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Partial Measurement of Planar Surface Ion Balance Analysis

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ABSTRACT

This paper reports the experimental results of the partial surfaces ion balance analysis on ionised planar surface to identify the fine-grained level of ioniser balance measurement. The standard 6″×6″ charged plate was exposed to ionised air supplied through the DC corona ioniser to measure the ion balance. A one square inch charged plate had been used to measure the ion balance in the 36-segment partial measurement points which were ordinary arranged on that planar surface. The 36-segment partial results were analysed to image the ion balance distribution on that planar surface. The experiment revealed that fined-grained levels could be identified behind the coarsely results which had been measured by the standard charged plate. The surface plot could image the ion balance distribution on that planar surface which was ionised by the ioniser thoroughly. This ion balance imaging could be used to enhance ioniser performance analysis related to ion balance and distribution along the ionised surface.

Keywords: Ion balance, ioniser measurement, partial surface, ion balance distribution

INTRODUCTION

The electrostatic discharge (ESD) had been a problem in electronics industry because the ESD events could damage devices, harm the systems or induce particulate contamination on the charged surfaces due to electrostatic forces (ESD Association, 2014). In general, ground connecting is a simple method for making an equipotential surface to drain out the electrostatic charges to the system ground. However, this method is less effective for removing electrostatic charges from the insulator surface or conductive particles (Glor, 1985; Robinson, Brearey & Szafraniec, 2009) due to the availability of conduction and conductivity in them. To prevent these electrostatic issues, air ionization is widely used to remove the electrostatic charges from

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the insulator surfaces or the tiny conductive objects unable to connect the ground cable. The air ioniser provides the opposite polarity ions to neutralize the electrostatic charges on the object. It is necessary to measure the balance of these supplied ions because the ionisers could generate electrostatic charges while the sourced ions are unbalanced.

The ANSI/ESD STM3.1-2015 (ESD Association, 2015) is a standard test method (STM) for characterising the ioniser performance. It describes the ion balance as the electrostatic potential value caused by the ion collecting on a floated 6″×6″ conductive plate with 20pF capacitances. This configuration was agreed with a typical silicon wafer at the time of drafting the standard in the late of 1980s (Rodrigo, Bellmore, Diep, Jarrett, Jonassen, Newberg, & Turangan, 2004). However, many manufacturers of electronics working on the small scale require the ion balance within +/-1V or tighter to ensure the safety of electrostatic sensitive (ESDS) devices (Kraz, 2004). They might concern to the precision of ion balance measurement because the actual devices are much smaller than the standard charged plate. The smaller plate reports a less ion balance voltage than a larger plate (Rodrigo et al., 2004). The small charged plate analysers were launched to serve the sub-1V ion balance measurement such as the ioniser controllers on US patents 6,985,346 B2 (Kraz, Cruz, & Martin, 2006), US 7,522,402 B2 (Kraz, Cruz, & Martin, 2009) and the biased-plate monitor (Crowley, Ignatenko, & Levit, 2004). These analysers provide alternative methods to identify the ion balance with the miniaturized plates to collect the ions from ioniser and correlate the result to the standard charged plate monitor result described on STM.

Ions distribution as reported in the electrohydrodynamics theory depends on the drift velocities and the airflow velocities of particular ioniser models (Ohsawa, 2013). The electrostatic potential on each foot-step might not uniform due to fluid dynamic functions. The modelling (Plong-ngooluam, Jindapetch, Wounchoum, & Sompongse, 2015) has mentioned that ion balance measurement precision could be enhanced by the surface dividing. This simulated result still needs the field measurement in the ionised environment to validate its feasibility.

In this work, the ion balance on the 6″×6″ planar surface was partially analysed by the miniaturized charged plate, arranged in the same area as the standard charged plate measurement. The partial results were imaged by the surface plot to express the ion balance distribution along the 6″×6″ planar surface which was neutralized by the ionised air from the DC corona ioniser.

ION BALANCE MEASUREMENT

The ioniser is an equipment that provides either positive or negative air ions to neutralize the electrostatic charges on the surface or a tiny object. The typical corona ioniser generates the ions through the collision between the neutral molecules and electrons which are accelerated by an electric field which exceeds the inception level (Ohsawa, 2005). The emitted air ions could attract an object surface and neutralize it. Ion balance can be described by the electrostatic potential (V) of the positive ion (n_p) and negative ion densities (n_n) as

$$\nabla^2 V = \frac{-e(n_p - n_n)}{\varepsilon_0}, \tag{1}$$

where e is an elementary charge and ε_0 is the permittivity of free space.

The motions of positive ion (n_p) and negative ion (n_n) in (1) depend on the air velocity as

$$\frac{\partial n_p}{\partial t} + \nabla \cdot (n_p \mathbf{u}_p) - D_p \nabla^2 n_p = -\beta n_p n_n \qquad Positive, \tag{2}$$

$$\frac{\partial n_n}{\partial t} + \nabla \cdot (n_n \mathbf{u}_n) - D_n \nabla^2 n_n = -\beta n_p n_n \qquad Negative, \tag{3}$$

where $\mathbf{u}_p$ and $\mathbf{u}_n$ are air velocities of positive and negative ion mobilities, D_p and D_n are positive and negative ion diffusion coefficients, and β is the ion-ion recombination coefficient.

Since the ion balance is defined by the electrostatic potential value caused by an accumulation of positive and negative ions, it could be expressed by the ratio of the total amount of charge (Q) which is accumulated on that plate and ion receiving plate capacitance (C) as

$$V = \frac{Q}{C}. \tag{4}$$

Assume that charge distribution on the ion receiving surface and electrostatic field are uniform, the total amount charge (Q) can be defined as

$$Q = \rho_S A, \tag{5}$$

where the ρ_S is the density of charge on the ion receiving surface (A). This charge density is the summed result of ion balancing term of (1) which can be defined as

$$\rho_S = e(n_p - n_n). \tag{6}$$

By the substitution (5) on (4), the electrostatic potential (V) proportionally depends on the ion receiving surface and the charge density as

$$V = \frac{\rho_S A}{C}. \tag{7}$$

Based on this assumption, it could be concluded that the ion balance which is measured by the smaller surface will be lower than that of a larger surface when the ion distribution is uniform and the plate capacitance is fixed conditions. However, the surface charge density on (6) depends on the ion motion (2) and (3) which are concerning to the air velocity. The 6″×6″ planar surface with the fixed 20pF capacitance which is constituted by the STM might not represent the suitable grain result which depends on the ion motions.

EXPERIMENTAL SETUP AND ANALYTICAL METHOD

This section describes the apparatus, the ioniser configuration, the 6″×6″ charged plate, the arrangement of the 1″×1″ charged plate, and the partial measurement evaluation.

Apparatus

The charged plate analyser Trek model 157 with the standard 20pF 6″×6″ planar surface plate was used to measure the ion balance as the standard ioniser measurement. A partial measurement was performed using the 1″×1″ miniaturized plate. With this plate, the total capacitance still fixed at 20pF as same as the standard plate capacitance. The 36-segment partial measurement points were ordinary arranged over the standard 6″×6″ planar surface plate as shown in Figure1. The DC corona ioniser MKS model 5802i was installed over the non-obstructive workstation with a grounded surface. The ioniser was located at the centre of the workstation with 60 cm in height from the grounded surface. The charged plates were placed at 45 cm under the ioniser facing with the 15 cm from the grounded surface as describes on the STM.

Partial Measurement Evaluation

Evaluation began by adjusting the ioniser balance to -1.0 Volt which was measured by the standard 6″×6″ plate following which ioniser the standard 6″×6″ plate was moved out then placed the 1″×1″ charged plate and measured the ion balance at the arranged points as shown in Figure1. The measurement was performed from the first segment through the 36th segment sequentially. Then repeat the evaluation with the 0.0 Volt and +1.0 Volt ion balance adjustment.

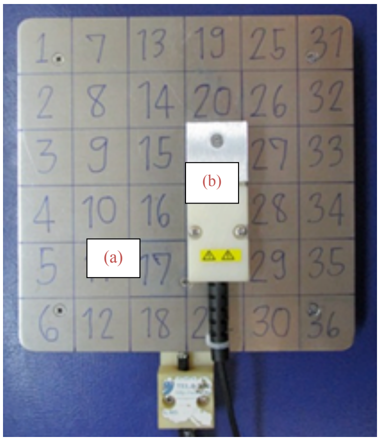

Figure 1. The partial measurement point on the planar surface arranging;
(a) The standard 6″×6″ charged plate, (b) The 1″×1″ square plate

Analytical Method

The Minitab, a statistical software, provides the wireframe plot to image the relationship between three variables in the x, y and z coordination. In this work, the 36-segment partial measurement results were assigned as response values z which were arranged in the x-y plane according to the plate arrangement in Figure 1. The Minitab also provides the distance method (Ryan, Joiner, & Cryer, 2010) to interpolate the unknown data points between measured data points.

All data points which are interpolated by this method always within the range of measured data points. It works well in a wide range of circumstances. The number of x and y meshes could be determining the resolution of the regular grid. In this experiment, the distance method was using to interpolate the ion balance distribution over the 6″×6″ planar surface with the regular 50×50 mesh from the 6×6 measured data points as the arrangement in Figure 1. This interpolation is proposed to enhance the fine-grained levels of ion balance results beyond the actual results measured by the 36-segment partial surface.

RESULTS AND DISCUSSIONS

The partial measurement had reported the results in the six rows and six columns. The rows are intersections in the y axis and intersections in the x axis. The ion balance distributions have been analysed and imaged with the wireframe plot with the 50×50 meshes data interpolation using distance method. The partial measurement results of ion balance from the -1.0 Volt ioniser adjustment are summarized in Table 1. The measurement values varied from -1.0 to -0.4 Volt. These results could be used to image the ion balance distribution as shown in Figure 2. The image is expressing the fine-grained levels over the 6″×6″ planar surface and vary around -0.5 Volt from the settled point which was adjusted and measured by the standard 6″×6″ charged plate.

Table 1
The partial measurement results of ion balance from the ioniser with -1.0 Volt adjustment (unit in Volt)

	C1	C2	C3	C4	C5	C6
R1	-0.8	-0.7	-0.4	-0.8	-0.7	-0.7
R2	-0.8	-0.7	-0.6	-0.8	-0.9	-0.8
R3	-0.9	-0.8	-0.5	-0.8	-0.9	-0.6
R4	-0.6	-0.8	-0.7	-0.8	-0.8	-0.8
R5	-0.7	-0.7	-0.7	-0.8	-0.7	-1.0
R6	-0.7	-0.7	-0.7	-0.7	-0.8	-0.9

The partial measurement results of ion balance from the 0.0 Volt ioniser adjustment are summarized in Table 2. The measurement values were varying from -0.3 to 0.3 Volt. This result proves that the tested ioniser is capable with the sub 1V ion balance control workstation requirement because all data points are within the range of +/-1 Volt. The ion balance distribution image of the 0.0 Volt ioniser adjustment expresses the fine-grained levels which vary around +/-0.3 Volt from the settled point is shown in Figure 3. However, the minimum and the maximum points are not locating in the same positions as the ion balance image in Figure 2. The suspicion might be the variation of the turbulence of the air that was driven by the fan unit which was install in the ioniser. This turbulence could affect to the ions mobility mechanisms in the ions transport region, regarding to the electrohydrodynamics theory which is the interactive mechanism between the electric fields and the surrounding fluid.

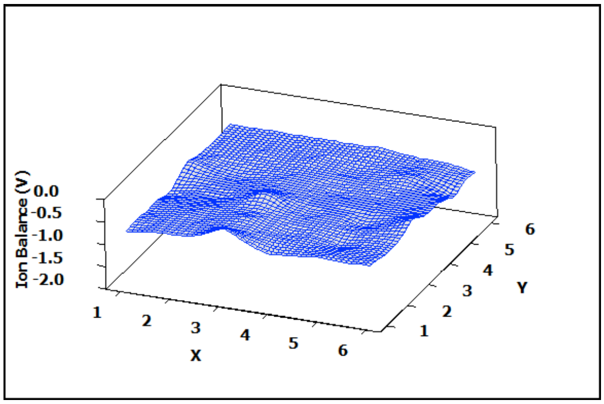

Figure 2. The ion balance distribution image with -1.0 Volt ioniser adjustment

Table 2
The partial measurement results of ion balance from the ioniser with 0.0 Volt adjustment (unit in Volt)

	C1	C2	C3	C4	C5	C6
R1	0.0	0.1	0.3	0.0	-0.1	-0.2
R2	0.0	0.0	0.1	0.3	-0.1	-0.1
R3	0.0	0.0	0.0	0.0	0.2	-0.2
R4	0.1	0.0	0.1	0.0	0.0	0.0
R5	0.0	0.1	-0.3	0.0	-0.1	0.2
R6	0.0	0.3	-0.3	0.0	0.0	0.2

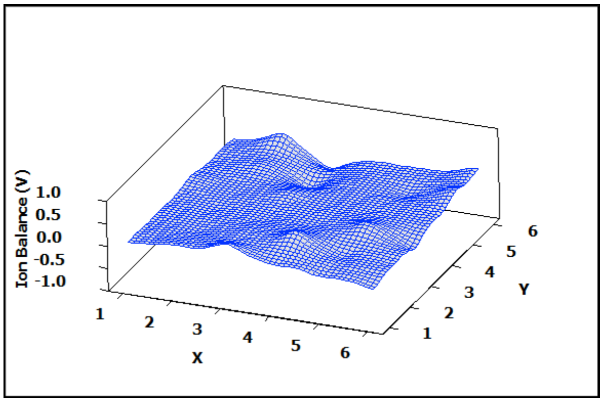

Figure 3. The ion balance distribution image with 0.0 Volt ioniser adjustment

The partial measurement results of ion balance from the 1.0 Volt ioniser adjustment are summarized in Table 3. The measurement values varied from 0.5 to 1.7 Volt. The ion balance distribution image is illustrated by the wireframe plot as shown in Figure 4. The fine-grained levels of ion balance are expressing over the 6″×6″ planar surface as same as the ion balance distribution images from the -1.0 Volt and the 0.0 Volt adjustments. Based on these results, the ion balance was distributed over the 6″×6″ planar surface with +/-0.5 Volt variation. It validated the ioniser capability which needs for the workstation which requires to control the ion balance within +/-1Volt because these fine-grained levels could be identified by the partial measurement technique. The ion balance results on the regular 50×50 mesh of the wireframe plots consist of measurement data points and interpolated data points. These data points were plotted at the at the x-y intersections of the mesh.

Table 3
The partial measurement results of ion balance from the ioniser with 1.0 Volt adjustment (unit in Volt)

	C1	C2	C3	C4	C5	C6
R1	0.8	1.6	0.7	0.7	0.7	1.0
R2	0.8	1.6	0.7	0.9	0.5	1.1
R3	0.8	0.7	0.7	0.5	0.5	0.8
R4	0.8	0.8	0.1	0.8	0.7	0.7
R5	0.5	1.0	0.7	0.7	0.6	0.7
R6	0.7	0.8	0.7	0.6	1.1	0.7

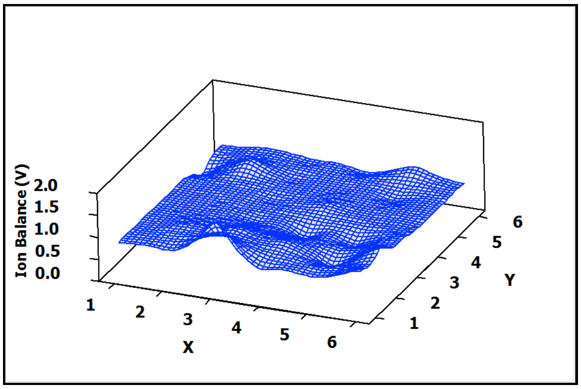

Figure 4. The ion balance distribution image with 1.0 Volt ioniser adjustment

CONCLUSION

Experimental results validated that partial surface measurement could identify the fine-grained levels of ion balance measurement result which could not be identified by the standard charged plate measurement. The results show the variation of the voltage levels on different areas of the planar surface, indicating different areas have different voltages. The ion balance results measured by the large planar surfaces are losing such fine-grained voltage levels on different areas of the planar surface because the given result is the summation of all ions which are collected from the whole surface.

The above partial measurement results also identified the ionised air uniformity over the 6″×6″ planar surface which is subjected to be neutralized. The partial measurement results also provides methods for suitable plate improvement of the ion balance measurement of electrostatic protective areas.

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REFERENCES

Crowley, J. M., Ignatenko, A., & Levit, L. B. (2004). Biased-plate characterization of pulsed DC ionisers. *Journal of Electrostatics, 62*, 219-230.

ESD Association (2014). *Electrostatic discharge (ESD) technology roadmap-revised*, 7900 Turin Road, Bldg. 3, Rome, NY.

ESD Association (2015). ANSI ESD STM 3.1-2015, The *Protection of Electrostatic Discharge Susceptible Items-Ionization*. 7900 Turin Road, Bldg. 3, Rome, NY.

Glor, M. (1985). Hazards due to electrostatic charging of powders. *Journal of Electrostatics, 16*(2-3), 175-191.

Kraz, V. (2004, September). Notes on maintaining sub-1V balance of an ioniser. In *Electrical Overstress/Electrostatic Discharge Symposium Proceedings* (p. 194). ESD Association.

Kraz, V., Cruz, S., & Martin, K. A. (2006). *US Patent No. US 6,985,346 B2*. Washington, DC: U.S.

Kraz, V., Cruz, S., & Martin, K. A. (2009). *US Patent No. US 7,522,402 B2*. Washington, DC: U.S. Patent and Trademark Office.

Ohsawa, A. (2005). Modeling of charge neutralization by ioniser. *Journal of Electrostatics, 63*(6), 767773.

Ohsawa, A. (2013). 2-D electrohydrodynamic simulations towards zero offset voltage with corona ionisers. *Journal of Electrostatics, 71*, 116-124.Patent and Trademark Office.

Plong-Ngooluam, S., Jindapetch, N., Wounchoum, P., & Sompongse, D. (2015). 3-D Computational Simulations of Electrostatic Potential in Partial Surfaces towards the Precision of Ion Balance Analysis. In *Applied Mechanics and Materials* (Vol. 781, pp. 308-311). Trans Tech Publications.

Robinson, K., Brearey, R., & Szafraniec, J. (2009). Sheet sticking caused by charge flow in a buried conducting layer. *Journal of Electrostatics, 67*(5), 781-788.

Rodrigo, R., Bellmore, D., Diep, J., Jarrett, T., Jonassen, N., Newberg, C., & Turangan, J. (2004, September). CPM study: discharge time and offset voltage, their relationship to plate geometry. In *Electrical Overstress/Electrostatic Discharge Symposium Proceedings* (p. 200). ESD Association.

Ryan, B. F., Joiner, B. L., & Cryer, J. D. (2010). *MINITAB Handbook: Update for Release 16, 6th Edition*. Brooks/Cole Publishing Co., Pacific Grove, CA, USA.