Full-Screen Fingerprint Display with Embedded Sensor Pixels Capable of Adjusting Light-Receiving Angle

Kwangsoo Bae[1], Gun Hee Kim[1], Soo Yeong Hong[1], Seoyoung Lim[1], Jungwoo Park[1], Taekyung Ahn[1], Byunghan Yoo[1], Seunghyun Moon[1], Jae-Kyoung Kim[1], and Yongjo Kim [1,*]

[1]Display Research Center, Samsung Display, Giheung-Gu, Young-City, Gyeonggi-Do, Korea
*ks98.bae@samsung.com

1. Introduction

Recently, the emergence of the smart mobile device, which enables more versatil functions, the frequent access or exchange sensitive personal information are more prevailed in the applications such as digital payments and personal authentications etc. As a result, the needs for the personal information pretection are higher than ever. Among the various biometrics, fingerprint identification is one of the most common authentication methods being deployed in the current smart mobile device as of its high level of security and user convenience characteristics. The mainstream of the existing fingerprint sensing technology is employing an add-on type ultrasound or optial sensors which is attached at the bottom of the display or side of the mobile device thus results in thicker and complicated module structure. As a result, it hinders the slim mobile device. Most importantly, the current sensors have a size limitation of several mm^2 as the cost per sensing area increase exponentially, so it restricts the fingerprint sensing in the limited predetermined area only which is cumbersome in the real user scenario. To overcome these limitations, several pervious literatures had attemped to integrated the sensor into the display. However due to the technical limitations, it only obtained lower resolution or implemented with the additional optical systems [1-3].

In this paper, we developed an OPD sensor panel that improved the quality of the fingerprint sensor using the multi-BM optical structure. Differentiated from the optical system of the OPD panelusing a conventional color filter (CF) and black matrix (BM) structure, the distance between the OPD pixel and the BM hole was increased to narrow the light receiving angle to the OPD pixel area, and the sensor image quality was enhanced by reducing the light receiving area per pixel. Under the window thickness increse, the capturing width can be minimized to reduces the difference in reflection luminance gap of the ridge and valley caused by the difference in thickness of the cover layer for each product when applied to various productsunder the window thickness increse, the capturing

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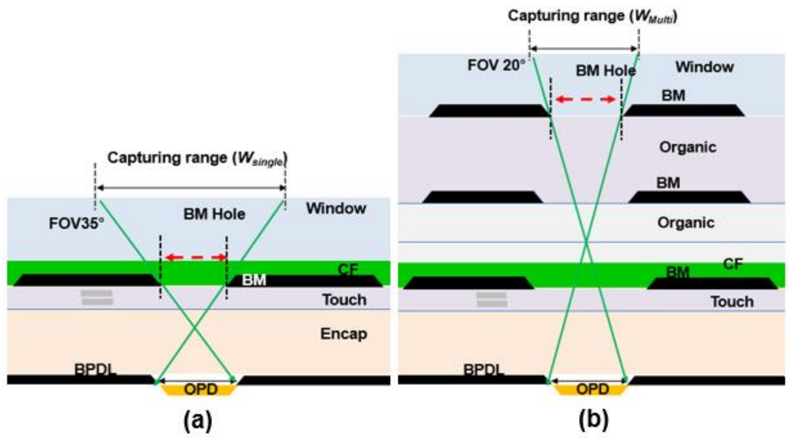

Figure 1 Schematic diagram of optical path and optical structure of the in-cell fingerprint display with (a) single BM hole and (b) multi BM hole

width can be minimized to reduces the difference in reflection luminance gap of the ridge and valley caused by the difference in thickness of the cover layer for each product when applied to various products. Consequently, we made the novel optical structure that could secure constant sensor performance even under various cover window conditions directly to the sensor panel in various product lines such as watch, smartphones, and display for automobiles.

2. Technical Concepts of the Fingerprint Sensor Embedded Display Panel

Figure 1 is a cross-sectional view of an improved in-cell sensor panel. It has the same backplane structure as the panel first introduced in SID 2024 last year. However, the most noticeable difference is that the sensor optical system was implemented using the multi-BM structure formed at the top of the encapsulation layer. Currently, this optical structure is commonly used to implement the privacy mode of the automotive application panel. As shown in Figure 1, the position of the optical hole capable of adjusting the angular distribution of the light received by the sensor pixel unit three organic layers and a BM layer was located at the top of the existing structure. hrough these structural changes, it was possible to minimize the angle of light entering the OPD pixel unit by placing it as far away from the panel internal structure as possible based on the OPD pixel unit. The OPD pixel of the panel presented in the previous paper increased by approximately twice the length to the optical system hole, which allowed the angular distribution of light reflected from the ridge and valley of the fingerprint reflected by the light source inside the panel to be narrowly implemented. Due to the effect of more than doubling the distance l value from the OPD pixel to the optical system hole, the FOV can be reduced from 35° to 20°, and due to this

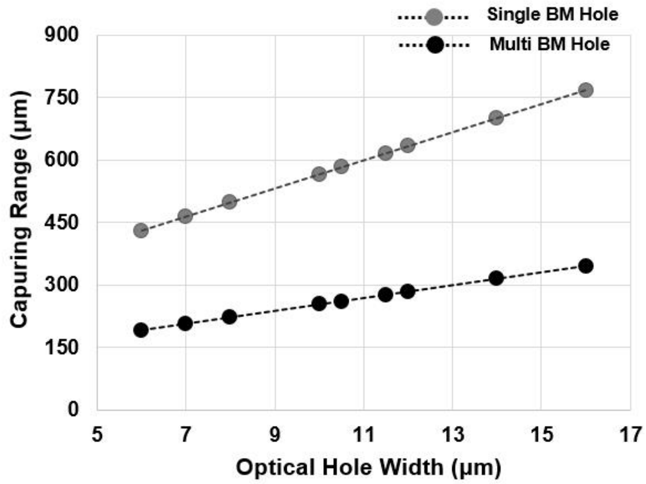

Figure 2 Capturing range change according to the BM hole area change of sensor panels with single BM optical hole and multi BM optical hole

effect, the fingerprint area that can be received from one pixel can be reduced from 565 μm to 300 μm or less. This improvement effect can clearly distinguish the difference in reflected luminance of the ridge bone in the fingerprint within a set amount of light received, and can bring advantages to the fingerprint sensing ability.

3. Technical Evidence for Proving Improvement of Fingerprint Acquisition Capacity

As mentioned above, the effect of reducing the field of view (FOV) can be an advantage in increasing sensor image quality, but it is necessary to maintain a certain level of light reflected from the light source. Therefore, it is important to secure the size of the OPD pixel and the size of the BM hole as much as possible, which affect the amount of light entering the OPD pixel, and to receive a large amount of light in the sensor pixel area.

In the panel structure in the form of a single BM stacked structure, when the OPD BM hole or OPD pixel area is increased by 50% from the current standard to increase the amount of light under l conditions, the capturing range increases rapidly (increased by 65μm or more: e.g. 600 → 665μm). Even if a sufficient amount of light enters the sensor pixel, the increase in the capturing range reduces the difference in the amount of reflected light between the actual fingerprint-shaped valley area and the ridge area, resulting in a decrease in SNR performance. On the other hand, even if the sensor panel of the multi-BM optical system presented in this paper increases the size of the OPD pixel and BM hole to secure the amount of light, it can secure a sufficient distance from the OPD pixel to the BM hole, which is one of the factors that determine the capturing range, thereby significantly reducing the increase in the capturing range. The calculated data in Figure 2 is an example

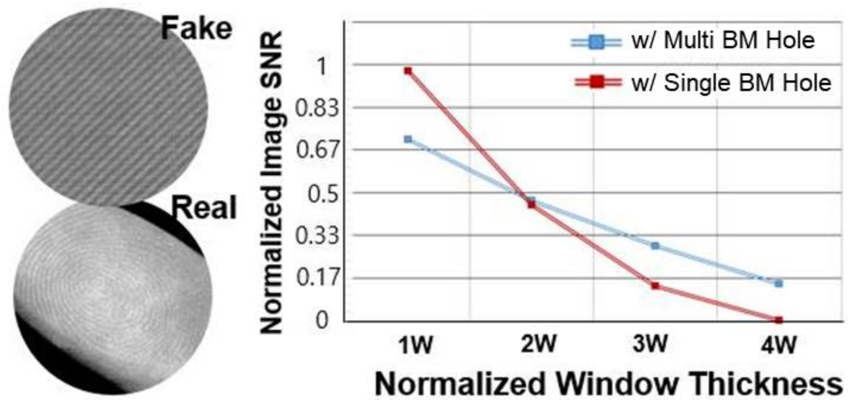

Figure 3 Captured fingerprint images of window with 2W thickness application sensor panel and SNR numerical change according to increase of the window thickness

of predicting a change in the capturing range according to an increase in the size of the BM hole. It can be seen that the variation of the capturing range decreases in the multi-BM structure. In fact, when the single BM structure is applied, the experimentally obtained capturing range limit range (<600μm) or more increases, and eventually, the fingerprint sensing ability decreases. If the OPD hole or pixel area is expanded under the same conditions in the multi BM device, the capturing range is increased only (268 → 296 μm).

That is, it is possible to secure the maximum amount of light entering the sensor panel to which the multi BM structure is applied under the condition of the fingerprint detecting area that does not affect the sensor quality degradation. As a result of the SNR evaluation, the SNR has a level of 5 : 1 over and has secured sufficient sensor capability for fingerprint sensing as shown in Fig. 3. Our improvement structure can respond to conditions in which the thickness of the cover film varies depending on the situation desired by the customer in the commercialized product. Figure 3 is the result of measuring the change in SNR performance according to the window thickness condition attached to the top surface of the panel. The single BM structure was applied to the Ref panel, and the multi BM structure was applied to the improvement panel. At this time, the OPD pixel size and the BM uppermost hole size of each panel were manufactured at the same value. As can be seen from Figure 3, in both panels with thin window thickness, the fingerprint capturing area is formed narrowly even in the single BM structure. In addition, due to the formation of a wide incident wide angle under the same aperture size condition, the initial SNR value has a higher value than the multi-BM method. However, the SNR value of the sensor panel applied with Multi BM is reversed based on the 400 μm application point, and the thick window condition can eventually increase the applicable window thickness range based on the minimum SNR achievement value. Through this, it was indirectly confirmed that the in-cell sensor technology can be applied to various display products.

4. Impact

We developed the world's first in-cell sensor Embedding the OPD pixels inside the OLED display with full-screen fingerprint sensing is assisted while maintaining the high-resolution display quality. Based on the results of this technology development, panel performance was proved by applying a new sensor optical system structure that can minimize sensor image quality degradation due to window thickness change of display products. We are confident that the in-cell sensor panel technology introduced in this paper can be applied to more product lines of commercialized display products.

5. References

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