FINGERPRINT SENSOR TECHNOLOGY

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***Abstract*—This paper presents the latest fingerprint sensor technologies including optical sensors, DC capacitive silicon sensors, RF capacitive silicon sensors, pressure sensors, thermal sensors and also ultra-sound sensors. The advantages and drawbacks of each technology are also reviewed. The suitable applications of each technology are also presented.**

Keywords—fingerprint; sensors; optical, capacitive, thermal component;

I. INTRODUCTION

Fingerprint solution has been received a lot of attention for the past year. Apple launched iPhone5S in Oct 2013 with fingerprint recognition function. Samsung has announced that its Galaxy S5 also has fingerprint sensor integrated and the phone will be available in the market in April 2014. The new China Resident Identity Card Law requires citizens to have their fingerprints recorded when applying for, renewing or replacing their resident identity cards. Chinese government started to add fingerprint information to its National ID card from Jan 2014 [1] [2]. China has more than a billion resident ID cards in circulation and that number is expected to grow. Unique Identification Authority of India had also kicked off an ambitious program to give an identity to 1.2B Indian residents using unique ID number and fingerprints [3]. More and more applications and devices have been considering using fingerprint for security and also for convinience. For example, fingerprint door lockers, fingerprint time attendent machine. These are the significant market drivers for fingerprint solutions.

Fingerprint system is considered a fingerprint sensor and a CPU or controller to process the fingerprint and also to do the fingerprint matching. A fingerprint sensor is an electronic device used to capture a digital image of the fingerprint pattern. The captured image is called a live scan. This live scan is digitally processed to create a biometric template (a collection of extracted features) which is stored and used for matching.

Commonly used fingerprint sensor technologies including optical sensors, capacitive sensors, RF capacitive sensors, pressure sensors, thermal sensors and also ultra-sound sensors.

In the next sections, the major sensor technologies and their advantages and also drawbacks are discussed. Finally a conclusion is given.

II. FINGERPRINT SENSOR TECHNOLOGIES

A. Fingerprint sensor technologies

There are a few kinds of fingerprint sensor technologies. The oldest one is optical sensors which were developed in 1974. The later technologies including semiconductor based capacitive sensors and also sensor on Low temperature Poly Silicon (LTPS). Next, we will discuss each technology in details.

B. Optical fingerprint Sensor

The oldest 'live-scan' fingerprint sensors use frustrated refraction over a glass prism (when the skin touches the glass, the light is not reflected but absorbed). The finger is illuminated from one side with a LED while the other side transmits the image through a lens to a camera as follows.

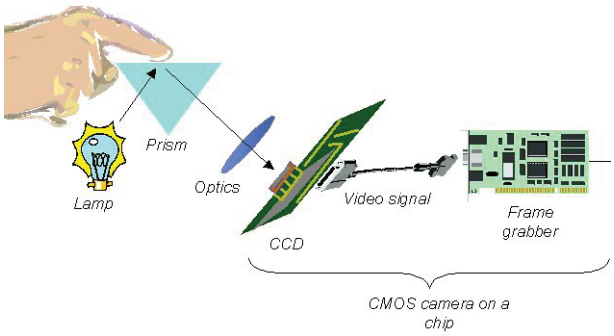

Figure 1, Optical Fingerprint Sensor Technology [4]

Optical Sensors are the traditional and low cost solutions fingerprint sensor technology. It contains the following technologies: Optical reflection, Optical transmission, Optical Sweep, Optical touchless, Optical TFT and Electro-Optical.

The major advantages of the optical fingerprint sensor technologies are low cost and it is strong to prevention of Electro Static Discharge (ESD). The disadvantages of the optical fingerprint sensor are big in size and high in power consumption. It is difficult to work under the strong light for example under the Sun light. It also has difficult to work with certain fingers such as dry fingers, wet fingers and for old and very young age groups. There are new technologies also

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developed to improve the performances of the optical fingerprint sensors. However, the cost of such improvement is relatively high compare to the capacitive fingerprint sensors.

Most commonly used applications are the fingerprint door lockers, time attendance and other indoor devices which do not care about size.

C. Capacitive Fingerprint Sensors

To overcome the drawbacks of optical sensor technology, capacitive silicon fingerprint sensor technology was introduced. Capacitive sensors use the electrical property of "capacitance" to make measurements. Capacitance is a property that exists between any two conductive surfaces within some reasonable proximity. A change in the distance between the surfaces changes the capacitance as defined by

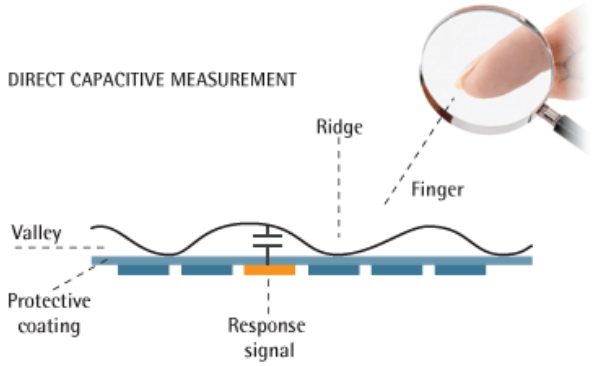

Figure 2, Capacitive Fingerprint Sensor Technology [4]

$$C = \frac{Q}{V}$$

$$C = \varepsilon_0 \varepsilon_r \frac{A}{d}$$

Where C is the capacitance; Q is the charge in coulombs; V is the potential in volts; ε_0 is the permittivity of free space, measured per meter; ε_r is the dielectric constant of the insulator used; d is the separation between the electrodes, measured in meters; A is the area of each plane electrode, measured in square meters (50µm x 50µm for 500 dpi; 60µm x 60µm for 385 dpi).

1) Direct Capacitive Fingerprint Sensor

The measurement of the capacitance between the skin and the pixel is the most physical effect used to acquire fingerprints. Where there is a ridge or a valley, the distance varies, as does the capacitance. The sensors use small sensing surfaces and as result are positioned close to the targets. The measured capacitance values are then used to distinguish between fingerprint ridges and valleys as explained in Figure 2.

2) Active Capacitive Fingerprint Sensor Technology

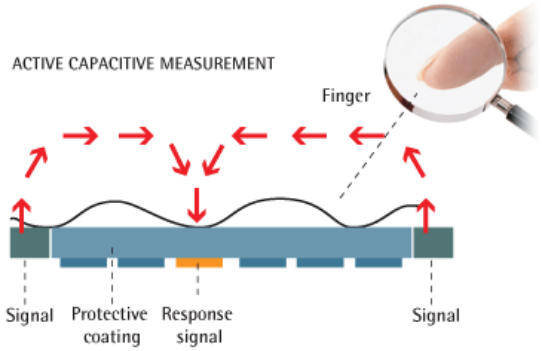

Figure 3, Active Capacitive Fingerprint Sensor Technology [4]

Figure 3 is the illustration of the active capacitive fingerprint sensor technology. Because an electrical field is measured and the distance between the skin and the pixel must be very low to provide enough sensitivity, the coating must be as thin as possible (a few microns). To have a thicker coating, RF based AC capacitive fingerprint sensor technology was introduced.

A low radio frequency (RF) signal is injected into the finger and then read by the pixels on the silicon acting like antennas. The signal strength depends on the capacitance/resistive connection, so from the distance between the skin and the pixel.

The advantages of the capacitive silicon fingerprint sensor technologies are small in size, low power consumption and work for almost everyone. The significant drawbacks are vulnerability to strong external electrical fields, the most dangerous being ESD and the high cost of the silicon area sensors.

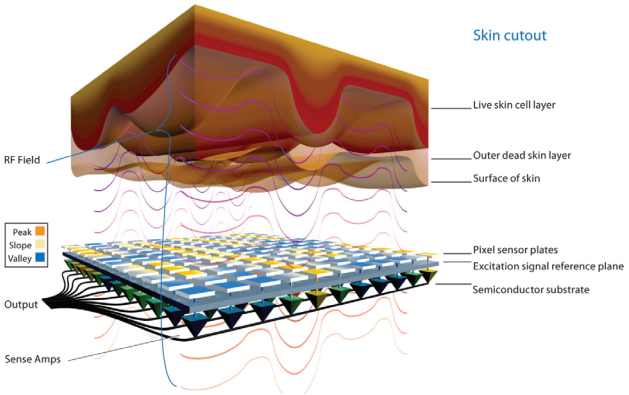

Figure 4, Active Capacitive Fingerprint Sensor

The capacitive silicon fingerprint sensor technologies have been widely used in mobile phones, laptops and other

handhold devices. Apple's iPhone5S uses RF based active capacitive fingerprint sensor technology.

Currently, most of the major fingerprint sensor companies use capacitive fingerprint sensor technology. These companies are Validity (acquired by Synaptics in Oct 2013) [5], Fingerprint Card[6], IDEX[7] and Digital Persona[8].

D. Pressure Fingerprint sensors

When you put your finger on something, you apply a pressure. The pressure-based sensor reads the difference of pressure caused by a fingerprint.

Piezo-electric material is used for pressure fingerprint sensors. However, the sensitivity of this material is poor. As a result, the fingerprint image is not good. To overcome this problem, some new technologies of pressure fingerprint sensor are introduced. Contact membrane on TFT was developed in 2002 by Hitachi in 2002 as illustrated in Fig.5. JP Sensor [9] claims that it has good pressure fingerprint sensor.

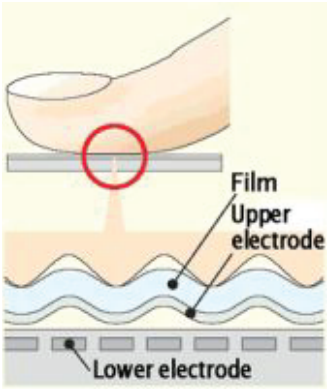

Figure 5, Pressure Fingerprint Sensor

E. Thermal Fingerprint Sensors

Pyro-electric material is able to convert changes in temperature into a specific voltage. This type of sensor doesn't measure the difference of temperature between the skin in the ridges and valleys, because the difference is negligible. In fact, as the finger is directly placed on the material, the ridge's temperature is what's measured, as it's in contact. The valleys don't make contact, so the temperature of the pyro-electric material under the valleys remains almost unchanged.

A drawback of the technique is that the image disappears quickly. When you place your finger on the sensor, there is a big change of temperature, and therefore signal, but after a short period (less than a tenth of a second), the image vanishes. The finger and the chip have reached thermal equilibrium, and as there is no change in temperature, there is no signal. This effect disappears when you sweep your finger over the sensor, because of the touch/no touch of ridge/valley. Atmel developed sensors based on this technology, but there is no new product developed since 2008 [4].

To overcome the drawback of the image disappears quickly of this technology, an active thermal technology was introduced by Ngoc [10]. The Active Thermal Sensing Principle is based on heat transfer. A low power heat pulse is applied to each sensor pixel over a short period of time and a response is measured. This response is quite large and different for pixels in proximity to a finger's ridge or valley.

Figure 6, Thermal Fingerprint Sensor principal

Next Biometrics [11] launched fingerprint sensor products based on this technology. LTPS production technology is used for produce the sensor on poly silicon. An ASIC is designed to read process and communicate these signals in a high quality image to the host system. All this is done in a very short period of time and with the user not feeling any heat.

Figure 7, Next Thermal Fingerprint Sensor

The major advantages of this technology are low cost and work for everyone especially for people who have wet, dry and oily fingers. The disadvantage of this technology is the power consumption is relatively higher than silicon capacitive sensors.

F. Ultra-sound Fingerprint Sensors

Ultra-sound fingerprint reading is not common. Ultra-sound sensing requires quite a big device with mechanical parts, and is quite expensive. Moreover, it takes a few seconds to grab an image. It is not suited for large production volumes at low cost. Its main advantage is the reading of the derma, the sub-surface of the skin, rather than the surface.

Ultrasonic sensors make use of the principles of medical ultrasonography in order to create visual images of the fingerprint. Unlike optical imaging or silicon capacitive, ultrasonic sensors use very high frequency sound waves to

penetrate the epidermal layer of skin. The sound waves are generated using piezoelectric transducers and reflected energy is also measured using piezoelectric materials. Since the dermal skin layer exhibits the same characteristic pattern of the fingerprint, the reflected wave measurements can be used to form an image of the fingerprint. This eliminates the need for clean, undamaged epidermal skin and a clean sensing surface.

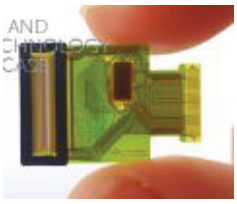

Figure 8, Sonavation Fingerprint Sensor

Sonavation [12] commercialized the Ultra-sound fingerprint sensors. Fig.8 is a Sonavation sensor.

The main advantage of the Ultra-sound fingerprint sensors are high reliability compare to the commonly uses capacitive fingerprint sensors and also optical fingerprint sensors since it measures the differences between the acoustic impedance of the ridges and valleys on user's finger. But its main disadvantage is that the cost is high. To overcome the cost issues of the problem, Mao and Przybyla [13] proposed to use piezoelectric micromachined ultrasound transducers (pMUTs) in fingerprint recognition sensors. Since pMUTs, like capacitive sensors, are built using micro-fabrication technology, this results in simple, very-low cost systems that could increase privacy and security in consumer electronics.

III. FINGERPRINT SENSOR DEVELOPMENT

The leading fingerprint sensor company AuthenTec was acquired by Apple in Oct 2012 and after Apple launched iPhone5S, many more players step into fingerprint sensor design.

Microsoft aims to replace password and PIN-code systems with higher level biometric systems. "We have investigated every biometric trait; the only solid technology is fingerprint. The swipe sensor format is unreliable and inconvenient. We want to move away from the swipe sensors." [11]

We believe, the fingerprint sensor will go for area sensor and also low cost. There will be a few new fingerprint sensors based on Capacitive and also Thermal technologies launched in 2014. The low cost is an important factor to expends the fingerprint market. Next [11] claims that its technology results in the cost of the sensor is largely reduced by 70% compare to the similar capacitive fingerprint sensors. Hope more new technology will be developed to reduce more of the fingerprint sensor cost.

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