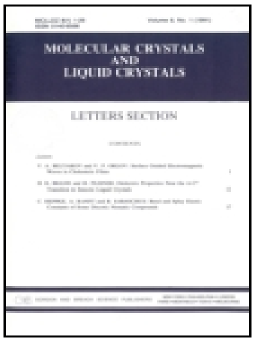

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Color Control of Hydroxypropyl Cellulose

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Hydroxypropyl cellulose (HPC) aqueous solution has cholesteric liquid crystal phase and is colored by a selective reflection. Because the wavelength of the selective reflection depends on the kind and concentration of an additive ion, the color can be changed by applied voltage which can change a local concentration by electrophoresis. However, many tiny bubbles appear on the electrodes of the HPC liquid crystal device due to electrolysis, and the color change response is inhibited by the bubbles. In this study, the bubbles were decreased by another type of voltage application.

Keywords hydroxylpropyl cellulose; cholesteric; selective reflection; liquid crystal

1. Introduction

Cellulose which is present in high amounts in the cell walls of plants has attracted much attention as a material with low environmental impact, and its industrial application is studied intensely. Cellulose has many derivatives and hydroxypropyl cellulose (HPC) is one of them. It is known that HPC aqueous solution forms a cholesteric phase in which the light of a certain wavelength can be reflected selectively[1][3]. The cholesteric phase is one of the phase of liquid crystals. The molecules in the cholesteric phase align as a spiral structure that gives rise to the selective reflection. The dominant wavelength of the selective reflection coincides with the pitch of the spiral. And a bright and colored reflection depending on the pitch can be observed. Because the selective reflection wavelength of HPC depends on a concentration of inorganic salts, the color of the HPC solution can be changed by an applied electric field that can move ions[2][4][5]. However, to realize the industrial application of this electrooptic effect, there are many problems that must be solved. In this study, the color control of reflection wavelength was improved by new voltage application method and the bubbles were decreased successfully.

2. Experimental

A sodium chloride solution of 0.5 mol/L in concentration was produced and HPC powder was mixed with the solution in a weight ratio of 3:5. Because of the high viscosity of the

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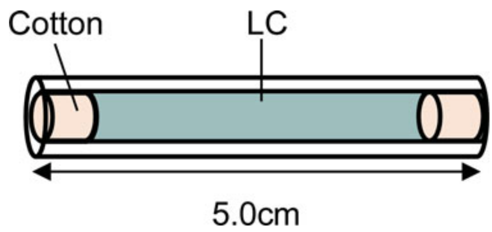

Figure 1. Schematic of the tube cell 1.

mixture, this compound was grounded for about five minutes with a mortar and a pestle. A lot of small bubbles appear during this mixing procedure and disturb the molecular arrangement in the HPC solution, so that the selective reflection cannot be observed. In order to remove the bubbles, an autoclave instrument was used. An Autoclave is a machine that sterilizes instruments in experimental biology. The HPC liquid crystal in the screw tube was transferred into the autoclave. Then the autoclave was set to a temperature of 121°C and a pressure of 0.1 MPa. The screw tube was taken out of the autoclave and put in a refrigerator to settle the contents. The screw tube was preserved for three days while frequently being inverted. By performing these operations, the small bubbles could be disappeared from the HPC liquid crystal, and selective reflection could finally be observed in the color blue. It seems that liquid crystal molecules were oriented by themselves.

The conventional sandwich cell which contains the HPC aqueous solution and two platinum sticks (ϕ0.7 mm) between two glass plates is difficult to be made, because the HPC solution has high viscosity and cannot enter the cell by only capillary force [6]. Therefore, the HPC solution was injected to a tube cell with a syringe. Figure 1 shows a schematic figure of tube cell 1. The tube cell 1 is made of PVC (polyvinyl chloride) tube (50.0 mm in length). The HPC solution was injected into the tube. The both ends of the tube were sealed by cotton.

Figure 2 shows circuit diagram of the experiment with the tube cell 1. Two water tanks are connected by the tube cell 1. NaCl solution were poured into the tanks and the tanks

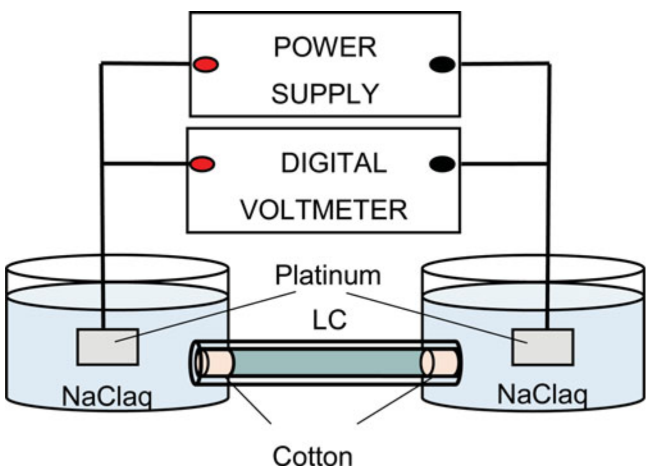

Figure 2. Circuit diagram of the tube cell 1.

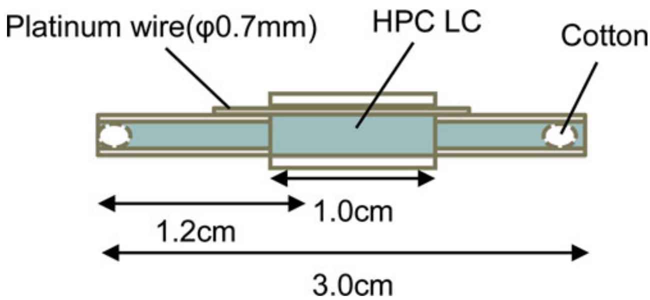

Figure 3. Schematic of the tube cell 2.

were electrically bridged by the tube. Two electrodes were settled in the tanks. One of the electrodes was connected to the cathode of DC power supply and the other was connected to the anode. The voltage was applied to the tube cell 1 by those electrodes.

Figure 3 shows a schematic figure of a tube cell 2. The tube cell 2 is composed of three PVC tubes, a thicker center tube (10.0 mm in length, 3.0 mm outside diameter, 2.0 mm inside diameter) and two thiner tubes (12.0 mm in length, 2.0mm outside diameter, 1.0 mm inside diameter). The thiner tubes were connected to the thicker center tube. Total length of the tube cell 2 was 30.0 mm. The HPC solution was injected into the tube cell 2. The both ends of the tube were sealed by cotton. A platinum wire (ϕ0.7mm) was put in the center tube.

Figure 4 shows the circuit diagrams of experiments with tube cell 2. The tube cell was connected to 2 tanks of sodium chloride aqueous solution. In application I, the platinum wire is anode and the two platinum plates are cathode. In application II, the platinum plate is anode and the other platinum plate is cathode.

Figure 5 shows a schematic figure of a tube cell 3. A PVC tube of 30.0 mm in length was used. The HPC solution was injected into the tube. Two platinum wires were put into both ends and sealed with epoxy adhesive.

A function generator was used to change duty ratio of applied voltage. Duty ratio means a ratio of applying duration in one period. For example, when a voltage of 21[V] was applied to the cell for 2.5 seconds and 0[V] for 7.5 seconds continuously as shown in Figure 6, a notation of the applied voltage is “21 V, 0V, 0.1 Hz, duty 25%”.

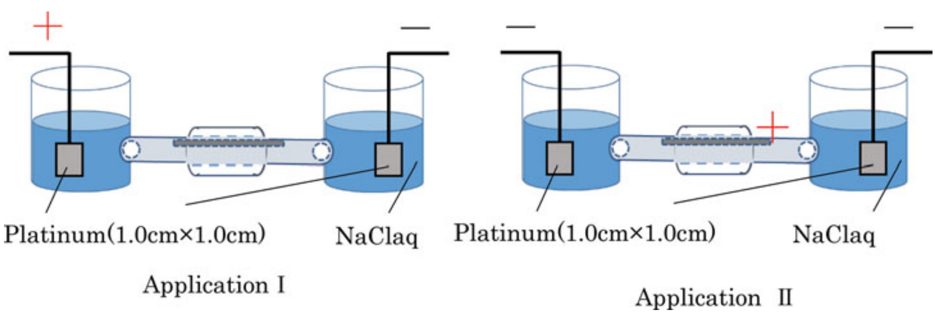

Figure 4. Circuit diagrams of the tube cell 2.

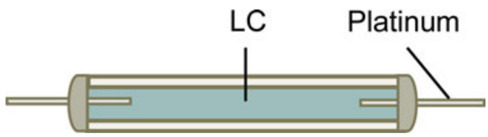

Figure 5. Schematic of a tube cell 3.

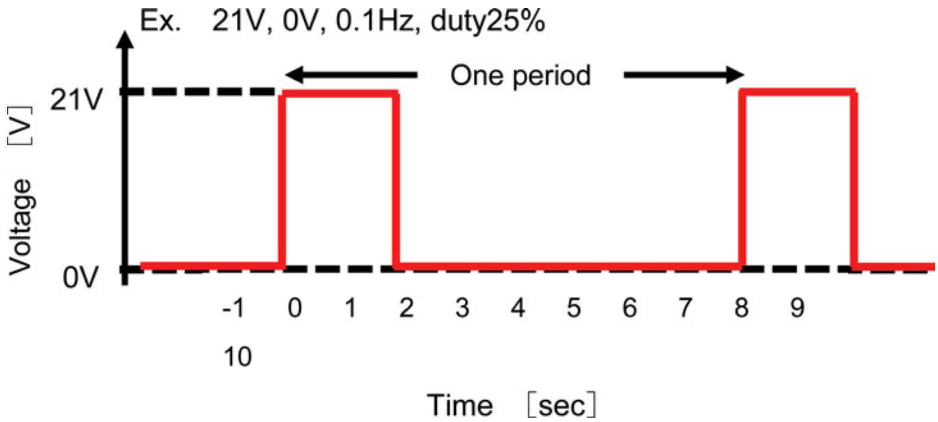

Figure 6. Applied voltage.

3. Results and Discussion

3.1. Tube cell 1

Figure 7 shows time course pictures of the tube cell 1 under 63 V application. The color of left side has been changed from blue to red for 36 hours. However, chlorine gas was produced on the anode. The chlorine gas disturbs the electrical current in the tube and makes the response slow.

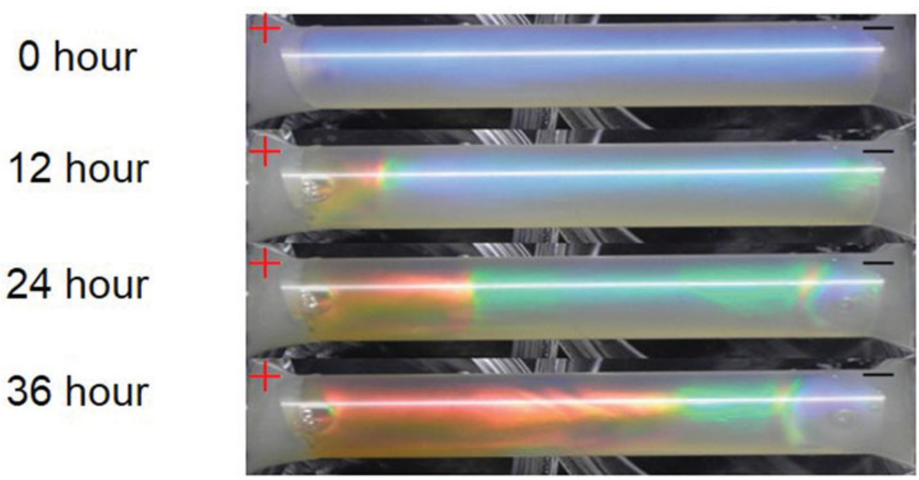

Figure 7. Color change of tube cell 1.

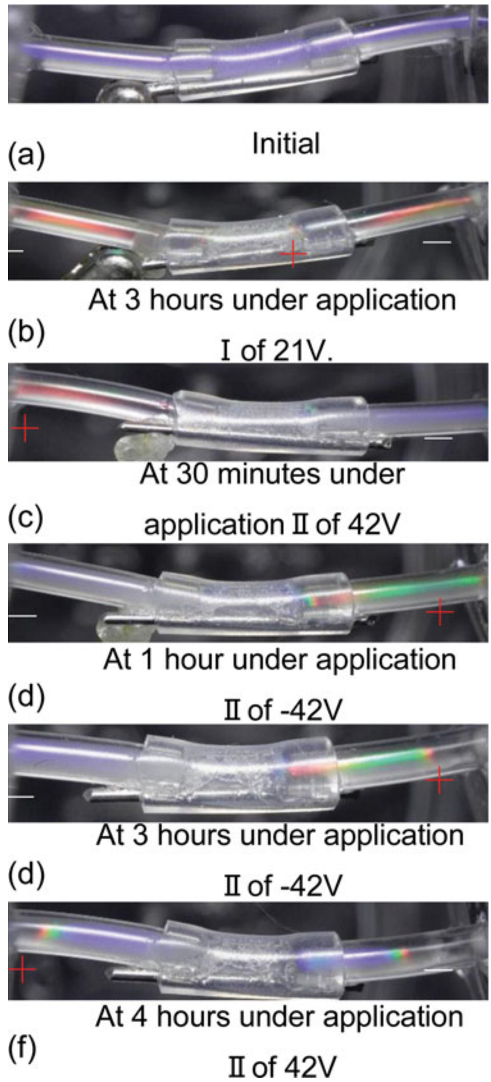

Figure 8. Color change of the tube cell 2.

3.2. Tube cell 2

DC voltage of 21 V was applied to the tube cell 2 by the application I for three hours. Figure 8 shows time course pictures of the cell 2. Figure 9 shows spectra change at both sides of the tube. The color at the both sides was changed from blue to red by application I, as shown in Fig. 8(b). After that, the tube was connected to the application II and a DC voltage of 42 V was applied to the tube. Only the right side returned to be blue, as shown in Fig. 8(c). And then, the polarity of the applied voltage was inverted. The right side was changed from blue to green in 1 hour, as shown in Fig. 8(d). The right side did not become red by additional application, as shown in Fig. 8(e). The green colored right side could return to original blue color by the following inverse application II, as shown in Fig. 8(f).

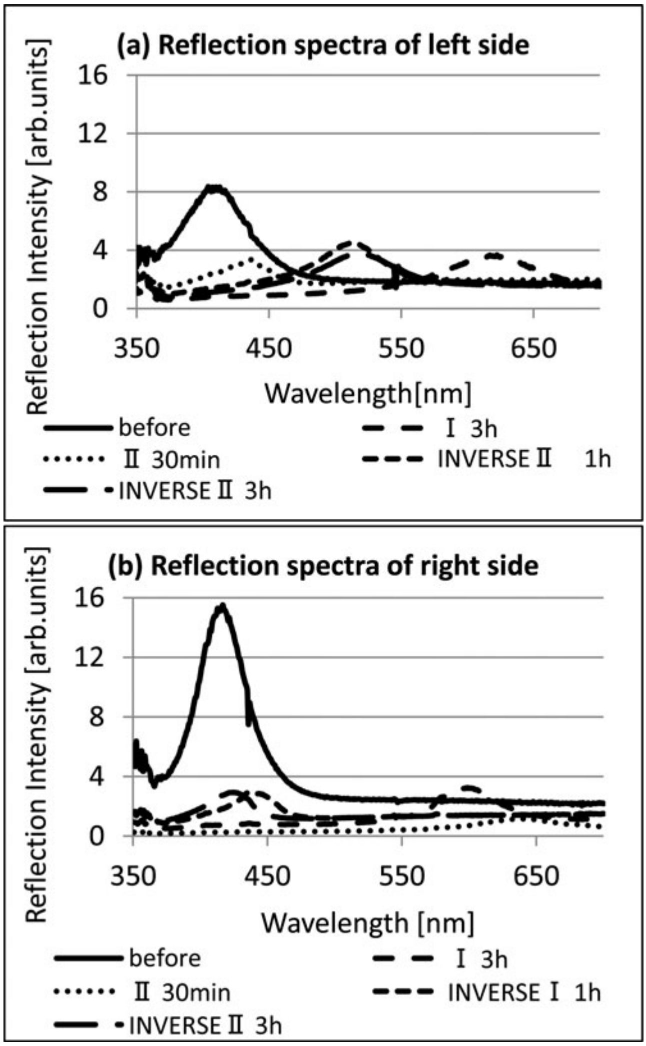

Figure 9. Reflection spectra of tube cell 2.

According to the pictures and reflection spectra, it is found that the color of HPC liquid crystal could be changed successfully.

3.3. Tube cell 3

The tiny bubbles which are produced at the anode push the HPC and remain as gas area without HPC in the tube, as shown in Fig. 10. The length of the area can represent amount of the generated gas. The duty ratio dependence of the length of the gas area was measured. Table 1 shows the length for the duty ratio of 25%, 50% 75% and 100%. It was found that the length of the area decreased as the duty ratio decreased. It can be explained as follows. The HPC tube worked like a fuel cell, and the chlorine gas was consumed as fuel at the applied voltage of 0V in each period.

Table 1. Quantity of bubbles in each duty ratio

Duty	Empty length [mm]	Reaction time [hour]
25	1.8	12
50	2.4	6
60	3.5	5
75	8.7	4
100	11.8	3

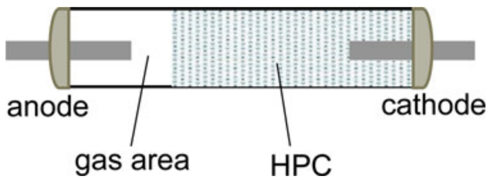

Figure 10. Produced gas area in the tube.

4. Conclusion

The reflection color of the HPC liquid crystal was changed from blue to red by applied voltage. However, the voltage application makes many tiny chlorine bubbles on the anode due to electrolysis, and the response is inhibited by the bubbles. And it is found that the bubbles deteriorate HPC aqueous solution. Asymmetric pulse voltage application is effective to decrease the bubbles. It can be assumed that the HPC tube cell can work as a fuel cell under 0 V application and chlorine bubbles are reduced to chloride ions.

Acknowledgments

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