Creating / Hiding of Information using Elastic Property of Different Liquid Crystal Phases

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ABSTRACT

Liquid crystals have different elastic properties depending on phases. Twist deformation is allowed in nematic, but not in smectic phase. We showed devices that can create, hide, and manage information using the difference of elastic properties. Information is created in the alignment layer in smectic, expressed as texture in nematic

1 Introduction

As the economy and society develop, society is becoming more complex. Huge amount of information is being created and exchanged. The information itself may have importance, or related hidden values may be protected through the information. So, creating, protecting, and managing information is becoming very important. Several technologies for dealing with information are being developed [1]. We intend to use liquid crystals (LCs) to handle the information.

LCs are soft and have self-ordering properties. Among LCs, thermotropic LCs have different phases depending on temperature. The macroscopic physical properties of LCs vary depending on the phase [2]. The electrical and optical anisotropies make control possible and the results of control can be easily confirmed optically.

Here, we propose devices using elastic properties that vary depending on the LCs phases [3]. We examine the possibility of creating and protecting information. And we show the confirmation process whether information has been leaked with the devices.

2 Experiment

A cell composed of two glass substrates was fabricated. One substrate was coated with a polyimide for planar alignment and uniformly rubbed, so that it aligned LCs in a certain direction. The other substrate was coated with a photo-active material and rubbed so that LCs were aligned in a direction as well. The photo-active material causes the LCs to line up in a direction perpendicular to the polarization when UV light is incident. In the cell fabrication process, we aligned the orientation directions of the two substrates so that they are parallel to each other. We adjusted the cell gap using a spacer, and fixed with epoxy. For the LC, 4'-octyl-4-biphenyl-carbonitrile (8CB), which has nematic and smectic A phases, was used. After injecting the LC in a high-temperature of isotropic phase, lower the temperature so that it passed through nematic phase and became smectic A phase.

Since rubbing direction of both substrates were adjusted in the same, if the alignment direction was the same as a polarizer, a dark texture was shown in the crossed polarizers. After that, UV light having a designed pattern and polarization parallel to the rubbing was incident on the LC cell from the DLP having a wavelength of 405 nm.

3 Results

Fig. 1 Change of texture with the variation of temperature. (a) Smectic A phase, (b) Nematic phase, (c) Transition of phase from nematic to smectic A (d) Smectic A phase.

The samples prepared above were observed under a polarizing optical microscope. When the

LC was in smectic A phase, the texture shown in Fig. 1(a) appeared. The director did not react even though the designed pattern had been made on the photo-active layer by already irradiating the light. That is, there was no visible change so that it could not be determined whether the pattern had been created or not. When the sample was rotated, it showed a uniform brightness change.

However, when the temperature of the sample was raised and the nematic phase was reached, the director turned the direction perpendicular to the rubbing on the patterned regions where the light was incident. And it appeared with a change in texture as shown in Fig. 1(b). In the numerically patterned regions, the twist nematic (TN) configuration was made as desired and changed to be bright. The remaining regions showed a dark texture while maintaining the original parallel alignment.

Here, if the temperature was further raised, the LC became isotropic, and the entire LC phase was lost and the whole texure became dark. On the other hand, if the temperature was lowered again from nematic to smectic A, a change in the pattern appeared as shown in Fig. 1(c). This showed a different image from nematic at the moment of change from nematic to smectic A phase.

Fig. 1(d) shows the texture of the cell in the smectic A phase. Overall, all the texture images of patterned region were broken. Despite the same smectic A phase, unlike Fig. 1(a), it did not return to the original distinct texture, and it could be seen that the remnants of the orientation pattern remained.

The change of texture depending on the phase indicates that this phenomenon is closely related to the characteristic of LC phases. In the nematic phase, the LC allows elastic deformation corresponding to splay, twist, and bend. On the other hand, twist deformation is not allowed in the smectic A phase. So, the above result can be said to reflect the change of elastic property.

That is, when light that can be aligned in a direction perpendicular to the existing alignment direction is irradiated in a parallel aligned smectic A phase, the alignment layer itself acquires the ability to line up in a new direction. However, in smectic A phase, it is difficult to rotate the director because twist is not allowed, and alignment is already performed under stable conditions. Therefore, even if a new alignment pattern is formed as shown in Fig. 1(a), there is no change in texture in the smectic A phase. If the temperature of the LC cell is raised and changed to nematic, the LC shows the TN configuration as it is aligned because the twist is allowed. That is, it forms a TN configuration and shows an alignment pattern image.

If the temperature is lowered again to change the LC to smectic A phase, the TN configuration is not allowed and the image is ruined. However, in the smectic A phase, the elastic constant is very large and eventually lines up macroscopically in the average direction of the orientation of the upper and lower substrates. However, from a microscopic view, LCs have an unstable structure for uniformly arranging, and eventually form defect structures depending on the location.

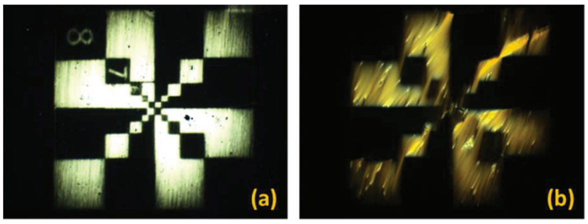

Fig. 2 The difference in texture for different pattern size. (a) Nematic phase. (b) Smectic A phase.

The visibility of the pattern was dependent on the pattern size as shown in Fig. 2. In the nematic phase, all the patterns were shown in experimental range. However, in the smectic phase, patterns with small size or with thin lines lost almost of the visibility and the texture is deformed.

4 Conclusions

Here, by using the property of varying elastic properties depending on the phase, it was shown that the texture made with the alignment pattern can be displayed or hidden.

This is a very simple tool to create, hide and detect information leaks. In addition, it is a tool that easily and simply guarantees the reliability of storage at an appropriate temperature for temperature-sensitive medicines, foods, and chemicals.

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