Double Side Charging of Glass Substrates

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Abstract— **The paper describes a simplified, two-sided, electrostatically charged glass substrate model typically used in flat panel display and semiconductor processing industries. The conditions of efficiently neutralizing charge on glass panels are discussed.**

Experimental part describes test method dissectible glass substrates for non-contact generation of surface charges, measurement of electrostatic fields created by these charges and estimate efficiency of static charge neutralization on glass substrates.

I. INTRODUCTION

Glass plates used in the flat panel display industry are prone to accumulate surface charges. The plates are characterized by high surface and volume resistivity and the ability to keep charges for long periods of time. Another specific feature of glass plates is their relative thickness, so electrostatic charge can be accumulated independently on two surfaces (top and bottom sides of the glass) at the same time. This can cause two surfaces to have charges of the same polarity and different magnitudes, or positive charges from one side and negative charges from the other. These glass plate features make both measuring surface charges and neutralizing charge difficult tasks.

II. THE CHARGED GLASS PANEL MODEL

To analyze the electrical field distribution created by different variants of charge on glass panels or substrate, we may consider a simplified model of a flat piece of dielectric, both sides of which are able carry surface charges σ1 and σ2.

The solution for calculating electrostatic fields on both sides of a sheet of dielectric in case of electrets is discussed by G. M. Sessler [1]. More specific cases where surface charges are deposited on dielectric layers attached to a grounding plate (related to the xerographic development electrode) are discussed by J.M. Crowley [2].

In many semiconductor and flat panel industry processes a stationary dielectric plate exists with evenly distributed surface charges on surfaces S1 and S2 positioned between two grounded surfaces. A simplified model is shown in Figure 1. The Sf line represents a ground floor surface separated from the panel P by distance d1 having a dielectric constant ε =1 (air at normal atmospheric condition). The upper line Sc represents a control surface that may be configured as a grounded field intensity measuring device or static charge neutralizer positioned at air gap d2 from the panel P.

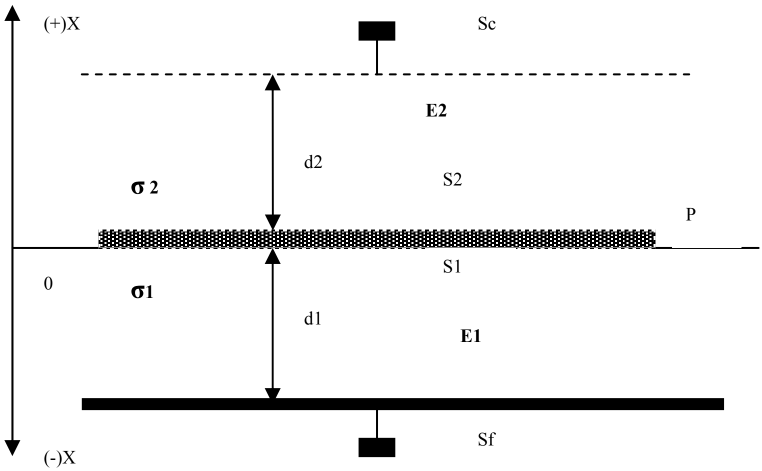

Fig. 1.

The thickness of the panel is presented as G and dielectric constant is εg. If surface charge density (+/-) σ1 is located on the surface S1 (at x = 0) and the surface charge density (+/-) σ2 on the surface S2, and G << d1 or d2, according to Gauss's law of field intensities, the electrical fields will be:

$$E1 = (-)\,[\sigma1\, G + (\sigma1 + \sigma2)d2]/\, \varepsilon o\, (d1 + d2) \qquad (1)$$

$$Eg = (\sigma1\, d1 - \sigma2\, d2)\, /\varepsilon g\, \varepsilon o(d1 + d2) \qquad (2)$$

$$E2 = [(\sigma1 + \sigma2)d1 + \sigma2\, G/\, \varepsilon g]/\, \varepsilon o(d1 + d2) \qquad (3)$$

where: E1 and E2 are field intensities outside glass panel and Eg is field intensity inside the panel, εo is vacuum permittivity or electrical constant, εo =8.854xe-12 F/m.

Equation 1 and 3 shows that if the panel has one side or both side charged with the same polarity and positioned closer to the ground floor Sf than to the control surface Sc, when d1<< d2, the field intensity E1 in the gap will rise to the maximum.

$$E1 = (\sigma1 + \sigma2)/\, \varepsilon o. \qquad (4)$$

A high intensity field will accelerate the attraction of contaminating particles and may be reason for spark discharges [3].

At the same time, the field intensity in the gap between the glass and the control surface will be small.

$$E2= \sigma 1 \ (d1/d2)/ \ \varepsilon o. \qquad (5)$$

Under these conditions, both charge neutralization efficacy and charge or field intensity measurement accuracy will be low.

Equation 2 shows that if charges on both sides of the panel have the same polarity and the panel is positioned in the middle between ground Sf and control surface Sc, the field intensity Eg inside panel will be close to zero.

However, if in the same position, both sides of the panel carry charges of the opposite polarity, the glass (including any surface films and layers of materials deposits) will be stressed twice as much compared with the field intensity of one charged side.

This situation may occur as a result of "efficient" charge neutralization. For example, a glass panel may be originally positively charged up to a density (+)$\sigma 1$ only on one side (S1) and later discharged by static neutralizer positioned at the surface (Sc). The result of this single-side static charge neutralization is the deposition of negative ions on the surface (S2) and a generation charge density of (-) $\sigma 2$, which has a magnitude approximately equal to $\sigma 1$. According to equation 2, the electrical field inside the glass is

$$Eg = 2 \ \sigma 1/ \ \varepsilon o \ \varepsilon g. \qquad (6)$$

If charges of the same polarity exist on one side or both sides of the glass and distance d1 is close to d2, the difference between E1 and E2 will be small because $(\sigma 1+ \sigma 2)d1 >> \sigma 1G$. So, it is difficult to determine which side of the glass panel carries the charge by measuring field intensity.

If the glass panel carries charges of opposite polarity on surfaces S1 and S2 (for example, as a result of "efficient" charge neutralization) and originally positioned in the middle of the gap between surfaces Sg and Sc, then both E1 and E2 are close to zero. However, if the glass panel after charge neutralization is placed in close proximity to the grounded surfaces Sg and magnitude of gap d1 is close to zero, and the field intensity on the top surface S2 of the glass will rise up to

$$E2 = \sigma 2G \ / \ \varepsilon g \ \varepsilon o \ d2. \qquad (7)$$

Efficient charge neutralization may be achieved if positive or negative charges positioned only on surface S2 and installation of charge neutralizer can satisfy conditions when distance d1 is greater than d2.

The basic result of the model analysis was experimentally verified using a test method of dissectible glass plates.

III. THE DISSECTIBLE GLASS PLATES METHOD

The goal was to develop a simple test method for the non-contact generation of surface charges, the measurement of electrostatic fields created by these charges, and to estimate the efficacy of static neutralization on glass plates.

The method includes the assembly of a stack comprising two flat panel substrates or glass panels, charging both sides of the stack with a flow of ions from a bipolar ionizer, and measuring generated charges and neutralizing both sides of the stack.

To measure the real effect of two-sided charge generation and the charge neutralization, the stack of glass panels may be dissected and field intensity or charge density on each panel measured individually.

A. Test Fixture

The test fixture is composed from two parts: charging and charge-field measuring units. A diagram of the charging unit is shown in Figure 2. The unit has a flat charging plate (2) installed on a group of isolative supports (6). The glass plate or glass stack under test (1) is installed on the top of flat charging plate (2). The glass stack (1) may be positioned at a relatively short distance of about 0.1- 1 mm from the surface of the charging plate (2) by placing isolative spacers (5) on the top surface of the plate. Another variant is to place isolative film spacers along the edges of the bottom side of the glass or glass stack (1). The glass stack is assembled from two similar glass plates. The top plate (1T) is marked by dark grey color and bottom plate (1B) by light gray color (see Figure 3).

The charging plate (2) is connected to a high voltage power supply (3) (model PS 350 from Stanford Research Systems). The output voltage of the power supply (3) can be adjusted in the range from (+) 50 - 5000V and from (-) 50 -5000V.

The bipolar ionizing neutralizer, (in this example, an MKS, Ion Systems QuadBar Model 4630 [4]) can be moved back and forth at a short distances (5-10 mm) along and across of surface of the glass plate (1). The ionizer (4) is connected to a low voltage AC power supply (5) (Model 7001) and grounded.

A diagram of the charge measurement and neutralization unit is shown in Figure 3. The glass stack composed of two plates (1T and 1B) is taken from the charging unit and installed on isolative supports (9) in the electrostatic field measuring unit. The distance between bottom surface of the glass plate (1B) and the electrostatic fieldmeter (7) (an MKS, Ion Systems Model 775 Fieldmeter) is about 5 mm. The fieldmeter is calibrated as an electrostatic voltmeter for that specific distance. The calibration plot is shown in Figure 4. The calibration ratio E = 0.55 * (Model 775 Fieldmeter reading) in [V/m].

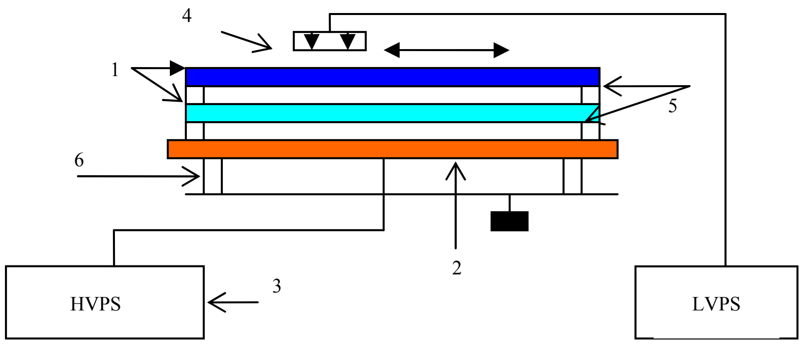

Fig. 2.

The fieldmeter is equipped with an enlarged grounded guard plate (8). A second, identical fieldmeter may be positioned at a variable distance from the top side of the glass plate (1T). Plate 10 can be positioned close to the top surface of the glass plate (1T).

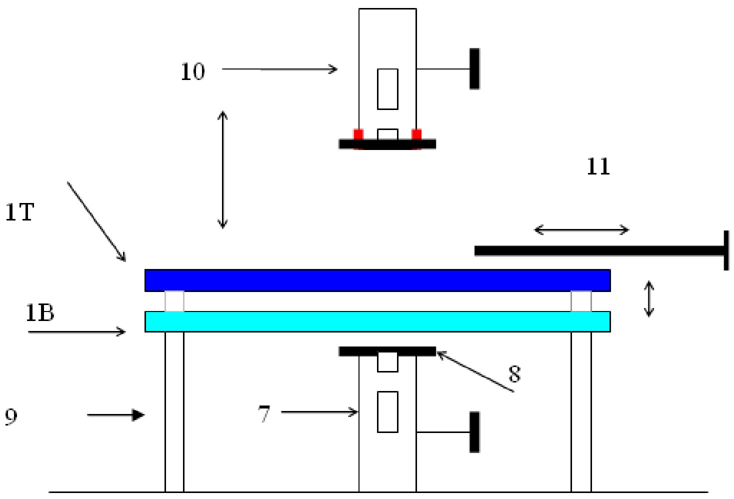

Fig. 3.

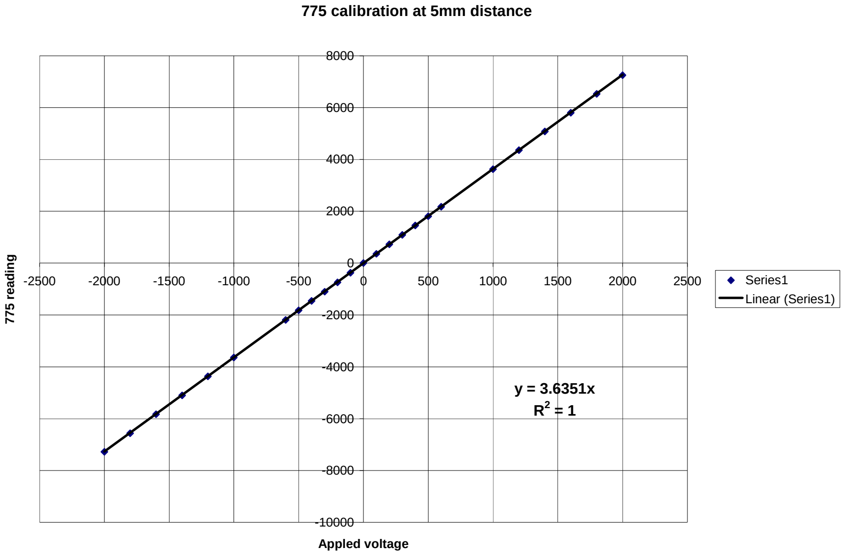

Fig. 4.

The test was performed with glass plates manufactured by Corning Inc. The plates were characterized by a standard chemical composition (common for glass plates used in flat panel displays) and have dimensions of 14 x 14 inches (35.5 x 35.5 cm) and a thickness of 0.028 inches (0.73 mm). The plates were carefully cleaned and dried before running the test.

B. The Test Method

To characterize the charge accumulation and neutralization processes in the glass plates we used a stack of two dissectible identical glass plates (4 and 9). These two plates mimic the two surfaces (S1 and S2) of a real single glass plate. Plate 1 were separated from plate 9 with a small gap about 0.05-0.1 mm defined by four non-conductive spacers made, for example, from Mylar film. By this way direct contact and frictional charging of the two plates can be avoided during their assembly and separation.

The test method includes following steps:

1. Discharge each glass plate before testing (using, for example, a small ionizing blower providing a balanced flow of ions). Assemble a stack of two glass plates (1T and 1B) with Mylar spacers between them. Non-contact charging of the stack of glass plates starts by placing the stack in the charging unit.

Connect the charging plate (2) to a high voltage power supply (3) and adjust the voltage up to (-) 500V. After that the ionizer (4) moves back and forth several times along and across the upper glass plate surface. Turn off the ionizing bar (4) first and then the high voltage power supply (3).

2. Place the stack in the charge measuring unit with both glass plates positioned the same way as they were in the charging unit (for example, plate 1T is on the top). Record the electrostatic field measured by the fieldmeter (7) from both sides of the stack, neutralize charges on both sides of the stack, and then disassemble the stack. Finally, measure charges on both plates 1T and 1B. Examples of typical test results are summarized in Figure 5.

In Figure 5, step 1 illustrates the charging process, where a charging plate (2) is connected to (-) 500 volts from the power supply (3). The ionizer (4) is moving near the top glass surface (S1) of the stack and depositing positive ions (charge) on the surface (negative ions are repelled from the glass surface by negative field generated by charging plate [2]).

Step 2 in Figure 5 shows the results of field intensity measurements from the bottom side (1B) of the stack by the fieldmeter (7). The magnitude of field intensity is in the high range of 5.0-5.5 kV/cm. This field intensity is about half of broken down field intensity in the air at normal atmospheric conditions. This result illustrates that glass substrates positioned on the ground plate can be charged by unbalanced ionizer.

Step 3 in Figure 5 shows the results of field intensity measurements when the glass stack was flipped over. Now the positively charged surface of the stack is closer to the fieldmeter and as a result the field intensity is higher.

Step 4 in Figure 5 illustrates the charge neutralization process of the stack with the ionizer (4) moving along and across the surface (1B).

The effect of the charge neutralization is shown in step 5 in Figure 5, where negative ions (compensating fields created by positive charges on glass [1T]) are deposited on the surface of the glass (1B). As a result the field density near the surface (1T) drops more then hundred times.

Step 6 in Figure 5 shows the effect of positioning a grounded plate (10) in close proximity to the neutralized surface (1B) of the stack. The ground plate diminishes the influence of negative charges deposited on the surface (1B) of the stack. As a result, field intensity created by positive charge rise about five times. (This effect would be significantly more dramatic if the fieldmeter was positioned closer to the glass surface [1T]).

Step 7 in Figure 5 shows the results of field intensity measurements when the stack is flipped over. Now a negatively charged glass surface (1B) is closer to the fieldmeter. In this situation the effect of charge neutralization looks very efficient. The field intensity drops almost to zero.

Step 8 in Figure 5 shows the effect of placing the grounded plate closely to the top glass (1T) of the stack. In this case the grounded plate diminishes the influence of positive charges and the significant field created by negative charge became measurable (field intensity rises about 50 times).

Steps 9 and 10 in Figure 5 show the results of field intensity measurements for a disassembled glass stack when the real surface charges accumulated on each side of the glass plates (1T and 1B) can be measured. Plate 1B, which originally had no surface charges (see step 1), now carries a huge negative charge creating a field up to E = 5.4 kV/cm. The second plate (1T) actually keeps the original positive charge intact by creating field intensity of about 5.0 kV/cm (see results in step 1T).

These results illustrate the possible problem of neutralizing charge on the “wrong” side of the glass. The dissectible glass plate test method allows us to distinguish the real effect of charge neutralization from pseudo charge neutralization in dielectric substrates. The test results show the range of positive and negative charges that can be generated without contact on both side of the glass plate. It also shows the effects of positioning grounded surfaces close to the charged plate.

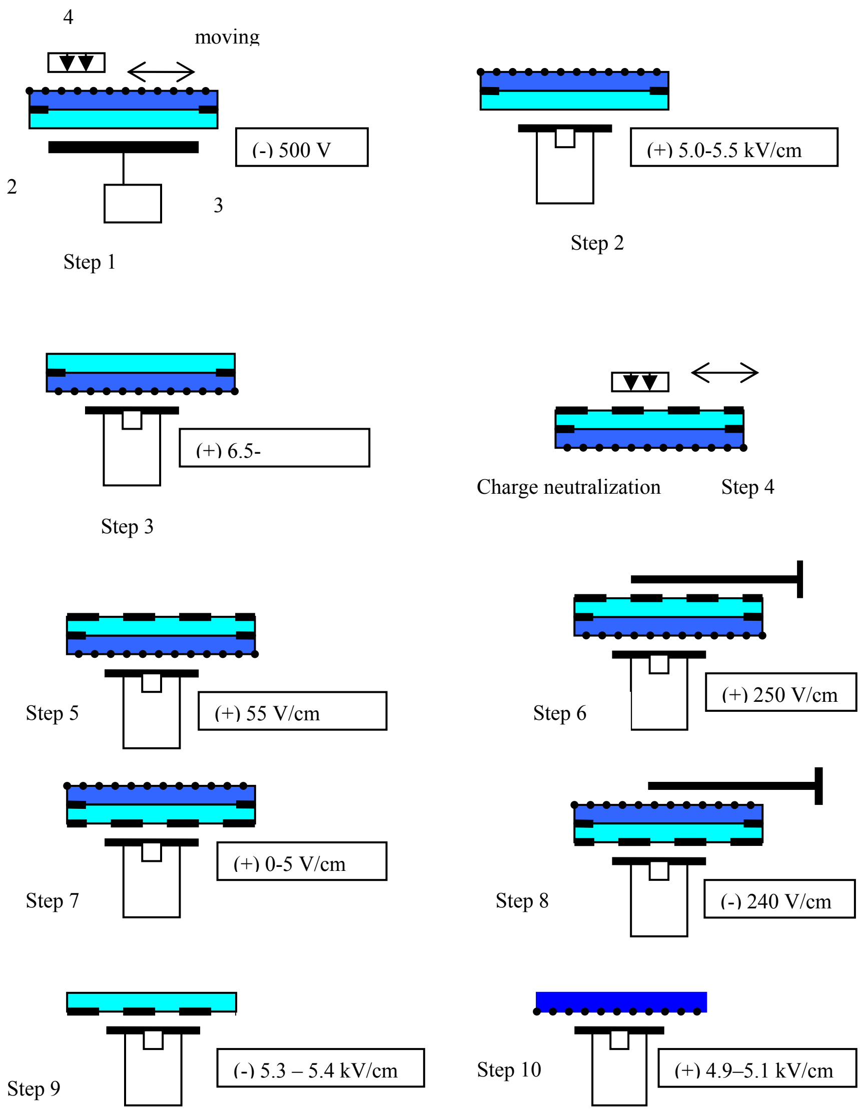
4
moving
(-) 500 V
2
3
Step 1
(+) 5.0-5.5 kV/cm
Step 2
(+) 6.5-
Step 3
Charge neutralization
Step 4
Step 5
(+) 55 V/cm
Step 6
(+) 250 V/cm
Step 7
(+) 0-5 V/cm
Step 8
(-) 240 V/cm
Step 9
(-) 5.3 – 5.4 kV/cm
Step 10
(+) 4.9–5.1 kV/cm

Fig. 5.

IV. Conclusion

1. A model of double-sided charging on glass substrates makes it possible to predict electrostatic fields inside and outside of plates.

2. Surface charges may create high field intensities and electrical stress inside the glass and deposited on glass surface layers.

3. Efficient charge neutralization of glass substrate requires a proper understanding of the distribution of surface charges on both sides of the plate.

4. The dissectible glass plates test method can be used for developing measurement procedures of charge distribution.

5. The method demonstrates the effects of real and pseudo charge neutralization.

6. The method demonstrates the effects of positioning grounded surfaces close to the charged plate.

References

[1] G. M. Sessler, "Electrets v 1," Laplacian Press, Morgan Hill, California. pp. 13–17.
[2] J.M. Crowley, "Fundaments of Applied Electrostatics," Laplacian Press, Morgan Hill, California. pp. 40-43.
[3] L. B. Levit, P. Gefter, "Ionization applications and pitfalls for charge neutralization in substrate handling," *EOS/ESD Symposium Proceedings,* 2006, pp.4B.4-1-4B.4-7.