Mobile LCD Device with Transparent Infrared Image Sensor Panel for Touch and Hover Sensing

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***Abstract*—In this paper, we propose a novel mobile LCD device for simultaneous touch and hover sensing. A transparent infrared image sensor panel allows the device to display contents and to detect touch and hover actions alternately. The proposed system has an advantage over touch screen devices in that a user interacts with a mobile device by not only touching the display screen but also hovering over the display screen.**

I. INTRODUCTION

Touch screen device market is rapidly growing since it provides an intuitive way to interact with display devices. Touch screen device can accurately map positions of user's fingers on the display screen onto input commands which allow various tasks to be performed through different commands based on touch actions. However, since mobile devices have a small screen size such as 3.5" and 4.3", touching the screen with fingers sometimes occludes displayed contents. Moreover, touch-only devices limit user interaction to a 2-dimensional plane on the display screen. Thus, adding the capability of sensing hover actions in a touch display provides more natural interaction means for mobile devices.

Previously, an optical sensing system using retro-reflective opto-sensors integrated with an infrared (IR) emitter and an IR detector which is placed behind an LCD panel was proposed to detect touch and hover points [1]. However the architecture in [1] has several problems in that display image quality is degraded and sensors behind the LCD panel might be visible due to the removed diffuser plate. Another approach to simultaneously detect touch and hover is to integrate photo-sensor circuit into a TFT-LCD during manufacturing process [2]. But this requires changing an LCD manufacturing process to insert photo sensors in cell.

In this paper, we present a mobile LCD device for concurrent detection of touch and hover actions. A key element of the proposed architecture is a transparent IR image sensor panel which sense fingers placed on or near the display surface while uniformly distributing light from a backlight to the LCD screen. Since it is fabricated with amorphous silicon (a-Si), we can use an a-Si TFT LCD process which is common to TFT LCD fabrication.

II. THE PROPOSED SYSTEM

A. Display Architecture for Touch and Hover Sensing

We propose a mobile LCD device to sense touch and hover simultaneously. Compared to a conventional LCD display, the proposed architecture includes additional two layers of a front illumination unit and an IR image sensor panel. Figure 1 illustrates an optical structure of our proposed architecture to concurrently detect touch and hover. It is composed of (1) a front illumination unit to beam IR light toward objects on and above the display surface, (2) an LCD panel, (3) prisms and light enhancement films, (4) a transparent IR image sensor panel to sense the reflected IR light from objects, (5) a diffuser film, and (6) a backlight unit. The front illumination unit radiates IR light to an IR light guide for touch detection based on frustrated total internal reflection [3] and beams IR light toward near object for hover detection in the same time. Then the reflected IR light is captured in the transparent IR sensor panel.

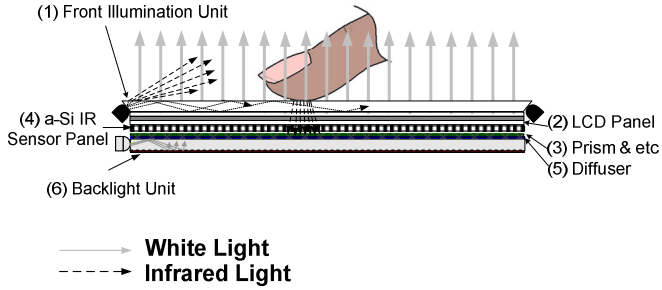


Fig. 1 Optical structure of the proposed mobile LCD device for touch and hover detection

B. Front Illumination Unit

The front illumination unit causes near object to cast reflected IR light for hover illumination while trapping IR light in the light guide plate for touch illumination. As shown in Fig. 2, the front illumination unit includes an obliquely cut edges of an acrylic light guide plate. IR light beamed at two obliquely cut edges travels to the inside of the plate for touch while heading toward the outside of the plate for hover.

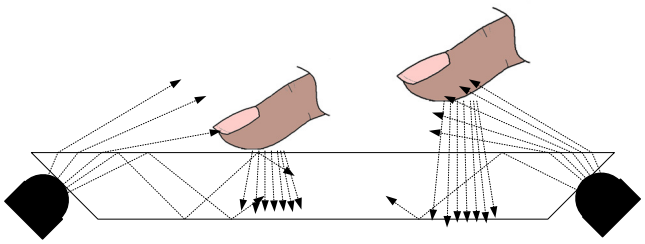


Fig. 2 The front illumination unit for simultaneous touch and hover illumination

C. *Transparent IR Image Sensor Panel*

Since a traditional image sensor panel is opaque, using the traditional sensor panel to sense touch and hover prevents a backlight from distributing visible light on a surface of an LCD panel for displaying contents. Instead of that, we propose a transparent IR image sensor panel which includes optically transparent pixels. The transparent pixels and the sensor pixels are interleavingly located in the sensor panel so that light from a backlight can be uniformly transmitted to the LCD screen. Figure 3 represents a microscopy image of the transparent IR image sensor panel we have fabricated. It has a photoconductor of a finger structure with $100\times100\mu m^2$ active area out of a $153\times153\mu m^2$ physical sensor area and has a transparent pixel with $153\times153\mu m^2$. The transparent IR sensor panel is fabricated with a-Si in that we can use an a-Si TFT LCD process which is common to TFT LCD fabrication as shown in Fig. 4. Since the size of the sensor panel is 3.5", a spatial resolution of the sensor panel is 480×320 pixels including transparent pixels. In order to secure enough sensitivity to near IR light around 850nm, thickness of the a-Si:H layer was chosen to 5000Å.

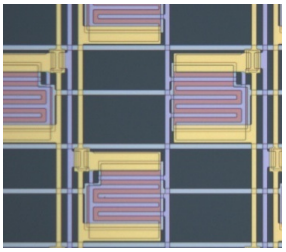


Fig. 3 Microscopy image of the transparent IR sensor panel

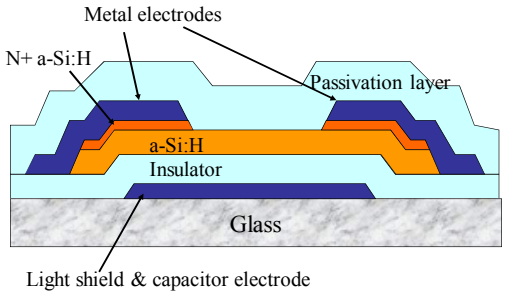
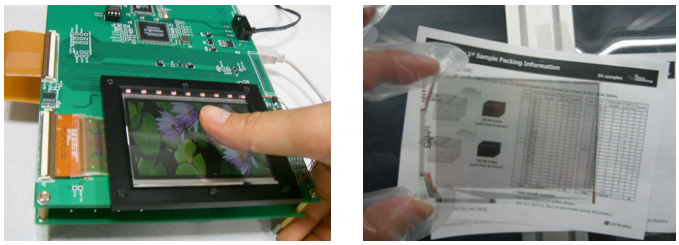
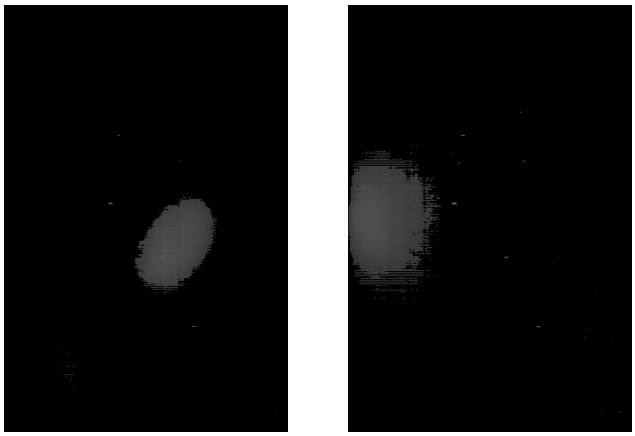


Fig. 4 Cross sectional view of the photoconductor



(a) Mobile LCD prototype (b) Transparent IR sensor panel

Fig. 5 Microscopy image of the transparent IR sensor panel



(a) Touch image (b) Hover image

Fig. 6 Calibrated sensor image for touch and hover

III. Experimental Results

We built a 3.5" mobile LCD prototype with the front illumination unit and the transparent IR image sensor panel for touch and hover detection as shown in Fig. 5(a). The fabricated transparent IR image sensor panel inside of the prototype is shown in Fig. 5(b). The sensor panel is transparent so that we can see a paper behind the sensor panel. Figure 6 represents calibrated sensor images from the prototype. When a finger touches the surface of the LCD panel, the touch region is clearly sensed as shown in Fig. 6(a). When a finger hovers over the display screen at 20mm, the hover region is captured as depicted in Fig. 6(b). The hover image is slightly blurred compared to the touch image.

IV. Conclusion

We have presented a mobile LCD device for touch and hover sensing. By employing a transparent IR image sensor panel and a front illumination unit, it is possible to detect both touch and hover events. Due to the transparency of the proposed sensor panel, display image quality of the device is maintained since light from a backlight is uniformly distributed to the LCD panel. We believe that our proposed system can provide more natural interaction means which touch-only devices cannot offer.

References

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