Investigations of process factors in the sensitivity of embedded digital switching TSP

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Abstract

Effect of process factors on the sensitivity of inner-type digital switching TSP was analyzed. From these results, we have successfully fabricated inner-type digital switching TSP embedded in 3.2-inch WQVGA PLS mode LCD panel. During many factors, TFT sensor structure for reducing the PI thickness and a separation distance of 0.3µm between the conductive column spacer (C/S) and TFT sensor were essential. Glass thickness and main C/S density were also important factors. This technology can be applied to wide angle of view hand-held phones, personal digital assistants (PDAs), and tablet PCs.

1. Introduction

Touch screen panel (TSP) technology has attracted a great deal of attention as an input device for many electronic applications due to user-interface benefits. It is expected that in the near future, the touch screen will become the main input device for most mobile electronics. Until now, the conventional TSP has been an external device, requiring additional components to detect touch events with a sacrifice of picture quality and increased module thickness. Thus various approaches to integrate the touch screen function into the LCD panel have been implemented, such as optical [1], capacitive sensor [2].

Recently, digital switching type embedded TSP technology have been reported, which was realized in 12.1-inch a-Si:H TN mode LCD[3,4]. In that method, internal electrodes in the upper and lower glasses are shorted by touch event, and the touch signal is sent to a readout IC. It has an advantage of direct hand writing as well as finger touches in front of the LCD panel which can be realized and its logic algorithm is simple. However, in terms of touch sensitivity, the digital switching type TSP showed non-uniform and poor touch sensitivity. Moreover the crucial factors affecting the sensitivity of TSP in the fabrication process were not analyzed systematically. In addition, TN mode has a significant problem of panel bruising in the TSP.

The goal of this work is to analyze the critical process factors on the sensitivity of inner-type digital switching TSP. From these, we proposes a high sensitive TSP embedded in bruising-free plane-to line switching (PLS) mode LCD.

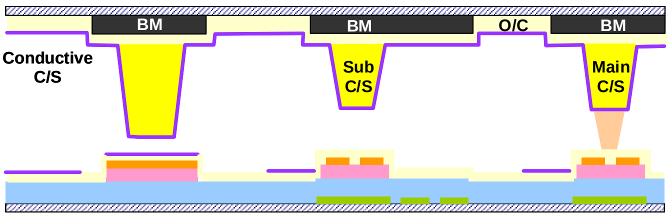

Fig. 1. Schematic cross-sectional view and each column spacer

2. Results and discussion

Figure 1 shows the basic principle of digital switching-type TSP schematically. In this structure, the conductive column spacer (C-C/S) formed on the CF glass acts as a sensor switch which connects the Vcom signal. When a finger touches the upper glass

TABLE 1. Factors affecting the sensitivity of digital switching TSP

Structures	items	Factors
C/F	Column spacer	• Height, area, profile, and structure
	Relation between each C/S	• Density and supporting area of main and sub C/S
		• Height difference between main and sub C/S
		• Arrangement of main and sub C/S
TFT	contact layer	• Contact layer's shape
	PI effect	• PI effect
Glass	Glass thickness	• Glass thickness (upper glass)
Polarizer	Polarizer thickness	• Upper polarizer's thickness or hardness

of the LCD panel, the gap between the C-C/S and contact area are reduced, and finally they can make mechanical contact. Lower density of the main column spacers increases touch sensitivity, but this can create long-term mechanical reliability side effects. This issue is resolved by adding sub-C/Ss. The sub-C/S has an advantage in that the panel load can be supported in case of touch events without a need to increase the main C/S density. The zero force gap space between the conductive C/S and the TFT sensor electrode is around 0.2~0.6μm.

Table 1 shows the several process and design factors affecting the sensitivity of digital switching TSP. There are many factors affecting the touch sensitivity as well as the sensor reliability. The fabrication of each C/S is an important point in digital switching TSP. The exact height and uniformity of each C/S over the entire panel are critical in the point of touch sensitivity. During many factors, the essential point was examined.

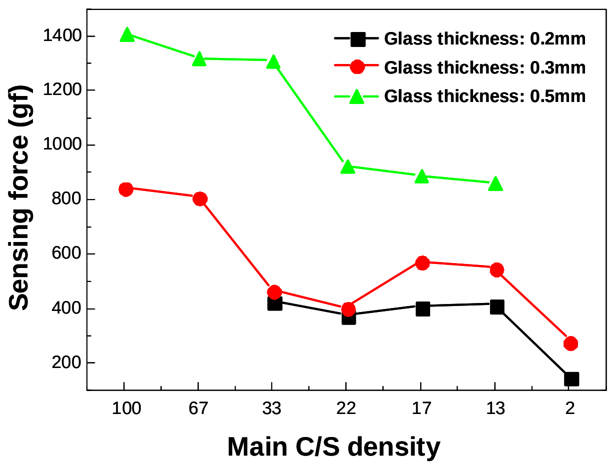

Fig. 2 Change of TSP sensing force as a function of main C/S density and upper glass thickness

Figure 2 shows the change of TSP sensing force as a function of main C/S density and upper color filter glass thickness. As the glass thickness was reduced by etching to 0.2 or 0.3mm, the sensitivity was enhanced dramatically. The reduced main C/S density makes it possible to easily bend the upper panel glass, thereby lowering the force needed for mechanical touch contact. The effect of polarizer thickness on the upper glass was insignificant.

In order to confirm the reduced main C/S density will have no impact on display quality, mechanical reliability tests were conducted to confirm long-term stability. Three kinds of mechanical reliability tests were conducted, pitting (sharp object depression), sliding and smear (blunt object depression) tests. With respect to the sliding test, it still needs a further improvement.

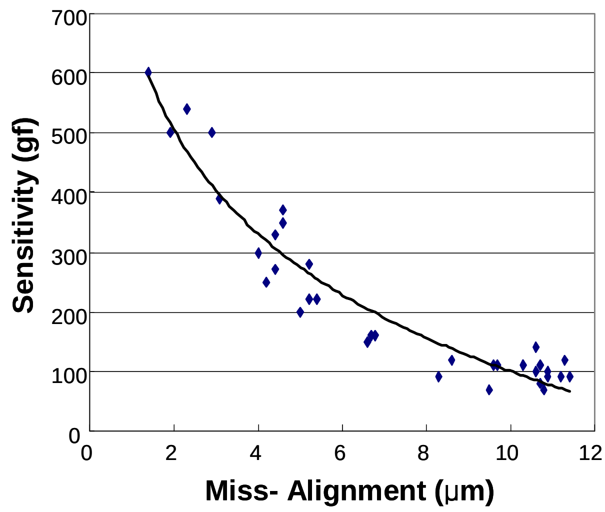

Fig. 3 Change of TSP sensing force as a function of miss-alignment between conductive C/S and TFT contact layer

Basically, LCD panel is fabricated by the assembly of TFT and CF glasses. During the assembly process, the alignment accuracy is important in the LCD panel production. During the sensitivity measurements, it was found that miss-alignment between upper and lower glass is closely related to the touch sensitivity. Figure 3 shows the sensitivity as a function of miss-alignment between conductive C/S and TFT contact layer. As the miss-alignment is increased, the sensor performance was improved. This observation is related with the polyimide (PI). The PI layer is an insulator which is used to anchor the LC molecules on the TFT and CF surfaces. In the edge area, the thickness of PI is lower than that of flat area, and we found that when the sensor C/S is come in contact with edge area, it showed the better touch sensitivity. This indicated that the sensitivity of the TSP can be changed according to the PI thickness. Therefore, during the active layer (a-Si:H, n+) steps, three bar-type patterns of embossed shapes are inserted in the TFT sensor area. In addition, during the SiN_x passivation step, two bar-type patterns are etched near the sensor area on either side of the 3-bar pattern, forming trenches. When PI is coated on the sensor, it reflows into the peripheral trenches, resulting in reduced PI thickness in the sensor area.

Fig. 4 shows sensitivity as a function of TSP sensor to conductive C/S distance in the fabricated TSP. When touching the panel with a stylus, outstanding sensitivity of 20-gf has been achieved at sensor to C-CS range from 0.2μm to 0.3μm. Sensitivity deviation across the entire panel was measured and has been found to be minimal.

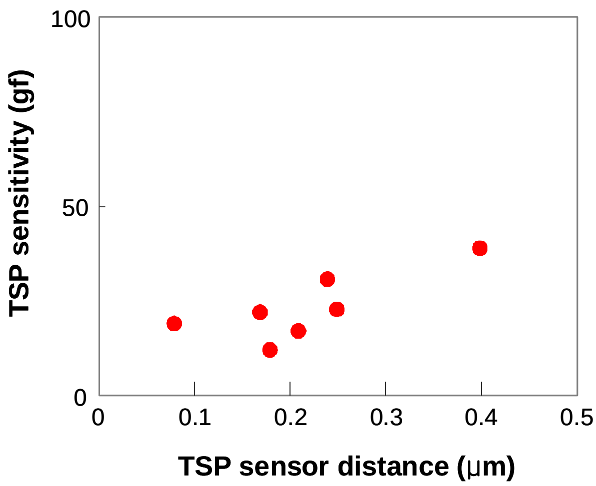

Fig. 4. Change of TSP sensitivity as a function of sensor distance between C-C/S and TFT sensor area

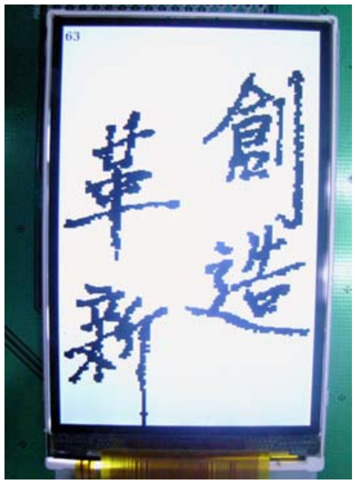

Fig. 5. Photograph of 3.2-inch internal digital switching TSP

Figure 5 shows a photograph of the 3.2-inch internal TSP prototype LCD. The handwriting capability is supported by high speed scanning. Incremental cost of the integrated touch screen is minimized by integrating the readout circuits into the source and gate driver ICs.

Table 2 shows key characteristics of the 3.2-inch WQVGA internal TSP LCD adopting the top com based PLS mode. Use of a display with WQVGA (240 x 400 x RGB) resolution along with integration of a high resolution digital touch sensor enables the detection of tiny movements. The panel has 4.6% transmittance with a contrast ratio of 615:1 and a response time of 25ms. Compared with an external-type TSP, it reduces the weight and thickness of the LCD module and enables realization of a high quality LCD display.

3. Summary

We have successfully developed inner-type digital switching TSP embedded in 3.2-inch WQVGA PLS mode LCD panel. Touch sensitivity has been optimized to 20-gf at a separation distance of ~0.3μm between the conductive column spacer and TFT sensor. This panel has advantages of higher transmittance, wider viewing angle, less bruising effect, and slimmer design. Therefore, this device has potential for broad use in applications such as wide angle-of-view hand-held phones as well as other small-medium sized LCD applications such as PDAs and mini-PCs.

TABLE 2. Key characteristics of the 3.2-inch WQVGA internal TSP LCD adopting top com based PLS mode

PARAMETER	SPECIFICATION
Display size (diagonal)	3.2”
Number of dots	240(H) x 400(V) x RGB
Dot pitch	58(H) x RGB x 174(V) um
Number of colors	262K colors
Color reproduction	60%
Operating temperature	-20 ~ +60 °C
Transmittance	4.6% (Aperture ratio: 57%)
Response time	25 ms
Contrast Ratio	615:1

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