Research on Optical Fingerprint Recognition System with Integrated Microlens Array

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ABSTRACT

This paper reports an optical fingerprint structure based on an integrated microlens array. The structure is manufactured by TFT backplane technology and can be used with an OLED screen to realize full-screen fingerprint recognition. In this paper, we studied the influence of the height of the microlens, the position of the collimating layer, and the position of the sensor, and achieved an optical fingerprint recognition structure with high signal-to-noise ratio, high utilization of collimated light, and thin thickness.

1. Introduction

The full-screen fingerprint recognition has received increasing attentions, but the cost based on the existing technologies (optical type and ultrasonic type) is very high. LTPS-TFT backplane technology has been proven to can be used to manufacture fingerprint recognition sensor, it can significantly reduce costs. In this paper, we designed a TFT fingerprint recognition system with integrated microlens array (MLA). Through optical simulation and optimization, the signal-to-noise ratio (SNR) is effectively improved while ensuring a high collimated light transmittance.

Fig. 1 is the schematic diagram of the structure reported in this article, the light emitted by the OLED is reflected on the finger, then passes through the OLED screen and is refracted on the surface of the MLA, and finally passes through the collimator to the TFT sensor. Due to the difference in the reflection of the valleys and ridges of the fingerprint, the sensors in different positions receive different light energy, so that generate different response currents, and finally achieve the purpose of identifying fingerprint images.

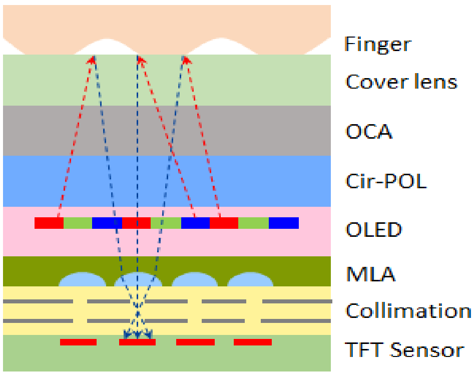

Fig. 1 Cross section of the structure proposed

2. Microlens design

The total thickness of the TFT layers can't be too thick, otherwise it will increases the difficulty of process. The microlens converge the light as shown in Fig. 2, the vertical light at different position is refracted by the lens and converges at the focal position, so the focal length (F) determines the length of the optical-path system. The *F* has the following relationship with the refractive index and the radius of curvature of the lens:

$$F \approx \frac{N_2 * R}{N_1 - N_0} \quad (1)$$

$$R = \frac{(D/2)^2 + H^2}{2 * H} \quad (2)$$

Generally, there are two ways to reduce the focal length: one is to increase the refractive index of the lens material, and another is to reduce the radius of curvature of the lens. We know that it is not easy to adjust the refractive index of the microlens material, and the benefit is small. While adjusting the radius of curvature is relatively easier to achieve. Fig. 3 shows the relationship between *F* and *H*. When the lens height ≥ H6, a smaller focal length can be obtained, and the TFT layers thickness can be thinner, which is conducive for manufacturing.

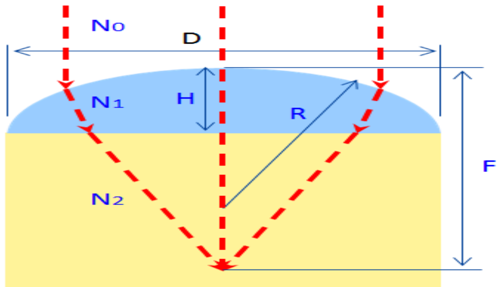

Fig. 2 Structure of microlens

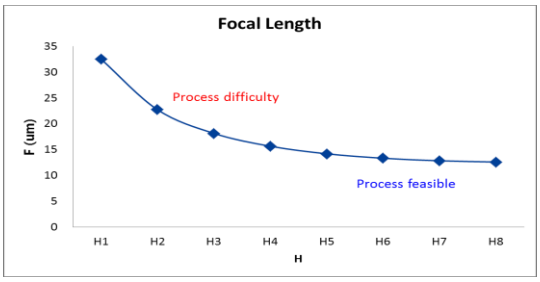

Fig. 3 Focal length under different lens height

3. Collimating system evaluation method

The light reflected by the fingerprint contains various directions, and its angular distribution is shown in Fig. 4 (a). In order to obtain a clear fingerprint image, the fingerprint light-path must design a collimator to collimate the light. Theoretically, if the light-path is more collimating, the fingerprint image will be clearer, and the recognition accuracy will be higher. But in fact, if the optical-path is too collimating, it will cause the optical signal significantly decrease, so that the optical signal does not meet the requirements of the sensor, which makes recognition difficult. We know that the valley-ridge period of a human fingerprint is 200~500um, and the distance between the sensor and the fingerprint is 0.6~1.0mm. In order to ensure sufficient signal and high collimation at the same time, we set the light with the incident angle ≤ θ as the effective signal, as shown in Fig. 4(b), the light with incident angle > θ is noise, as shown in Fig. 4(c). Through evaluating the received light energy and the system SNR, we have established the optical path structure shown in Fig. 5. The entire optical path structure is mainly composed of MLA, collimating layer S1, collimating layer S2, sensor and intermediate transparent layer. The collimating layers S1 and S2 are provided with collimating holes.

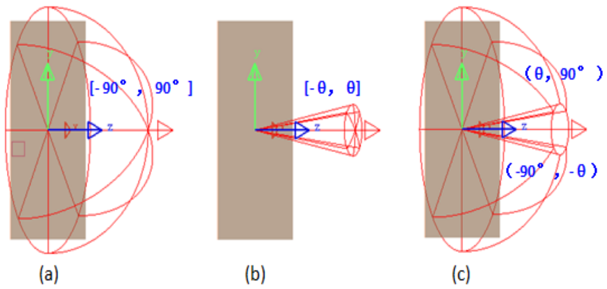

Fig.4 (a) Angular distribution of total light (b) Angular distribution of effective signal (c) Noise distribution

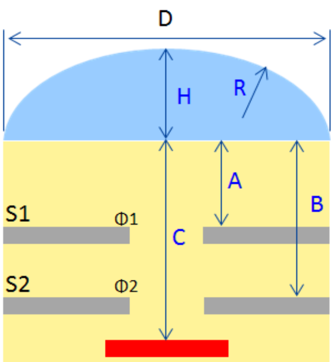

Fig. 5 Structure of TFT-optical fingerprint recognition

4. Collimating system and Sensor design

Collimating layer design must consider the influence of the effective signal. We hope that most of the collimated light can pass through S1, i.e. the first collimating layer. Fig. 6 shows the relationship between the position of S1 and the effective signal transmittance. When the *A* increases, the effective signal will gradually increase until it reaches saturation point. When the *A* continues to increase, part of the effective signal starts to be intercepted, and the effective signal begins to decrease. In order to obtain a higher effective signal and keep a longer distance between S1 and S2 to improve SNR, *A* is chosen near the saturation point, namely A3~A5.

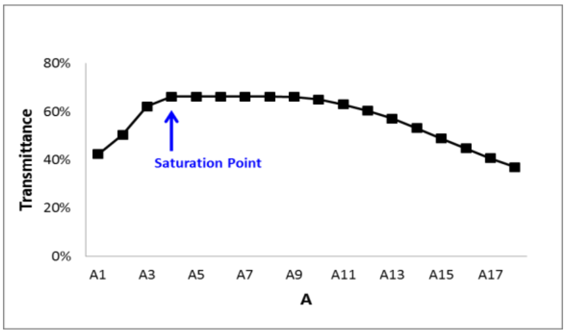

Fig.6 Effective signal T% at different S1 positions

The main function of the second collimating layer S2 is to intercept non-collimating incident light and improve the SNR of the optical-path system. In order to intercept large-angle light more effectively, the diameter of the collimating hole of S2 cannot be larger than S1(Φ2≤Φ1). Fig. 7 shows the influence of S2 position on SNR. When *B* increases, SNR will gradually increase, and reach a peak near B6, and then begin to decrease. The SNR peak point is located near the focal point of the lens. At the same time, we can also find that if the value of *A* is smaller, the peak SNR will be higher. Fig. 8 shows the relationship between the total transmittance and the *B* value. The larger *B* value, the lower total transmittance, so there is a trade-off relationship between SNR and total transmittance on the selection of *A* value.

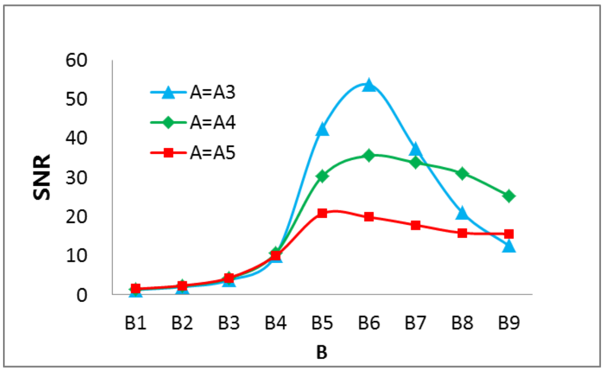

Fig. 7 SNR at different S1and S2 positions

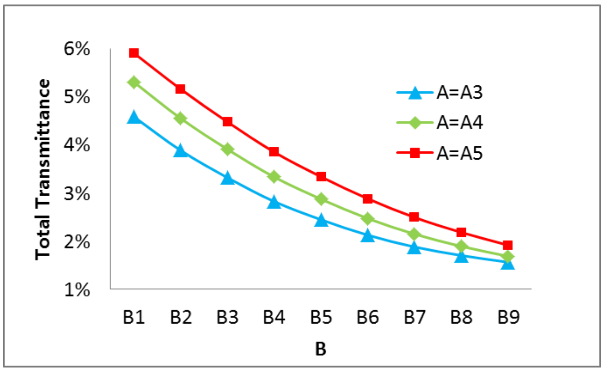

Fig. 8 Total T% at different S1 and S2 positions

$$SNR = \phi_{signal} / \phi_{noise} \tag{3}$$

Fig. 9 shows the relationship between the received light energy of the sensor, SNR and the position of the sensor. It can be found that the received light energy basically does not change with *C*, and the SNR has the same rule. But if the sensor is too close to S2, it will cause the light to be too concentrated on the sensor, so that the central area may be overexposed, and the position far away from the central area cannot receive light. Fig. 10 shows the illuminance distribution on the sensor when *C*=C2~C5, we can find that increasing the distance appropriately can make the illumination more uniform.

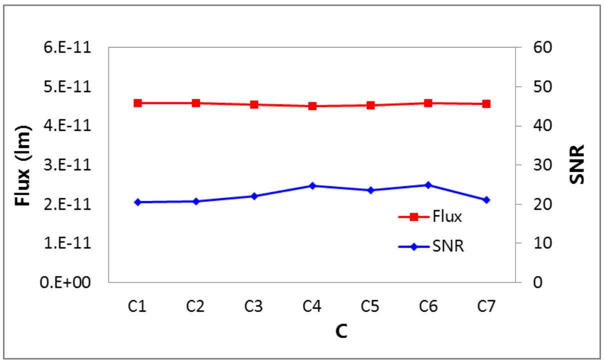

Fig. 9 Effect of sensor position on signal and SNR

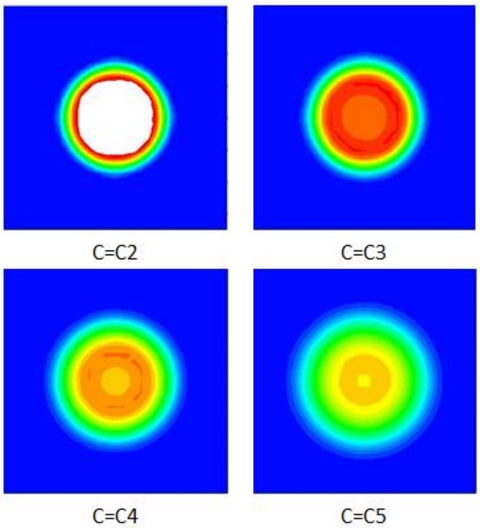

Fig. 10 Effect of sensor position on uniformity

5. Result

Through simulation optimization, we have obtained a fingerprint recognition optical system with a total T%=2.5% , SNR=35.6, and the collimated light T%≥41%. Fig. 11 shows the result of the fingerprint valley-ridge difference based on the simulation of this system. We can find that the sensors under different positions of the fingerprint have obvious energy difference, which can better restore the fingerprint information.

Table1 Final Result

Thickness	SNR	Total T%	Collimated light T%
11.0 um	35.6	2.5 %	41.1 %

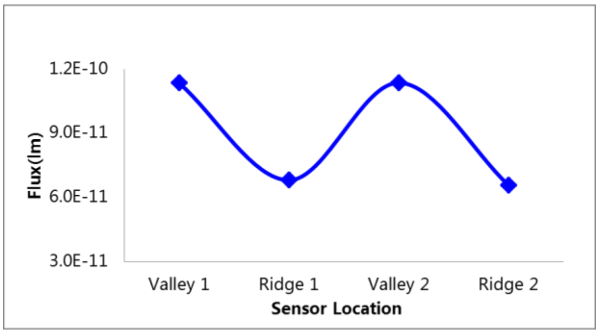

Fig. 11 Result of fingerprint simulation

6. Discussion

This paper does not discuss the impact of the aperture diameter on the signal energy and SNR. In fact, this is also a very important factor. Actually we have done a lot of simulations to determine the appropriate aperture diameter. In addition, because of the long development cycle of the MLA process, this paper does not present the final result of fingerprint recognition on the actual products. This part will be supplemented in subsequent articles.

7. Conclusion

In this paper, we established a complete TFT optical fingerprint system based on a MLA through simulation, and studied the influence of related parameters on SNR and transmittance. The simulated SNR value and transmittance value can be used to evaluate the quality of the collimating system and provide a reference for product design.

8. References

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