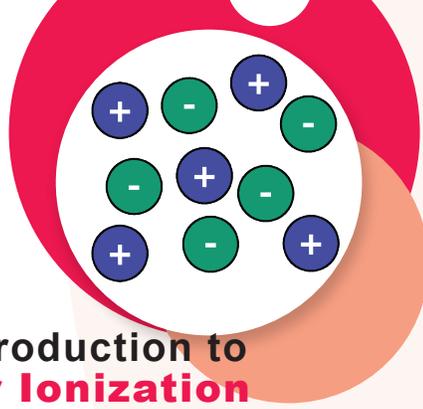




Introduction to Air Ionization

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Ionization Technologies, Selection, Applications, Performance Verification & Maintenance

About the Author :

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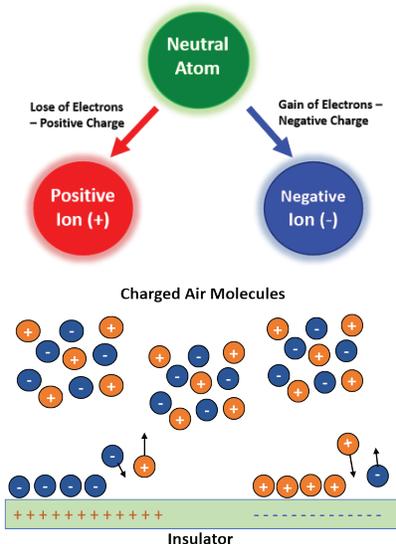
Foreword

This is an informative article that serves to provide an insight into the basics, fundamentals, selection, available ionization technologies and applications of ionization, including maintenance tips . All you wanted to know but was too afraid to ask – basically Ionization 101.

What is Air Ionization ?

Air Ionization is the process by which a neutral atom or molecule acquires a positive or negative charge– ie, it is a process of making the air more conductive (refer to Figure 1) so as to eliminate static charges that already exist in the environment via triboelectric (frictional) charging or induction charging . Charged atoms or molecules are called Ions. The formation of air ions starts with an electron being knocked off a neutral air molecule, which rapidly attracts a number of polar molecules (10 to 15) - mostly water and this cluster is called a positive air ion . The lost electron probably attaches itself to an oxygen molecule and this negative molecule in turn attracts a number of water molecules (maybe 8 to 10) and forms a cluster of negative air ions. This happens rapidly and as such positive and negative air ions are produced – either naturally by radioactive materials or artificially via field or corona ionization .

Figure 1 : Air Ionization



Ionization Technologies

Basically there are two different forms of ionization technologies currently available – ie, field (or corona) ionization and natural (or nuclear) ionization .

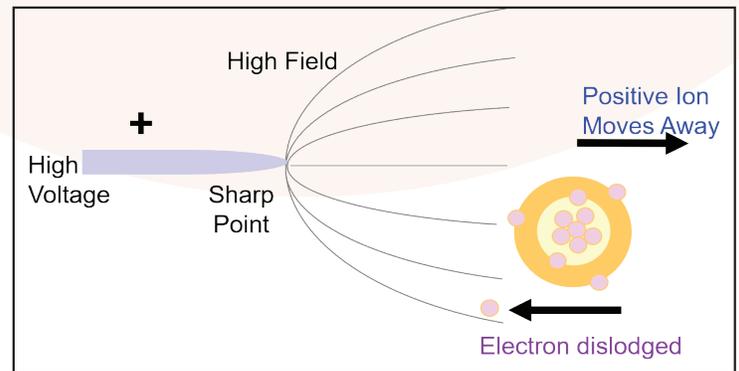
• Natural (or Nuclear Ionization)

Here radioactive isotopes (eg : Polonium 210) are used to produce ionization where alpha particles emitted as a result of the radioactive decay of the source, collide with air molecules and hence ionize them. Both polarities of ions are therefore produced . In some applications soft X-rays (or photonizers) have been used to provide complete ionization , basically within tools – however , these tools need to be completely enclosed to prevent exposure to the X-rays from such ionizers. As such there are only minimal applications for such ionizers.

• Field (Corona) Ionization

In this form of artificial ionization, a high electric field is applied to a sharp conductive needle or wire point via a high voltage power source. Depending on the polarity of the high voltage source, positive or negative ions are therefore produced (refer to Figure 2). This is the most common form of ionization technology currently used when designing bipolar (implies both positive and negative ions are produced) ionizers and are available in the following forms :

Figure 2 : Corona Ionization



AC Technology

High voltage is applied to a number of closely spaced emitter points that cycle alternately between negative and positive at the incoming line frequency of the voltage source, ie, 50/60Hz. Due to this very fast cycling and resultant ion recombination, AC systems must have high airflow to blow the ions away from the emitter points.

Steady State DC Technology

here dedicated emitter points are provided for each polarity and as such one half of the emitter points continuously produce negative ions and the other half continuously produce positive ions . Steady state DC ionizers work with low as well as high airflow , providing the emitter points are spaced far enough apart to reduce ion recombination, without creating hot spots

Pulsed DC Technology

similar to steady state DC ionizers, where dedicated emitter points are used to provide positive and negative ions . The difference here is that the high voltage to the emitter points is alternately turned on and off thereby creating clouds of positive and negative ions. Pulsed DC ionizers can perform fairly well even in low airflow cleanrooms because of the reduction in recombination due to the turning on and off of the high voltage to the emitter points. In very low airflow cleanrooms the "off" timing can be increased to reduce recombination and improve efficiency.

Pulsed AC Technology

similar to AC technology where emitter points are alternately turned on and off by tuning to different frequencies. Variable Frequency or Modulated Pulse ionizers are just an extension of this Pulsed AC technology. (Caution : Note that Pulsed AC ionizers should not be used in close proximity to ESD sensitive products as these ionizers can produce very high offset voltages of few hundred volts which cannot be captured by traditional Charged Plate Monitors . It is advisable to use available Charged Plate Monitors which can detect the offset voltages from such high frequency ionizers or oscilloscope with appropriate antenna that can qualify such ionizers prior to implementing them in critical processes where highly ESD sensitive products are being handled) .

In my opinion – the steady state DC & Pulsed DC ionizers are the preferred choices for implementation in production & process lines.

●●● What can Ionizers Do ?

Basically, bipolar ionizers can be used to eliminate the following :

- Electrostatic attraction (ESA) which causes particles to be attracted to surfaces and thus creates contamination
- ESD events which can cause damage to circuits/dies on wafers, read/write heads etc
- Microprocessor / Robotic lockup which can result in the lost of yield and high downtime (ESD events create radiated EMI)
- Product handling problems caused by charge build up thereby causing a reduction in process speeds
- Risk of injury to personnel caused by static discharges (to a lesser extent)

Ionizers should be used to complement other ESD control measures like grounding of flooring material, worksurfaces and tools etc and not to replace such measures .

●●● Selection of Ionizer :

Before a suitable ionizer can be selected the following needs to be established :

- Effective coverage area required (the type of ionizer selected will depend on the area to be effectively covered by ionization)
- Purpose of having ionization (Contamination control , ESD control or for microprocessor lock up)
- Specification of ionizers in terms of balance / swing voltage , decay times (1000V to 100V) - This depends a little on the damage threshold of the part or component based on the human body model (HBM) or charged device model (CDM) – which are models used to ascertain the ESD damage threshold)
- Environmental conditions like Temperature, RH (the lower the RH , the higher the probability of producing static) and airflow velocity in cleanrooms.
- Cleanliness of emitter points – there are various materials of emitter points available ranging from Stainless steel to Tungsten to Titanium to Single crystal Silicon. Due to the application of high voltage at the emitter points and due to gas to particle chemical reactions that occur at the tips, proper emitter points need to be selected which are compatible with the cleanliness class of the cleanroom and process . Ensure also that the emitter point material doesn't result in process contamination issues as a result of poor maintenance .
- Ceiling height of facility where general room ionization is required. This will impact the distance of the ceiling ionizer (or the length of the rods of ceiling ionizer) from the worksurface and affect the spacing between ionizers, depending off course on the specifications as well .

Once you have all the answers, you will probably be able to decide whether an AC, a Pulsed DC or a Steady State DC ionizer is required . Where for example room ionization is required in a cleanroom with say a > 4m ceiling height, a Pulsed DC ionizer with adjustable on and off timings should be used because of the inherently low airflow in cleanrooms. From experience, the effective distance between the emitter point of the ceiling ionizer and the worksurface should technically be between 1.6m ~ 1.8m to achieve good neutralization . At longer distances, the neutralization will be much longer. For minienvironment or tools ionization where the airflow is higher and more uniform a steady state DC ionizing bar for example can be used for the purpose of providing ionization as the proximity to the worksurface is much closer now (between 450 to 915mm in most cases). Off course a Pulsed DC ionizer can be used as well . In instances where close to zero balance is required, either nuclear ionizers can be used or steady state DC ionizing blowers with feedback sensors /controllers be used to provide close to zero balance with fast neutralization times (eg : 1000V to 100V < 5 secs at distances of between 400 to 610mm) .

●●● Types of Ionizers / Applications

There is a whole range of ionizers available depending on the application – refer to figure 3. To summarise, the ionizers can be broken down into the following few categories

a. Room Ionization

These ionizers offer general room ionization coverage and are installed from the ceilings in most cases. The ionizers can be spaced anything from 1.2m to 2.4m between ionizers and typically about 2.4m between adjacent rows. The ionizers should be located to adequately cover product transfer routes , holding areas of products like racks , open workstations where product is exposed and at load/unload areas or process tools .

b. Workstation / Tools / Minienvironment Ionization

In such applications where ionizers need to be installed above workstations or within minienvironments or tools (with Fan-Filter Units) for instance, ionizing blowers and/or ionizing bars can be used - eg : within the EFEMs (Equipment Front End Module) or process tools of semiconductor tools or within Clean Air devices where not just cleanliness but ESD control is necessary .

i. Fan-type ionizers can also be used for critical applications but evaluation needs to be done to ensure that these ionizers do not end up creating turbulence within, especially clean environments where particle control is just as critical (turbulence could result in contamination) . So the decision on using fan type ionizers should be dependent on which is more important – ESD control or particle control (as mentioned especially so in cleanroom environments) .

ii. For some critical applications where a very good offset voltages of less than $\pm 35V$ is required & fan type ionizers cannot be used – air assist steady state DC bar type ionizers should be used . Do take note that when using air-assist ionizers that use Clean dry air (CDA) for better ionization coverage & decay times – it is advisable to incorporate a cartridge filter at the inlet of the CDA line to the ionizer to ensure that your work area (or target area) is kept clean at all times – it is always better to ensure cleanliness or you will end up solving ESD issues but create a contamination issue (filter cartridges with nominal filter rating of 0.01um are recommended).

iii. And if close to zero offset (balance) voltage is required, then only alpha ionizers can be used to achieve the desired level of ionization . The alpha ionizers are available in bars , blowers and very small spot configurations . (Note : Alpha ionizers require licensing , proper importation & management documentation & licenses , proper disposal as the lifetime of an alpha ionizer is probably only 1 ~2 yrs max which makes implementation of alpha ionizer a hassle not to mention the psychological impact on operators / employees for fear of exposure to radiation)

c. Speciality (CDA/N2) applications

Such applications involve the use of customized or gas ionizers . In very packed environments where bars or ionizing blowers cannot be used , gas in line or nozzle type ionizers can be used to introduce a stream of ionized clean dry air or nitrogen within the environment . Other applications involve the usage of an ionized blow off gun to clean small parts before packaging.

Figure 3 : Types of Corona Ionizers

Benchtop (Fan Type Ionizer)



Ceiling Ionizer

Air Assist Bar Type Ionizer



3 fans Overhead Ionizing Blower



Air Gun Ionizer



●●● How to measure the performance of ionizers ?

Basically a charged plate monitor (CPM) is used to measure the offset / balance voltage and decay time of the ionizer. Typically, the decay time is measured from an initial voltage of 1000V to a final or stop voltage of 100V, ie a 90 % decay. Typically the CPM is located at the working height (see figure 4), during verification or adjustment of the ionizer. It is also good practice to record the distance / height to the CPM, the airflow at point of calibration and the adjusted settings of the ionizer (which will vary from ionizer to ionizer – eg : Ionizer cycle timings, ionizer output (swing voltages) etc)

Figure 4 : Verification / Adjustment of Ionizer



All ionizers need to be measured in the field (at site) upon installation. Subsequently these ionizers should be adjusted (& verified) by measuring the above parameters at least on an annual basis, though a semi- annual or quarterly frequency is much better in terms of ionization control. In critical applications, the ionizer should be verified and / or adjusted on a monthly basis.

●●● What affects the performance of ionizers ?

The following factors affect the performance of ionizers in most instances :

- Large grounded objects in the vicinity of the ionizer (this absorbs the ions produced by the ionizer).
- Airflow velocity (for ionizers without built in fans) and the type of cleanroom design , ie , unidirectional or non - unidirectional airflow cleanroom. Generally the airflow velocity should be within 0.45m/s + 20%, at point of measurement , if the velocity is lower the decay time will increase substantially.
- Build up of dirt and particles on emitter point of ionizers (this is a normal phenomenon because of the process of corona ionization which will attract Airborne Molecular Contaminants or AMCs that will form as “fuzzballs” on the emitter points - attracted by the high electric field from the emitter points).
- Obstruction of airflow in cleanrooms.
- Ceiling height, especially for room or ceiling ionizers.

●●● What kind of maintenance needs to be done ?

All corona ionizers require maintenance – there are no “maintenance free” corona ionizers . Basically the emitter points of the ionizer need to be cleaned with electronic grade IPA and foam / polyester swabs or available small emitter point cleaning capsules that fit snugly into the emitter point holders to clean effectively . The frequency of cleaning can range from 1 week to 3 months interval depending on the type of ionizer , the working environment (cleanroom, non-cleanroom, presence of chemicals or solvents in working environment etc) and the type of manufacturing process being carried out within the facility (eg wafer fab , disk drive etc) . Over time , all corona ionizers will begin to collect dirt and particles around the emitter points due to the gas to particle chemical reactions that occur at the tips, and if not properly maintained and cleaned, these “fuzzballs” might dislodge and fall onto your workstation thereby creating process contamination issues. Maintenance is therefore not an option but a must. Typically , the emitter points (eg : Tungsten, Titanium, Silicon) should be replaced every 2 to 3 yrs depending on level of erosion or degradation. Nuclear or the commonly used Po 210 alpha ionizers are , off course, maintenance free and the sources need to be replaced at a predetermined frequency, normally yearly but not limited to this frequency. Extension of the usage of the source depends on the half life (138 days in the case of Po210), the deterioration of the performance (ie, balance voltage and decay time) and governmental requirements which state that these sources need to be wipe or leak tested annually in most countries. There are currently auto - clean options available for fan-type benchtop or In - tool ionizers which can be activated by turning ON & OFF the ionizer. When the ionizer is Turned OFF this activates a retracted brush to extend to rub against the emitter points and then retract again when the ionizer is tuned ON again. This process of Turning ON & OFF the ionizer can be activated manually or via a set frequency within the ionizer menu (eg : every 24hrs). However do take note that when this cleaning takes place you can expect some particle fall out and this needs to be evaluated especially within cleanroom environments so as to ascertain that particle contamination is kept to a minimum within the work environment and all exposed product (s) are covered during this cleaning process. There are feedback sensors cum controllers currently available that can help monitor the offset / balance and decay time parameters for Steady State DC ionizers located within tools & work environments . In most instances , the ionizer could not be performing optimally due a lack of preventive maintenance cum re-verification due to the lack of available downtime to perform maintenance. So having a sensor located within the worksurface of the tool to monitor the necessary ionization parameters helps to ascertain when the ionizer needs to be maintained & adjusted. These sensors come with necessary LEDs or a separate display module that can be mounted outside the tool for easy observation by the technician or operator. Once any of the set alarm thresholds are exceeded, the display module will show an alarm and in this way necessary remedial action can then be taken. To summarise- All corona ionizers require maintenance and even if there are auto clean options or feedback sensors incorporated – wet cleaning of the emitter points using foam swabs / IPA is necessary at least on an annual basis or more frequently for those ionizers without these options (1 to 3 months interval).

●●● Ionizer Control for Critical Applications

For critical applications where the offset (balance) voltage needs to be tightly controlled (say for eg to +1V), ionizer feedback sensors or controllers are available that can continuously monitor the ionization level at the critical location and then feedback to the ionizer via a necessary cable connection to adjust accordingly. This kind of ionizer feedback controllers can actually help to reduce the re-calibration frequency for the ionizer by continuously providing a closed loop feedback and maintaining the balance to the desired level. The ionizer emitter points still need to be cleaned but generally the cleaning frequency could also be reduced depending upon the environment and process. The feedback sensor or controller is normally small enough to be located within the working environment and can come complete with the necessary monitoring LEDs and alarms. When selecting such a controller cum sensor it is important to select one that does not react to static voltages or fields inadvertently introduced within the environment but solely to ionization levels. If the sensor reacts to static voltages, then this will send false signals to the ionizer causing the ionizer to always re-adjust and balance itself unnecessarily, possibly resulting in the ionizer going out of balance rather than keeping its balance—this situation could have a drastic effect on the product. Therefore selection of the right feedback controller is of paramount importance. However do note that in most cases it is a challenge to place the antenna / sensor at the correct product handling location as the antenna / sensor causes an obstruction to the operator and or robotic arms within process tools. Also locating the antenna / sensor within the immediate work area where the product is handled can cause us a lot of interference which could result in wrong static voltage data being sent to the ionizer causing the ionizer to adjust unnecessarily (this could end up causing voltage spikes). Locating the antenna / sensor further away from the product handling area (target area) essentially then defeats the purpose of incorporating such a feedback sensor. Proper evaluation is necessary or else there is loss of productivity and unnecessary cost incurred.

●●● Available Ionization Documents (from the ESD Association & IEST)

The following documents can be referenced when more information about ionizers and test methods are required :

- ANSI/ESD STM3.1 : Ionization (Standard)
- ANSI/ESD SP3.3 : Periodic Verification of Ionizers (Standard Practice)
- ESD TR53 : Compliance Verification of ESD Protective Equipment & Materials (Technical Report)
- IEST-RP-CC052 : Understanding, Identifying & Controlling Electrostatic Charge in Cleanrooms & Other Controlled Environments (Recommended Practice from IEST)

●●● Common Misconceptions About Ionizers

1. “ Maintenance Free ” corona ionizer - There is no such thing as a “ maintenance - free ” corona ionizer as corona ionization is produced by applying a high voltage to a sharp emitter point. Over time the emitter will become dirty and the offset voltage will drift. The emitter points need periodic cleaning as explained earlier in the article.
2. If you have ionizers you do not need to implement other ESD controls – Note that ionizers compliment other ESD Controls like grounding, conductive or static dissipative flooring, ESD - Safe packaging, seating, static control garments, wrist straps & monitors, etc to name a few. Ionizers do not replace these other ESD controls.
3. All Ionizers must meet the required offset voltage specifications of $\leq \pm 35V$ as stipulated in ANSI / ESD S20.20 – This is NOT a must. If you are preparing to get S20.20 certified then you have to follow this specification if the product being handled has a HBM damage threshold of less than 100V and/or CDM damage threshold of less than 200V. In all other cases where HBM > 100V or CDM > 200V is permissible (ie, handling less ESD sensitive product(s)) – than an offset voltage of greater than $\pm 35V$ is fine. This has to be ascertained by one's internal ESD Committee based on the sensitivity of the product being handled. If the facility has a room ionization system (ceiling ionizers) installed, it is impossible to maintain an offset of $< \pm 35V$ as these ionizers are rated to perform at $< \pm 100 \sim \pm 150V$ or else their efficiency will be much reduced. However a tailoring statement can be incorporated to say that the room ionization system is essentially

for ESA reduction and / or control of ESD related equipment problems. Additionally, the tailoring statement should specify that if there is a need for ionization for control of process required insulators (to less than 125 volts/inch at one inch), or isolated conductors (to less than ± 35 volts), local point-of-use ionization will be used. And as part of the ESD control program, all ionization including the room ionization system will be audited and maintained at appropriate intervals.

4. Ionizers will solve all ESD issues – Air ionizers will provide the required ionization coverage especially for critical applications within process tools or workstations but ionizers cannot solve 100% of all issues as ESD events happen in nanoseconds. The ionizer(s) will help to mitigate charge build up, keep static levels within manageable levels and prevent catastrophic ESD failures in most cases.
5. Ionizers end up charging materials – this is possible for out of balance ionizers. However, proper and regular maintenance can overcome this issue. Proper maintenance implies – regular cleaning of emitter points as well as checking of the offset voltage & balance using a charged plate monitor. And it is advisable to connect the ionizer(s) to a monitoring software or to the FMCS (Facility Management Control System) so that any alarms can be detected in a timely fashion. Most ionizers have relay-based or Modbus type communications output(s) that can be easily interfaced to the FMCS (software).

●●● Conclusion

Though ionization is not an exact science, it helps solve your basic problems caused by static charge build up. Selection of the correct ionizer for each specific process application is important & this ensures that your EPA (ESD Protected Area) & Process tool or workstation is adequately covered & protected. And regular maintenance & adjustment with a CPM (if applicable) is required to ensure that your environment remains protected for continuous optimal performance within the EPA.