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Near Infrared Transmission System for Under LCD Sensor Displays

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ABSTRACT

Near Infrared Transmission System is transforming the security of LCD smartphones with biometric sensing capability under the screen. This optical film system is allowing IR sensors to image through the entire LCD module while maintaining the picture quality of conventional smartphones. The NITS system enables thin and full screen design.

1 INTRODUCTION

1.1 OLED vs. LCD displays

Historically, the smartphones with the best security and the highest screen quality have come at a premium value. OLED (organic light emitting diode) displays provide crystal-clear images in full screens that go edge to edge. As for safety, biometric sensor security allows for fingerprint recognition or facial recognition from the front screen, personalized to the individual. This makes it incredibly difficult to break into a phone should it be lost or stolen.

Alternatively, phones with LCD (Liquid Crystal Display) are easier to manufacture and cost less to produce. Therefore, they are much more affordable and much more common in all markets around the world.

LCD smartphones are good but have historically been limited. There typically isn't an edge-to-edge full screen. Security measures usually involve typing in a password or number. And if included, biometric fingerprint sensors must be housed in a home button, on the front face or the back of the phone.

3M's new backlight optical film system allows infrared optical sensors in the back of the phone to image fingerprints through the backlight and LCD panel. This technology is new to the world and has numerous noteworthy benefits: full screen with brightness and picture quality, advanced biometric security, and sustainability for LCD models, all with an affordable cost compared to high value phones.

1.2 Conventional optical films in LCD smartphones.

Conventional LCDs, are shown in Fig.1, collimate light emitted from LED sources and improve efficiency of the LCD module with a reflective polarizer, prims film, diffuser film and a specular reflector. However, these films are not optimized to transmit IR light; prism films and diffuser refract and diffuse IR image (Seen in Fig.2) and the reflector completely blocks an IR image from being taken (Seen in Fig.3). Therefore, biometric fingerprint sensors can not be used behind conventional LCD modules.

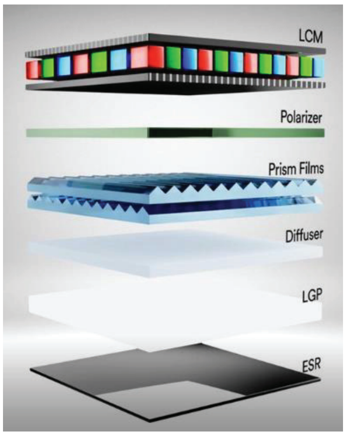

Fig. 1 Optical films in conventional LCD

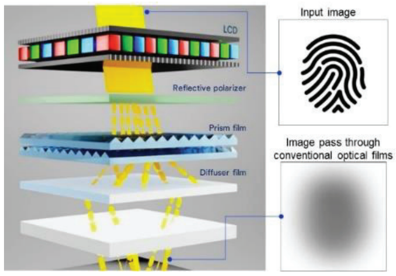

Fig. 2 IR image refraction and diffusion by conventional optical films

Fig. 3 IR light blocking by conventional reflector

2 EXPERIMENT

2.1 Near Infrared Transmission optical films

Since optical films in conventional LCD backlight are not allowed to transmit IR light for biometric sensing, 3M™ developed a system of new optical films which transmit IR light and maintain brightness and picture quality required in smart phones today.

To achieve these requirements, the 3M Near Infrared Transmission System (NITS) is composed of 3 new optical films: Collimator, Diffuser, and Reflector as shown in Table. 1 and Fig. 4.

Table. 1 Near Infrared Transmission optical films

Component	Near Infrared Transmission System powered by 3M	
	Films	Performance
LCD Panel	Optimized	-
Reflective Polarizer	Conventional	
Prism Film	**Collimator film: 3M NITS-C**	**~42% Visible Haze ~75% 940nm Specular T**
Diffuser Film	**Diffuser film: 3M NITS-D**	**~80% Visible Haze ~55% 940nm Specular T**
Light Guide Plate	Optimized	-
Reflector	**Reflector: 3M NITS-R**	**~98% Visible Reflectivity ~80% 940nm Specular T**

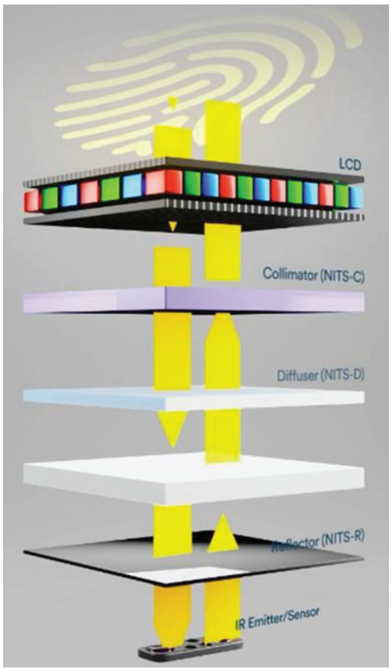

Fig. 4 Near Infrared Transmission system

2.1.1 Collimator film

The image of Spectral Transmission with respect to on-axis unpolarized light of the Near Infrared Transmission System-Collimator (NITS-C) is shown in Fig. 5. NITS-C is a multi-layer based reflective polarizer film that reflects light otherwise lost by the LCD panel's absorbing polarizer. Its design also provides polarized "collimation" allowing the removal of prism films that are difficult to image through. The top side 3M nanovoid polymer gel coating enables defect hiding and improved image quality while maintaining IR imaging.

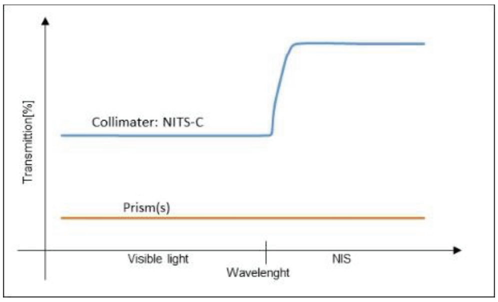

Fig. 5 Transmittance image of collimator film

2.1.2 Diffuser film.

The image of Spectral Transmission with respect to on-axis unpolarized light of the Near Infrared Transmission System-Diffuser (NITS-D) appears in Fig. 6. NITS-D utilizes 3M nanovoid polymer gel coating technology to optimize visible light scattering, similar to conventional diffuser films, while minimizing 940nm scattering for exceptional imaging capability.

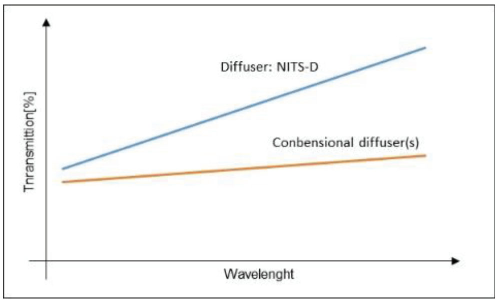

Fig. 6 Transmittance image of diffuser film

2.1.3 Reflector film

The image of Spectral Transmission with respect to on-axis unpolarized light of the Near Infrared Transmission System-Reflector (NITS-R) is shown in Fig. 7. NITS-R is specifically designed to reflect 98% or more of the backlight's visible spectrum for optimal display brightness while transmitting the majority of 940nm light for imaging applications.

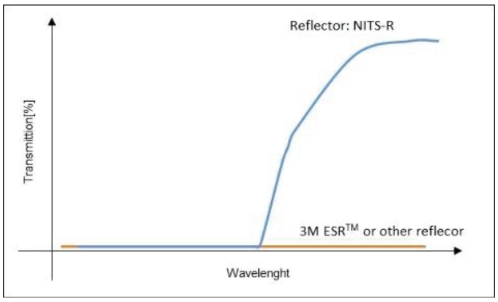

Fig. 7 Transmittance image of reflector film

2.2 Visible light control in LCD backlight

The visible light control mechanism of the Near Infrared Transmission System is shown in Fig. 8. Since LCD backlights require appropriate brightness performance, the components of NITS were designed as follows:

(1) Light TIRs (Total Internal Reflections) down the lightguide with efficiency support from NITS-R. The extracted light is at a very low angle with respect to the lightguide plate.

(2) NITS-D broadens the light output & refracts the majority of the intensity closer to on-axis or orthogonal to the panel.

(3) NITS-C reflects most of off-axis light. The reflected light gets scrambled & recycled until its polarization becomes parallel to pass axis of NITS-C—and rear absorbing polarizer—and is primarily transmitted on-axis. Recycling leads to an effective collimation.

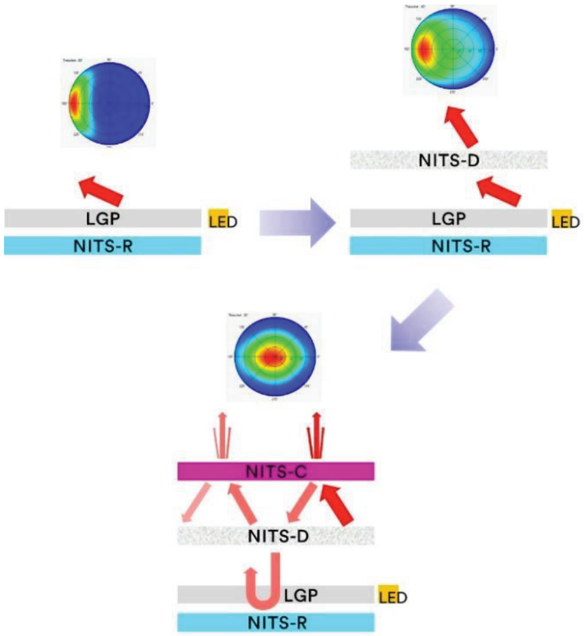

Fig. 8 Visible light control mechanism of near infrared transmission system

3 RESULTS

3.1 Near Infrared Transmission performance

An IR camera image through the Near Infrared Transmission System is shown in Fig.9. This evaluation was done using a Rose Noise target as showed in Fig. 10, designed with many different printed frequencies for MTF (modulation transfer function) analysis, on top of a 940 nm light source.

The captured image quality through the Near Infrared Transmission System is close to the target image and will enable to the accuracy and detail required for biometric fingerprint sensors in smart phone applications. Meanwhile, the image quality of conventional system didn't recognize the target image and simply captured a defocused image of the IR camera sensor and lens, as shown in Fig. 11.

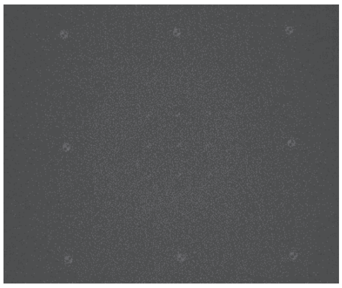

Fig. 9 Near Infrared Transmission system (at 940nm)

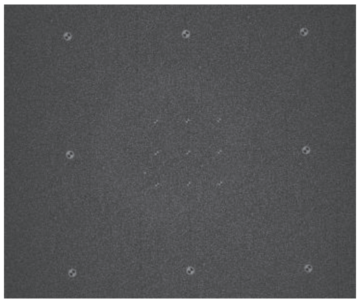

Fig. 10 Rose Noise Target (at 940nm)

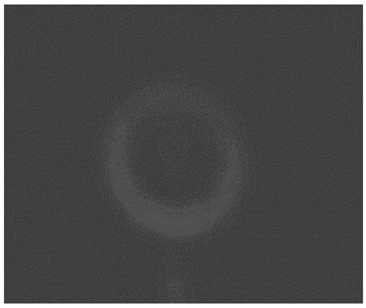

Fig. 11 Conventional system (at 940nm)

3.2 LCD optical performance.

The optical performance of the Near Infrared Transmission System has been evaluated in some smartphones and modules, which can be seen in Fig. 12. Since prism film in a conventional system contributes strongly to light collimation and system brightness, the current Near Infrared Transmission System has a challenging task of meeting the same brightness performance (70% compared with conventional film stacks). However, the system has space for further optimization factors like a thicker, more efficient lightguide plate and LED design, and panel optimization which has enabled efficiency improvements of at least 97% the conventional system.

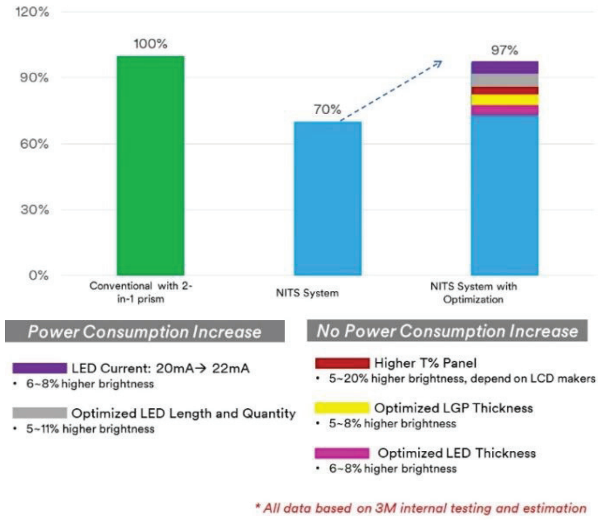

Fig. 12 Optical performance of near infrared Transmission system

4 CONCLUSIONS

The Near Infrared Transmission System powered by 3M provides at least 97% brightness efficiency in an LCD module and enables the use of advanced biometric fingerprint sensors, with equal thinness compared to the conventional LCD system.

3M materials have been inside displays since thin, LCD computers and TVs first came on the market. We know a lot about optics and we keep learning. It's exciting to see the new 3M NITS sensing technology come to life, allowing for front-enabled biometric security and a bigger screen on LCD smartphones.