Comparing Room Ionization Technologies in FPD Manufacturing

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Abstract – In Flat Panel Display (FPD) manufacturing, automated handling charges both sides of the glass panels. Conventional ionization technology has a limited effect for ESD and particle contamination control as most of the ionizing bars are put over the top of the glass panels. But the glass has also been charged on the bottom of the panel, and as the glass gets bigger and panel transportation speeds increase, higher residual charges cause more damaging ESD Events and attract more particles. This paper examines the physical factors that have changed in FPD manufacturing and proposes alternative room ionization technology to improve ESD and particle control.

I. Introduction

The FPD industry has made extensive use of ionizers throughout its facilities. They were expected to solve problems of ESD damage and particle contamination on the glass panels. But changes in FPD manufacturing technology have made many of these ionization methods less effective.

This paper shows the limitations of using conventional ionization technology to neutralize charge on glass panels. It describes the performance of these ionizers, showing the residual charges left on the glass. Measurements are made in the same applications to show the effectiveness of an alternative ionization technology. Finally, this paper proposes a different neutralization target for yield improvement from ESD and particle contamination.

II. Experiment Description

The electrostatic fieldmeter and electrostatic voltmeter were used for the experimental measurement of charge on the glass panels and conveyor rollers. A Charge Plate Monitor was used to measure the charge neutralization time to compare conventional room ionizers with alternative room ionizers. In addition, FPD process yield improvement data is analyzed with or without alternative room ionization technology applied.

A. Residual Charges

Contact and separation generates charge on glass panels and items that they come into contact with such as plastic conveyor rollers, lift pins and stage materials. In many cases, to neutralize the charge on these objects, ionizers are mounted over the conveyor rollers and on top of process tools. However, this method has a limited capability to neutralize charge at the bottom of glass panel and over the entire area of plastic conveyor rollers. Often Teflon®, which is a very highly charging static generator particularly when in contact with glass, is used as the conveyor roller material (see Figure 1). Alternately, there are some processes that use dissipative or conductive plastic rollers. (See Figures 2 and 3) However, while this limits charging of the rollers, in either case the bottom side of the glass panels will still charge, as shown in the measurements of Table 1. The backside charge on the bottom of a glass panel is as destructive as the charge on the top.

Figure 1. Conventional Teflon Conveyor Rollers

Figure 2. Static Dissipative Conveyor Rollers

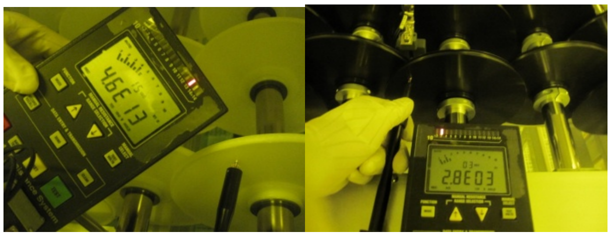

Figure 3. Resistance Test both Teflon and Conductive Conveyor Rollers

Charge	Teflon	Conductive	Coated Stage
Test 1	-1,700V	2,500V	12,000V
Test 2	-2,350V	2,650V	15,000V
Test 3	-3,670V	5,500V	25,000V

Table 1. Glass Panel Tribocharge Generation Tests with Conventional Teflon, Dissipative Conveyor Rollers and Dissipative Stage Materials.

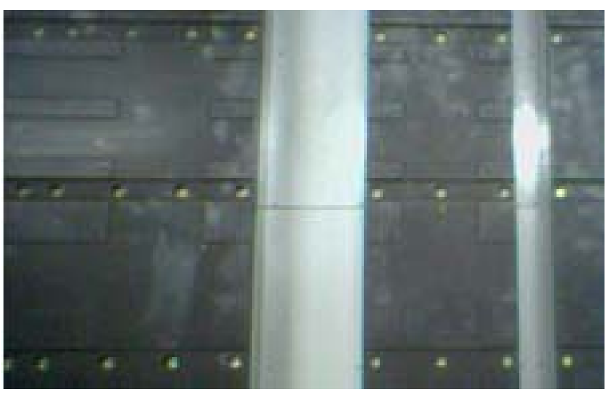

Figure 4. Static Dissipative Coating on Process Tools

Static dissipative stage coatings (see Figure 4) were applied by the FPD industry, but they are not the solution for static control on glass panels. The resistance range of the coating material is typically measured between 10^7 to 10^{11} ohms. Even using static dissipative stage coatings, glass panels will still charge when they are lifted by pins. This is shown in Table 2 for anodized aluminum and Durastone stage materials, and a dissipative coating applied to a metal stage. Refer to Figure 5 and Table 2.

It should be noted that using static dissipative coatings on stages and other materials that contact the glass does have a benefit. The coatings remove the possibility that residual charges on these surfaces will induce charge on the glass panels that contain electric field sensitive devices. Controlling charged objects with dissipative coatings will not, however, control the generation of charge on the glass itself.

Anodizing	Stone	Dissipative
15kV	20kV	24kV
16kV	18kV	13kV
14kV	15kV	15kV

Table 2. Glass Panel Charge Generation Test Result

Figure 5. Glass charge detected at 1.98kV when separated from stage by lift pin

To neutralize charges on the glass panels and the insulative plastic rollers, conventional clean dry air (CDA) assist gas bar ionizers are used over the top of the glass panels and at some points between the conveyor rollers. See Figure 6. This approach was not very effective for ESD and particle contamination control in process areas for a number of reasons. These included charge on the bottom of the glass panels, induction charging from the plastic conveyor rollers, physical constraints requiring ionizer installations at long distances from the glass panels, and the grounded metal environments surrounding the glass. Another typical installation of conventional CDA assist gas ionizers is shown in Figure 7.

Figure 6. Conventional CDA ionizers in FPD process areas

Additionally, glass transportation speeds are relatively fast, moving at 4.3 ~ 5 m/sec when handled by robots or when over the conveyor rollers. This makes it more difficult to neutralize the charge on glass panels, as they are exposed to the ionizers for only a short time. To protect against physical damage from moving machine parts, most ionizers are installed a relatively large distance from panels, typically 300 mm to 600 mm. The large ionizer installation distance from the fast moving insulative glass panels makes the ionizers less effective for charge neutralization. This is shown in Figure 7 and the measurements of Table 3.

Ionizer Off	Ionizer On
12.5kV	10.5kV
13.5kV	13.0kV
14.3kV	13.5kV

Table 3. Glass Panel Passing by Robot Arm with Ionization

Figure 7. Ionizer installed at load area and robot arm deliver glass panel 5m/sec.

For qualification of CDA assist gas ionizers, a charged plate monitor (CPM) is the standard test equipment and methods of ANSI/ESD STM 3.1 are used. The CPM uses a 150 mm square metal plate and has a relatively small capacitance of 20 picofarads (pF). Generation (Gen) 8 glass panel size is 2160x2400 mm with a thickness of less than 0.6mm. This means that the Gen 8 glass panel capacitance will be about 2,000 pF, if the dielectric constant is assumed to be 7.5. This is about 100 times larger capacitance than the standard CPM. The higher capacitance glass panel will take longer than the CPM plate to neutralize and ionizers used for FPD manufacturing will need a higher current output. Higher ion densities are very important to neutralize glass panels and large area conveyor rollers in FPD manufacturing processes.

Overall, the operating requirements for ionizers in FPD manufacturing processes are very complex. These include large area, high capacitance glass insulators, large operating distances, fast glass panel moving speeds, charged conveyor rollers, and often inaccessible bottom charges on the glass panels. Making measurements with the 150 mm isolated metal plate of the CPM would appear to have little relevance to FPD manufacturing conditions. ESD standards working groups may need to consider and research alternative test methods for FPD and other ionization applications with large insulators.

B. Low Efficiency Applications

Unfortunately, there are many ionizers used in FPD manufacturing processes that have little or no effect on glass charge neutralization and provide no production yield improvement.

For example, Cassette Stocker areas are a typical location where ionization is not effective for neutralization in the process. As shown in Figure 8, large area glass panels are closely stacked here, there is very strong air turbulence interfering with the transport of ionization, and the ionizers can only be located at the corners of the panels, outside of the robot moving zone where the panels are transported. While ionization may reach the top center of the panels over a long exposure time, the bottom side of the panel only receives a minimal amount of ionization as each glass panel is added to the stack. Whether on the top or bottom of the panel, ionization operation is hampered by very strong air turbulences and robotics handling the panels.

There are many other places in FPD manufacturing processes where the pitfalls of ionizer application have resulted in overkill of ionizer use with no evidence for either effective particle contamination reduction or ESD damage controls.

Figure 8. Conventional Stocker Area

As FPD technology changes, it is becoming an essential part manufacturing processes to control static charge on glass panels. This is due to device sensitivity increases to particle contamination and ESD. Currently most of FPDs are high definition (HD) which means there are over two million pixels. With these changes over earlier panel designs, new glass panels have become more static sensitive than previous technology panels and facility static control levels need to be reduced.

In addition, the FPD industry will be moving to a 4 times higher definition display, Ultra Definition (UD), which will have over 8 million pixels. This means physical gaps between array patterns are getting even smaller. The critical particle size for causing defects also gets smaller and ESD occurs at lower voltages. Since it is recognized that today killer particle sizes are around 10 µm, in the future it will be around 2.5 µm. Smaller particles are more plentiful and more easily attracted by static charges on the glass. Control of static charging to lower levels to prevent particle attraction and ESD becomes even more important.

This means that static control will be even more of a challenge for ionizers used in the FPD industry as smaller geometries combine with higher capacitance glass and faster glass transport speeds. There will be less time available for effective neutralization.

C. Alternative Room Ionization

Most of the static-related problems in the FPD industry are particle contaminants on glass panels and ESD. To control these problems, using conventional CDA ionizers is inefficient in most process areas.

As described previously, the major charging sources in FPD process areas are the glass panels and plastic conveyer rollers. Control of static charge will need to consider residual charges on glass tops and bottoms, glass transportation by plastic conveyor rollers and robots, the large capacitance of glass panels, and large, sometimes turbulent air flows in FPD process areas. These issues are to be addressed by the higher ion densities provided by alternative room ionization and its implementation in FPD processes.

1. Alternative Room Ionization Technology

Alternative room ionization technology has been designed to target the key control items. To lower residual charges on large capacitance glass panels and conveyor rollers, a higher ion current output is the most important technical element.

To increase ion current output without offset voltage increases and air turbulence, more ion emitters need to be added in the same spaces compared with conventional CDA assist bar ionizers. Pulsed DC ionization technology has been applied to get more ion density and less ion recombination.

Conventional room ionization using dual-rod ionizers mounted to the cleanroom ceiling still has some application for charge neutralization and cleanroom environmental control. At short distances they are not applicable as each rod emits a single ion polarity. The result is that the glass panel gets a stripe effect. This is shown graphically in Figure 9.

Since most FPD production occurs within the process equipment, conventional CDA assist bar ionizers will be compared with the alternative ionization method.

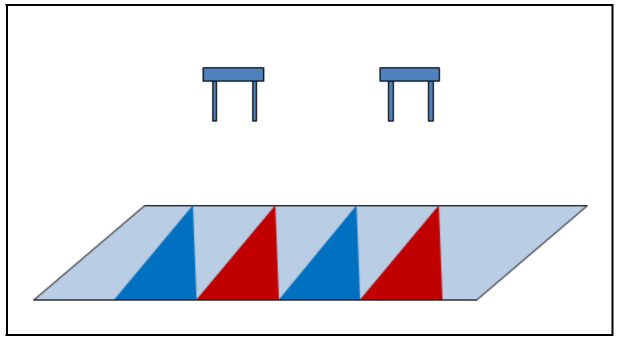

Figure 9. Stripe effect by conventional room ionizers

2. Test Procedures

The CPM of ANSI/ESD STM3.1 can be used to measure the results of ionizers with large glass panels, but STM3.1 does not cover test locations needed for these measurements. Target measurement areas are where the glass is moving very slowly between processes to see the differences in the level of static charges and the possibilities of yield improvement.

Uniformly neutralizing large insulative material with ionizers, such as Gen 8 glass panels (2160 mm x 2400 mm) requires multiple ionizers and more integrated ionization systems. In this case, it is less meaningful to use individual ionizer test methods.

STM 3.1 needs to be updated with test procedures for this type of ionization system, rather than allowing the user to define or modify standard procedures.

In many FPD manufacturing processes, glass panels pass horizontally on conveyor roller arrays and are then placed by robots on the stages, similar to work benches. Proposed test locations are shown in Figures 10 and 11.

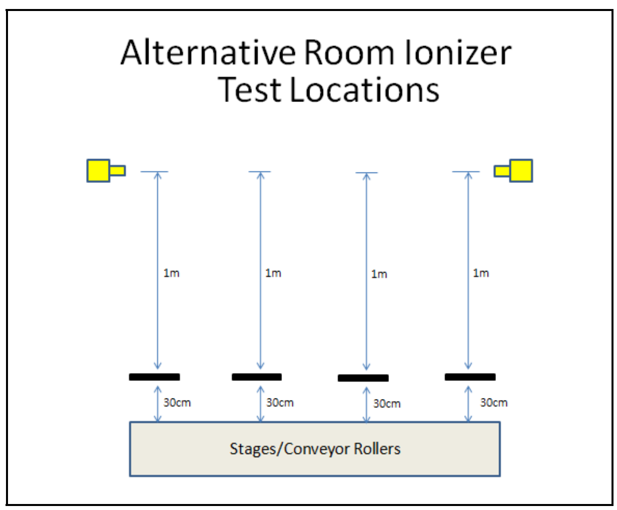

Figure 10. Test Locations for Alternative Room Ionization – Side View

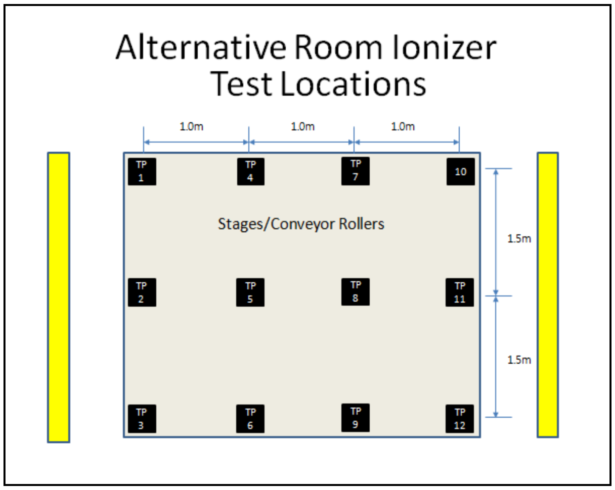

Figure 11. Test Locations for Alternative Room Ionization – Top View

Using the test locations shown above, standard ionizer test methodologies, discharge and offset voltage (balance) were applied. Voltage swings and discharge time limits are defined by the related device sensitivities of end users. Typical application required limits are ± 300V and less than 20 second discharge time. The results of tests of the alternative ionization system at all the test locations are shown in Table 4.

Average Test Data	Ion Balance	+ Decay	- Decay
Room Ionizers	-249~156V	2.4sec	2.9sec

Table 4. Average Test Data from Alternative Room Ionization

Direct comparison of operating parameters for conventional ionizers and alternative room ionizers is not as important as the results of their operation in an FPD process. Residual charge testing results using an electrostatic fieldmeter shows the differences in neutralizing large glass panel substrates by different types of ionizers. In this test, glass panels moved over the conveyor rollers at relatively slow operating speeds of 0.15 ~ 0.2m/sec.

Type of Ionizers	Residual Charges on Glass
CDA Ionizers	1150kV
Alternative Room Ionizers	120 ~ 150V

Table 5. Residual charge detection testing results using an electrostatic fieldmeter

3. Residual Charge Tests in Production Line

Testing was then done in an actual production line to determine the impact of conveyer speed on residual charging. Previous measurements in FPD manufacturing processes found different charge levels based on different speeds of conveyors. The test setup is shown in Figure 12.

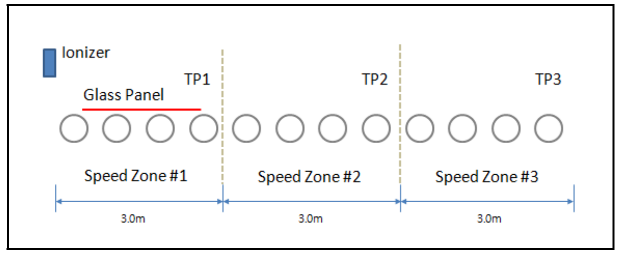

Figure 12. Conveyor roller charge measurement on glass panels

Each conveyor speed zone is about 3 m long. The high speed zone operates 2.5 times faster than the low speed zone. The distance from the glass to the cleanroom air filters is 1.2 m and the ionizers are mounted in front of the filters. The speeds of the conveyors were changed in different patterns to see if this would have an impact on the measurements. Test results for the conventional ionization are shown in Figure 13, and for alternative ionization in Figure 14. When all three zones were at low speed, residual charge on the glass panel was only 150V with both types of ionization. When the panels passed though the high speed sections of the conveyor, charge levels increased over 2800 V (Figure 13) with conventional ionization. There was hardly an increase over 150 volts with the alternative ionization.

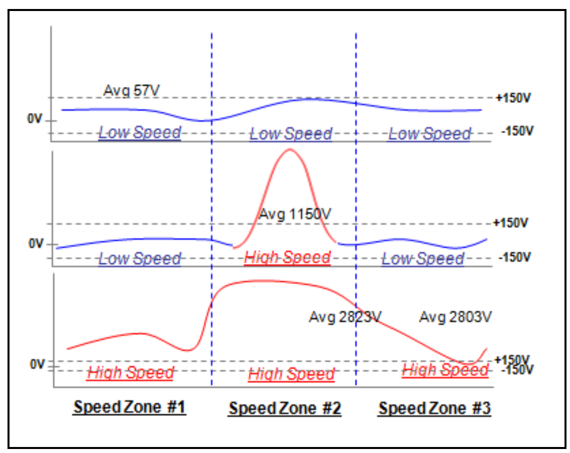

Figure 13. Glass panel charge generation testing of conveyor roller speed differences without alternative ionization.

4. Contamination and Yield Tests in Production Line

Alternative room ionization was installed in the production line to measure its effect on particle contamination and yield. The results are shown in Figure 15.

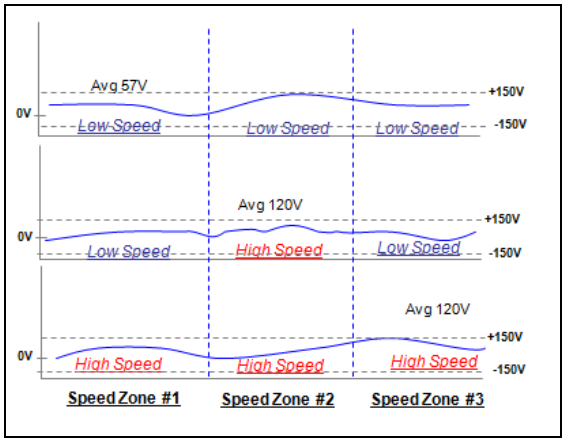

Figure 14. Glass panel charge generation testing of conveyor roller speed differences with alternative ionization.

The operation of the ionization related directly to a reduction of the particle contamination defect ratio and improved yields. Yield data showed differences on both a daily and weekly basis. There was a significant change with alternative room ionization at 3.58% better yield over three months.

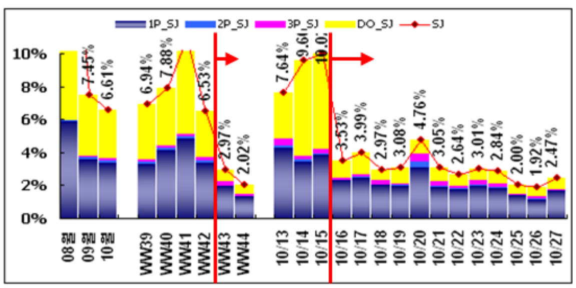

Figure 15. Particle contamination defect ratio decreased from 6.53% down to 2.95% (down 3.58%)

Alternative room ionizers have shown similar particle test results and improved yield data from many process areas throughout FPD manufacturing facilities. By contrast, with conventional ionizers installed in both short and long distance applications, the evidence of any differences in yield are very difficult to find with or without ionizers.

5. Advantages of Alternative Room Ionization

The major difference between alternative room ionizers and conventional room ionizers is the very high density of air ions available with laminar flows. This enables large area neutralization including glass panels, conveyor rollers, etc. By using alternative room ionization, static charge in areas up to 5 m square and 8 m in height can be effectively controlled. This is accomplished by operating in Pulsed DC mode and with very high emitter point densities compared with most other types of ionizers.

Alternative room ionization systems are operated as dual bar systems. This allows discharging of much wider areas on both the glass plates and the interior of the conveyor roller tunnel minienvironment. Many FPD processes are now using this type of minienvironment laminar flow cleanroom for transport of the glass panels The mini-environment tunnel has better air flow control of airborne particles and exhausts particles out of this space through access ports in the floors.

Most conveyor rollers are made of Teflon or other plastics which generate high level electrostatic fields inside the minienvironment tunnels. This causes glass contamination and ESD damage. The tunnels are relatively long, 10 to 20 meters, and the high density of ions produced by alternative ionization is more effective in neutralizing charges along the entire expanse of the tunnel. With the charge neutralized by the alternative ionization, particles remain in the laminar airflow of the tunnel minienvironment and are removed through the exhaust ports. There are obvious yield improvements when data for alternative ionization ON is compared to the same operation with the alternative ionization OFF.

Conclusion

Experiments demonstrate that in larger area FPD processes, it is not effective to neutralize charge on glass panels and plastic conveyor rollers with conventional CDA types of gas ionizers, whether AC or DC technology is used. Installation distances, nearby conductive materials, ion recombination, air flow turbulences and glass movement speeds make effective charge neutralization difficult. Instead, conventional CDA gas ionizers create additional turbulence and poor quality ionizers actually increase offset voltages on glass panels. In addition, gas ionizers require electrical power and CDA air consumption increasing the effective cost of these ionizers.

Higher ion densities available with an alternative room ionization solution offers benefits of more effective charge neutralization, lower operating costs, and increased production yields. This will be of increasing importance as ESD and contamination control strategies change to keep pace with FPD technology changes.

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