Development of a Thin Double-sided Sensor Film “EXCLEAR” for Touch Panels via Silver Halide Photographic Technology

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Abstract

Fujifilm has developed a sensor film named "EXCLEAR" for touch panels using silver halide photographic technology. This sensor film comprises a conductive silver mesh pattern on both sides of a thin PET film, and a thin transparent sensor. Earlier, indium tin oxide (ITO) was mainly used as the sensor film for the touch panel; however, its conductivity was insufficient for the application to large-size touch panels. Moreover, it tends to easily crack if bent. Furthermore, the supply of indium is limited, which made it a major concern. ITO is resisted as a specific chemical substance. Therefore, there was a need for alternative materials for constructing the sensor film. "EXCLEAR" is a novel sensor film that overcomes these issues related to ITO and responds to the market demand.

1. Introduction

Touch sensors are being increasingly used for not only mobiles devices including smartphones and tablets but also laptops. As a transparent conductive film for touch panel, indium tin oxide (ITO) has been mainly used, but various problems are emerging. As touch panels are getting larger, ITO’s conductivity is becoming insufficient. It is particularly not enough for 10-inch or larger touch panels. ITO also does not quite fulfill diversifying needs, such as pen input and enhanced touch performance. In addition, indium, which is a material of ITO, is rare metal and the supply is likely to be limited. The production load is high due to a gas phase process including sputtering. Therefore, a, alternative material is required.

As an alternative sensor material for an ITO film, a metal mesh film and other non-ITO films are attracting attention. In the touch sensor market, expected to be constantly growing, non-ITO films are becoming widely used as a key material for large-size touch panels. In 2014, the non-ITO film market size was 1.72 million m². In 2016, it was expected to reach 4 million m² (2.3 folds in two years) (Fig. 1). On this backgrounds, we developed EXCLEAR, a touch panel sensor film that comprises thin PET with a mesh pattern of several µ m wide lines on both sides, using our black and white photographic technology and silver halide photographic technology in 2015 (Figs. 2, 3 and 4).

2. Development background

2.1 Touch panel configuration and principle of touch detection

Fig. 5 shows the most commonly used configuration of a touch panel and the principle of touch detection. A panel is divided into cells and each cell is a capacitor consisting of two ITO transparent conductive films and a dielectric layer between them.

A top ITO film and a bottom ITO film have patterned electrodes arranged in different directions (X direction or Y direction). One electrode scans a pulse signal and the other electrode senses it to read a change in the capacitance in a touched position and detect the position.
2.2 Problems of medium- to large-size panel sensors

The percentages of medium to large sizes (10 to 24 inches) in all the touch panels are expected to rise\(^5\) as demand for tablets is growing and touch panels are increasingly introduced to laptops and all-in-one computers.

When the size of a touch panel is increased, the number of detection points is increased. This means that the scan rate to store an electric charge in each cell must be increased, and the electrode resistance must be reduced. For a 10-inch or larger panel, there is concern that the conductivity of an ITO film will be insufficient.

In addition, when the size of a touch panel is increased, the production yield tends to decline as misalignment occurs more frequently in the process of bonding the conductive films. For this reason, highly productive modularization process is required.

2.3 Demand for alternatives for ITO

Indium used for ITO films is rare metal and the supply is likely to be limited. Furthermore, ITO is listed as a specified chemical substance in recent years. It is not desirable to use ITO because of safety.

There is also a concern that the process load, such as (1) gas-phase film forming process, like sputtering, is required, (2) the photolithography process for patterning is complicated, and (3) separate process for peripheral wiring is needed, is high for the sensor production using ITO film.

3. Features of EXCLEAR touch panel sensor

3.1 Configuration of EXCLEAR

EXCLEAR is provided with conductivity by silver mesh patterning. Fig. 6 shows a schematic diagram of a silver mesh pattern. A silver mesh pattern is formed on both sides of the transparent base. Each pattern consists of (1) sensor electrodes and (2) trace lines connected to the sensor electrodes. The electrodes (1) are formed into a pattern with several \(\mu\) m wide lines not to block the LCD image below the sensor and...
not to cause noise. The trace lines (2) are placed in the frame section (outside the visual area). As a thin flame is required to maximize the display area, those lines are usually several tens of μm in width (the same number of lines as that of electrodes are placed in parallel several tens of μm apart from each other).

3.2 Patterning process

The silver mesh pattern of EXCLEAR is formed using the photographic image forming process. Silver halide, a sensitive material, is exposed and developed to be converted to metallic silver (developed silver). Fig. 7 shows the overview of the process. Compared with production process using a resist for patterning, this process is simple.

3.3 Comparison with the conventional sensor ITO

EXCLEAR has highly conductive silver patterned in the form of mesh. That provides EXCLEAR with both optical transmission and electric conductivity and reduces the resistance to a lower level than that of ITO (Fig. 8).

Furthermore, EXCLEAR has features that conventional sensor ITO does not have. They are simplified touch module process, reduced sensor film thickness (total sensor thickness is 40 μm) and flexibility. Those features are explained in the sections below.

(1) Simplification of touch module process

We have developed the following two mass-production technologies (a) and (b) to improve the touch module process.

![EXCLEAR silver-mesh patterns](image)

**Fig. 6** Illustration of EXCLEAR silver-mesh patterns

**Fig. 7** Comparison of various conductive processes

EXCLEAR (Features below show only one side of the film)

- Silver halide layer (Coating)
- Trace line
  - Exposure and Photographic developing

ITO

- ITO layer (Sputtering)
- Trace line
  - Photolithography
  - Printing of trace line

Metal-Mesh (Cu plating)

- Catalysts of Cu plating (Printing)
- Adhesive layer (Printing)
- Trace line
  - Blacking layer (Plating)
  - Conductive layer

**Fig. 8** Schematic of the correlation between transmittance and resistance
and helped ease the production load (Fig. 9).

(a) Simultaneous forming of sensor electrodes and trace lines

For an ITO film, the sensor electrodes are formed first and then trace lines are formed in separate process. In the case of EXCLEAR, the sensor electrodes and the trace line are simultaneously exposed to form a pattern and the man-hours are reduced.

(b) Mono-sheet sensor

In the modularization process of a touch panel using ITO films, two patterned ITO conductive films are to be bonded. In this process, misalignment is likely to occur and that increases the production load. In the case of EXCLEAR, patterns are positioned accurately on both sides of the base and that reduces the production load.

(2) Reduction in sensor thickness

Coupled with the use of the mono-sheet sensor, the thinned base helps EXCLEAR reduce the sensor thickness to 40 μm and that leads to reduction in the thickness and weight of the device (Fig. 10).

(3) Flexibility

The conventional sensor ITO is liable to crack when bent. It needs great care in handling during production. EXCLEAR is highly flexible, thanks to the right choice of the type and amount of binder. It has much higher bend performance than that of ITO. Fig. 11 shows changes in resistance when EXCLEAR is wound around a 4-mm diameter rod and bent repeatedly. In the case of ITO, a change in the resistance (from the initial level) increases as the number of bending is increased. There are few changes in the resistances with EXCLEAR.

4. Technical features of EXCLEAR

This section explains the newly developed silver halide sensitive material and its process (pattern exposure and development).

4.1 Silver halide sensitive material

The newly developed sensitive material is made by applying several hundreds of nm silver halide particles (silver halide for photography is in several μm) using a polypeptide binder onto a transparent substrate. To give the developed silver high conductivity, an ultrahigh density silver halide sensitive material is newly developed by reducing the percentage of the polypeptide binder, which raises the conductivity between the developed silver particles, to about 1/100 of that used for a conventional photographic sensitive material. (Figs. 12 and 13).
4.2 Pattern exposure

Silver halide is a high-efficiency photo sensor. Various precision patterns can be formed by pattern exposure on the sensitive material. We have also developed the roll to roll production method to enable pattern exposure with accurate positioning on both sides of the substrate and achieved monosheet double-sided sensor.

4.3 Development

In exposed silver halide, latent images (silver nuclei that trigger development) are formed and they are reduced to silver by the reducing agent in the developing fluid (Fig. 14). Undeveloped particles are made soluble by the fixing agent and removed from the film.

After the chemical development above, EXCLEAR takes on a black tone that comes from the silver filament shape. We have also developed a formula of developing fluid that matches the new sensitive material as below.

(1) Balancing black tone and conductivity

Fig. 15 shows comparison in silver shape and color tone between EXCLEAR and silver plating as an example of conventional metal material.

In EXCLEAR, microscopic structures composed of dispersed fine filament silver are formed. It is noteworthy that it achieves the neutral black color tone, which reduces light reflection on the surface and does not reflect visible light of particular wavelengths, without requiring blackening processing.

In addition, using the layer design of the sensitive material and process conditions, the silver density is controlled in the thickness direction (high density in the bulk and low density on surfaces) to achieve both the black color tone and high conductivity (Fig. 16).

(2) Development of new fluid formula

As the polypeptide binder is reduced, we had to take measures (a) and (b) below for development process.

(a) Reduction of noise (silver nuclei developed in unexposed areas) caused by agglomeration of silver halide particles
(b) Reduction and stabilization of silver ions increasingly dissolved into the developing fluid

We have developed stabilization technology of developing fluid combining an adsorption stabilizer for silver halide and silver (to reduce noise and reduce silver dissolution into developing fluid), of which a common example is mercapto compound, and reduction inhibitor for dissolved silver. Thanks to the technology, we have achieved stable serial production.
5. Conclusion

We have developed EXCLEAR, a thin double-sided sensor film. We have explored new pattern forming methods using a photographic sensitive material and succeeded in balancing conductivity and film strength and improving the reliability as an electronic material. Demand for photograph films has dramatically declined, but we have applied the core technology we developed for photograph films to present needs and come up with a new product.

EXCLEAR is well received on the market for its contribution to thinning touch panel modules, quick response (low resistance) and support of large-size panels. It is also recognized to reduce production load in manufacture of the touch panel modules because of its mono-sheet structure (conventionally, one-sided conductive films are bonded) and simplified module process by simultaneous forming of the sensor pattern and trace lines.

EXCLEAR is expected to be used for new sensors, such as 3D sensors and wearable sensors, as it is great in flexibility. Thanks to the high-definition photographic properties, various conductive patterns can be formed. The possibilities of applying to various transparent electrodes, electromagnetic shields and heaters are already being discussed, and it is expected to be used for a wider range of applications as well.

To meet those expectations and customer needs, we will seek further user-friendliness and greater performance.

In closing, we thank all the people who gave us guidance in this research and cooperation in the development of the material.

References


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