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POLYMER MORPHOLOGY AND ELECTRO-OPTIC PROPERTIES OF PSCT DEVICES

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Abstract The relations between the polymer morphology and electro-optic properties in polymer stabilized cholesteric textures (PSCT) were investigated. SEM analysis revealed that the polymer matrix consisted of submicron-order-diameter spherical particles, which are connected with each other and forms three-dimensionally networked wire. The network spacing which evaluated from a number of the polymer particle in volume was the main factor determining the electro-optic characters of the device. With the larger network spacing, the improved properties of PSCT device such as lower driving voltage and higher contrast ratio were attained.

INTRODUCTION

A polymer-stabilized cholesteric texture (PSCT)[1,2] device is a new class of the display consisting of cholesteric liquid crystals and a dispersed polymer. The device has been attracted much attention because it is easily prepared and can be driven without polarizer. To be applicable to the display, the PSCT device must have a low driving voltage, a high contrast, and a small hysteresis. So far, many attempts[3-7] have been made to reveal the relations between the electro-optic properties and the dispersed polymer. Nevertheless, detailed investigation of the polymer morphology has been limited, because of the difficulty in observation for the polymer dispersed in liquid crystal. Recently, we have found that the polymerization conditions, such as monomer concentration and intensity of UV-irradiation, affect the polymer morphology and electro-optic properties of the PSCT devices. In this paper, we will describe the relations between the electro-optic properties of the PSCT device and the polymer morphology observed by scanning electron microscopy (SEM).

EXPERIMENTAL

The PSCT devices were produced by the polymerization-induced phase separation method.[8,9] A mixture of UV-curable monomer 4,4'-bisacryloyloxydieylstilbene, liquid crystal TL215, chiral dopant S811 (helical pitch: 3.4 μm), and benzoinmethylether initiator was spread between two glass substrates coated with ITO and an alignment layer (polyimide; homogeneous alignment). The cell gap was 10 μm. The cell was exposed to UV-irradiation with a high-pressure mercury lamp (365 nm) at 303 K in order to form the polymer network.

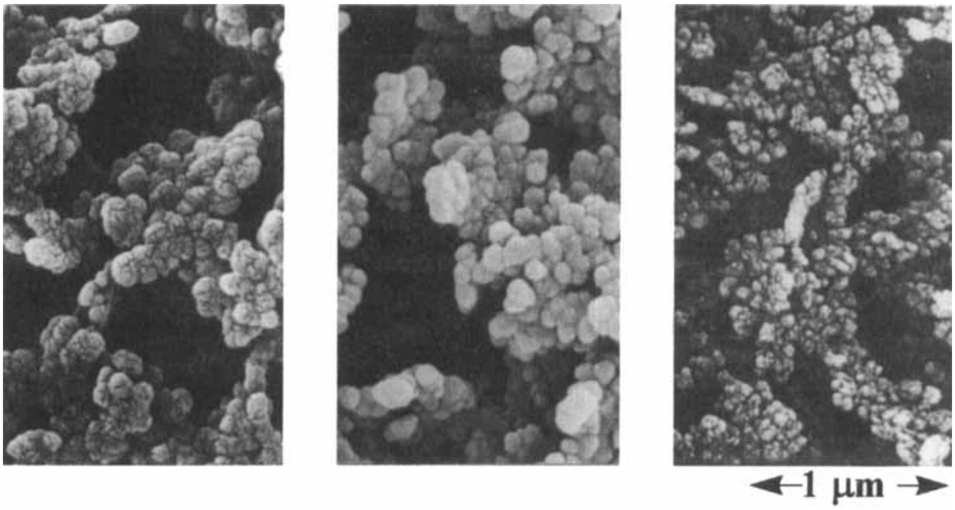
Electro-optic properties were measured by using a photodiode at a collection angle of 2° (half angle) to estimate the intensity of a He-Ne laser beam (λ = 632.8 nm) that was passed through the PSCT device at room temperature. An electric field was applied to the device using a 100 Hz rectangular wave. Driving voltage was the voltage at which the transmission reached $0.1 \times (T_{max}-T_{min})+T_{min}$. Where, T_{max} and T_{min} were the maximum and the minimum transmission in the transmission-voltage curve, respectively. The contrast ratio was represented by T_{max} / T_{min}.

The morphology of the dispersed polymer in the PSCT device was observed using SEM. The sample was prepared by extracting the liquid crystal with hexane for 10s after removing the top glass substrate in liquid nitrogen.

RESULTS AND DISCUSSION

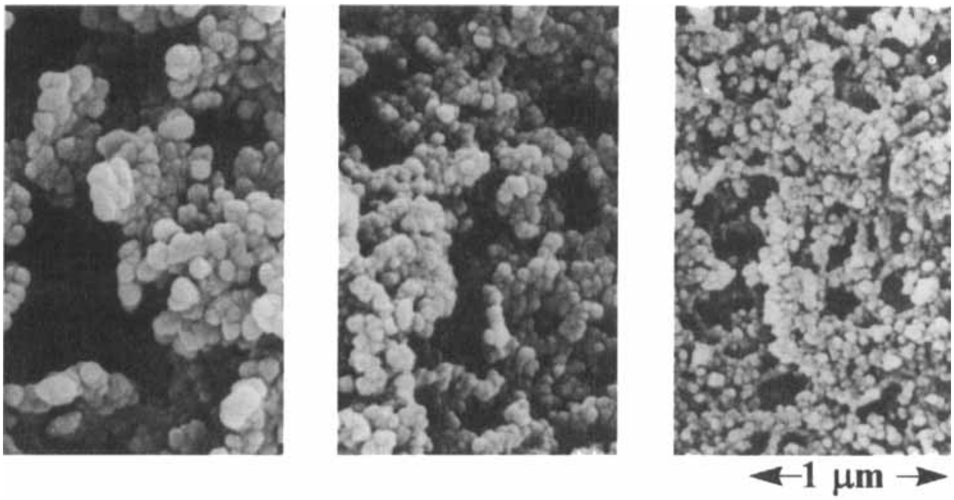
Figure 1 and 2 show SEM photographs of dispersed polymer in PSCT devices prepared under the conditions of various monomer concentration and UV-irradiation. It is observed that the polymer matrix consisted of submicron-order-diameter spherical particles, which are connected with each other and forms three-dimensionally networked wire. Obviously, the diameter of the polymer particles and the network spacing vary with the monomer concentration and the intensity of UV-irradiation, that is, both of the parameters decrease with increasing the monomer concentration and intensity of UV- irradiation.

The diameter of the polymer particle is enable to measure from the SEM photographs directly. However, the spacing of the extracted and dried polymer network is considered to be different from that in the liquid crystal matrix. Thus, the polymer network spacing is estimated from the particle diameter and total polymer volume in feed by assuming the network dispersed in the cell randomly. The calculated network spacing is in the range from 0.5 to 1.5 μm.



1.5 wt% 2 wt% 3 wt%

FIGURE 1 Polymer morphology of PSCT devices prepared in various polymer concentrations with the same level of UV-irradiation(0.12 mW/cm^2 × 720 min.)



0.12 mW/cm^2 8.3 mW/cm^2 333 mW/cm^2

FIGURE 2 Polymer morphology of PSCT devices prepared in various levels of UV-irradiation (total energy : 5 J/cm^2, polymer concentration : 2 wt%).

ELECTRO-OPTIC PROPERTIES AND POLYMER MORPHOLOGY

Figure 3 shows the plot of driving voltage of PSCT devices against the diameter of dispersed polymer particle. It is observed that the driving voltage decreases with increasing the particle diameter and saturates to 10 V. At the diameter less than 0.1 μm, the driving voltage affected by the monomer concentration or polymer volume. It indicates that the particle diameter is not a determining factor of the driving voltage. Figure 4 shows the relation between the contrast ratio of PSCT devices and the diameter of dispersed polymer particle. The contrast ratio increases with increasing the particle diameter.

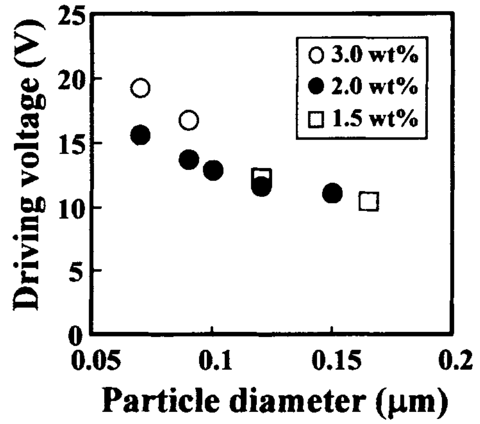


FIGURE 3 Plots of driving voltage of PSCT devices prepared from various polymer concentrations vs. particle diameter.

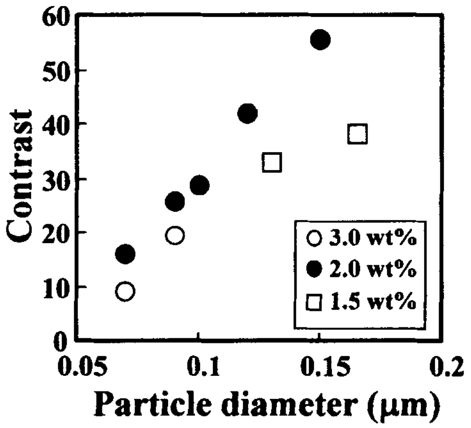


FIGURE 4 Plots of contrast ratio of PSCT devices prepared from various polymer concentrations vs. particle diameter.

Figure 5 and 6 show the relation between the driving voltage and the contrast ratio on the network spacing. Both of the electro-optic properties of PSCT device prepared from various conditions are converged on the relation with network spacing. That is, the driving voltage changes with network spacing in inverse proportion. Contrary, the straight line fit is found for the contrast ratio. These results indicate that the electro-optic properties depend on the network spacing of the dispersed polymer which should be associated in the size of the liquid crystal droplet.

Figure 7 shows the transmission curves of PSCT devices of large (a) and small (b) network spacing, which have the same diameter of polymer particle.

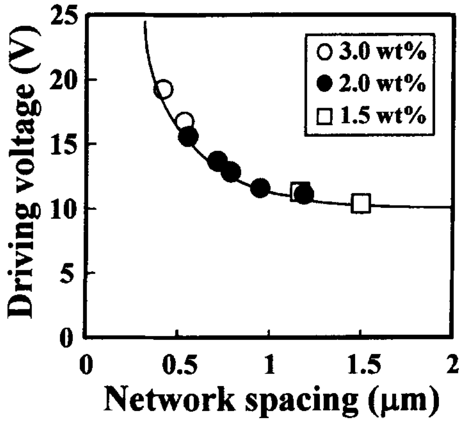


FIGURE 5 Dependence of driving voltage of PSCT devices prepared from various polymer concentrations on network spacing.

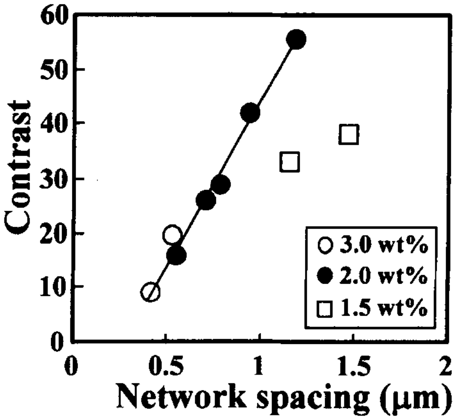


FIGURE 6 Dependence of contrast ratio of PSCT devices prepared from various polymer concentrations on network spacing.

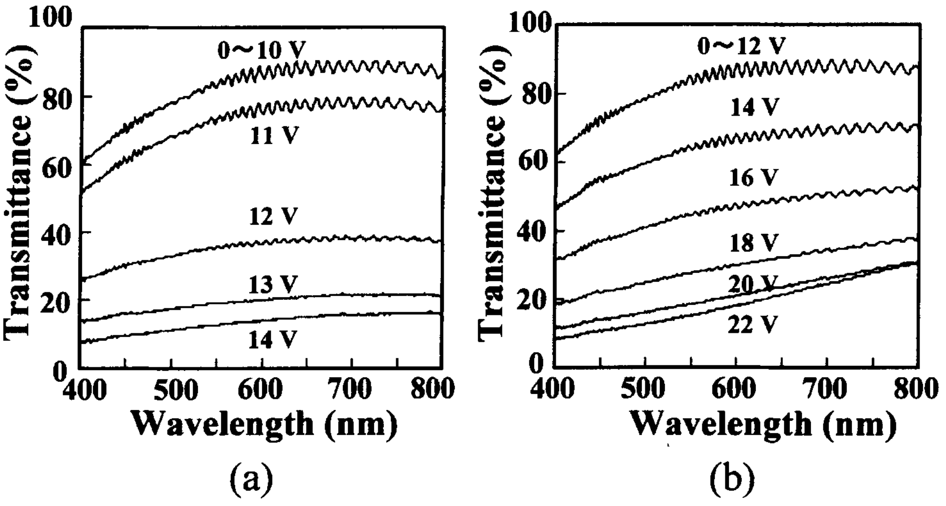


FIGURE 7 Transmission curve of PSCT devices at various applied voltages.
(a) polymer concentration: 2 wt%, UV-irradiation: 27.7 mW/cm^2 × 3 min.
(b) polymer concentration: 3 wt%, UV-irradiation: 2.8 mW/cm^2 × 30 min

In the case of the PSCT device with large network spacing (a), the transmittance decreases in the whole range of visible wavelength with the increase of applied voltage and finally complete light scattering are accomplished over 14 V. On the other hand, in the case of (b), the high transmittance is observed in long wavelength for high applied voltage. It suggests the small contrast ratio of the devices. The results obtained in this work suggest that the electro-optic properties depend on the network spacing of the dispersed polymer which should be associated in the size of the liquid crystal droplet.

CONCLUSIONS

In conclusion, it is shown that the polymers in PSCT devices have a three-dimensionally networked morphology composed of spherical particles with submicron-order-diameter. Furthermore, the network spacing associated in the size of liquid crystal droplet affected the electro-optical properties. With controlling the network spacing, the PSCT device with excellent characteristics such as low driving voltage, high contrast ratio and narrow hysteresis has been attained.

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