A Needs Based Algorithm for Ionizer Performance Optimizes Ionizer Operating Consideration

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Abstract
We have developed a formula for the Discharge Time required of air ionizers in FPD process tools to achieve substrate neutralization. The equation relates the Discharge Time to the charge density on the substrate (or electric field) and the speed the substrate moves through the tool. Setting ionizer discharge performance based upon this formula avoids the common practice of running the ionizer harder than necessary. Requiring too much from the ionizer results in excessive use of costly CDA, shortened cleaning cycle and worsened MTBF. These issues are evaluated and discussed.

Introduction
Electrostatic charge is generated efficiently in FPD cleanrooms. Surface charge on substrates attracts contaminants to their surfaces and charge can arc to a nearby object on or near the substrate, resulting in damage to the product[1]. Air ionization dissipates static charge on insulating surfaces like substrates. It works by making the air slightly conductive by adding of positive and negative air ions.

Ionizers are adjusted using a Charge Plate Monitor[2] (CPM). It is common to select ionizers based only on the CPM discharge time. Other ionizer parameters and settings dramatically affect the operating cost of the ionizer (cost of air, maintenance schedule and long term reliability). Ionizers can be set for lowest cost of operation or for maximum discharge speed. When discharge speed is the only consideration, operating cost suffers. We have calculated an algorithm for the discharge time requirement for various applications.

Ionizers in FPD Applications
Ions are created by corona discharge and are moved to the product by electric fields and air assist. On the way ions are lost to ground and recombination with the opposite polarity. This dictates that the ionizer to target distance should be kept to a minimum to minimize losses.

Computing Discharge Time Required

The ionizer performance that is needed for a given application can be calculated by treating the moving substrate as a sheet of moving charge under an ionizer. This comprises a current. Determining the average current collected by nthe CPM plate while measuring the Discharge Time and seting it equal to the current from the product yields

$$\mathbf{T_d=350/Eu} \qquad \mathbf{(1)}$$

Here E is the field at the substrate in V/inch, u is the substrate speed in m/sec and T_d is the discharge time in sec. This is calculated for a CPM discharge from 1000 to 100 V. This equation is shown graphically in Figure 1.The formula was tested in a Gen 7 fab on 3 different tools and the discharge time required by equation 1 produced good discharge performance.

Use of CDA

FPD ionizer bars have many emitter points in air nozzles along their length, all cycled positive and negative. Ions of each polarity are pushed away from the nozzle by the air. More air means more ions which in turn provide faster discharge times.

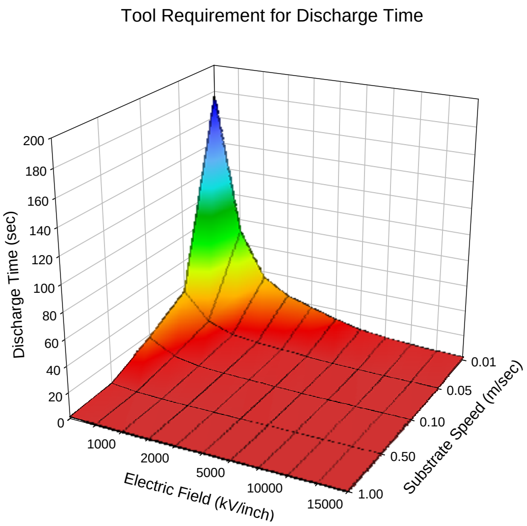

Figure 1 The CPM Discharge Time requirement vs electric field and substrate speed

This philosophy worked well for Generation 1 and 2 substrates, but as the substrate size grew, bars became longer and the number of nozzles requiring air also grew. For a Generation 2 bar with 50 mm nozzle spacing, 7 nozzles were required but for a generation 10 bar, 57 nozzles will be needed, using nearly 10x more air. The cost of this air for 1-15 lpm. per nozzle, taking US$0.0125/m^3 and 24/7 operation was calculated. See Figure 2. Further, the same results are shown in Figure 3 for a fab using 1000 bars.

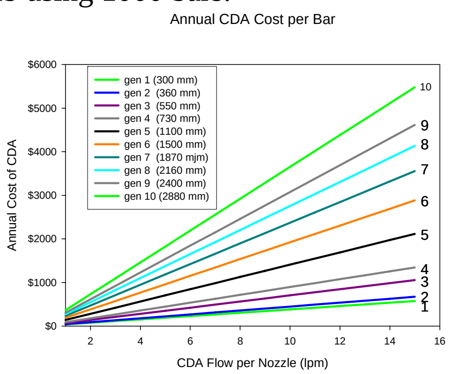

Figure 2 Cost of CDA per ion bar per year.

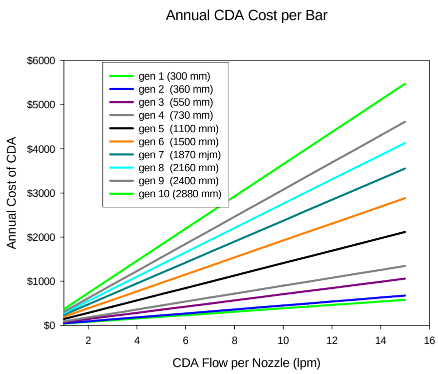

Figure 3 Cost of CDA for a 1000 bar fab

Use of CDA improves the discharge time and allows ions to travel further. This is especially important if fast discharge time is required and the ionizer is positioned far from the target (e.g. ionizers around a cassette). Ionizers placed far from the target must be pushed for exceptionally high performance. Also, requiring the ionizer to deliver performance well in excess of that calculated in Equation 1 demands more of the ionizer than is necessary. In either case, in Figures 2 and 3 show that for modern substrates, the annual cost of the CDA is considerably higher than the cost of the bars them self.

Operation of Bar at 100 % Power

To achieve the fastest discharge times the emitter points must be pulsed to the maximum voltage available from the power supplies. While the ionizer is designed to operate to its full output, this still has consequences. Emitter points wear down more quickly and the MTBF of the entire product will suffer. This is no different than operating an automobile continuously at its maximum speed- it becomes less reliable.

The agglomerating material onto the emitter is more rapid at 100% power. requiring more maintenance (cleaning) of the bar. This is a major expense as it requires manpower and, worse still, tool down time to accomplish the cleaning. To estimate of the cost of such maintenance, it takes ~15 minutes to clean all of the ionizers in a single tool. This represents 15 minutes of personnel time and 15 minutes of tool down time. The difference between an ionizer running at 100% power and one running at 75% power is estimated to be 12 vs 6 cleanings per year. This is a net savings of 1500 man hours for a 1000 tool fab per year. Additionally it will represent 1500 tool hours of down time per year.

Conclusions

The discharge time required for a given configuration can be specified. Faster times do not improve electrostatic control but they do increase the cost of operation.

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[1] Semi E78-1102. Electrostatic Compatibility – Guide to Assess and Control Electrostatic Dischage and Electrostatic Attraction for Equipment., Semiconductor Equipment and Materials International, 3081 Zanker Rd. San Jose CA 95134 USA ,October 2002.

[2] ANSI/ESD STM3.1-2006 – For the Protection of Electrostatic Discharge Susceptible Items - Ionization, ESD Association, 7900 Turin Rd. Rome NY 13440, USA, Feb 26, 2006.