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Polyimide-free Flexible Polymer Network Liquid Crystal Using Mesogen Dendrimers for Smart Window

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ABSTRACT

We have developed flexible polymer network liquid crystals using liquid crystalline dendrimers that induce spontaneous vertical alignment without alignment film. Flexible PNLC with high haze value and high flexibility was realized by the electrohydrodynamic convection due to the liquid crystalline dendrimers.

1 Introduction

Smart windows reduce the power consumption of lighting and air conditioning, and can even be used as screens for projection displays. It is expected to have applications in a wide range of fields, including buildings, airplanes, and automobiles. Among the light modulation methods for smart windows, the method using vertically aligned polymer dispersed liquid crystals (VA-PNLC) has the features of high transmittance and fast response speed. Research and development for the practical use of PNLC are in progress. In recent years, vertically aligned flexible PNLCs using plastic substrates have been attracting attention. Flexibility makes it possible to install PNLCs on curved windows or to stick them on existing windows.

However, the durability of curved flexible VA-PNLC is an issue. As shown in Figure 1, flexible VA-PNLC has a polymer network in the liquid crystal. When flexible PNLCs are curved, the deformation of the substrate causes the liquid crystal to flow. As a result, the orientation direction of the polymer network changes. In addition, the process of forming a vertical alignment film on the substrate is expensive.

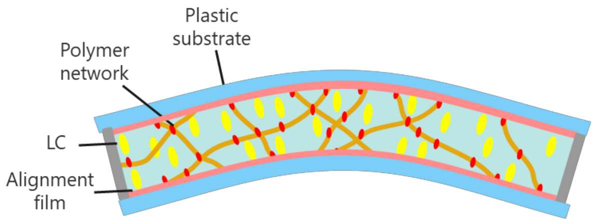


Fig.1 Structure of flexible VA-PNLC.

To address these issues, the UV pattern exposure method has been proposed to form lattice-shaped polymer spacers in the liquid crystal to suppress the flow of the liquid crystal [3][4]. However, the problem remains that the polymer network is not sufficiently resistant to localized impacts.

To solve these problems, we proposed a method of adding liquid crystalline dendrimers, which have the property of inducing spontaneous alignment of liquid crystals. Its liquid crystalline dendrimer generates electrohydrodynamic convection when added to a negative type liquid crystal. This increases in haze value. Therefore, it is possible to increase the haze value without forming a polymer network in the liquid crystal and to suppress the decrease in transmittance when the voltage is turned off during curvature. In addition, since liquid crystals can be aligned without the use of alignment films, it is possible to use plastic substrates with low heat resistance. Furthermore, lower production costs can be expected.

In this paper, an alignment film-less flexible VA-PNLC using liquid crystalline dendrimers is investigated.

2 Proposal of the method

The principle of alignment control by liquid crystalline dendrimers is shown in Fig. 2. Liquid crystalline dendrimers have a symmetrical molecular structure with a mesogenic group on the side chain, and when added to a liquid crystal they form a monolayer on the surface of the substrate. The dendrimers in this monolayer produce an alignment force by extending their mesogenic groups towards the bulk.

When a negative liquid crystal is vertically aligned using this liquid crystalline dendrimer, an electric charge is generated by the Kerr-Herflich effect when a voltage is applied. This charge generates an electric convection current (Fig. 3). As a result, the change in orientation of the liquid crystal molecules due to electroconvection causes a difference in refractive index, which increases the haze value [5].

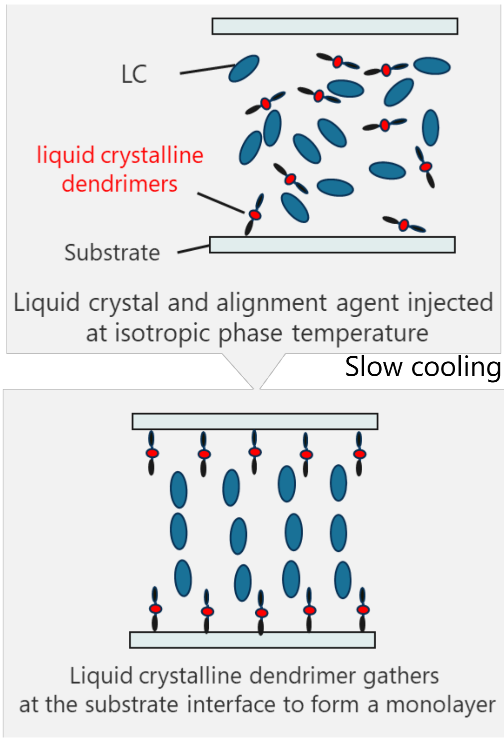


Fig.2 Alignment control by the liquid crystalline dendrimers.

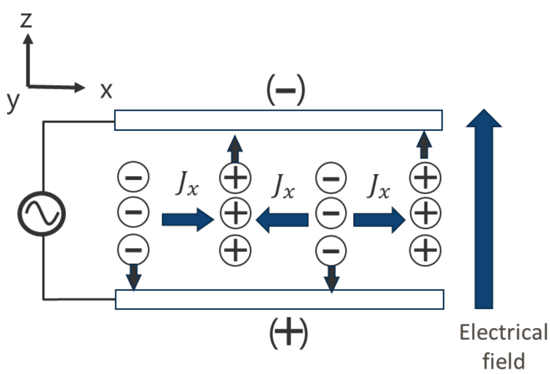


Fig.3 Electrohydrodynamic convection in liquid crystals.

When a negative liquid crystal is vertically aligned using liquid crystalline dendrimers and a voltage with a frequency of a few hundred Hz is applied, the electrohydrodynamic convection occurs. This electro-hydrodynamic convection generates haze. Since there is no polymer network in the liquid crystal, the increase in haze due to electrohydrodynamic convection has a high resistance to curvature and impact.

The structure of the flexible PNLC in this study is shown in Fig. 4. The LCs in the proposed liquid crystal device has high fluidity because there is no polymer network in the pixel area. This makes it difficult to maintain the cell structure during curvature. Therefore, in this study, polymer walls were formed in the liquid crystal to bond the top and bottom substrates.

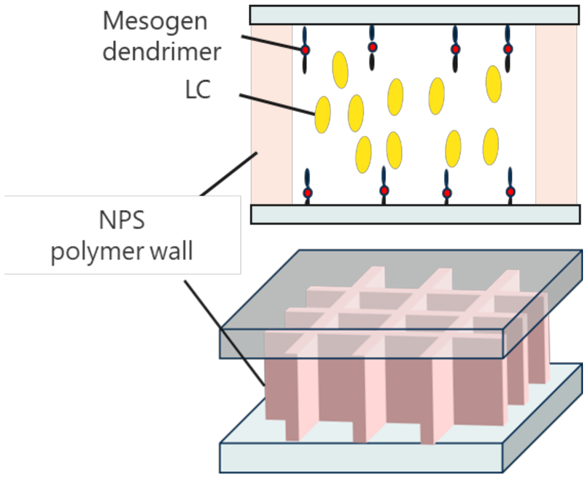


Fig.4 Structure of the proposed flexiblePNLC.

Here, to form polymer walls, it is necessary to mix UV polymerization type monomers with the liquid crystal. However, if a polymer network is formed in the pixel area, the transmittance decreases when the voltage is turned off due to the change in orientation direction during curvature. To suppress this problem, we used nano-phase separated liquid crystal (NPS-LC) as the liquid crystal in this study.

As described above, we can reduce the cost by eliminating the need for an alignment film, and realize a structure with high transmittance when the film is in off-state and high haze value when the film is on-state by electric convection. In addition, the polymer spacers provide high curvature performance, and the absence of a polymer network in the pixel area is expected to provide impact resistance.

3 Experiment

The fabrication procedure of the PNLC cell is shown below. The 1 wt% of liquid crystalline dendrimer D2-6PC5 were added o the liquid crystal mixture of NPS-LC NA-1220 (DIC). The mixture was heated to 140°C, and then injected into the empty cell using 100 μm thick polycarbonate substrates and cooled slowly. A 10 μm diameter beads were used as a spacer. After cell fabrication, polymer walls were formed by the phase-separation method by UV pattern exposure using a photomask at room temperature using a collimated UV light source (JATEC) with a wavelength of 365 nm (Fig. 5).

For the photomask, we used a lattice-shaped photomask with a pitch of 50, 75, or 100 μm in the masked area and a width of 10 μm in the exposure area. By changing the lattice size, the amount of monomer polymerized as a polymer wall was changed, resulting in a change in the density of the polymer network in the pixel area. The results are shown in Fig. 6. A square wave voltage of 100 Hz was applied to the prepared cells and the voltage-haze characteristics were measured using a haze meter (Murakami Color Technology Laboratory).

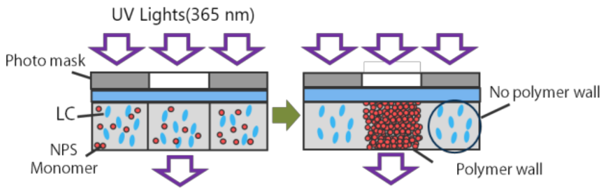


Fig.5 Fabrication process of polymer spacer by patterned UV irradiation.

4 Results and discussion

Figure 6 shows the voltage-haze characteristics of the fabricated PNLC cells for each lattice size. The results show that the electrical convection begins and the haze value increases at around 15 V for all lattice sizes. The smaller the lattice size, the smaller the haze value in the voltage-off state. This result indicates that the density of the polymer network formed in the pixel should be smaller to achieve a high transmittance in the off-state.

We also confirmed that as the lattice size decreased, the haze value of the PNLC in the on-state increased. We considered that it was due to the increase in the area with different refractive indices in the case of small lattice size .

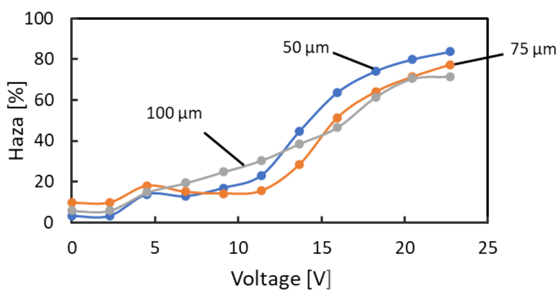


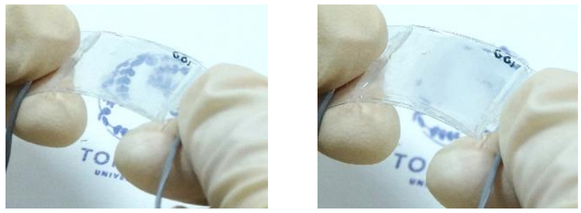
Fig.6 Comparison of haze characteristic of each lattice size.

To evaluate the impact resistance, we compared the NPS-PNLC with traditional vertically aligned PNLC using normal LCs. Each cell was impacted by dropping a weight of about 1 kg with a 1 cm diameter cylinder from 10 cm above. Table 1 shows the transmittance in the voltage-off state before and after the experiment. It is shown that the proposed structure can suppress the decrease in transmittance compared to the conventional one.

Table 1 Comparison of transmittance before and after the impact resistance test.

	before(%)	after(%)
NPS-PNLC	78.8	75.3
Normal PNLC	78.3	65.3

Figure 7 shows the PNLC cell when driven in a curved state. We succeeded in fabricating high-quality flexible PNLCs by switching between scattering and transmission states even when the cells are bent.



(a) Voltage: 0V (b) Voltage: 20V

Fig.7 Flexible PNLC cell in a curved state.

5 Conclusions

We proposed vertically aligned flexible PNLCs using NPS-LCs and liquid crystalline dendrimers. We fabricated the polymer spacers in the liquid crystals by UV pattern exposure to improve the shock resistance of the PNLC cells. In addition, we successfully achieved a high transmittance in the voltage off-state and a high haze value in the on-state by suppressing the formation of polymer networks in the pixel area by reducing the pitch of the polymer spacers.

This research is expected to lead to the realization of flexible PNLCs for smart window applications with higher performance and lower costs by eliminating the alignment film coating process.

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