrical light shutters with a wide range of applications.[1-4] This LC/P composite film has such advantages as high contrast and excellent brightness, since no polarizer is necessary in this device structure. However, in this LC/P composite film, the decay time is strongly influenced by tangential anchoring effect at the polymer-liquid crystal interface and by inherent properties of LC (viscosity, elastic constant), which are not easily controlled in usual liquid crystals. In order to improve this decay time, dual frequency addressable liquid crystals,[5] whose dielectric anisotropy is controlled to be positive or negative according to the frequency for the external electric field, are investigated for this LC/P composite film.

The LC/P composite films were prepared by an ordinary method.[6] The mixture of a monomer, an oligomer and a liquid crystal(the ratio is 1:2:4.5 in weight, respectively) was sandwiched between transparent conductive substrates, using a polyethylene film as a spacer(about 10 μm thick). Then the mixture was exposed to UV irradiation from a high pressure mercury arc lamp for 1 minute at 333 K. Butyl acrylate, ester-acrylate oligomer (Toagosei Chemical Industry Co. Ltd., M6200), and 2.2-diethoxy acetophenone were used as monomer, oligomer, and photo initiator, respectively. The dual frequency addressable liquid crystal NR-1013XX was purchased from Chisso Petrochemical Corporation. Electro-optical properties were investigated under various applied voltage magnitudes at room temperature. Electrical signals were generated using two function generators (Wavetek model75) coupled with an amplifier(NE4005). A light beam from the He-Ne laser(632.8 nm), which passed through an LC/P composite film, was measured by a photodiode connected to a storage oscilloscope.

The crossover frequency(fc) for liquid crystal NR1013XX, the frequency at which the dielectric anisotropy changed, was about 1 kHz. A lower frequency than the fc resulted in positive dielectric anisotropy and vice versa. The 100 Hz A.C.electric field was applied to raise the transmittance for the LC/P composite film. The 10 kHz A.C. electric field was applied to decay it.

Below the fc, an applied voltage, at sufficient magnitude aligned the LC molecules along the electric field, which resulted in refractive index matching between the LC and polymer matrix. Therefore, the LC/P composite film became transparent. Above the fc, the applied voltage aligned LC molecules perpendicular to the electric field, which made the film opaque. Usually, in this state, the LC/P composite film scattered light stronger than in non-activated off-state.[7] However, the LC/P composite films, prepared in this study, scattered light so strong that, even in non-activated off-state, there was only about 1% difference in transmittance between the non-activated off-state and the off-state activated by the high frequency voltage. Rise time is defined as the time between the instant when voltage is applied and the transmittance reaches 90% of the saturated transmittance. The decay time is defined as the time between the instant when voltage is removed and the transmittance decreased from 100% to 10% of the saturated transmittance.

Figure 1 shows the applied voltage dependence for the transmittance. The difference, between the non-activated off-state transmittance and that for the off-state activated at 50 V, is very small. This indicates that light scattering efficiency is saturated at both states. Figure 1 shows that this LC/P composite film becomes completely transparent when more than 40 V is applied at 100 Hz.

Figure 2 shows an example of decay time measurements on the LC/P composite films. When the higher frequency voltage was applied, owing to the change in the dielectric anisotropy sign from positive to negative, the decay time was much improved compared with the passive decay time(dashed line), which was observed under no applied voltage conditions. As mentioned above, this sample has almost the same transmittance between the non-activated off-state and the activated off-state, once the transmittance is decayed. Therefore, there is no need for applying voltage to maintain the scattering state.

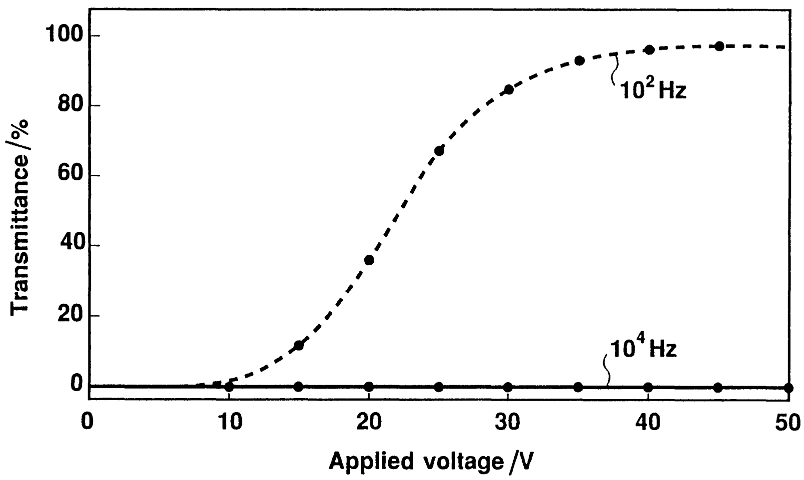

Fig.1. Transmittance dependence on applied voltage.

Figure 3 shows the applied voltage dependence for the decay time. The decay time decreases as the applied voltage increases. The decay time, under 50 V applied voltage, is about 10 times faster than the passive decay time.

The passive decay time, after activation by a voltage at low frequency(dashed line) is greatly influenced by this activation time period, probably due to charging the liquid crystal(Fig.4). This phenomenon is a serious problem for devices which need fast operation, and is inevitable as long as we use usual liquid crystals. The decay time change magnitude may be improved by changing the conductivity for the polymer or liquid crystals. However, this task seems to be a bit time consuming at this moment. On the contrary, the decay time for the LC/P composite film, using dual frequency addressable LC(solid line), is not influenced by the activation time period at all(Fig.4), which clearly shows the advantage of this method.

Thus, the response time can be varied by changing the applied voltage or frequency. In the case of usual liquid crystals, response time is controlled by the magnitude of the applied voltage, which automatically fixes the saturated transmittance. That is, response time and transmittance cannot be chosen freely. We have proposed a new method to control the response time at arbitrary transmittance. This involves, superimposing high frequency bias voltage on low frequency voltage. This method obviates the necessity to change the frequency from low to high or from high to low. By adjusting the high frequency voltage, the response time is controlled without affecting the transmittance. Figure 5 shows the changes in response time caused by

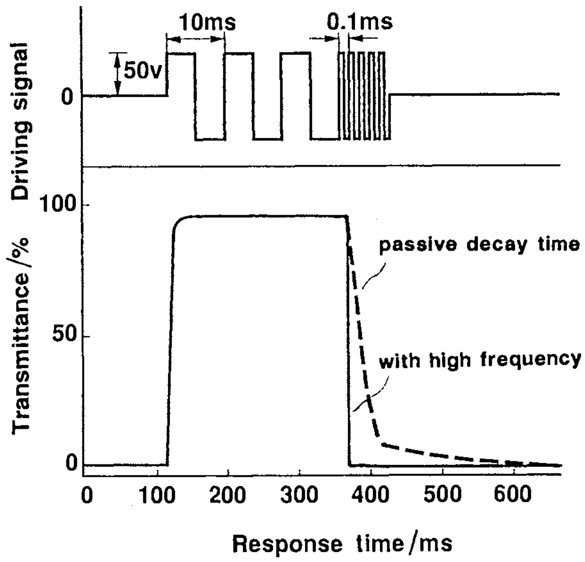

Fig.2. Decay time measurement of LC/P composite film.

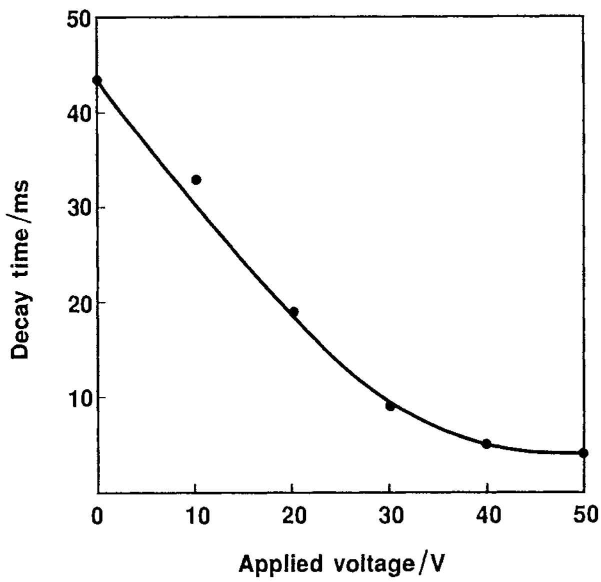

Fig.3. Decay time dependence on applied voltage.

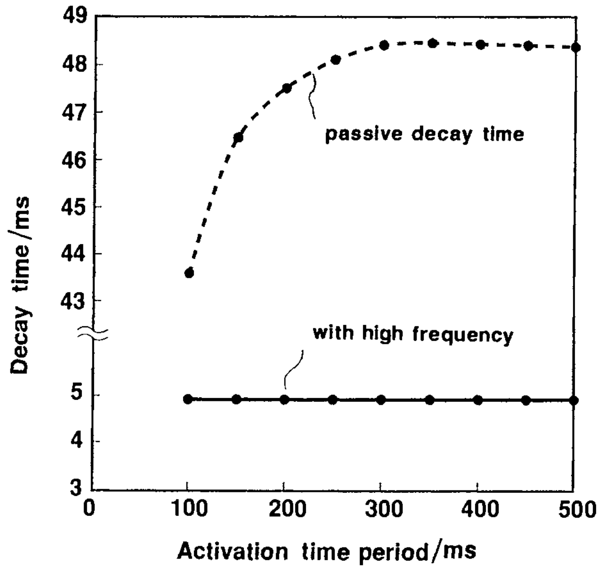

Fig.4. Decay time dependence on activation time period.

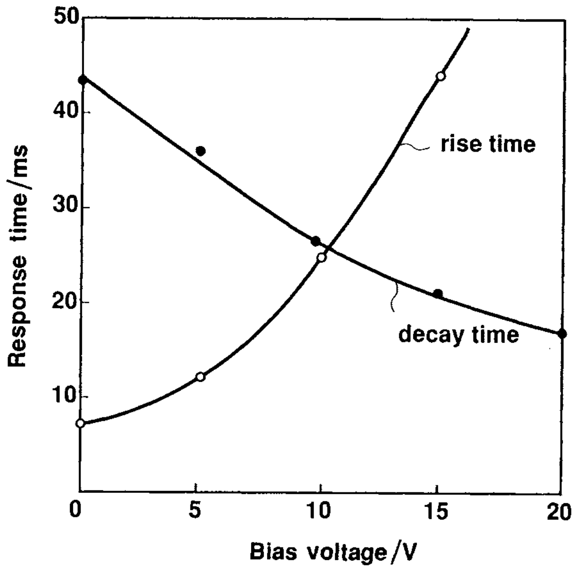

Fig.5. Response time dependence on high frequency bias voltage superimposed on 50 V low frequency voltage.

superimposing the 10 kHz bias voltage at up to 20 V on 50 V of 100 Hz. The decay time becomes equal to the rise time, by applying 10 V bias voltage of 10 kHz.

We have suggested the applicability of dual frequency addressable LC/P composite film to an optical switching device. It has been shown that the decay time is enormously improved by using dual frequency addressable liquid crystals. Furthermore, we have proposed a novel driving method with which the rise time and the decay time are controlled without changing frequencies, that is, by superimposing the high frequency bias voltage on the low frequency voltage. Dual frequency addressable liquid crystal is useful to control response times for the LC/P composite film.

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