Ionizer Qualification Test Experiment for an Advanced Package Device Application in a High-Speed Wafer Feeder

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Abstract – This study was performed as an ionizer qualification testing methodology for an advanced package device application of a high-speed wafer feeder (HSWF) process tool which does die pick up and placement. Per the specifications and design of the HSWF, the wafer table area and surrounding components should be subjected to the neutralization effects of an Ionizer. This is to neutralize any components and the die itself of any excessive static charge that could result in an ESD event during the die picking and handoff sequences when the die is coming into contact with the machine components. During this testing four different bar ionizers were installed onto our lab machine and using the Charged Plate Monitor, voltage levels of the pick area were collected for each ionizer under a set number of different conditions. Four ionizers were tested, Ionizer 1 being a standard AC ionizer, Ionizer 2 being a Dual AC ionizer, Ionizer 3 being an AC ionizer connected to an external charge monitoring device, and the fourth Ionizer being Core Insight's Model 7380d QuadPoint® DC Ionizer. All Ionizers were tested with and without connection to the air supply, air being used in bar ionizers to assist faster dissipation and overall coverage. Testing was to be done to get baseline readings of the range and levels each Ionizer could maintain in an environment in which no outside or excessive charges were introduced. This was due to concerns that our current ionizer's static balance range was too high for our goal of +/-10V. The results of the testing conclude that our current ionizer does in fact exceed the +/-10V range while another model tested was able to maintain a stable level with a range of ~5V in total.

I. Introduction

The Ionizers tested for this technical paper fall into two different categories, AC and DC ionizers. The main difference between the two types, being how ions are produced. AC ionizers have emitters that produce both positive and negative ions at a specified frequency, this frequency determines the typical range of offset voltage seen, as well as the time a given area switches from a net positive field to net negative field of static as in Figure 1. Both dual AC and self-regulated AC ionizers are reviewed in this paper.

DC ionizers have a set of emitter points that produce either positive or negative ions. The conventional DC ionizer typically alternates the; polarity of the emitter points across the bar so that you do not have two emitters of the same type of ions next to each other. See below in Figure 2. In this test, we used a patented QuadPoint® nozzle steady-state DC bar ionizer which generate ions in DC technology but has 4 emitters in a single nozzle construction and that can emit ions in both polarity with very low induction field. This is shown in Figure 3.

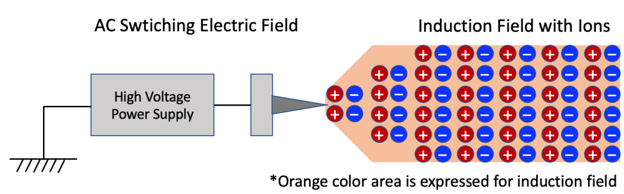

Figure 1 - Example of AC Ionizer Ion Pattern

In our test we only used bar ionizers, due to design and space constraints, and which have the ability to use an air supply to assist with the dispersion of ions. Test results will show the data collected from all ionizers with and without air connected. This is unique to our test case as most ionizers are designed to be placed a foot or more away from the area they are to neutralize, but our system uses the nozzle and emitter points of ionizers 5 to 6 inches away from our pick area, the area we seek to neutralize. This allows us to test the ionizers with and without air due to the proximity of the test area to the emitters.

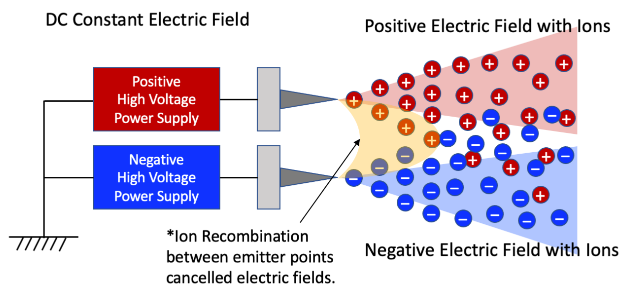

Figure 2 - Example of Conventional DC Ionizer Ion Pattern

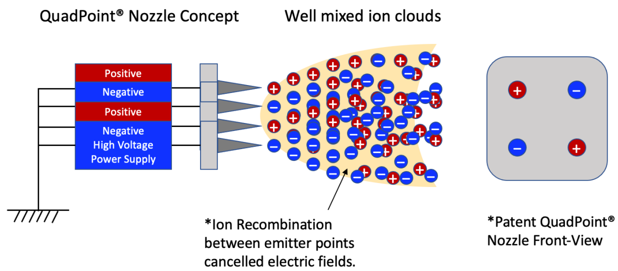

Figure 3 – Example of QuadPoint® Nozzle DC Ionizer Ion Pattern

II. Test Experiment

All four types of ionizers were installed and tested at the same location on a lab machine with the exception of physical dimension difference between ionizer constructions. Initial tests were conducted without a compressed air supply and the test results are as follows for each type of ionizers.

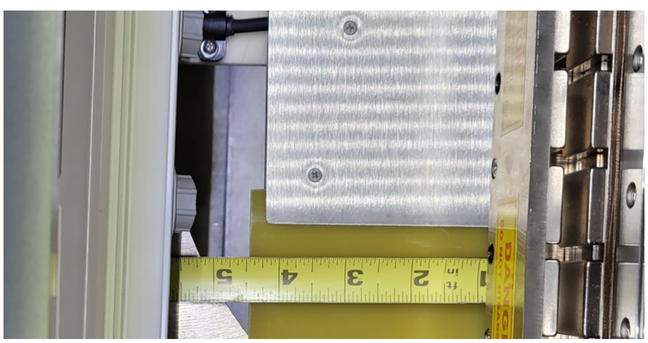

Figure 4 – Ionizer 2 Dual AC Bar Ionizer (Top-view)

Figure 5 - Ionizer 2 Dual AC (Side-view)

Figures 4, 12 & 18 shows the setup of three of four ionizers regarding their nozzle distance from the charge plate that is sitting in the estimated area of the die pick location during normal operating conditions. Figures 12 & 13 shows the distance of Ionizer 3's emitters to the charge plate, Figures 5 and 6 show the distance of Ionizer 2's, and Figures 18 and 19 show the distance of the Core Insight's Ionizer emitters to the charge plate. One note to make, Ionizer 3, the self-regulated AC ionizer is set a further distance back due to issues with our current bracket covering the power port and connection for the antenna needed for its self-regulation. From the results of the testing, that extra distance did not help nor hinder the ionization pattern seen at the charged plate monitor.

A. Baseline Reading

From the baseline test in Figure 6, we see that the nominal voltage level of the CPM was just below zero. This could be caused by the plate collecting a negative charge during handling, a natural slightly negative environment before testing, or the monitor adjusting to the ground reference. Regardless, the baseline is within an acceptable level as the reading is +1.2V to -2.3V peak.

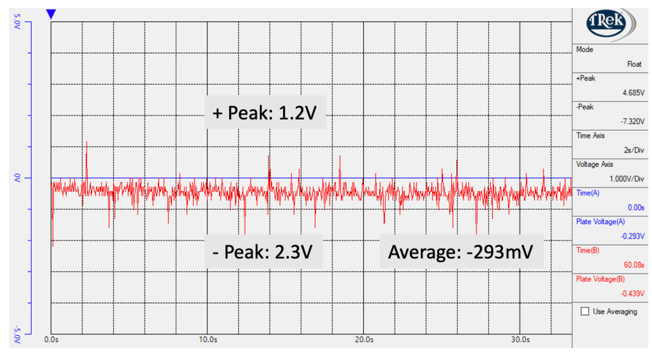

Figure 6 - Baseline Reading

B. No Air Assist Test Experiment

1. Ionizer 1: Standard AC Technology

Figure 7 below is the first test conducted using the current ionizer on lab machine, Ionizer 1 which is a standard AC ionizer. The ionizer was not turned on until the 10 seconds mark to establish a clear baseline and to highlight any change of state caused by the ionizer. This test was conducted without compressed air applied to the system with the ionizer operating at its 30Hz frequency setting. This is the highest AC frequency setting that both Ionizer 1 and Ionizer 2 have as a preset. From this graph we see that the min and max voltages were 850V and -383V respectfully.

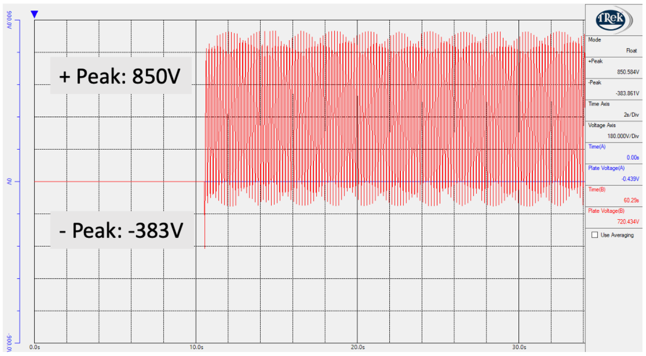

Figure 7 - Standard AC Ionizer Test Result w/o Air Assist

Figure 8 is the second reading of this test setup, which was taken to see if any further settling or additional neutralization occurred naturally.

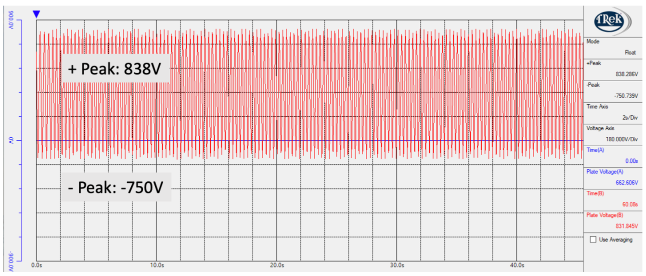

Figure 8 - Standard AC Ionizer after stabilized w/o Air Assist

As we can see from the second sampling of Ionizer 1 without air, no deviation occurs from the first sampling along with no self-regulations towards zero. This model has a manual dial that can be used to adjust the output towards zero. Figure 9 below shows adjustment to the zeroing dial. Using this ionizer in our application we can only center the overall range of the ionizer at zero but are unable to decrease the overall peak-to-peak range from +814V to -874V.

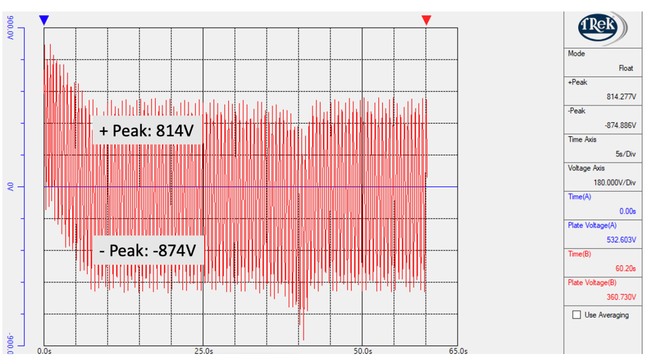

Figure 9 - Standard AC Ionizer Zero Adjustment w/o Air Assist

2. Ionizer 2: Dual AC Technology

Once again, the ionizer was not turned on until the 10 seconds mark to establish a baseline of the environment and CPM prior to ionizer interjection. See Figure 10. Here we see that voltage initially falls to -250V, then the voltage range moves towards zero over time. In Figure 11 below we see the continuation of the no air testing of Ionizer 2. In this test, we see the ionizer seems to stabilize a range between -35V and -69V.

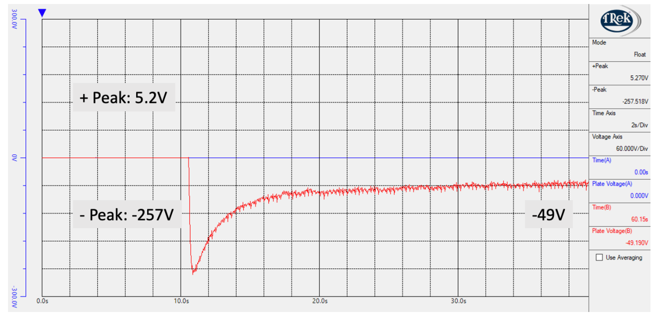

Figure 10 - Dual AC Ionizer w/o Air Assist

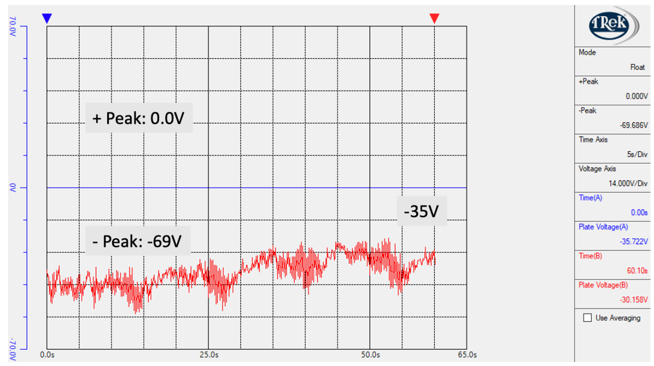

Figure 11 - Dual AC Ionizer after Stabilized w/o Air Assist

Ionizer 2 like Ionizer 1 has a manual Zero Adjustment dial. This dial did not appear to change the range of the ionizer in a positive nor negative direction. Thus, no data could be collected of how close to zero the ionizer could actually reach, or how stable it would be at that level of neutralization.

3. Ionizer 3: Self-Regulation AC Technology

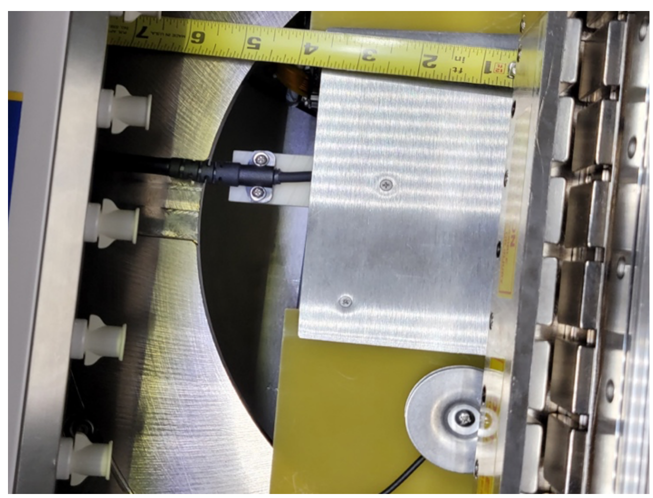

Figure 12 - Self-regulated AC Ionizer Actual Installation in Lab Machine w/o Air Assist (Top-View)

In Figure 12 and Figure 13, the puck like object next to the charge plate monitor is Ionizer 3's self-regulation device. This model ionizer does come in two other versions, one standalone with no self-regulation capabilities and one that has an external self-regulation system. The one tested has the self-regulation system integrated internally with the antenna feedback.

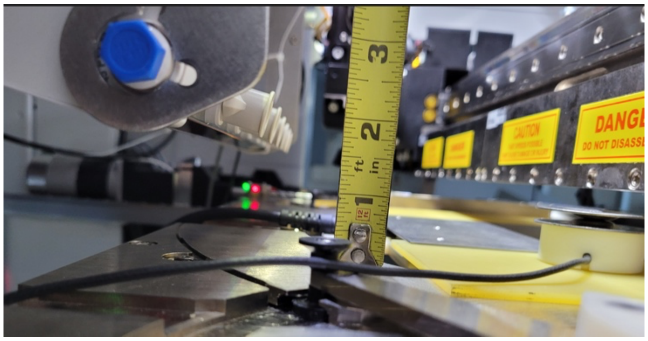

Figure 13 - Self-regulated AC Ionizer Actual Installation in Lab Machine w/o Air Assist (Side-View)

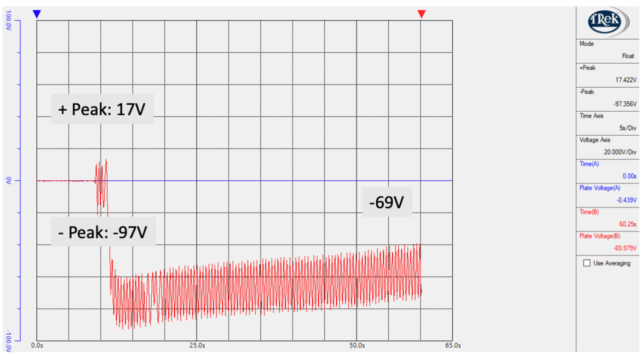

Figure 14 - Self-regulated AC Ionizer w/o Air Assist

Figure 14 above shows the first test of Ionizer 3 with their self-regulation device and no air assistance. Note that their self-regulation device is an antenna which acts as a charge plate monitor so that the ionizer can regulate its ion output to achieve a neutralization field that fits the environment. As shows in Figure 14, when the self-regulated AC ionizer turns on that voltage initially falls to -97V then the voltage range stabilizes to -69V.

Figure 15 is the sample taken of Ionizer 3 during the no air testing. The test starts at zero then decreases to a lower voltage range. It is not known if this is due to an issue with the charge plate monitors sampling rate not properly calculating the AC ionizers output at the beginning of the test. But what was seen was a stabilization after the first 10 seconds, as seen here that the ionizer stabilizes at a range of -19V to -47V overall. Due to the integrated self-regulation system on this unit, no manual adjustments could be made and tested with Ionizer 3.

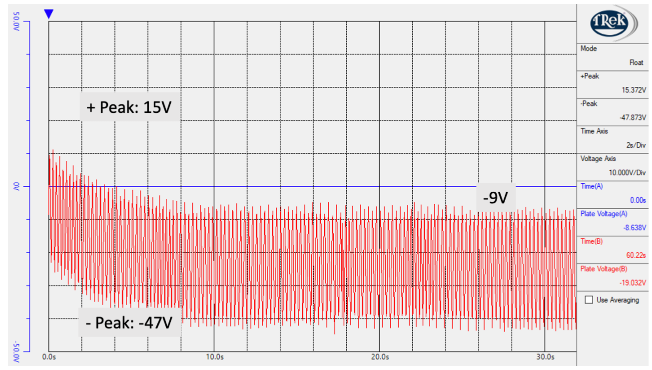

Figure 15 - Self-regulated AC Ionizer w/o Air Assist, Sample 2

4. Ionizer 4: QuadPoint® DC Technology

Finally, we tested Core Insight's Model 7380d DC Ionizer w/o air assistance. Figure 16 shows the initial testing of the unit over time, with an adjustment made to the ion output manually at the 30 seconds mark. For the first no air test the ionizer was powered on as close to the start of the test as possible, not powered at the 10 seconds mark like the other units. It was confirmed before this test was conducted that the charged plate monitor had an acceptable baseline reading at or near zero volts concurrent with baselines recorded before other ionizer tests.

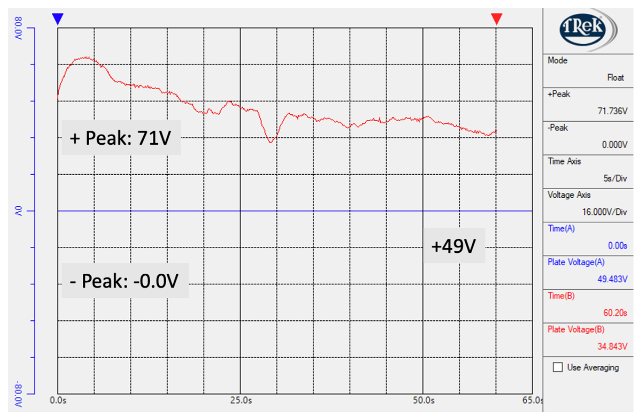

Figure 16 - QuadPoint DC Ionizer w/o Air Assist (initial)

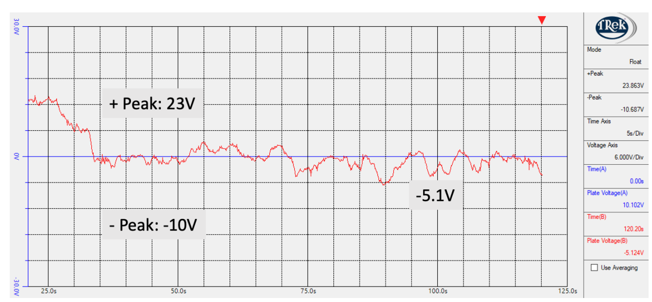

Figure 17 - QuadPoint DC Ionizer w/o Air Assist Adjustment

As mentioned previously, Figure 17 is the sampling taken during the no air testing on the QuadPoint DC ionizer with an adjustment made to increase the level of negative ions at around the 30 seconds mark. The graph was shifted to start at 20 seconds to include all collected test data that shows the stability of the system in the 80 seconds recorded after input changes were made to the ionizer settings. Finally, the QuadPoint® DC ionizer stabilized around -5V ranges.

Figures 18 & 19 shows exact same location and conducted comparison testing set up.

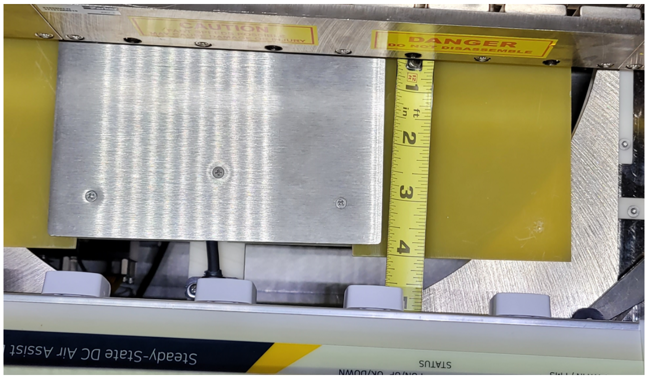

Figure 18 - QuadPoint DC Ionizer (Top-view)

Figure 19 - QuadPoint DC Bar Ionizer (Side-view)

C. Air Assist Applied Test Experiment

As the second experiment, all ionizers were connected to a compressed air supply, and we conducted ion balance testing as follows.

1. Ionizer 1: Standard AC Technology

Figures 20 & 21 shows the results of Ionizer 1, standard AC ionizer, the model currently used in our final system, with air assistance connected. Again, in Figure 20 the ionizer was turned on at the 10 second mark to show the effect on an already neutral environment. Test result shows swing voltage from +557V and -623V without using zero-adjustment dial.

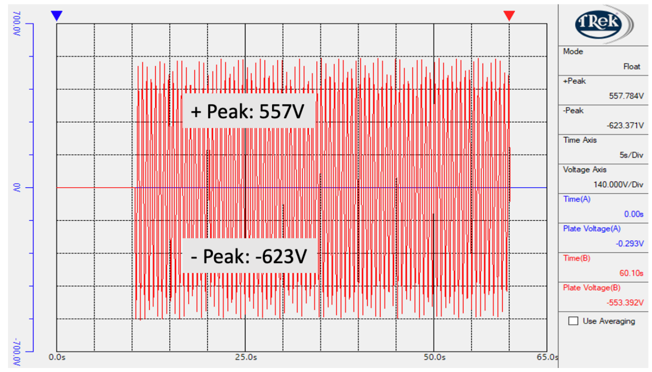

Figure 20 - Standard AC with Air Assist

Figure 21 shows that the initial voltage level has stabilized from output generated by Ionizer 1 after we used the zero-adjustment dial in our application lab machine. As similar with previous no-air test result, Figure 21 shows adjustment to the zeroing dial overtime, we can only center the overall range of the ionizer near at zero but are unable to decrease the overall range from +561V to -562V.

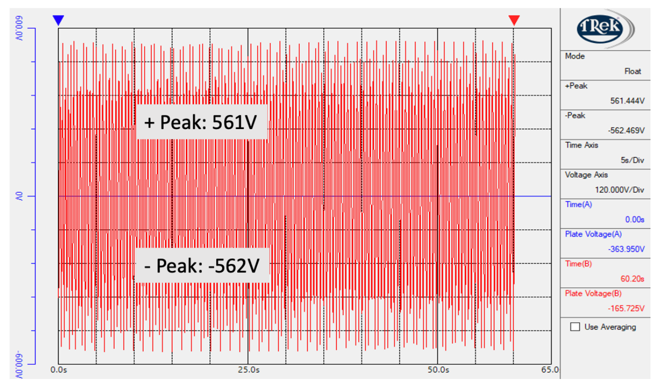

Figure 21 - Standard AC with Air Assist Adjusted

2. Ionizer 2: Dual AC Technology

The following two test results, Figures 22 & 23, are the results of Ionizer 2 with air assistance. Figure 22 shows the ionizer turn on at 10 seconds and then progress to a more stable neutral system. As we have seen in the previous test of Ionizer 2 without air, we see that voltage initially falls to -165V then the voltage range moves towards zero over time.

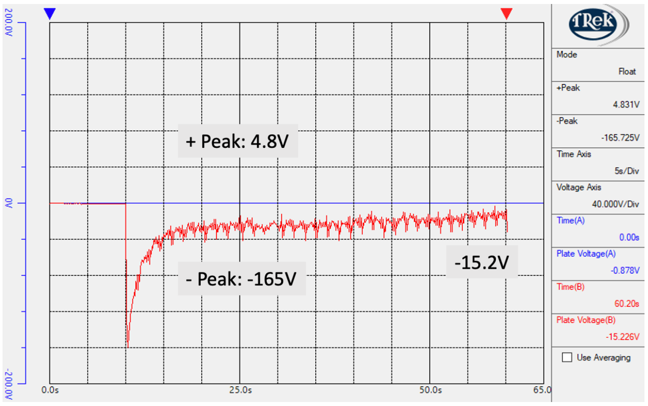

Figure 22 - Dual AC Ionizer with Air Assist

Figure 23 shows the stable output for this ionizer has been reached and the output range it can maintain in our application. Once again, this ionizer has a manual dial for zero adjustment, which seemed to not work on the unit tested so it is unclear if the stable range reached in this result could have been further centralized at zero volts. After the 50 seconds mark, negative peak voltage was monitored between -45V and -16V.

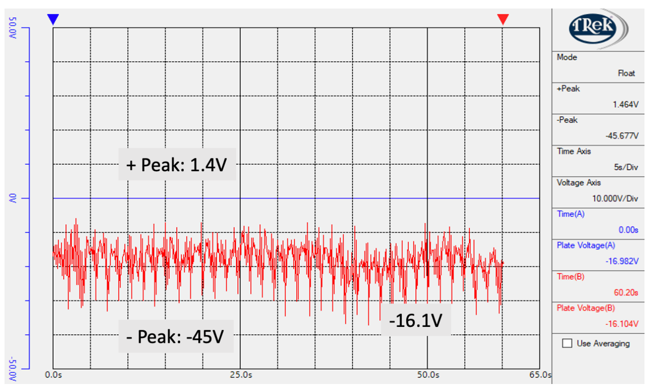

Figure 23 - Dual AC Ionizer with Air Assist Adjusted

3. Ionizer 3: Self-regulation AC Technology

The next two test results are the compressed air connected test for Ionizer 3 which is the self-regulation AC device. Figure 24 shows the initial result of the ionizer when it is turned on at 10 seconds, while Figure 24 shows the stable voltage range the ionizer settles into for our application.

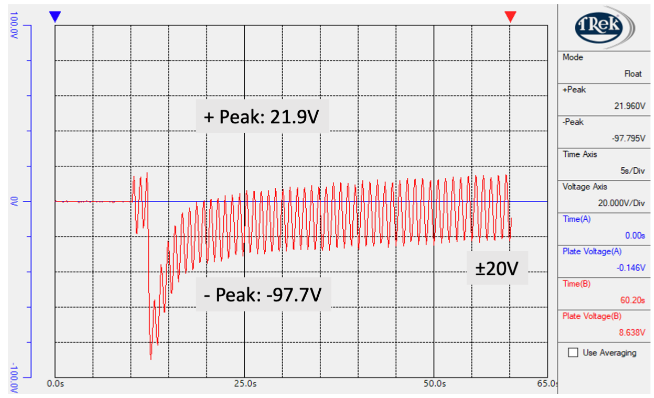

Figure 24 - Self-regulation AC Technology with Air Assist

As shown in Figure 25, when the self-regulated AC ionizer turns on that voltage initially falls to -97V then the voltage range stabilized to -20V, very similar results to the no-air test.

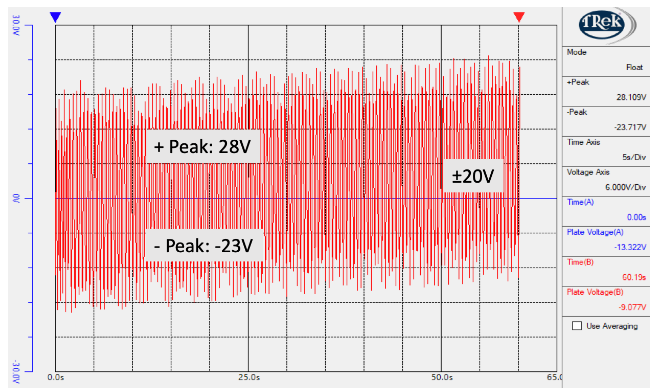

Figure 25 - Self-regulation AC Technology with Air Assist

Also similar to the no-air test, this test starts at zero then as seen here that the ionizer stabilizes at a range of +28V to -23V overall. Due to the integrated self-regulation system on this unit, no manual adjustments could be made and tested with Ionizer 3.

4. Ionizer 4: QuadPoint® DC Technology

Finally, the Model 7380d DC Ionizer with air assistance applied showed the following results.

Figure 26 shows the results of the ionizer turned on around the 10 second mark and its effect on the neutral baseline. Peak voltage was +49V and get stabilized +12V.

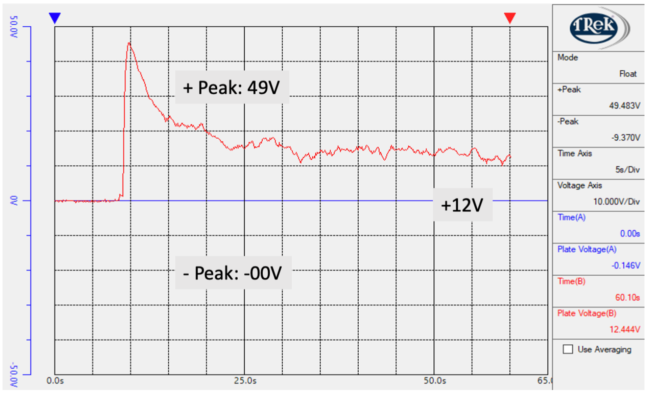

Figure 26 - QuadPoint DC Technology with Air Assist (Initial)

Figure 27 shows the self-stabilizing effects of the ionizer over an additional testing period and peak voltage has decreased to +23V and -3.3V.

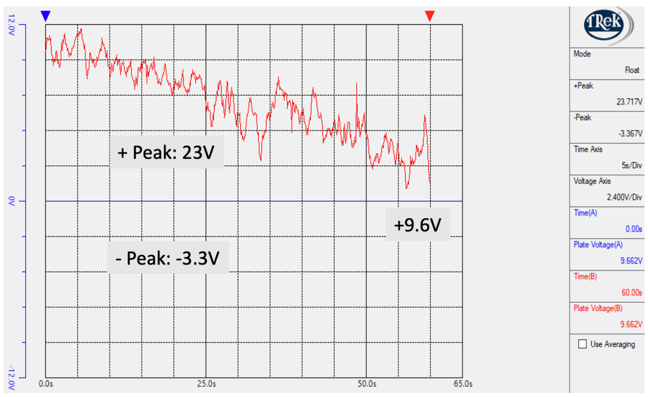

Figure 27 - QuadPoint DC Technology with Air Assist Self-Stabilized

Figure 28 shows the results of increasing the negative output of the ionizer from -2.65kV to -2.67kV. Note the voltage scale on the y-axis of Figure 28 was 12.0V min-max scale and Figure 28 has downed to 10.0V min-max scale compared to the typical scale of the previous results from the AC ionizers.

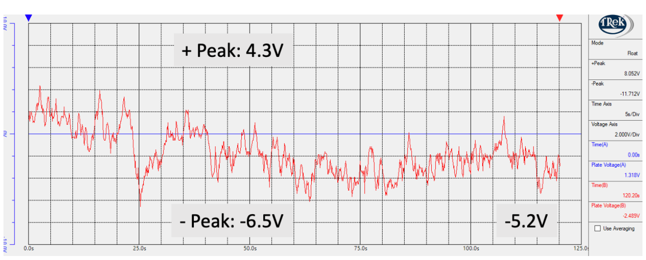

Figure 28 - QuadPoint DC Technology with Air Assist Output Adjustment

III. Summary

Out of the four ionizers that were evaluated in this technical paper, only two are the same type of ionizer. As stated previously and shown in Figure 1 and 2, there are fundamental differences in the ion pattern and emitter methodology between DC and AC ionizers, but there are also different types of AC ionizers.

AC type

+ ion and − ion layers reach the workpiece alternately, which increases the potential amplitude.

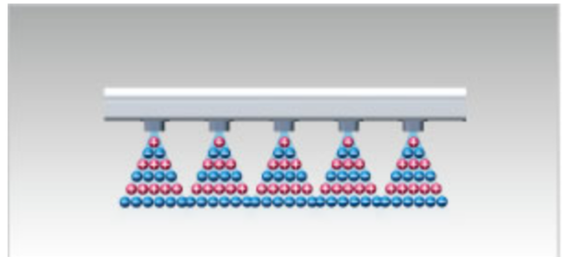

Figure 29 - Standard AC Ionizer Technology Showcase

Dual AC type/IZS42

+ ions and − ions are dis-charged at the same time to allow the + and − ions to reach the workpiece evenly, thereby reducing the potential amplitude.

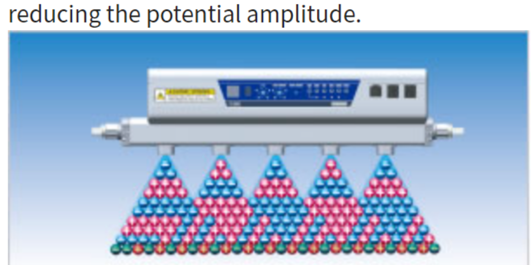

Figure 30 - Dual AC Ionizer Technology Showcase

Both Ionizer 1 and Ionizer 3 are standard AC ionizers, meaning that all their emitters output both positive and negative ions at the same time with the switch between ions happening at a specific operating frequency. For Ionizer 1 and 2, being from the same manufacturer and same product series, that frequency has several preset options ranging from 1Hz to 30Hz, 30Hz being the setting at which all tests were conducted. Ionizer 3's frequency changes depending on the feedback of the integrated self-regulated system. The other type of AC ionizer tested was Ionizer 2, being a Dual AC ionizer. In Dual AC ionizer emitters still alternate between creating positive and negative ions. The main difference is that instead of all emitters creating the same ion at the same time as standard AC ionizers do, ion emission occurs from pairs of ion emitters. Any two emitters physically next to one another on a Dual AC ionizer will have the opposite polarity ion emission from each other, both at the same frequency. This means that two emitters next to each other are never creating the same polarity ion. Figure 29 and 30 shows the ion patterns of standard AC and dual AC ionizers for further illustration of the different AC types [3].

Beside the two standard AC ionizers and the Dual AC ionizer tested, the Model 7380d is a QuadPoint® nozzle integrated into a steady-state DC bar ionizer. This type of ionizer has set emitters that only produce positive or negative ions. Of note is the difference of this DC ionizer when compared to others. Instead of having a single emitter at each nozzle the Model 7380d model has four emitters per nozzle, two of which produce negative ions and two of which produce positive ions. These four emitters are arranged in a square formation with the same ion emitters located diagonally from each other as in Figure 3 right corner.

Understanding how the standard AC ionizer works explains the reason they have a typical voltage switching range as seen in the results. Unlike the DC and Dual AC ionizers the standard AC ionizer creates a pattern of voltage swinging from a typical positive peak value to a typical negative low value. This rate of switching and overall magnitude is determined by the ionizer's high voltage output frequency and response time limitation of the Charge Plate Monitor (CPM). Due to slow response time, current CPM technology is very limited to accurately measure the real peak voltage of faster switching AC high voltage ionizers which operating 10 Hz, 30 Hz, 50 Hz, 100 Hz, 300 Hz and a maximum of 70 kHz. Based on this understanding, we also see why the Dual AC ionizer's mixed signal is not accurately measurable.

QuadPoint steady-state DC ionizers were able to better maintain a smaller and more stable range of voltage levels. As they are constantly emitting both positive and negative ions, which cancels the induction field around the nozzle and maintains low offset voltage at close applications. A major factor in the data seen above is the overall distance between the ionizers and the distance to the target area, or in our tests case the charged plate. Most AC ionizers are meant to be much further away from the area they are meant to neutralize, as that distance allows for better dispersion and intermingling of the ions over an area which would result in a smaller voltage range seen at the target location or test plate.

IV. Conclusion

When looking at the data from the plots above, clearly for our application's needs, the Model 7380d provides a more acceptable base voltage range that is more stabilized compared to the others. Both Standard AC ionizers, Ionizer 1 and Ionizer 3, have voltage swings that are far too high for our goal of +/-10V overall. The Dual AC ionizer needs further investigation along with an alternative ion balance measurement technique.

When you have a larger voltage swing you have a higher chance of an ESD event occurring, which would damage an advanced package device. This is likely if you pull a die out of the ion field at the peak of either negative or positive voltage swing. At that point, instead of neutralizing it you have instead added charge to it. Given the nature of our system, the handing off of the die to the pick head or even placing the die on the customer's board, if any surface is conductive and at a different charge level, then ESD damage is more likely to happen. Ionizer 2 being a Dual AC ionizer did significantly better than the standard AC ionizers, but from looking at Figure 21 we see that at its most stabilized set of data it still has an average swing of ±20V overall compared to the around 5V range of the DC ionizer. Also, we know the Dual AC ionizer measured overall voltage ranges are not accurate and there is a risk from the real peak voltage due to the CPM response time limitation.

The Model 7380d steady-state DC bar ionizer did much better than all the AC technology ionizers in terms of typical voltage range and overall stability. Note that no testing was done for its ability to neutralize a charge. No data was collected in this test to show how quickly it could neutralize any external charge that was either implemented in the area or brought into the ion field. This information would need to be gathered in a different technical paper before any conclusions could be drawn on that subject.

IV. Acknowledgements

Special thanks to Richard Strube and co-author, Craig Pettingill at Universal Instruments Corporation who helped and supported this study and shared their full test results.

IV. References

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