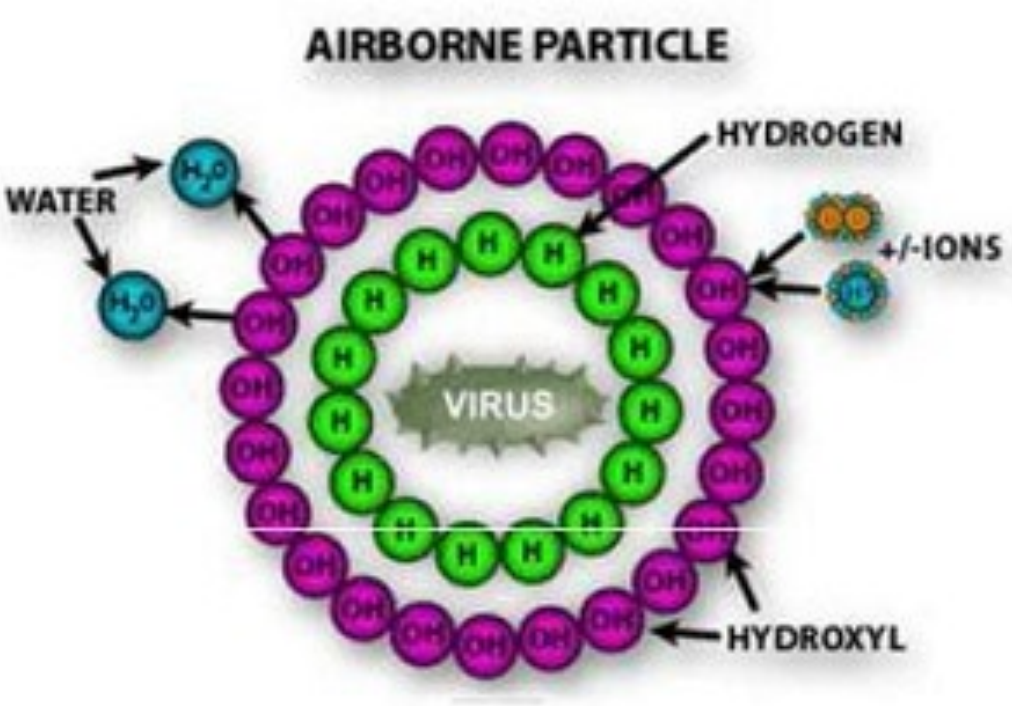
MCI™ Multi-Cluster Ionization

What it is and How it works...



MCI
(multi-cluster ionization)

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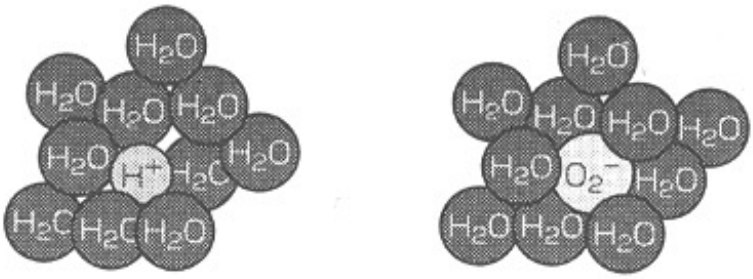
Chapter 2. Ion Cluster

The ion is an electrically charged atom or atom group, which is generated when a neutral atom or atom group loses an electron (+ ion) or gains an electron (- ion). The cluster refers to a number of things of the same kind. Therefore, the ion cluster means a number of grouped ions. However, in terms of pollutant removal, the ion cluster has a specific meaning. It refers to an ion cluster where H_2O is bonded with H^+ or O_2^-. It is known that H^+ or O_2^- bonded with H_2O molecules is effective in removing pollutants, germs and viruses. [1]



Positive Ion Cluster Negative Ion Cluster

Figure 2-1 Ion Cluster

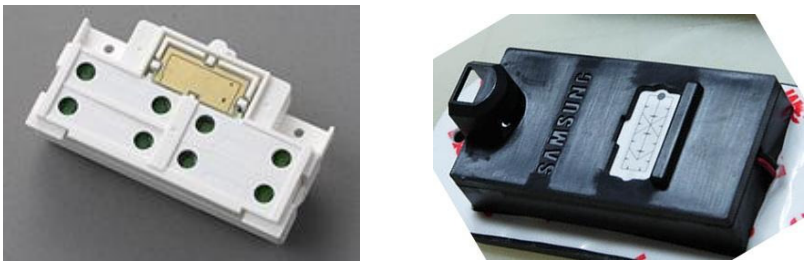
Also, the ion surrounded by H_2O molecules has a longer life of around 120 seconds than the single ion. [2]

2-1 Ion Cluster Generator and Its Principle

When a voltage is applied to electrode plates with the air between them, if the applied voltage exceeds a certain level, the air layer is ionized to flow the current between electrode plates, creating, so-called, an arc discharge. If electrode plates are separated by 1cm, when a 30,000 volt is applied, a discharge occurs. (In the air, if the intensity of the electric field is more than 30kV/cm, a discharge occurs.) At this time, ions are created, they are bonded with surrounding water molecules to produce, so-called, ion clusters.

When plate electrodes are used, it is difficult to control the current because an arc discharge creates a high current. The arc discharge is limited to where large energy is required such as welding and cutting. Therefore, needle electrodes, brush electrodes or wire electrodes are used to generate a discharge, which is called a corona discharge. Since a week current flows continuously, it is controllable so that it is widely used for ion clusters.

Depending on the maker of the ion cluster, the type of the electrode varies. In case of Sharp from Japan, a pair of needle electrodes is used to create positive and negative ion clusters by applying voltages to each electrode, which is marketed with a name of Plasma Cluster Ion. Samsung Electronics of Korea is manufacturing ion cluster generators called SPi (Super Plasma Ion) where needle electrodes are used for negative ions and sharp coated ceramic plates are used for positive ions. As electric charges are gathered at the sharp end, if the needle electrode is used, a discharge mainly occurs at the end of the needle. Since the needle electrode is vulnerable to pollution, its life is short.



(a) Ion Cluster Generator from Sharp (b) Ion Cluster Generator from Samsung Electronics

Figure 2-2 Two Different Ion Cluster Generators

Another way to create a discharge is DBD (Dielectric Barrier Discharge) where a voltage is applied to the dielectric between electrodes. Thanks to a dielectric between electrodes, the distance between electrodes can be reduced and destruction of the electrode by over current can be prevented. Figure 2-3 shows the DBD cylinder ion cluster with the power supply inside of the cylinder. In general, for safety reasons, the external electrode is grounded, and an AC voltage is applied to the internal electrode to create a discharge in the air layer between dielectric and external electrode (ground). Since an AC voltage is used, both positive and negative ions can be generated from the single ion cluster.

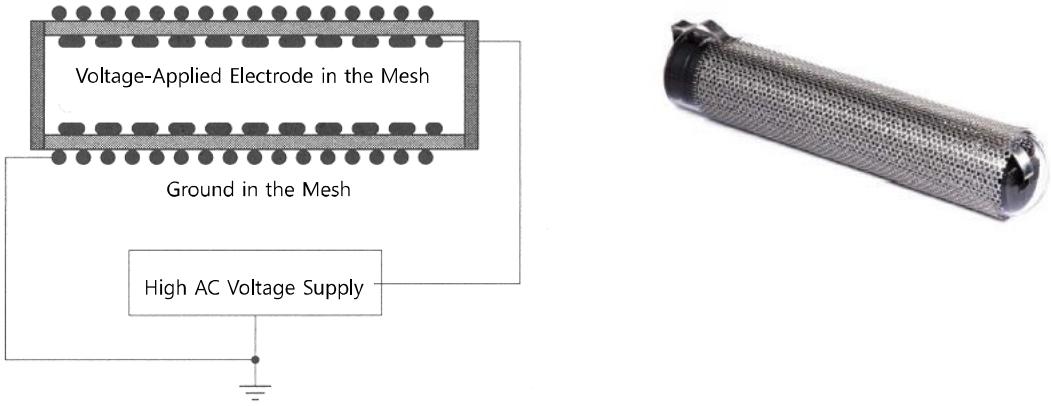
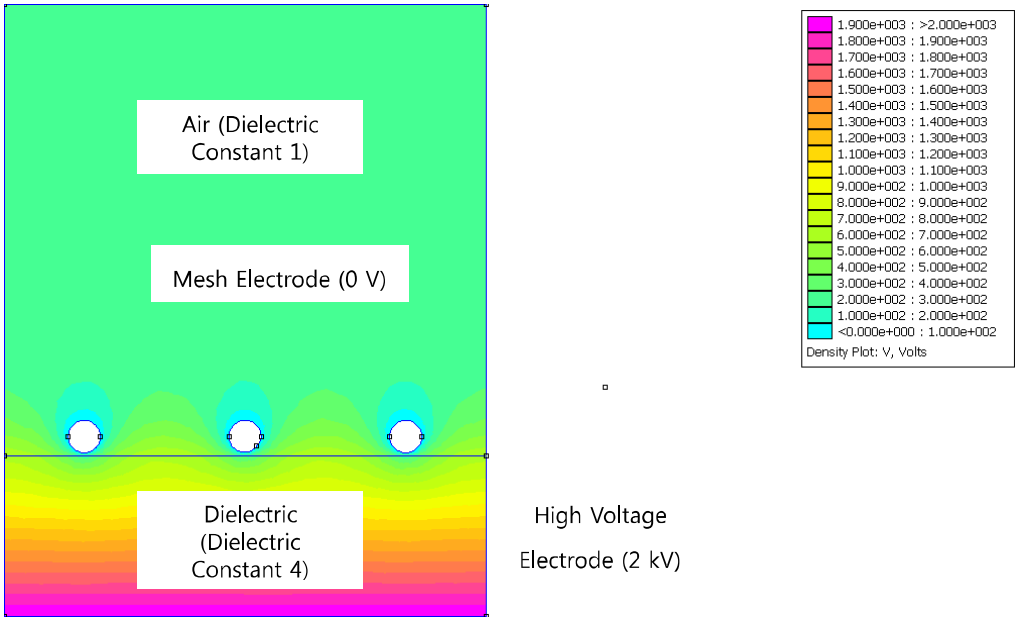
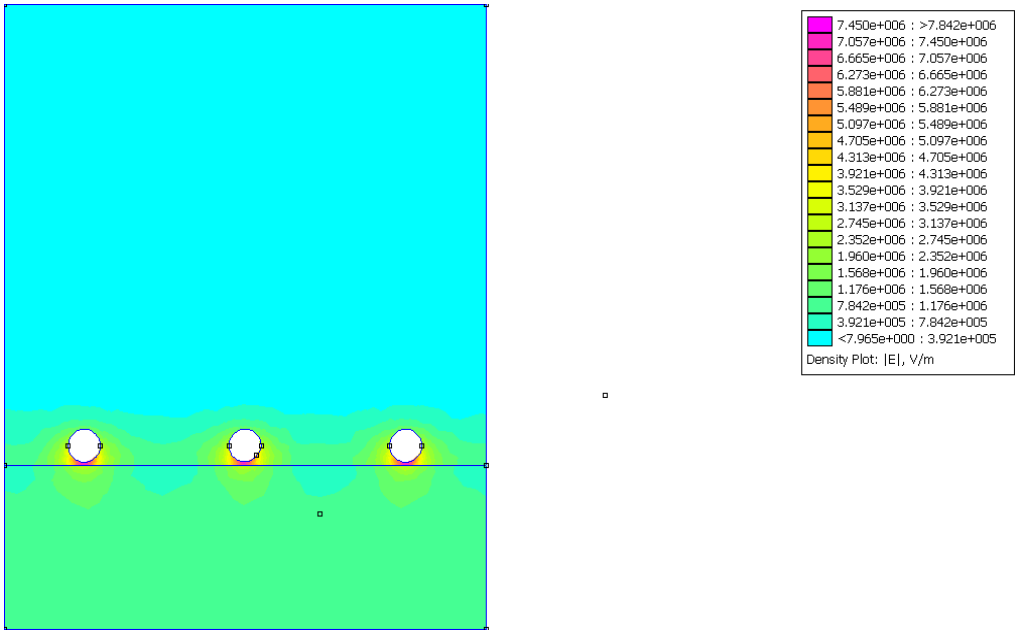


Figure 2-3 DBD Cylinder Ion Cluster

In general, the mesh electrode is used for the external electrode for easy contact with the air. For the internal electrode, it is not necessary to use the mesh electrode. However, if the internal electrode does not adhere to the dielectric uniformly, a discharge occurs non-uniformly. A material with a high dielectric constant is helpful for discharging. The higher the dielectric constant, the more charges are collected on the dielectric surface. Though ceramic has a high dielectric constant, it is not selected often because it is less workable and contains humidity. In general, glass is used commonly. As the premium material, quartz is also used.



(a) Distribution of Electric Potential



(b) Distribution of Electric Field Intensity

Figure 2-4 Electric Potential and Electric Field Intensity between Dielectric and Mesh Electrode

Figure 2-4 shows electric potential and electric field intensity when 2kV is applied to the high voltage electrode with 1 mm-thick dielectric and 0.2 mm-diameter mesh electrode. As shown in the figure, there is the 30 kV/cm or more (discharge threshold) electric field in the air layer between mesh electrode and dielectric. Therefore, a discharge occurs in the air layer to produce the ion cluster.

Figure 2-5 is the computer simulation of EEDF (Electron Energy Distribution Function) for dielectric barrier discharge according to the distance between electrodes.[3] The shorter the distance between electrodes is, the higher electron energy is.

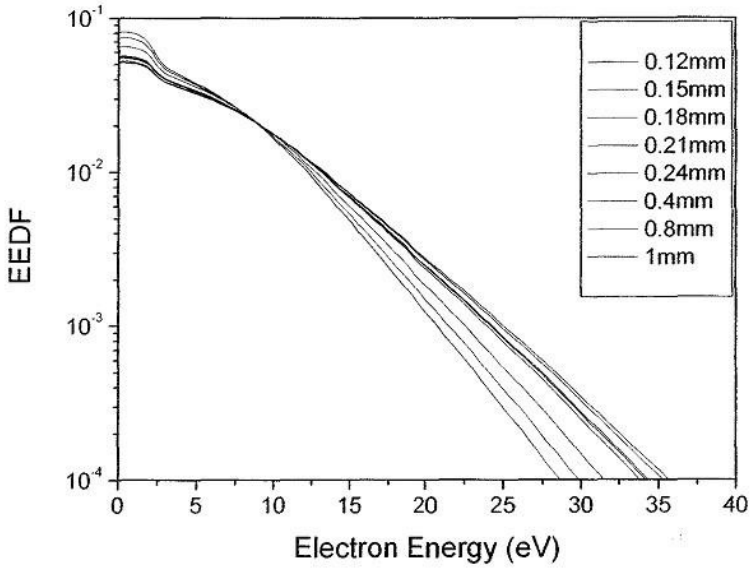


Figure 2-5 EEDF in DBD According to the Distance between Electrodes

2-2 Principle of Germ and Hazardous Substance Removal

(A) Germs and Viruses

Many test data have proven negative and positive ion clusters remove germs and viruses. Especially, Sharp from Japan is pursuing the plasma cluster business strategically and uses as its marketing tools studies and tests on the effect of the ion cluster on germ and virus suppression from various institutes around the world.

Table 2-1 Ion Test List of Sharp's Plasma Cluster (From: Sharp Korea's Website)

Hazardous Substance	Type	Verified by	Period
Viruses	H1N1 Human Influenza Virus	Kitasito Environment Science Center → Certificate	Sep. 2003
		Seoul National University, Korea	Sep. 2003
		Preventive Medicine Institute, Shanghai, China	Dec. 2003
		Kitasito Medical Center Hospital, Kitasito Institute	Feb. 2004
	H5N1 Bird Influenza Virus	Retroscreen Virology, UK	May 2005 Aug. 2008
	New H1N1 Influenza Virus	Retroscreen Virology, UK	Nov. 2009
	SARS Virus	Retroscreen Virology, UK	Oct. 2005
	Polio Virus	Kitasito Environment Science Center	Sep. 2002

	Coxsackie Virus	Kitasito Environment Science Center Kitasito Medical Center Hospital, Kitasito Institute	Sep. 2002
	Corona Virus	Kitasito Medical Center Hospital, Kitasito Institute	Jul. 2004
Germs	Serratia	Professor Emeritus Mervin First, Public Health School, Harvard University, U.S.	Mar. 2007
	Colon Bacillus	Isikawa Preventive Medicine Association	Sep. 2000
	Colon Bacillus, White Staphylococcus, Candida	Preventive Medicine Institute, Shanghai, China	Oct. 2001
	Bacillus	Kitasito Environment Science Center T&T (Professor Atman, Aachen University of Applied Science , Germany)	Sep. 2002 Nov. 2004
	MRSA (Methicillin-Resistant Staphyllococcus Aureus)	Kitasito Environment Science Center Kitasito Medical Center Hospital, Kitasito Institute	Sep. 2002 Nov. 2004
	MRPA (Multidrug-Resistant Pseudomonas Aeruginosa)	Kitasito Medical Center Hospital, Kitasito Institute	
	Pseudomonas, Enterocoxsackie, Staphylococcus	University of Lübeck, Germany	Feb. 2002
	Enterococcus, Staphylococcus, Sarcina, Micrococcus	CT&T (Professor Atman, Aachen University of Applied Science , Germany) Coxsackie virus	Nov. 2004
Allergen	Mold, Pollen	Advanced Material Department, Hiroshima University Graduate School	Sep., 2003
	Mold	Molecular Pathology Lab, Medical Research Department, Osaka Municipal University Graduate School	Jul. 2009
Mycete	Cladosporium (black mold, mildew	Isikawa Preventive Medicine Association University of Lübeck, Germany (Proliferation Suppression) CT&T (Professor Atman, Aachen University of Applied Science , Germany)	Sep. 2000 Feb. 2002 Nov. 2004
	Penicillium, Aspergillus	University of Lübeck, Germany (Proliferation Suppression)	Feb. 2002
	Aspergillus, Penicillium (Two Types), Stachybotrys, Alternaria, Mucor	CT&T (Professor Atman, Aachen University of Applied Science , Germany)	Nov. 2004

Also, Sharp explained how the ion cluster removes germs and viruses, which is believed to be the most plausible so far.

▶ Step 1 – Ion Generation by the Plasma Discharge

The ion cluster generator uses the plasma discharge in the air to break water molecules to emit H^+ andO_2^-.

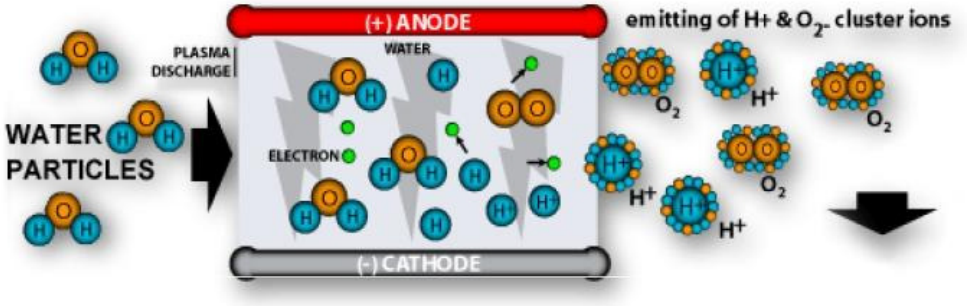


Figure 2-6 Ion Generation

▶ Step 2 – Creation of the Ion Cluster

Water molecule in the air is bonded with ions to create positive and negative ion clusters.

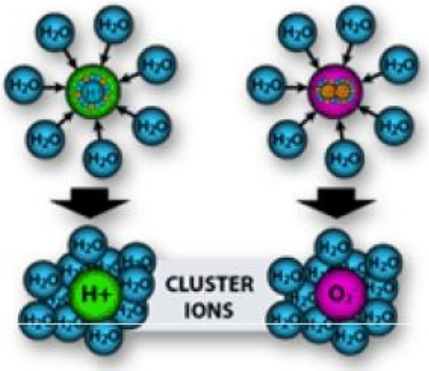


Figure 2-7 Creation of the Ion Cluster

▶ Step 3 – Ion Cluster's Surrounding of Germs or Viruses

The ion cluster surrounds germs and viruses in the air. At this point, chemical reaction in the virus surface creates OH radicals.

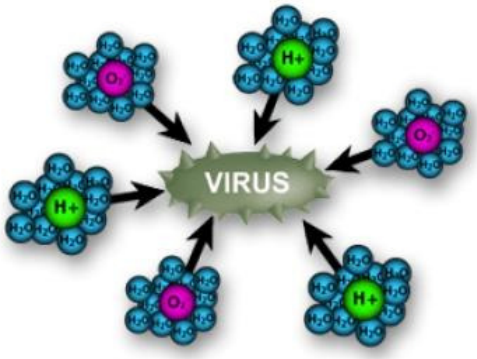


Figure 2-8 Ion Cluster's Surrounding of Germs or Viruses

▶ Step 4 – Neutralization of Germs and Viruses

OH radicals neutralize germs and viruses by removing hydrogen from cells with strong oxidization.

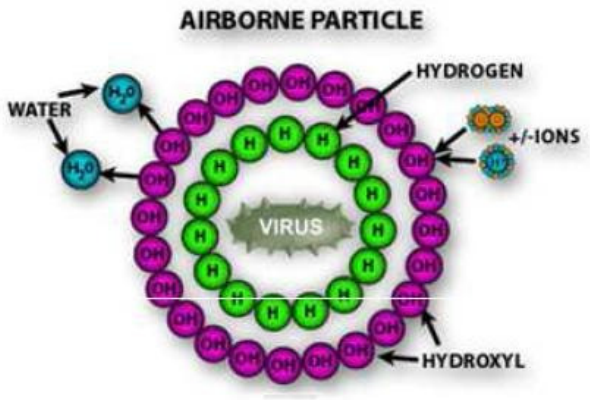


Figure 2-9 OH Radical's Neutralization of Germs and Viruses

▶ Step 5 – Conversion to Water

OH radical reacts with hydrogen taken from cells to be converted to water (H_2O).

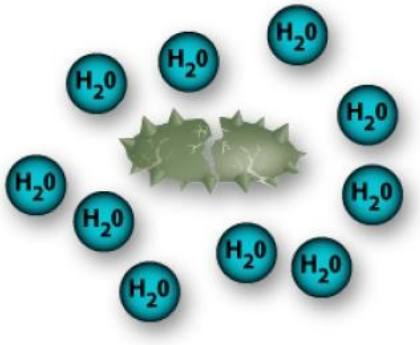


Figure 2-10 Conversion to Safe Water

At this point, OH^-, also called hydroxyl radical, plays an important role. OH^- is an oxidant stronger than H_2O_2 and works on germs and viruses to neutralize them. The following table shows oxidative power of various substances.

Table 2-2 Oxidative Power of Various Substances

RELATIVE POWER OF OXIDANTS	OXIDATION (OXIDANT POTENTIAL VOLTAGE)	RELATIVE OXIDATION (POTENTIAL POWER)
Flourine-	3.06	2.25
Hydroxyl Radical (OH)-	2.80	2.05
Atomic Oxygen (O1)-	2.42	1.78
Ozone (O3)-	2.07	1.52
Hydrogen Peroxide (H2O2)-	1.77	1.30
Per-Hydroxyl Radical (HO2)-	1.70	1.25
Permanganate-	1.67	1.23
Hypbromous Acid-	1.59	1.17
Chlorine Dioxide-	1.50	1.10
Hypochlorous Acid-	1.49	1.10
Hypoiodus Acid-	1.45	1.07
Potassium Monopersulfate-	1.44	1.06
Chlorine Gas-	1.36	1.00
Oxygen (O2)-	1.23	0.90
Bromine Gas-	1.09	0.80
Hypochlorite-	0.94	0.69
Chlorite-	0.76	0.56
Iodine-	0.54	0.40

For your information, Samsung Electronics says not OH radical but hydro ferroxyl radical(HOO^-) has this effect.[4, 5]

(B) Hazardous Substance

The hazardous substance refers to various VOCs, malodorous materials and PM (Particulate Matter). It has been proven that the ion cluster eliminates hazardous substances. [6-15] Compared to germs and viruses, it is more clearly proven how hazardous substances are removed. And the ion cluster has been widely used in garbage and waste water plants. [2]

The ion cluster generated by a plasma discharge produces various ROS's (Reactive Oxygen Species, O_2^-, OH^-, HOO^-) which chemically react with hazardous substances to convert them

to harmless ones. (Finally, hazardous substances are dismantled into carbon dioxide and water.)

VOC (Volatile Organic Compound) + ROS (Reactive Oxygen Species) -> CO_2 + H_2O

In this process, important is the IE (Ionization Energy) of organic compounds. IE is energy required to remove one electron from the molecule and is expressed in eV (electron volt). The lower IE is, the easier it is to set off chemical reaction, resulting in more effective removal with the ion cluster. Normal oxygen's IE is 12.07 eV. If a material's IE is bigger than this, it is difficult to remove such a material with the ion cluster. For example, the IE of toluene is 8.83 eV and that of formaldehyde is 10.88 eV. Therefore, the ion cluster can remove toluene more effectively than formaldehyde. See the annex A-1 for various materials' IE.

Also, as the ion cluster is attached to PMs and electrically charge them, PMs are electrically bonded to form bigger matters, which can be more effectively removed. Smaller PMs enter the respiratory system deeply to have negative impacts.

PM_x (Size x Particulate Matter) + Cluster Ion -> PM_y (Size y Particulate Matter), $y>>x$

2-3 Ozone

Ozone is highly oxidative and effective in removing germs, viruses and VOCs. However, to use ozone for sterilization and hazardous substance removal, highly concentrated ozone (10~ 99 ppm) is needed. [16] Therefore, if ozone is used for sterilization and hazardous substance removal, people should be evacuated from the building with the ozone generator. When generating ion clusters by using plasma, a little ozone is produced. Because of this, skeptics about the effect of ion clusters say sterilization and deodorization are attributable to ozone not ion cluster. To prove the effect of ion clusters, we conducted the test with Arcrenaissance, Japan.

▶ Ion Cluster Effect Test with Formaldehyde

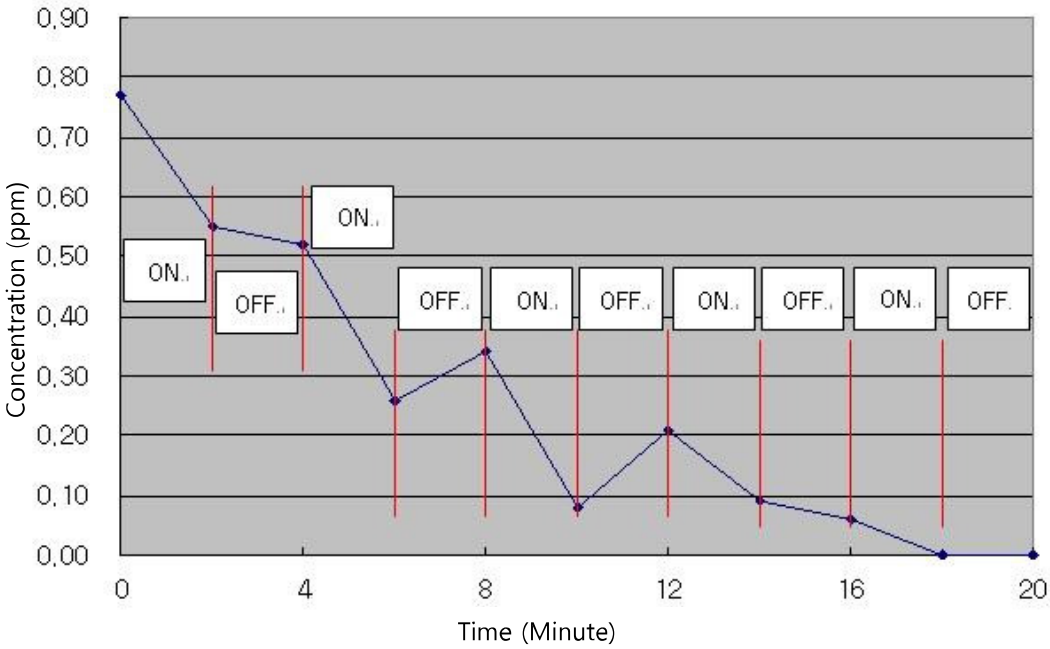
- Test Site: Utaz Hotel, Kagawa, Sikoku, Japan
- Test Date: July 9, 2010
- Test Method: Our ion cluster generator (model: AIO) was installed inside of the 20L acryl chamber, and then formaldehyde was injected. In an interval of two minutes, the ion cluster generator was turned on and off, and the Formaldemeter 400 from PPM Technology, UK was

used to measure the concentration of formaldehyde inside the chamber.

(a) Chamber with the AIO (b) Formaldemeter 400

Figure 2-11 Test Chamber and Formaldemeter 400

▪ Test Result:



Time (Minute)	0	2	4	6	8	10	12	14	16	18	20
PPM	0.77	0.55	0.52	0.26	0.34	0.08	0.21	0.09	0.06	0.00	0.00
ON/OFF	-	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF

Concentration (ppm)
Time (Minute)

As shown in the above test result, when the ion cluster was on, formaldehyde concentration dropped. When it was off, formaldehyde concentration dropped less or rose sometimes. (We think it happened because formaldehyde attached to the chamber wall was emitted.) If ozone is more effective in removing formaldehyde, even when the ion cluster generator was off, as ozone existed inside of the chamber, formaldehyde concentration should have dropped more when the ion cluster generator was on. This does not correspond to test results. Therefore, not ozone but ion cluster removed formaldehyde.

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