Writable Cholesteric Liquid Crystal Display and the algorithm used to detect its image*

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Abstract

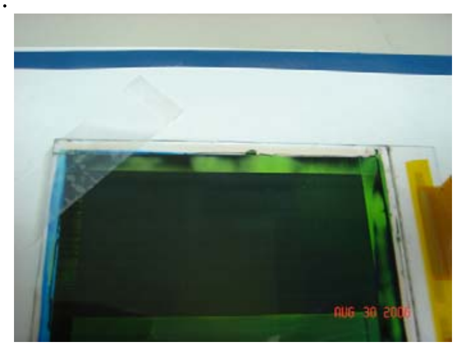
Writable Cholesteric Liquid Crystal Display and the algorithm used to detect its image were developed. We could use any hard tip, ex: the tip of a forefinger, to directly write an image on the surface of Cholesteric Liquid Crystal Display (CHLCD). By measuring the capacitance of one pixel of test cell (12mm x 15mm/ 1x1), F-state or P-state could be detected. By measuring the capacitance of one pixel of 4.1" CHLCD (241um x 241um/ 320x320), F-state or P-state could not be detected, due to the effect of parasitic capacitance. Therefore, high frequency measurement and the algorithm were developed to detect the image on CHLCD.

1. Introduction

"Writing by hand" was an important function of paper, but there were few researches focusing on this function for e-paper. US Patent 6,982,432[1] proposed a structure wherein the display panel was integrated on top of the touch panel to achieve "writing by hand" function and avoid glaring light. However, two panels were needed in such a structure, so the cost was high. Fuji Xerox[2] proposed a structure of CHLCD that was photo-writable. However, both OPC layer and a light source were needed in such a structure, and addressing light was incident from the back side, so the cost was high and it was not convenient for "writing by hand". Eastman Kodak[3] proposed a structure of CHLCD that was photo-writable. However, a light source was needed in such a structure, so the cost was high. In order to overcome abovementioned disadvantages, we developed "writing by hand" CHLCD and the algorithm used to detect its image in this paper.

2. Writable CHLCD

As shown in Figure 1, we could use any hard tip, ex: the tip of a forefinger, to directly write an image on the surface of CHLCD. Before writing, each pixel of CHLCD was driven to F-state (dark). After writing, the region where hard tip pressed on became P-state (bright).



(a) Before writing

(b) After writing

Figure 1: Writing an image on CHLCD

For a writable CHLCD, forming an image on CHLCD was only the 1st half, in the 2nd half, we needed a method to detect said image to truly accomplish the "writable" function. We figured out that measuring the capacitance of CHLC might be the method.

The reason for measuring the capacitance of CHLC was as follows. The optical state of F-state or P-state was determined by the arrangement of molecules of CHLC. On the other hand, the capacitance measured at low applied voltage of F-state or P-state was also determined by the arrangement of molecules of CHLC. Therefore, measuring the capacitance of CHLC at low applied voltage might be the method to detect the optical state of F-state or P-state.

Two experiments were developed, as shown in Figure 2. First, we measured the capacitance of one pixel of test cell (12mm x 15mm/ 1x1) to verify that the capacitance of F-state and the one of P-state really differed. Second, we measured the capacitance of one pixel of 4.1" CHLCD (241um x 241um/ 320x320) to verify that the capacitance of F-state and the one of P-state were also different for one pixel of 4.1" CHLCD. However, we found that parasitic capacitance was too large and varied to identify the capacitance of F-state or P-state of one pixel of 4.1" CHLCD. Therefore, we figured out the high frequency measurement and the algorithm that could be used to detect F-state or P-state of one pixel of CHLCD, while there was a large and varied parasitic capacitance.

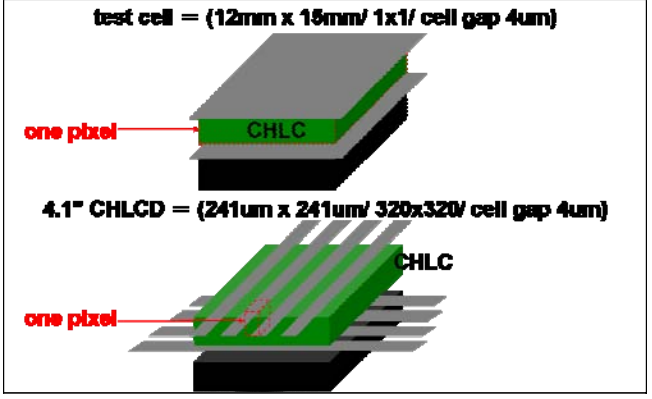
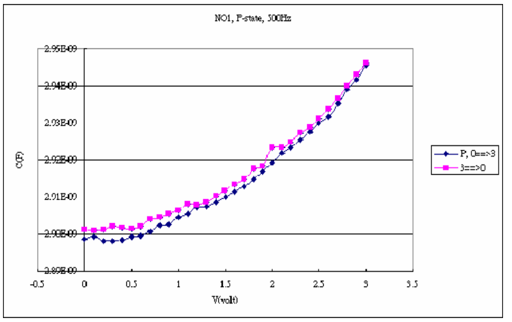


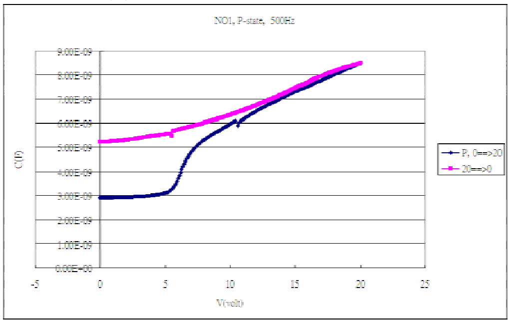
Figure 2: Measuring the capacitance of one pixel of test cell and 4.1" CHLCD

3. Capacitance of one pixel of test cell (12mm x 15mm/ 1x1/ cell gap 4um)

By using HP4284, capacitance of one pixel of test cell (12mm x 15mm/ 1x1) was measured as shown in Figure 3. According to Figure 3, we proved that the capacitance of P-state at 3V was 2.94nF and that the capacitance of F-state at 3V was 5.10nF. Therefore, for one pixel of test cell (12mm x 15mm/ 1x1), measuring the capacitance at low applied voltage really was the method for detecting the optical state of F-state or P-state.



(a) P-state: 0V➔3V➔0V



(b) P-state: 0V➔20V➔0V

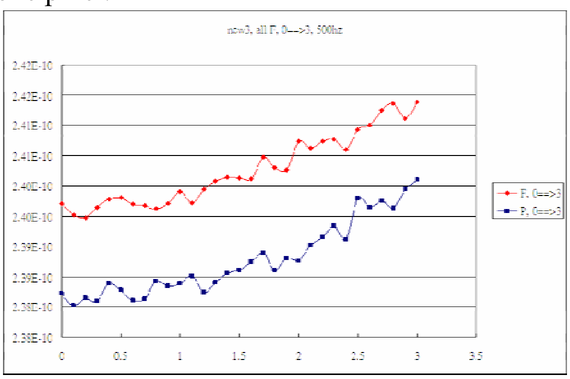
Figure 3: Capacitance of one pixel of test cell (12mm x 15mm/ 1x1/ cell gap 4um). Testing frequency 500Hz

4. Capacitance of one pixel of 4.1" CHLCD (241um x 241um/ 320x320/ cell gap 4um) ➔Parasitic Capacitance

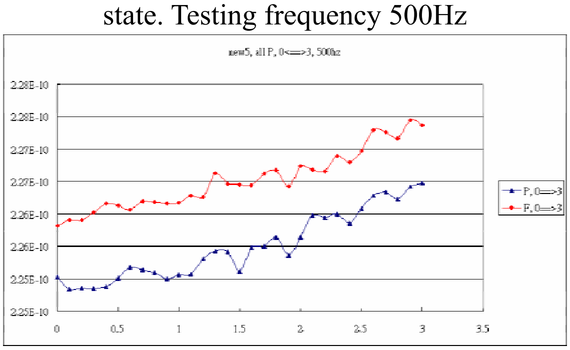
By using HP4284, capacitance of one pixel of 4.1" CHLCD (241um x 241um/ 320x320) was measured as shown in Figure 4. According to Figure 4, we proved that the parasitic capacitance was too large and varied to identify F-state or P-state of one pixel of 4.1" CHLCD. The explanation was as follows.

For 4.1" CHLCD, there were 320x320 pixels. We had to prove that measuring the capacitance of each one of 320x320 pixels could be used to detect its F-state or P-state. We figured out the following test method. There were two conditions in which F-state or P-state was most difficult to be detected. If F-state or P-state could be detected in these two most difficult conditions, then we could say that F-state or P-state of each one of 320x320 pixels could be detected. The 1st condition was that the central pixel of 4.1" CHLCD changed from F-state to P-state while all other (320x320－1) pixels were kept in F-state. The 2nd condition was that the central pixel of 4.1" CHLCD changed from F-state to P-state while all other (320x320－1) pixels were kept in P-state.

In Figure 4, for an applying voltage, ex: 3V, we found that there was no overlap in capacitance regions between F-state and P-state in Figure 4(a) and Figure 4(b). In Figure 4(a), at 3V, capacitance region was (240pF, 241.5pF). In Figure 4(b), at 3V, capacitance region was (226.5pF, 227.5pF). So we could not determine a specific capacitance value to distinguish F-state and P-state of the central pixel in these two most difficult conditions. This was due to the existence of parasitic capacitance. The driving structure of 4.1" CHLCD was passive matrix. So when we applied a voltage to measure the capacitance of one pixel in 4.1" CHLCD, we would get not only one pixel's capacitance but also neighboring pixels' parasitic capacitance. Unfortunately, in this case of 4.1" CHLCD, parasitic capacitance was too large and varied to identify the capacitance of F-state or P-state of one pixel.



(a) Capacitance of the central pixel of 4.1" CHLCD, while all other (320x320－1) pixels were kept in F-state. Testing frequency 500Hz



(b) Capacitance of the central pixel of 4.1" CHLCD, while all other (320x320－1) pixels were kept in P-state. Testing frequency 500Hz

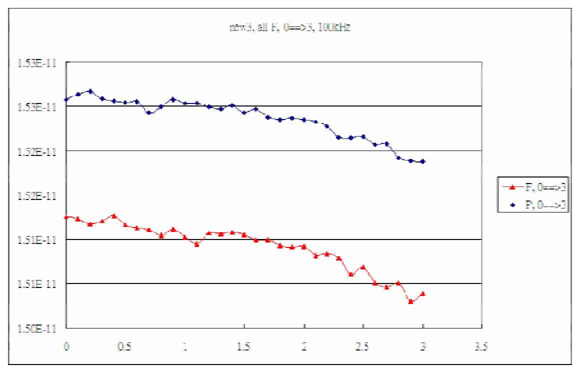
Figure 4: Capacitance of one pixel of 4.1" CHLCD (241um x 241um/ 320x320/ cell gap 4um). Testing frequency 500Hz

5. High frequency measurement of capacitance

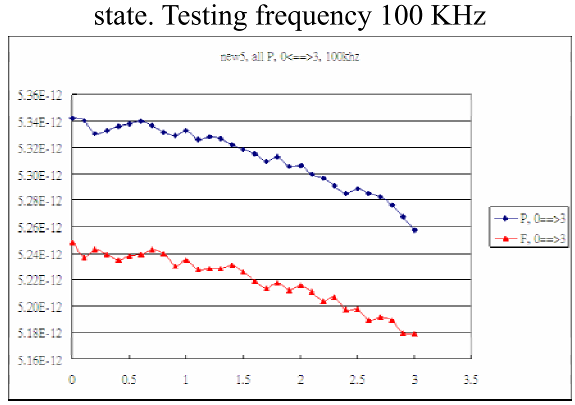
In order to reduce the influence of parasitic capacitance, we figured out high frequency measurement of capacitance, as shown in Figure 5. Compared to Figure 4, the testing frequency was raised from 500Hz to 100 KHz. The influence of parasitic capacitance was reduced, but it still could not solve the problem.

In Figure 5(a), △C/C was (0.15pF/15.03pF) when applying voltage 3V. In Figure 4(a), △C/C was (1.5pF/240pF) when applying voltage 3V. So the influence of parasitic capacitance was reduced, when we adopted high frequency measurement of capacitance.

But similarly, at 3V, we found that there was no overlap in capacitance regions between F-state and P-state in Figure 5(a) (15.03pF, 15.18pF) and Figure 5 (b) (5.18pF, 5.26pF). So we could not determine a specific capacitance value to distinguish F-state and P-state of the central pixel in these two most difficult conditions. The problem of parasitic capacitance remained unsolved.



(a) Capacitance of the central pixel of 4.1" CHLCD, while all other (320x320－1) pixels were kept in F-state. Testing frequency 100 KHz



(b) Capacitance of the central pixel of 4.1" CHLCD, while all other (320x320－1) pixels were kept in P-state. Testing frequency 100 KHz

Figure 5: Capacitance of one pixel of 4.1" CHLCD (241um x 241um/ 320x320/ cell gap 4um). Testing frequency 100 KHz

6. Algorithm used to detect F-state or P-state of one pixel of CHLCD

In order to fundamentally solve the problem of parasitic capacitance, we figured out the algorithm that could be used to detect F-state or P-state of one pixel of CHLCD, while a large and varied parasitic capacitance existed.

The algorithm was shown in Figure 6. First, measured the capacitance of the one pixel and memorized the capacitance value C1. Second, drove the one pixel into F-state (or P-state). Third, measured the capacitance of the one pixel again, and memorized the capacitance value C2. Fourth, compared C1 and C2; if $C1 = C2$, then the one pixel was F-state (or P-state); if $C1 \neq C2$, then the one pixel was P-state (or F-state), in this condition, we needed to finally drive the one pixel back into P-state (or F-state).

The advantage of this algorithm was that the influence of parasitic capacitance could be cancelled completely. No matter how large or varied the parasitic capacitance was, as long as the parasitic capacitance remained the same in the foregoing first and third steps, then we could precisely identify the state of the one pixel in the foregoing fourth step. Since we only drive the one pixel in this algorithm, it was reasonable to say that the parasitic capacitance remained the same in the foregoing first and third steps.

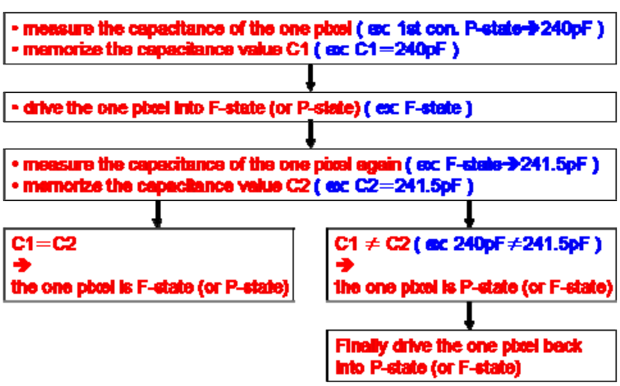


Figure 6: Algorithm used to detect F-state or P-state of one pixel of CHLCD

7. Conclusion

F-state or P-state could be detected by measuring the capacitance of CHLC. Parasitic capacitance became large and varied if pixel numbers increasing and pixel size decreasing of CHLCD. High frequency measurement could reduce the effect of parasitic capacitance, but could not cancel it. The algorithm was developed to cancel the effect of parasitic capacitance, and F-state or P-state of each pixel of CHLCD could be detected even though there was a large and varied parasitic capacitance. Based on this paper, "writing by hand" and "detecting what was written" became possible for e-paper CHLCD.

8. References

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