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# Application of Random Texture in Cholesteric Liquid Crystal for Security Devices

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# Application of Random Texture in Cholesteric Liquid Crystal for Security Devices

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*We proposed the application of fingerprint textures in cholesteric liquid crystal for a security device that can be used as an index for distinguishing individual artificial materials, for example, ID cards. The randomness of such texture was checked quantitatively by normalized cross-correlation and found to be high. For the fixation of the fingerprint texture a photo-polymerization technique was used, and the fixed pattern was invariable even at high temperature. These results indicate that fingerprint texture in cholesteric liquid crystal realizes the unique and permanent properties of human fingerprints.*

**Keywords** Artificial fingerprint device; cholesteric liquid crystal; fingerprint texture; optical texture; security device



## Introduction

In today's world, personal authentication is crucial for security. Patterns of fingerprint, iris or blood vessel are already used widely in personal authentication because the patterns of these physical characteristics are unique in individuals and have natural randomness. For example, no two fingerprint patterns are the same. Moreover, these patterns of physical characteristics are difficult to tamper with or copy.

Similarly, in credit card and passport identifications, assuring authenticity is also very important. For credit cards, digital data are used to distinguish cards and to check their authenticity. However, new counterfeiting techniques based on such digital technology as skimming have been developed. As long as digital information is used, the risk that new counterfeiting techniques will be developed will always be a subject of discussion. Borrowing an idea from the biometric authentication technique is one good choice. Natural randomness, in other words, uncontrollable variation in some features, plays an important role in providing unique and tamper-proof properties of features. Based on this concept, the application of the uncontrollable variation of electrical characteristics in poly-Si thin film transistors and

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inhomogeneous emission patterns in polymer light-emitting devices have been reported [1–4]. The device, whose random characteristics are used for distinguishing such individual artificial materials as credit cards, is called an artificial fingerprint [1–4].

We believe that the random textures in liquid crystal phases are suitable for an artificial fingerprint device because the structure of liquid crystal cells is simpler than transistors and polymer light-emitting devices. A liquid crystal cell with a random pattern can be embedded more easily into artificial materials than transistors and light-emitting devices. This research reports the application of random texture for a security device and focuses on cholesteric liquid crystals.



## Security Device Using Random Texture in Liquid Crystal

Various optical textures that reflect the nonuniformity of molecular alignment are observed by a polarizing microscope in a combination of liquid crystal phases and glass surface conditions. For example, a random pattern of black brushes in the nematic phase called a Schlieren texture and a random stripe pattern in the cholesteric phase called the fingerprint texture have been widely known [5]. Though these textures are easily obtained, their detailed pattern is random: not controllable. In every sample fabricated under the same conditions, similar patterns are obtained, but these patterns are distinguishable like human fingerprints.

Figure 1 shows the concept of a security device using the random texture of liquid crystal. Three samples were fabricated under identical conditions and their patterns were fixed by polymerization. Then these samples are embedded into the A, B, and C ID cards. In this stage, each ID card has a unique pattern based on natural randomness like human fingerprints.

## Experimental

In this study, UV-curable liquid crystal (UCL-001-K1, DIC Co.) was used and doped with chiral dopant (S-811, Merck Co.). This mixed liquid crystal has an isotropic-cholesteric (chiral nematic) phase sequence. A commercial cell (E.H.C. Co.) was employed whose surfaces were treated to ensure homeotropic molecular alignment.

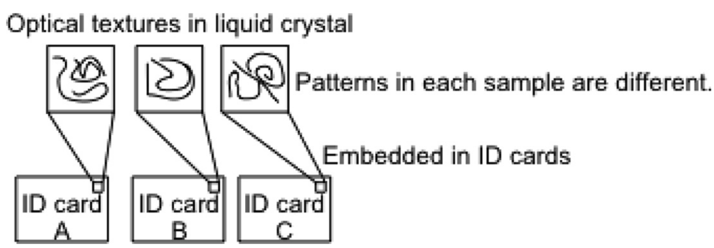
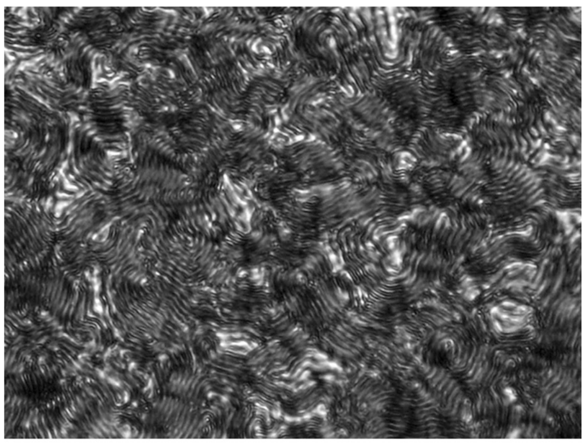



**Figure 1.** Concept of security device using random texture of liquid crystal.

## Results and Discussion

### *Influence of Concentration of Chiral Dopant*

First, we observed the optical textures of the cholesteric phase in liquid crystal with the following three concentrations of chiral dopant: 1.8 wt%, 3.1 wt%, and 9.3 wt%. Figure 2(a) shows the polarizing micrographs of liquid crystal with 1.8 wt% chiral dopant, and the so-called fingerprint texture was observed. Figure 2(b) shows that with 9.3 wt%, a fan-shaped texture was observed. In the sample with 3.1 wt% concentration, fingerprint and fan-shaped textures coexisted. Both textures will be used in this study because they seem to have randomness. From the point of view of texture complexity, we decided to use fingerprint texture. In all of the following experiments, a sample with 1.8 wt% concentration was used. The phase transition temperature from the isotropic to the cholesteric phase of this sample was 40°C.



(a)

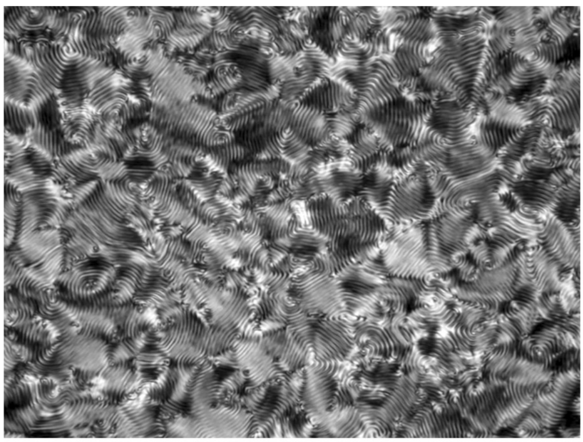
(b)

**Figure 2.** Polarizing micrographs of optical texture in cholesteric phase: (a) sample with 1.8 wt% chiral dopant and (b) with 9.3 wt% chiral dopant.

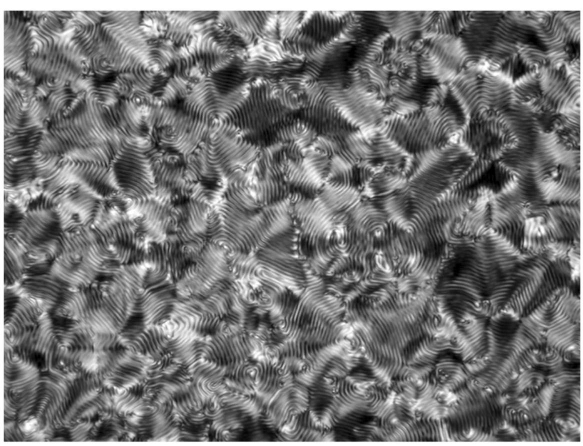
***Randomness of Fingerprint Texture***

For our purpose, the fingerprint texture pattern in liquid crystal requires uniqueness. The pattern obtained by a certain cell should not be obtained again in other cells, just as no two human fingerprint patterns are the same. To the best of our knowledge, quantitative research about the randomness or uniqueness of optical texture patterns has not been reported, although M. Nakagawa reported the fractal structure in the focal conics texture pattern in chiral smectic C phase from the viewpoint of theoretical physics [6]. The randomness or uniqueness of fingerprint texture in the cholesteric phase with homeotropic alignment was checked, and a condition was adopted under which the possibility of getting the same pattern would be raised the most. The fingerprint texture patterns were observed repeatedly at the same place of the same cell following every re-orientation process by heat treatment. By heating the sample to the isotropic phase, the optical texture disappears, and by cooling the





(a)



(b)

**Figure 3.** Polarizing micrographs taken in same place at every reorientation process by heat treatment. Micrograph width is 360 μm: (a) first observed pattern and (b) second observed pattern.

sample to the cholesteric phase again, the optical texture appears again. Note that in our proposed security system the patterns obtained by the re-orientation process in the same cell are never used, and the patterns of other cells are used, as shown in Figure 1.

Figure 3 show polarizing micrographs taken by the adjacent reorientation process. These patterns of Figures 3(a) and (b) are not same, although the type of both patterns is fingerprint texture.

Moreover, the randomness was estimated using normalized cross-correlation between the polarizing micrographs. The width of the polarizing micrographs was about 360 μm, and the resolution was $1600 \times 1200$ pixels. Figure 4 shows the coefficient of the normalized cross-correlation between the patterns after some reorientation processes and the first observation pattern. The first value of 1 was calculated as a normalized cross-correlation between the same patterns shown in Figure 3(a). The second value of 0.03 was calculated as a normalized cross-correlation between the first (Fig. 3(a)) and second observation patterns (Fig. 3(b)). Except for the first value, all values are about 0, indicating that the same pattern was not observed even though the same cell was used. So unique and random patterns can be easily obtained using the fingerprint texture of cholesteric phases and normalized cross-correlation can be used to match patterns.

### *Stability of Polymerized Pattern under High Temperature*

One reason why human fingerprints are widely used in personal identification is because they have a permanence property. Polymerization by irradiation of the UV light was employed as the pattern's fixation technique. The polarizing micrograph of the photo-polymerized sample taken under room temperature is shown in Figure 5(a). Figure 5(b) shows this sample at 105°C. The sample before

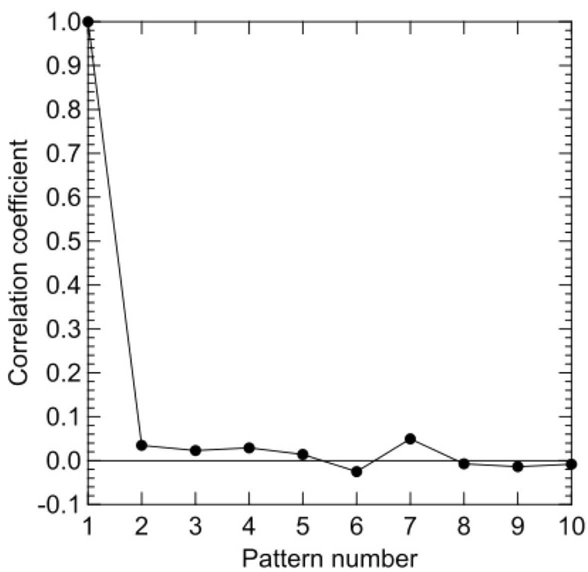
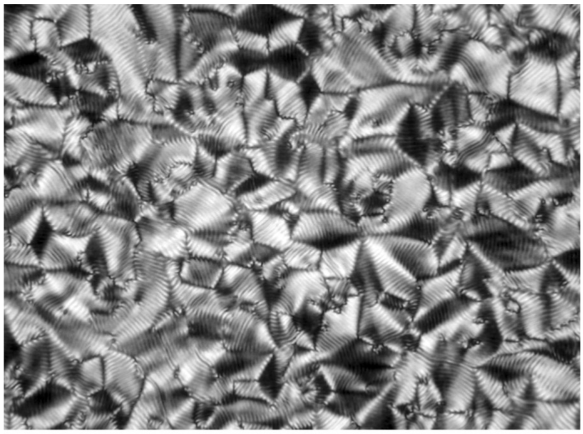
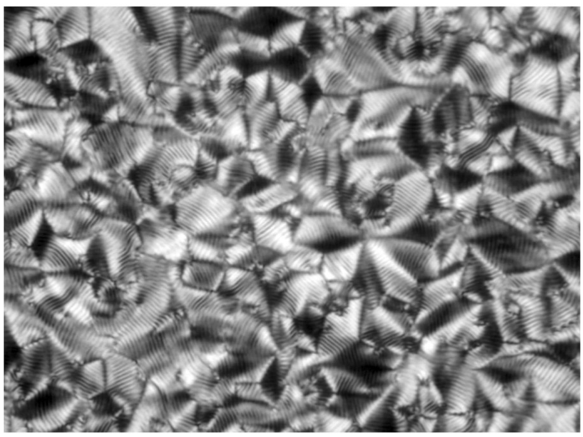



**Figure 4.** Normalized cross-correlation coefficient between pattern after some reorientation processes and first observation pattern.



(a)



(b)

**Figure 5.** Polarizing micrographs of photo-polymerized sample: (a) at room temperature and (b) at 105°C.

polymerization is in the isotropic phase at 105°C, and the optical texture does not appear. This result indicates that under a general temperature, the fixed pattern is invariable by using polymerization.

## Conclusion

We proposed an application of fingerprint texture in cholesteric liquid crystal for artificial fingerprint devices. This texture's randomness was checked quantitatively by normalized cross-correlation and correlation coefficients between other patterns was about 0. This result indicates high randomness. A photo-polymerization technique was used to fixate the optical texture. The polymerized sample kept the same pattern at 105°C. These results indicate that the fingerprint texture in cholesteric liquid crystal can get the same uniqueness and permanence properties as human fingerprints. The optical texture of liquid crystal is suitable for artificial fingerprint devices and as an index for distinguishing individual artificial materials.

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