Electrostatic Control and its Analysis of Roller Transferring Processes in FPD Manufacturing

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Abstract –In recent years, the structure of a-Si based TFTs have been getting more complex and glass transferring by conveyor rollers during each process were increased accordingly. Static electricity in transferring processes is becoming a major issue because most companies to pursue high productivity. In this paper, we analyzed a point defect which was induced by electrostatic discharge event in transferring processes. Based on the analysis, we proposed the effect of ionization to minimize triboelectric charge in glass transferring systems.

Ⅰ. Introduction

The most glass movement systems of production equipment in flat panel display have been using in-line transfer systems for its productivity. These systems are divided into a variety of conveyor system. Also the demand for LCD panels with low power consumption and high transmission ratio is getting more increased, the structure of TFT panels becomes more complex than conventional TFTs. Consequently, the fabrication steps to make a panel were drastically increased. Thus, the speed of glass moving to keep their productivity or the needs to meet tact time (production cycle time) was also increased. Due to elevated speed, glass substrates are exposed to the harsh environment of static electricity. This phenomenon affects production yield and quality. Thus, many companies have been making their efforts to control electrostatic problems.

We focused on charge generation and test method using various materials in our previous work [1]. The generation of triboelectric charge occurs during contact and separation processes between the glass and contact materials such as stage and lift pin.

In this paper, we investigated the factors of electrostatic discharge (ESD) and the effects of air ionization in transferring roller systems. We proposed the good solution not only the choice of roller materials but also ionization method to prevent failures caused by the ESD in transferring processes.

Ⅱ. Problems and Failure Analysis

Some yield loss had occurred, caused by point defects on a panel. Fig. 1 shows the defects as bright spots in a loupe image.

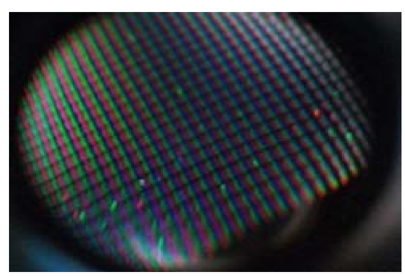


Figure 1: Loupe image of point defect

Fig. 2 shows a defect map of a full glass substrate having 6 panels. Defects are spread around the center area of glass. From this glass map, these defects were thought to have occurred during the glass movement. In order to investigate the source of defects, they were analyzed after removing CF glass (Fig. 4).

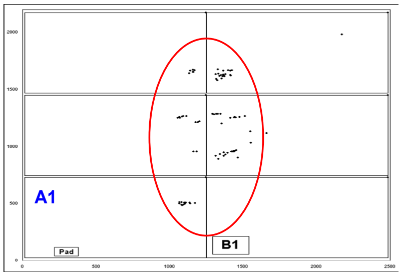
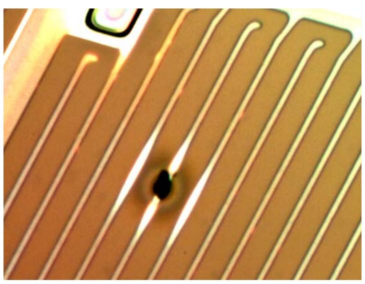
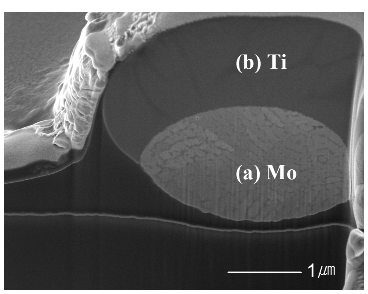


Figure 2: The Defect Map in Glass

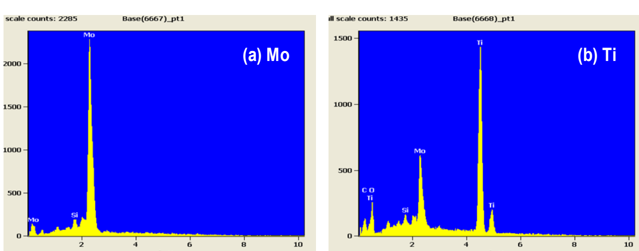
A particle was found located on pixel finger as shown Fig. 3 (a). The cross-sectional SEM view of the particle is shown in Fig. 3 (b). This particle consists of two different metals, molybdenum (Mo) and titanium (Ti), from EDS analysis as shown Fig. 3 (c). Mo was wrapped around Ti like egg white around the yolk. It seems likely that two metals were melted same time and became one particle through cooling down.



(a) Microscope image of defect



(b) FIB image of defect



(c) EDS Analysis result

Figure 3: Physical failure analysis of defect

Ⅲ. Results and Discussion

A. Problem in transfer system

In-Plane Switching panel fabricated in this work have the structure TFT/LC/CF sketched in Fig. 4.

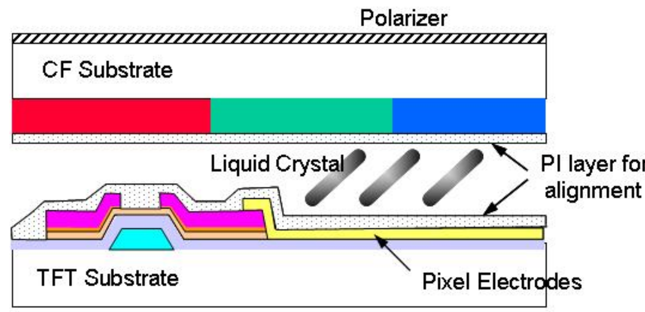
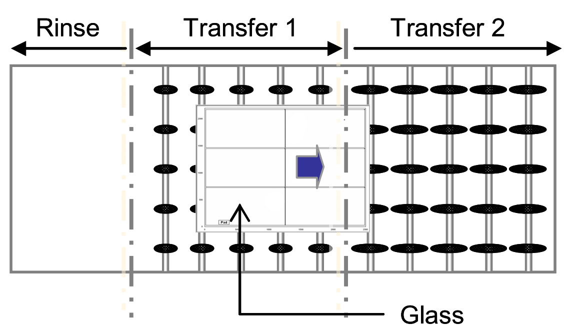


Figure 4: Schematic diagram of panel structure

General TFT-LCD modules use a liquid crystal between the TFT array and CF completion glass. The top layer of TFT array is pixel electrode using MoTi alloy. The position of particle is on this pixel layer and under the PI coating layer which is underlying the liquid crystal as an alignment film. Therefore, the process analysis was focused on transfer units and equipments from TFT completion to PI coating. Finally, the specific transfer unit inducing the failure before PI coating was founded as shown Fig. 5.



(a) Schematic diagram of equipment

(b) Actual image of transfer unit

Figure 5: Transferring unit occurred ESD event

This transfer unit is at the end of pre-cleaning before PI coating and composed of two different roller units. As shown in table 1, transfer1 and transfer2 rollers have some differences in materials, sizes and velocity conditions.

Table 1: Characteristics of two rollers in transfer units

Class	Transfer 1	Transfer 2	
Radius	Small	Large	
Surface Resistance	$10^5\ \Omega$	$10^{11}\ \Omega$	
Transferring Velocity	7000 (mm/min)	7000 (mm/min)	25000 (mm/min)
Static Voltage	-350 V	-2,550 V	-5,380 V
ESD Event	No	No	Occurred

The roller of transfer 1 unit has small radius and was made of static dissipative materials having the resistance of $\sim 10^5\Omega$. On the other hand, that of transfer 2 unit has large radius and consist of the insulative materials with the resistance of $\sim 10^{11}\Omega$. In addition, transferring velocity is accelerated from 7000 to 25000 mm/min in transfer 2 unit with the condition that a half of glass is not passed through the previous unit.

Measured static voltage was -350V at transfer 1, -2,550V with low velocity and -5,380V with high velocity at transfer 2, respectively. ESD events were detected 18 times by an EM-Eye meter (3M Inc.) during 24 glasses passed at the moment of velocity transition. The detected events were in the range from 80V to 420V and the average value was 234V in charged device model (CDM) mode.

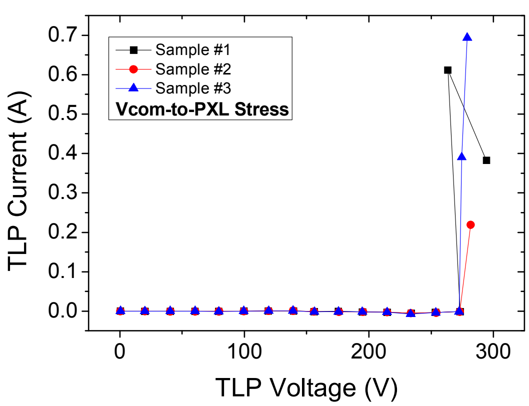
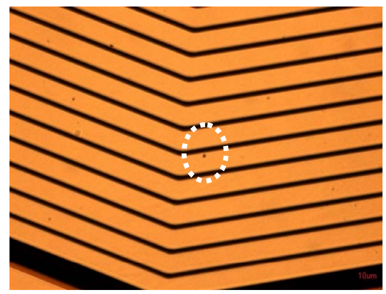


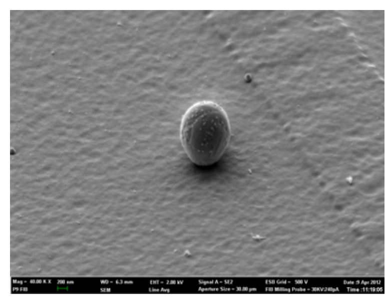
Figure 6: Results of TLP Stress

B. Reproducing particles using TLP

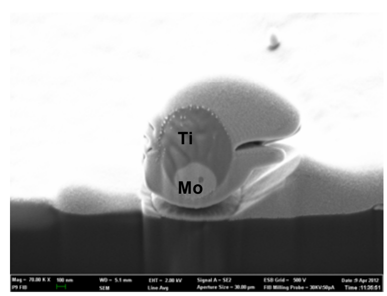
To clarify the failure phenomenon, a transmission line pulse (TLP) test was conducted on the panel. Fig. 6 shows the TLP stress results of the panel between two MoTi alloy metals. The TLP pulse was applied at pixel electrode and the other electrode was grounded. The applied pulse width and rising time were 100 ns and 10 ns, respectively. Two different metals were partially broken and shorted at the TLP voltage of 270V. Sub-micron particles were observed around the electrode after TLP stresses as shown in Fig. 7 (a).



(a) Microscope images



(b) SEM image



(c) Vertical image

Figure 7: The particle image after TLP stress

The magnified image of particle looks like a sphere as shown in Fig. 7 (b). The vertical image of this particle, as shown in Fig. 7 (c), looks like the particles that caused the point defects. The root cause of point defect is this spherical particle. It is created by ESD event in transfer unit 2 when the roller speed is changed. Because TFT and CF glass substrates were adhered in vacuum, the actual particles were slightly distorted.

The melting point of Ti and Mo are 1660℃ and 2600℃. Therefore, we assumed that the heat generated more than 2600℃ when the ESD event occurs on a glass in transfer unit 2. The melting two metals were scattered on a glass and cooled down according to different melting point during the glass movement. Because Ti has relatively low melting point than Mo, quickly chilled Mo is present on the inside first and Ti enfolds Mo at the outer of particles.

C. Triboelectric Charging in Roller

Transferring condition of two consecutive rollers is divided into three cases as denoted in table 1. The first condition is 7000mm/min velocity and glass placed on the static dissipative rollers with small radius (r_1) at transfer 1 unit. Under the second condition without changing speed, the glass lies on different rollers at the same time. The roller of transfer 2 unit has a bigger radius (r_2). The third condition is the time changing speed from 7,000 to 25,000 mm/min on two type's rollers having a different radius of curvature.

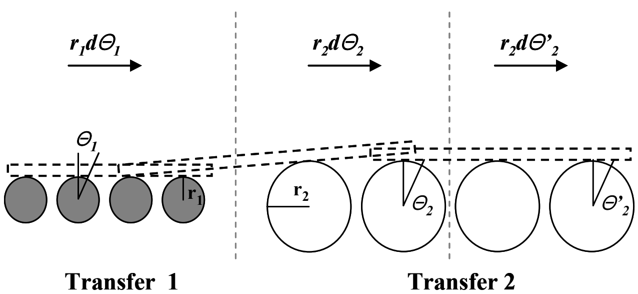


Figure 8: Schematic of two different rollers

Fig. 8 shows the schematic of two consecutive transferring units with different conditions. Under the first and second condition, the velocity of glass is the same as 7000mm/min at transfer 1 and transfer 2. Therefore, the moving distance of transfer 1 equals to that of transfer 2. Distance can be expressed as

$$D_1 = r_1 d\theta_1,\ D_2 = r_2 d\theta_2$$
$$r_1 d\theta_1 = r_2 d\theta_2$$

At this time, amount of triboeletric charges are different between two transfer units when glass and roller surfaces in contact separated because of different roller's resistance.

When the speed of transfer 2 is increased from 7,000 to 25,000mm/min, moving distance also change, such that

$$D'_2 = r_2 d\theta'_2 = (25000/7000) r_2 d\theta_2$$
$$d\theta'_2 \approx 3.57 d\theta_2$$

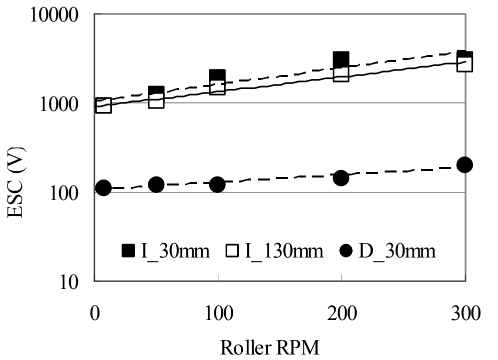
Moving distance is proportional to the strength of friction and related with higher level of charge generation. In fact, at high speed, electrostatic charge (ESC) generated higher. And due to different leveling of two axes, the first roller of transfer 2 applied a lot of force and the slip between a glass and the roller occurred. As a result, the first roller received a peak torque and peak triboelectric charging occurred when the roller speed changed. For this reason, ESD events were detected by EM-Eye at that time. So, pixel electrodes on a glass were damaged and this damage must be caused by high local temperatures resulting from heat generation by an ESD pulse [2].

Electrothermal instability is closely related with temperature and power. The partial derivatives of temperature were expressed as a function of voltage and temperature [3]. It is difficult to prove these relationships because constant voltage and current can't be assumed. Consequently, temperature of a pixel electrode exceeded 2600℃ at 270V TLP stress, resulting in divided two metals from an alloy.

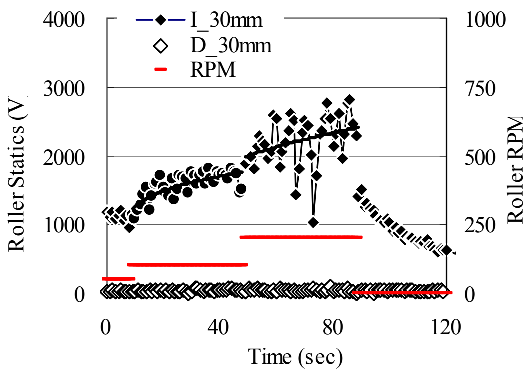
Ⅳ. Control Methods

From these result, change of roller speed led to friction charging and ESD events on the glass. Thus, the proper static control methods should be taken at the point of velocity transition. In our previous work, we suggested that dissipative materials are required to minimize charge build up and insulative materials should be used to prevent ESD events in contact and separation process. Indeed, the selection of contact materials is difficult because one material must prevent both ESC and ESD at the same time. Also, for productivity reasons, it is difficult to reduce the velocity of glass movement in the transferring system.

To investigate the friction charge by roller speed, measured the static level using electrostatic voltmeter (542-2, Trek Inc.) while varying the rpm of roller with a fixed glass. Insulative (I) and dissipative (D) rollers were used with radius of 30mm and 130mm. Each roller was grounded through roller shaft.



(a) ESC vs. Static rpm



(b) ESC vs. Dynamic rpm

Figure 9: Electrostatic levels to roller rpm

The electrostatic levels tend to increase with roller rpm as shown Fig. 9 (a). There was little change due to the roller size. A static level of using insulative roller is 10 times higher than dissipative rollers. This result confirms that the selection of material is a major factor influencing ESC generation. Fig. 9 (b) shows how the result varied according to changes of roller speed. In case of insulative rollers, static levels increased depend on the roller speed. The friction charges are not released but accumulated on an insulative roller. On the other hand, static levels remained less than 0.1kV with the dissipative roller. From these results, using dissipative materials clearly seems effective to electrostatic problems.

Many rollers cannot be grounded because of roller structure, floating roller shaft or other limitations. In one case, although a dissipative roller used, static level on the roller was 1,380V after passing glass. When the dissipative roller set was grounded by personnel touch, the voltage reduced to 140V.

The choice of dissipative material is important to ESC and ESD. But if it is necessary to use essential insulative materials, room ionizers can be used to minimize accumulated charges [4]. Thus, the cost-effective way to control static electricity is using room ionizers in transferring processes.

Table 2 shows the amount of electrostatic voltage difference between a roller and a glass. In each case, installing room ionizers and adding a bar-type ionizer was conducted sequentially.

Table 2: Comparison of static level

Classification	Ionization		
	None	Room Ionizer	Added Bar Ionizer
ESC (V)	5380	1730	550

To minimize the difference of static level between transfer 1 and 2, a couple of room ionizers were installed in transferring 2 regions and the static level was reduced up to 65%. In addition, remnant static charges were minimized through adding a bar-type ionizer to local elimination. Consequently, static voltage was reduced up to 90% comparing with initial values and the ESD events were drastically reduced up accordingly.

Ⅴ. Conclusion

An analysis of ESD in a glass transferring system, and the effective measures used to prevent it, are presented. Using different size and material rollers, led to static charge build-up and ESD occurring. This was worst where the speed of roller changed. We evaluated the friction charge increase due to acceleration of roller speed.

Sometimes, static dissipative materials cannot be used because of particle contamination or installation restrictions. An effective static control method when insulating rollers must be used is to use a room ionizer and local ionizers to neutralize charge. From installing room ionizer in roller transferring processes, roller voltage was reduced by 68%. After local ionization was added, voltages were reduced by up to 90%. Failures caused by ESD events were eliminated.

References

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