2019 EOS/ESD Manufacturing Symposium

ESD Risk Analysis using Pulsed AC Ionization Technology

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Outline

- **ESD and Contamination issues in FPD industry**
  - Static Issues and Possible Solutions
  - Early Ionization Issues and in FPD
  - Pulsed AC Ionization Technology for FPD Industry
- **Ionizer Measurement**
  - Lack of Definition for Ionizer Standard Test Method STM3.1
  - CPM Measurement Results
- **ESD Risk from Ionizers**
  - Discharge Current and Radiated EMI Signal Measurement Result with Test Electrodes under Pulsed AC Ionizers
  - EMI Signal Measurement with TFT LCD Module

ESD and Contamination Issues in FPD Industry

- Very likely wafer process, contamination is major issue in FPD industry from the beginning
- ESD is relatively new and became an issue when advanced panel technology adopted (e.g., higher dense of pixels, COG, LTPS, oxide TFT or thin gate insulator etc.)
- Both contamination and ESD damages are major failures of current panel manufacturing environment

Static Issues and Possible Solutions

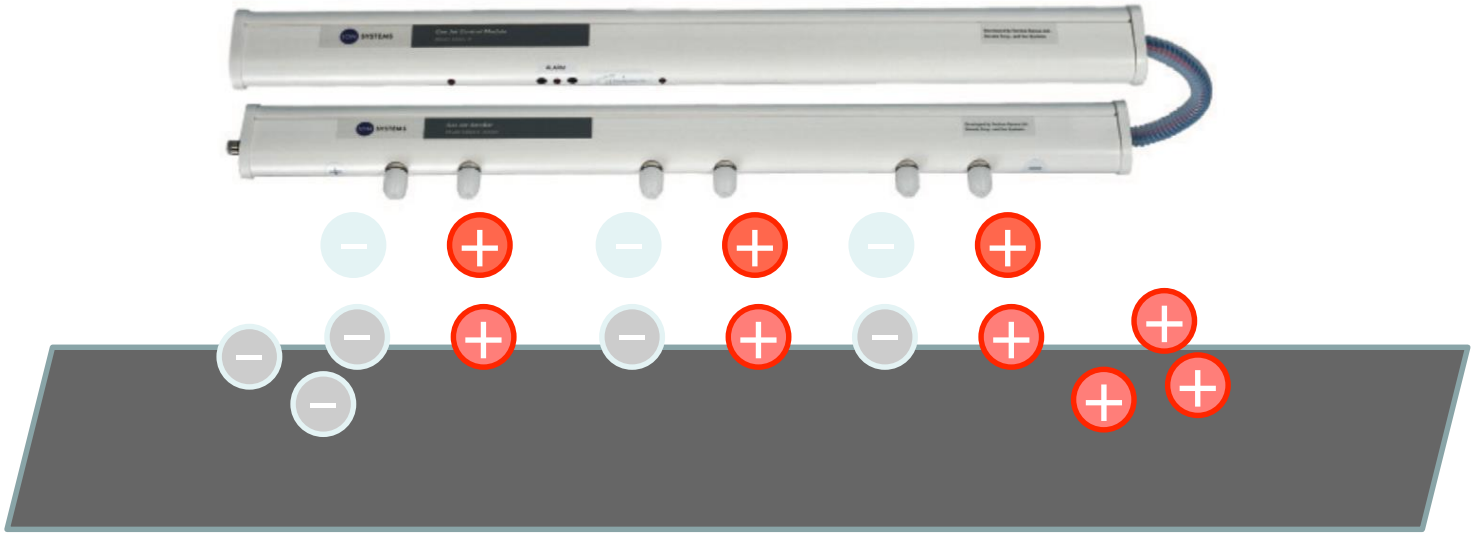
- Unlikely wafers, glass panel substrate are not able to use grounding procedure due to their resistance is high and not able to drain charge to ground

- Thus, electric field suppression method and use ionizations are possible solution to avoid contamination problem in the early days

- Recently, ESD event occurs when glass has sitting or placement on the conductive or even dissipative surface.

Early Ionization Issues can cause of ESD Damage on ESDS items

- More than a decade ago, Steady-State DC air assist bar ionizers used to solve ESD and contamination issues in cleanroom environment
- But, this type of ionizer makes another problem when they are applied in short distances applications around 300mm
- FPD panel get polarized and ESD event occurs after ionization



Pulsed AC Ionizer and Testing Gap

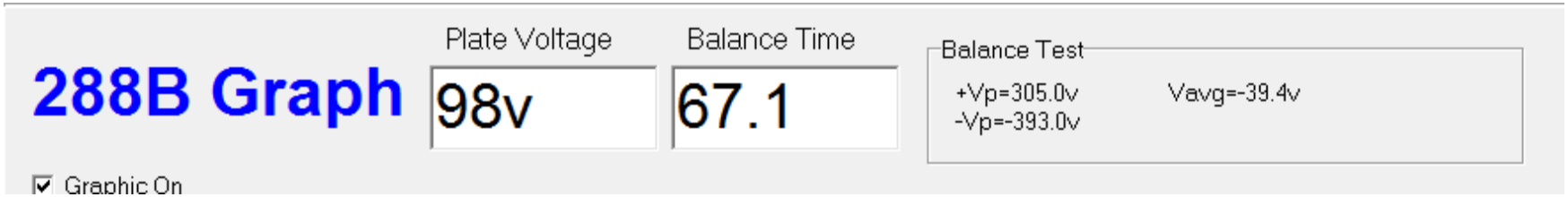
- Pulsed AC ionizer technology invented and constructed bipolar power supplies have joint output on each emitter points have uniform ionization on subject or CPM testing
- Pulsed AC Ionizer can change some output parameters to meet requirements less than ± 50V or ± 35V balance
- Pulsed AC ionizer have multiple nozzles has emitting ions and switching 3kV to 7kV at 10Hz to 70Hz around in use

ANSI/ESD STM3.1 and other related documents are created long before and limited measure this new type of ionizers accurately

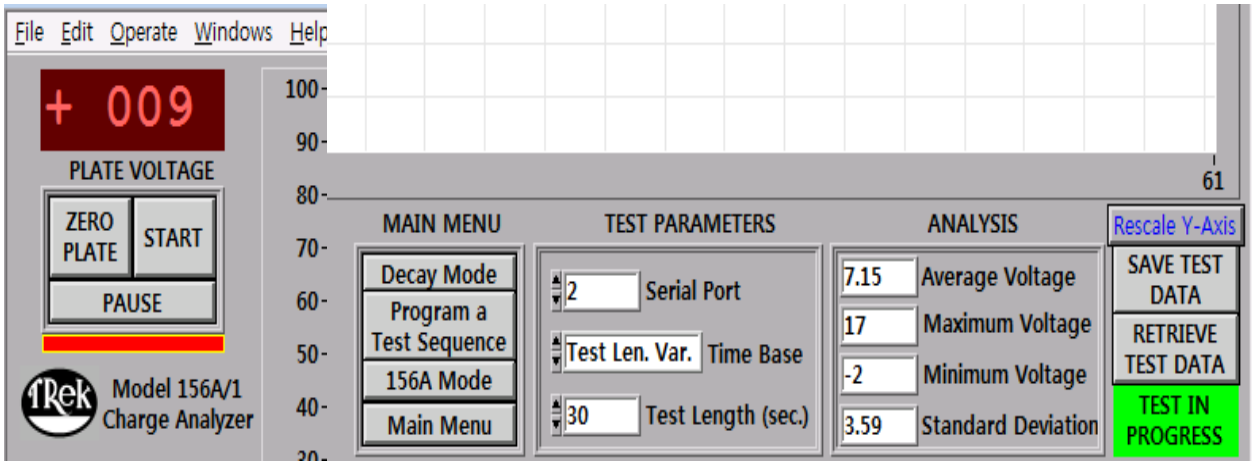
Ionization Test Method Issues

- There are some terms not clear enough in the definition in STM3.1 and other ionization related document from ESDA
  - Two type of testing methods are used for ionizer performance testing: Discharge Time and Balance Test
  - There is no clear definition or justification what balance measurement means: High/Low peak or Average
  - During Balance measurement, which number we should pick during measurement time duration
- In these days, most of CPM manufacturers provided average balance (or offset voltage) value on their hardware display and software
- ANSI/ESD S20.20 and IEC 61340-5-1 have limits that balance should be less than ±35 volts offset voltage
- This balance (or offset) terminology and average value could lead misinterpreting data from some type of ionizers such as AC, Pulsed AC and High Frequency AC Ionizers

Examples of CPM Measurement



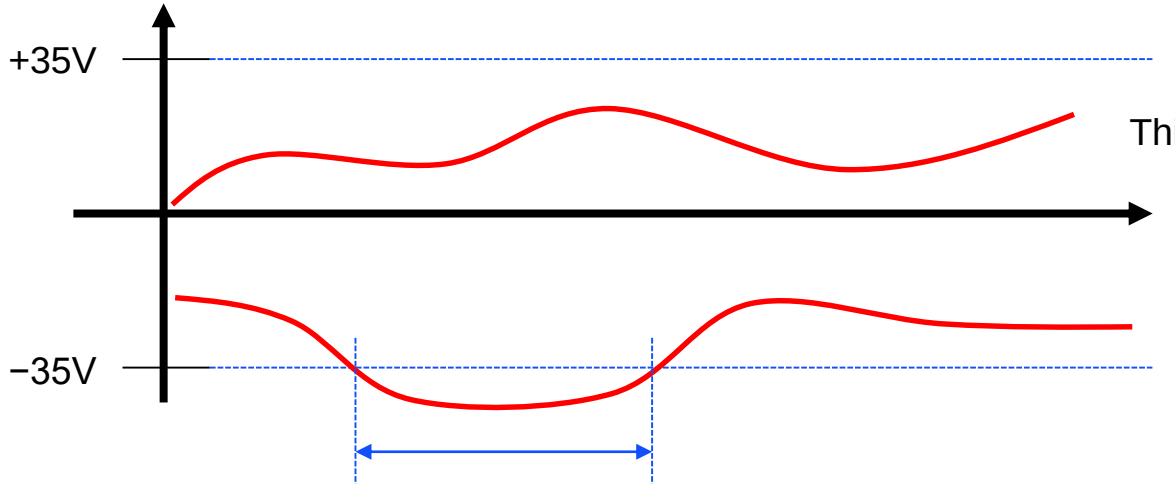
- Vavg -39.4V isn't matching average of +peak and -peak



- Average Voltage 7.15V isn't matching average of +peak and -peak

What Offset Voltage means?

- What does Offset Voltage means in Table 3?
- Or does this mean this as biased, shifted or average…?
- What if the value over once during measurement time?
- What does this offset value means on AC signal?



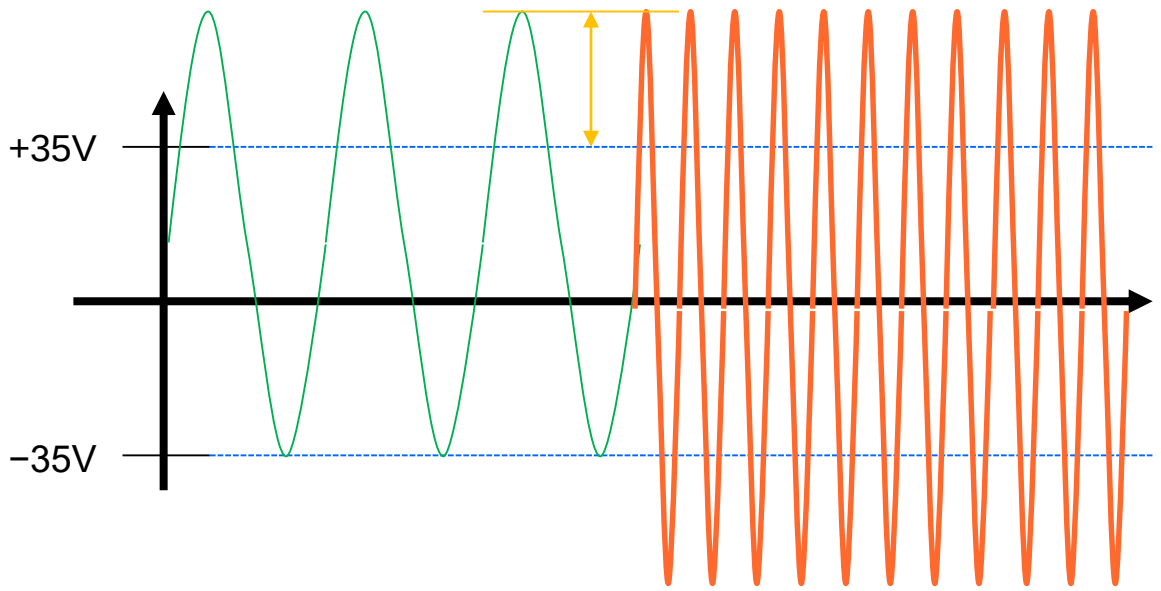
This result will be OK

This case we think peak value should not exceed 35V

- Is it OK if this time window less than 5 sec?
- What about over 1 minutes?

What Offset Voltage means?

- What does Offset Voltage means in Table 3?
- What does this offset value means on AC signal?
- Is Green line offset voltage what we want to control?
- Do we care about Orange area?
- Red line offset voltage will be very small – Is this OK?
- We should take peak value for balance to S20.20, TR53



Yellow Line
Average ≒ 0V..?

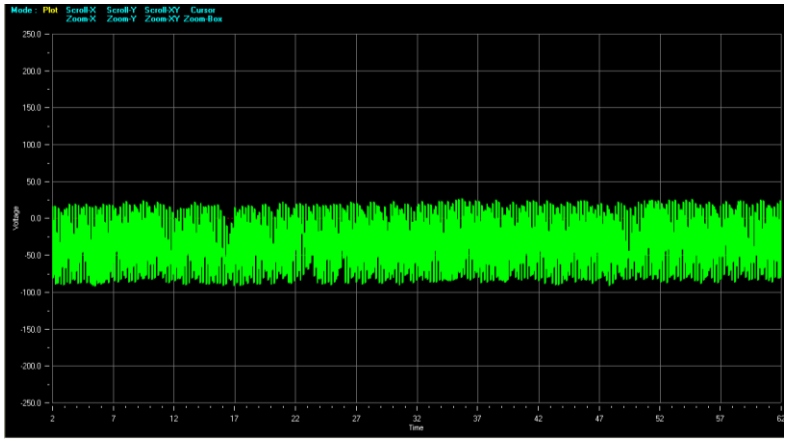
CPM Measurement Limits

- Most of CPM operating speed is quite slow around 10Hz for full scale of 2000Vp-p.
- Fast operation speed of CPM is 1kHz for small signal which is **20Vp-p only**.
- There are new type of ionizers within industry and their switching voltages are 30Hz to 70kHz

Model #	Speed of Response	Accuracy	Manufacturer
Model 300	6Hz	2%	Monroe
Model 288	1kHz 20Vp-p 10Hz 2000Vp-p	0.1% (-3dB)	Monroe
Model 156A/1	1kHz 20Vp-p 10Hz 2000Vp-p	0.1% (-3dB)	Trek
Model 157	80Hz	1% (-3dB)	Trek

Ionization Test Method Issues

- Conventional AC and Pulsed AC ionizers could give AC voltage switching field to ESDS items such as SAW filters, FPD panel or 3D IC Wafers and this could lead to ESD damage on them
- Using with various response speed of CPM, balance measurement results was so different
- Using with 6Hz response speed of CPM, -87V and +24V peak and 31V in average value measured when ionizer operating 12Hz. But, it also shows a lot of switching voltage monitored in thick colors as noise

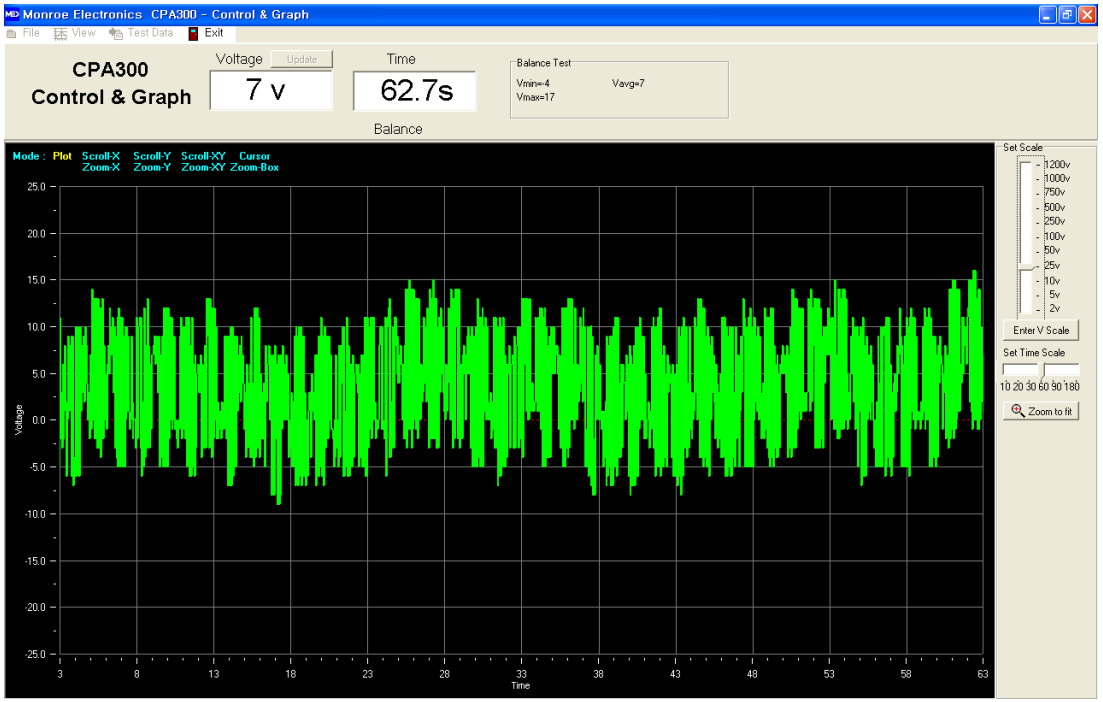


CPM Speed of Response: 6Hz

Ionizer Output: 5.5kV Pos. / 4.8kV Neg. with 12Hz

CPM Measurement Examples

- Ionizer's switching frequency changed from 12Hz to 30Hz, balance (or offset) value got much smaller such as average 7V, minimum at − 4V and maximum +17V only.
- CPM Speed of Response is still same at 6Hz and actual ionizer Output was 5.5kV positive and 4.8kV negative
- Is this real value or ionizer voltage drops without performance change?

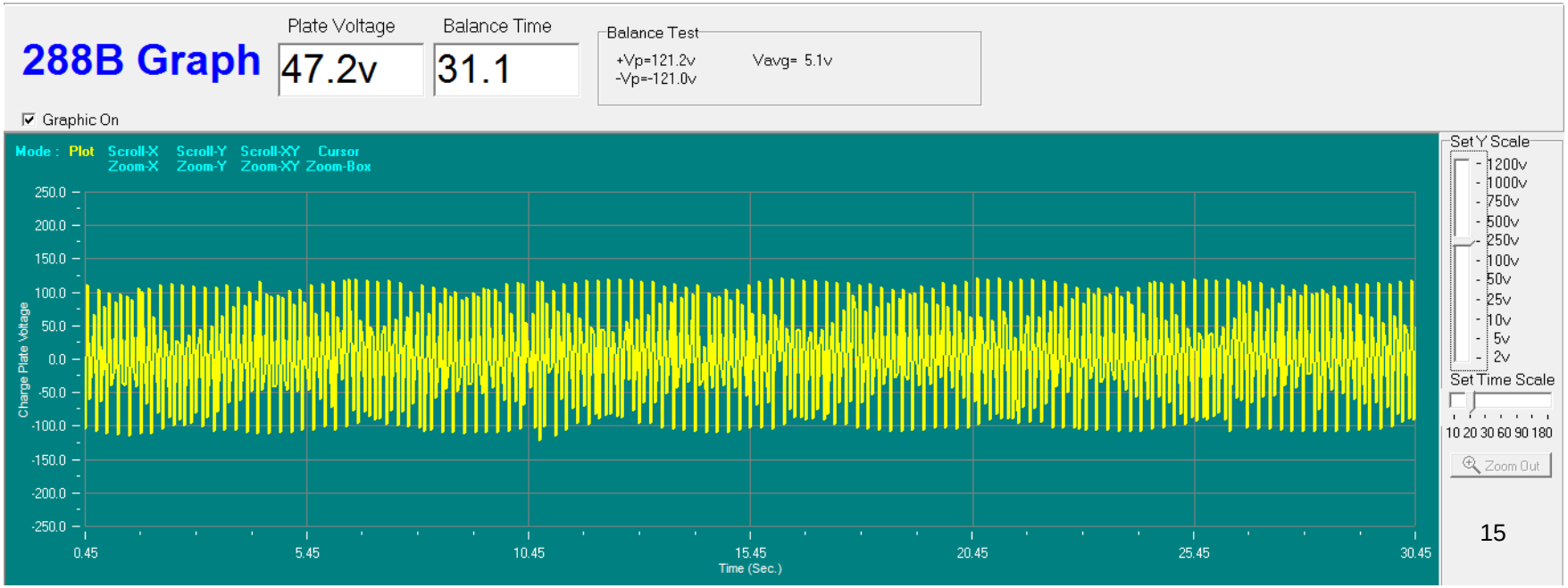


CPM Measurement Examples

- Changed CPM speed up to 10Hz Full scale and 1kHz 20Vp-p
- Ionizer Output: 5.5kV Pos. and 4.8kV Neg. with 12Hz as first test
- The peak-to-peak value greater than 6Hz CPM measurement
- Min (V) = -393V, Max (V) = +305V, Ave (V) = -39.4V
- Then, which number we should pick for balance in this result?
- There are thick yellow color area in the middle of this test which is similar represent with 6Hz CPM test result

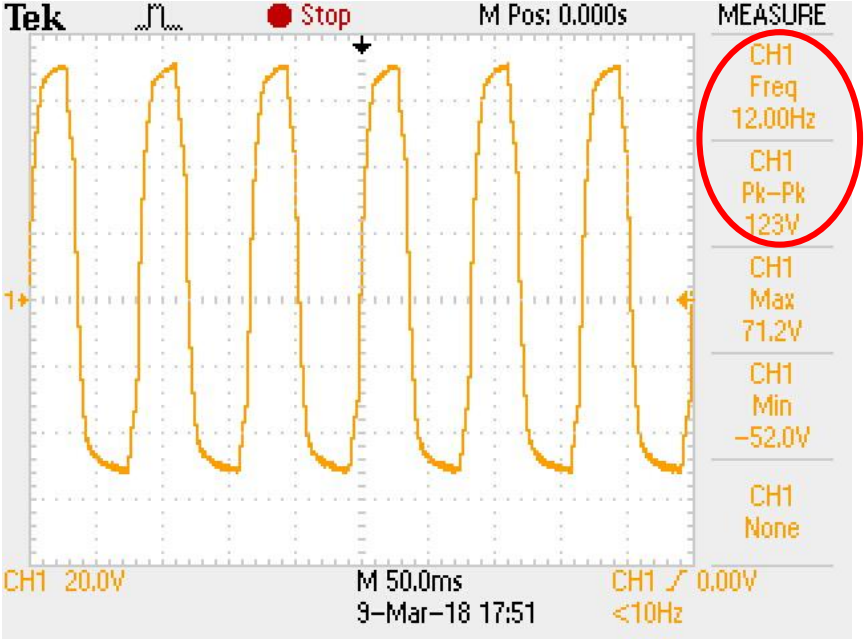
CPM Measurement Examples

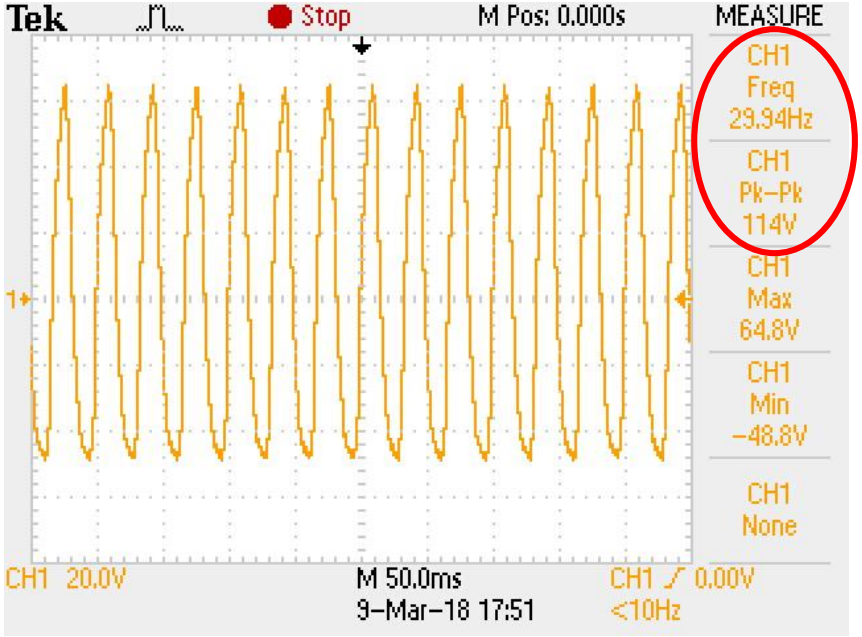
- Then, changed output frequency of ionizer at 30Hz as same as second test. It shows peak voltage drops with all same output parameters.
- CPM Speed of Response: 10Hz Full / 1kHz 20Vp-p
- Ionizer Output: 5.5kV Pos. and 4.8kV Neg. with 30Hz
- The peak-to-peak value significantly reduced measured than 12Hz
- Min (V) = -121V, Max (V) = +121V, Ave (V) = 5.1V
- Then, which test result are the accurate one?



High Voltage Measurement

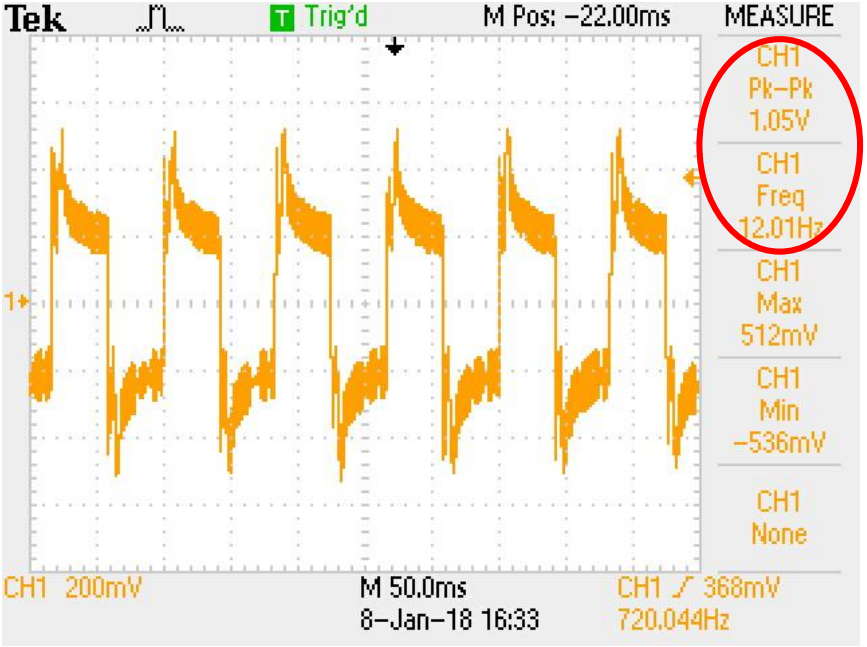
- It is important to measure real high voltage on emitter points and their changes are just frequencies as we change output of ionizers
- Output high voltage slightly drops from 12.3kV to 11.4kV (7%) when switching frequency changes from 12Hz to 30Hz. Tektronix TDS2022C Oscilloscope and P6015A High Voltage Divider

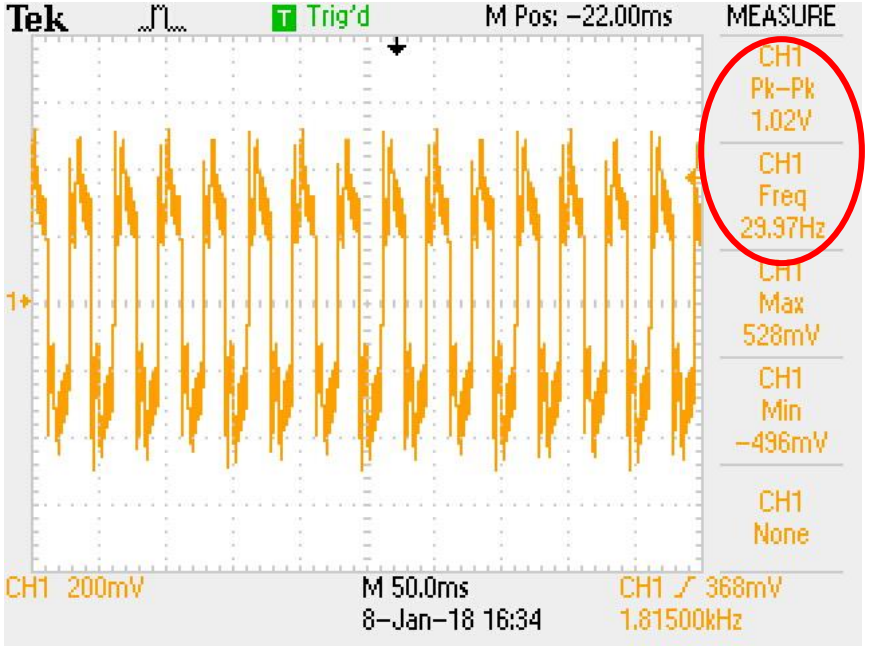




CPM Plate with Oscilloscope

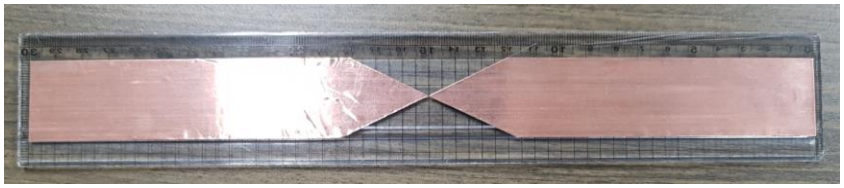
- Then connect CPM Plate to Oscilloscope which have 56 pF capacitance
- Ionizer Output: 5.5kV Pos. and 4.8kV Neg. with 12Hz/30Hz
- The peak-to-peak voltage values are almost same from this test result
- Frequency also measured for each 12Hz and 30Hz
- This represent output voltage from ionizers doesn't much changes, but CPM can't read full voltage scale due to lack of response speed



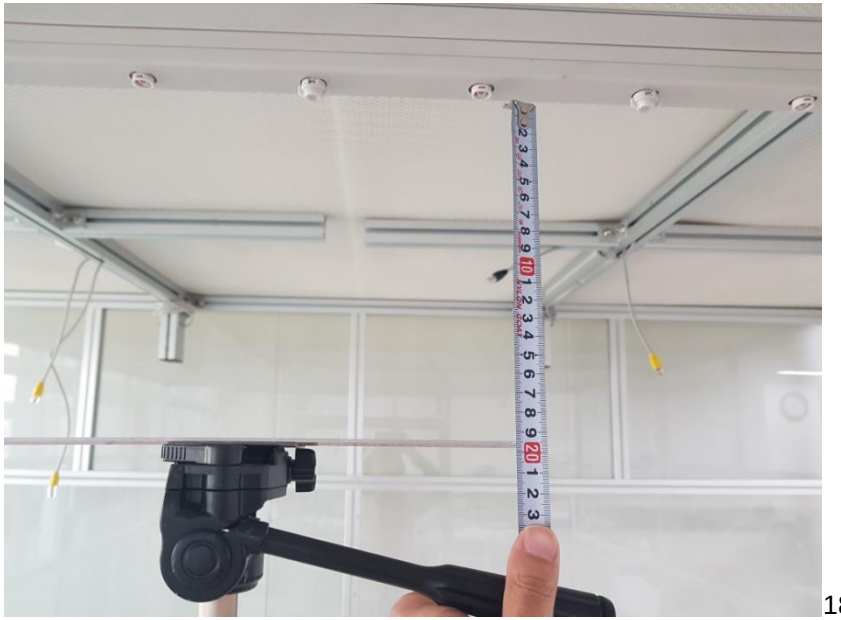


Discharge Current Measurement

- For ESD event measurement, copper taped insulator with micro gap apparatus prepared. CT-1 probe soldered one side to ground with TDS 3052B (500MHz) scope to measured discharge current.
- This test apparatus placed at 200mm distance from air assist ionizers and start ESD discharge current measurement
- 2GHz RF Antenna also located at 1m distance from ionizers to detect ESD event signature

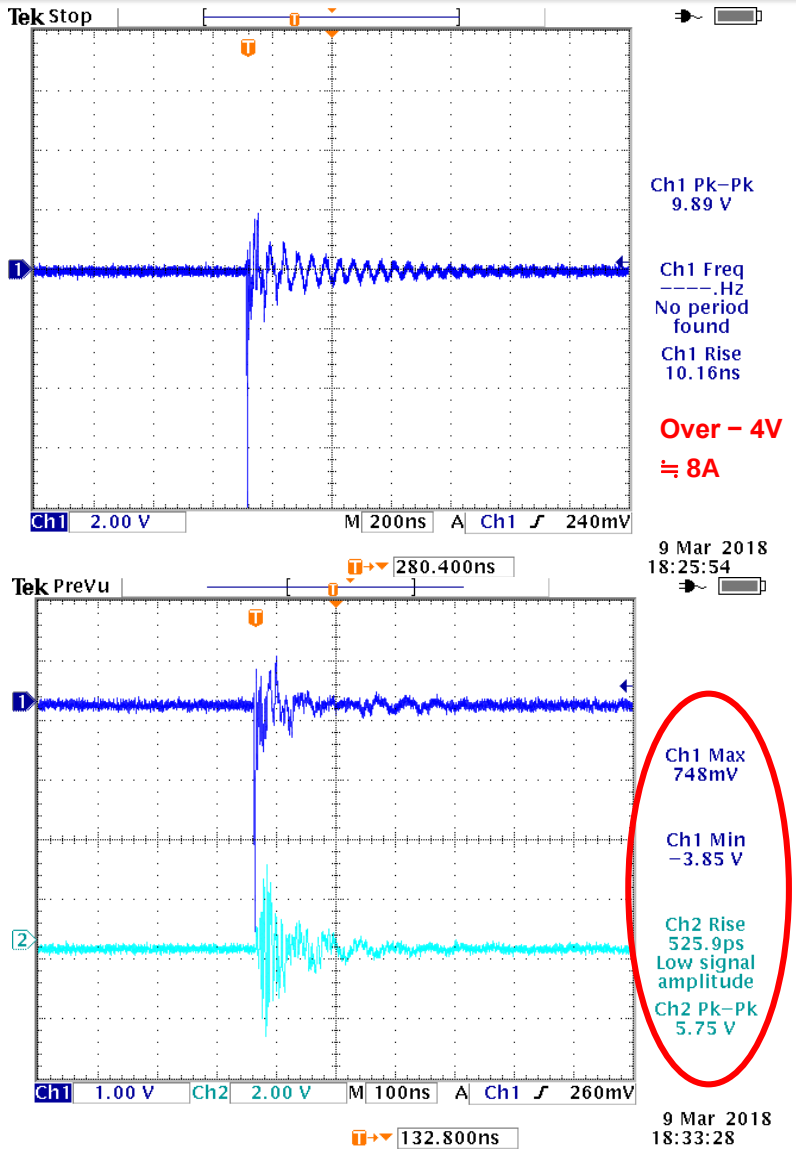


D.C. Smith, System Level ESD/EMI



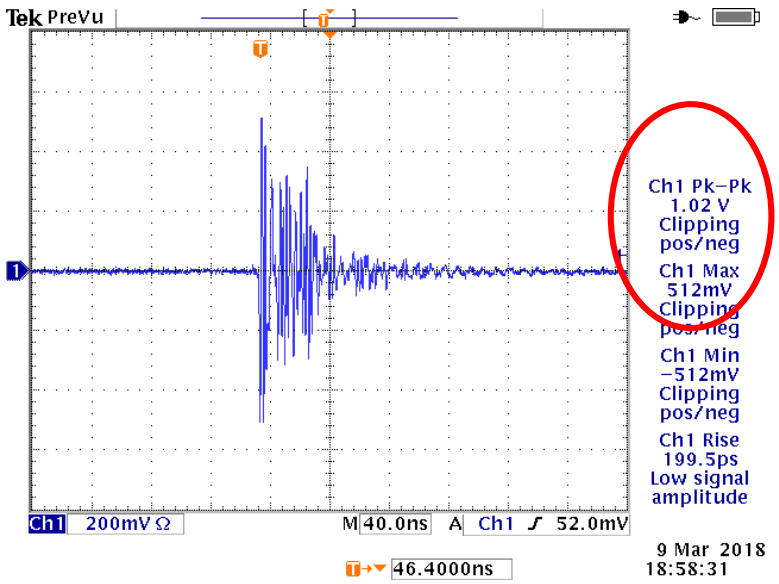
Experiments Results

- Discharge Current measured very high current over 8A through this test apparatus. This high current may be caused by big capacitance of copper tape
- At the same time, RF noise detected 5.75V peak-peak at 1 meter distance from ionizer as ESD event signature with short time delay
- This type of ESD event happen when test apparatus has ground through CT-1 probe and is repeatable



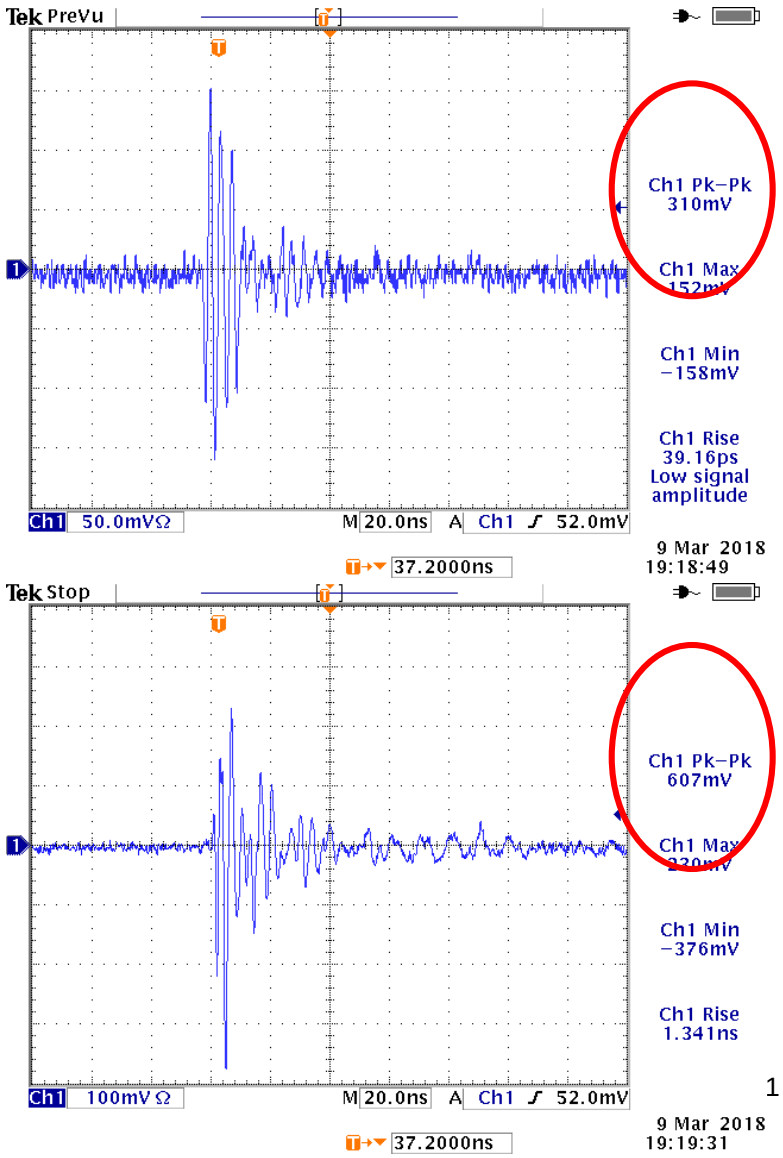
Experiments Results

- This type of ESD event also repeatedly occurs when test apparatus have no ground when apparatus movement such as conveyor system or robot handler transfer glass plates in FPD manufacturing processes
- Peak-to-peak value significantly reduced from 5.75V down to 1.02V
- This also can happen when ionizer output wasn't stable or when higher offset voltage was present



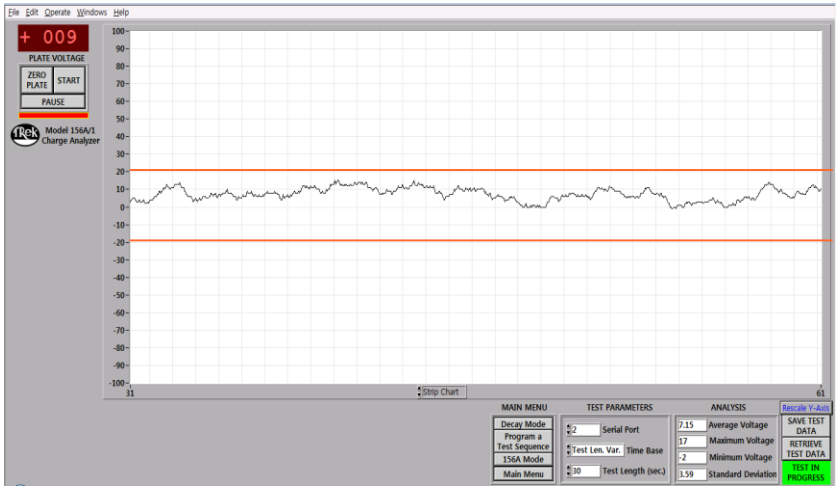
Experiments Results

- Instead of test apparatus, placed 4” smart phone TFT LCD glass at the same distance on tripod
- ESD event occurs on 4” display and measured with various peak values and could be repeated, but much less than test apparatus
- Measured value 310mVp-p to 607mVp-p
- It is clear that ESD event occurs on FPD when pulsed AC ionizer operating at short distance or some level of offset voltage



Alternative Solution Development

- Brand new ionization solution has developed and initial testing at same distance to CPM of steady-state DC air assist bar ionizers are indicating different test results without switching voltage and maintain less than 20V peak balance
- Thus, no ESD event occurs with same testing experiment



Peak Voltage Comparisons

Conclusion – Part 01

- Ionization test standard documents does not well address what balance or offset value records or collecting data during measurement especially for AC, Pulsed AC and High Frequency Ionizer Testing means for the ionizer performance
- CPM's response speed aren't fast enough to catch full switching voltages from switching type of AC ionizers
- For accurate measurements, voltage switching type of Ionizer requires much faster CPM test equipment or allow alternative ways of measurements
- We should update Ionizer related documents including S20.20, TR53, STM 3.1 and others to take peak value for AC, pulsed AC and high frequency AC ionizer balance measurement
- For the compliance verification, fieldmeter based instruments are not suitable for measuring balance measurement due to response speed is much slower to capture swing faster signals

Conclusion – Part 02

- It is clear that AC, Pulsed AC and High Frequency AC ionizers should not be used at short distances to ESDS items
- Due to more throughput of parts and products, ionizers integrated with process equipment are nowadays placed more often at short distances
- Risk Analysis need to be conducted for such applications and define safe distances vs. neutralization efficiency
- Alternative Steady-State DC air assist bar ionizer successfully indicating much lower peak value and better solution for ESDS items handling in automated process tool and EPA to avoid ESD event occurrence due to switching voltage from AC type of ionizers