

# Ozonize Mini Air Cleaner for ECO-Car By Applied Electrostatic

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**Abstract:** This research paper presents a design and construction of ozonize mini air cleaner by electric field based on electrostatic precipitator (ESP) and direct current (DC) high voltage switching power supply with 95 m<sup>3</sup>/hr re-circulated air capacity. By apply the working of switching circuit that control the high voltage of flyback transformer # FB015. It can make energized with potential up to 9.77 kV<sub>dc</sub> for ionization part, ozone gas generation and dust collector part. It has been designed to remove dust or small particles with diameter in the range 0.2 micrometer. The simulation test result which have been done by drawing dust through the until have proven that the proposed small air cleaner can trap dust. Then the value of average mass efficiency of dust collector part is 97.5% and the efficiency is 97.5% using the handy laser partical counter (CLL). One-hour operating yields the maximum ozone generating capacity of 25 mgO<sub>3</sub>/hr.

**Key words:** ozonize, air cleaner, electrostatic, high voltage, electric field

## 1. Introduction

Polluted substances in the air are any kinds of substances which affect human's health of other creatures, the undesirable things of human or the substances those are directly or indirectly disadvantage to the human's living. There are many sorts of toxin or mingled things such as dust, particles and smoke for example carbonmonoxide (CO) sulfide's oxide (so<sub>x</sub>), nitrogen's oxide (NO<sub>x</sub>), lead (Pb) and radioactivity's dust, etc. These can cause harmfully to human, animals and plants if they are too much. This toxin may acate effect to be able to die. Some types have chronic Effect to be died later. The toxin may enter into the body by touching breath in or indirectly such as to mix with the food, stick on clothes, then transfer into bodies.

## 2. Theory

### 2.1 Electric Field

**Table 1 General size of atom.**

Substances	Biggest size (micron)	Smallest size (micron)
Dust	200	20
Cigarette smoke	1	0.01
Permanganate smoke	0.2	0.01

The breakdown field strength [1, 2], E<sub>b</sub>, for the small air cleaner is based on electric field, dielectric properties, pressure, temperature and so on. The employed electrode used in this germination comprises of dissimilar electric field strength in each point. The uniformity of electric field strength is depended on a figure of electrode. Electric field strength can be calculated by general equation as follow

$$E_{\max} = \frac{V}{d\eta^*} \quad (1)$$

when

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$\eta^*$  = field utilization factor which is defined that  $\eta^* = E_{av}/E_{max}$  The ordinary value of  $\eta^*$  is  $\eta^* \leq 1$   
 $E_{av}$  = average value of electric field (V/m)  
 $d$  = distance between each plate of electrode (m)

## 2.2 Movement of Object

Force is the pulling or pushing that performs on object. Force is vector which possesses both size and direction. Resultant force makes object movement with acceleration in force direction. Acceleration proportion with resultant force to mass of object as following [3]:

$$F = ma \quad (2)$$

hence,

$F$  = resultant force (N)

$m$  = mass of object (kg)

$a$  = acceleration ( $m/s^2$ )

Force taken place from electric field is the different of potential between two points. If a test is placed in electric field, the resultant force and direction of movement of dust is depended on two forces as following this:

$$\vec{F}_T = \vec{F} + \vec{F}_e \quad (3)$$

if

$\vec{F}_T$  = the resultant force (N)

$\vec{F}_e$  = the electric field force (N)

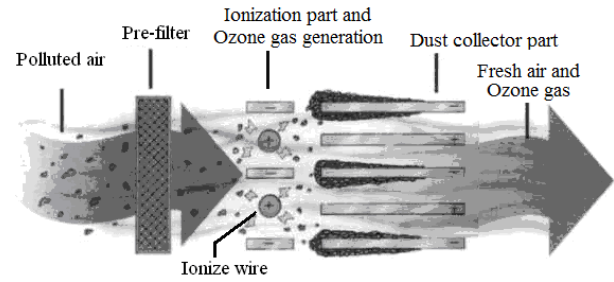
$\vec{F}$  = the motion force (N)

## 2.3 Structure of Ozone Gas Air Cleaner and Theories

Elements of the ozone gas air cleaner are

- Pre filter part
- Switching circuit part which controls high voltage directed current
- Electron separating series part using ionization principle and ozone gas generation part
- Dust collector part

For the general work as Fig. 1.



**Fig. 1** Diagram of ozonize mini air cleaner's working by applied uniform electric field.

## 2.4 Principle of Working

Ozonize mini air cleaner by applied electric field with high voltage directed current switching power supply is making the surrounding air to be the air cleaner by feeding the high voltage to the conductor that causes the high condensed electric field. When atom or molecule of air past, into inside, the air will be ionized. The dirty air, for instance, dust smoke and pollution are mixed. When they are into the air cleaner, this air will turn through pre-filter which is perculated the dust or the front big atom mingling things. Then this air is given the energy with high condused electric field til to be ionization and occur electric changing to the dust. After that, the electric charged dust will move to touch on collector plates which have the opposite electric charged. And there will get the clean and clear out of dust, particles, and smoke. In general air, has the quantity of dust smoke and diseases mixing in the air, so if we pass the air to be ionized with high voltage electric circuit, the dust will get the electric charged and move to perch beside the collector. So the air we breathe, is clean with atom and diseases to make our health get better.

## 2.5 Ionization Part

From the principle of occurring ionization phenomenon that the atom in gas have higher energy when there is high conduced electric field falling through gas. And when atom or molecule of gas has got enough energy, electron in atom or molecule will break and be able to out of the neutron molecule to be

positive ionizer, and when the strength of the electric field is static, the ionization will be taken place when

$$W \geq W_i$$

$$W = e \times E \times \lambda_i \quad (4)$$

When

$W$  = energy in separating electron (eV)

$W_i$  = energy that causes the ionization (eV)

$e$  = electron's charge =  $1.602 \times 10^{-19}$  (coulomb)

$\lambda_i$  = distance between gas (m)

$E$  = electric field (V/m)

So, the designing of electron separated set is based on the ionization by transferring the positive high pressure directed current to aluminium plate, then, it's connected to ground (negative pole) of switching the high pressure directed current power to another aluminium plates, there will have high condense between aluminium plate's positive and negative poles which make the atom in gas receiving the energy and the higher energy until to be the ionization phenomenon or the breaking of electron from atom or gas molecule. The breaking electron will move towards the positive electrode plate in accelerating rate value 1. One of this moving electron will cash with the other air's molecule to cause the continuous ionization phenomenon, the result is a great deal of positive ionization which, moves to the opposite power ground electrode plate, the negative poles. While the moving of this positive ionizer is crashing and attaching with atom of dust those move through this electric field, cause these atom and dust to also have positive pole. One of the very important conditions of trapping dust is the using as much as charging atom without the breaking down it may cause the very low efficiency in trapping dust charging of suspending atom in the air.

## 2.6 Field Charging

The field charging is advantage to the bigger atom than 0.25 micron. This type of charging, the charging lines will move across with particles. The ion that moves along electric field line will crash with atom

and is caught with image charge force, When the amount of crashed of ion with particles is moved and more, the quantity of atom will increase until saturation charge, the field charging on the atom will be equal with the outside electric field, the assumption is round atom and field charging from atom which are charged, are no effect to electric field to charge others and atom suspend always in field charging

$$q_s = 12\pi a^2 \epsilon_0 E_0 \quad (5)$$

When

$q_a$  = fully charging on atom in (coulomb )

$a$  = ray of article (m)

$\epsilon_0$  = Permittivity of Free Space =  $8.85 \times 10^{-12}$  F/M

$E_0$  = Density of charging field

Since  $q_s$  varies on the size of atom to square, the sizes of atom are important variances that set the Electrostatic filling and the time of atom use for being fully charged will vary on the Noion's density in charging area and the equations are:

$$q_{(t)} = q_s \cdot \frac{1}{\left(1 + \frac{\tau}{t}\right)} \quad (6)$$

When  $q_{(t)}$  = charging on atom at  $t$  time in (coulomb)

$$\tau = \frac{4\epsilon_0}{(N_0 e \mu)} \quad (7)$$

$t$  = time starts from charging in second

$N_0$  = the coudmsity of free ion ( $-/m^3$ )

$e$  = Electron charging =  $1.602 \times 10^{-19}$  in coulomb

$\mu$  = Ion's mobility =  $0.00022$  m<sup>2</sup>/volt – sec

The above Eq. (3) the charging to conducted atom. In case of the atom is not conductors, they calculated by multipling the fully charging equation  $q_s$  multiplier  $\epsilon/(\epsilon+2)$  [1] when  $\epsilon$  is the Constant of dielectric of Negative atom and the fully charging equation for general atom is:

$$q_s = 12 \frac{\epsilon}{\epsilon + 2} \pi a^2 \epsilon_0 E_0 \quad (8)$$

and the equation of charging to time is :

$$q_{(t)} = 12 \frac{\epsilon}{\epsilon + 2} \pi a^2 \epsilon_0 E_0 \frac{t}{t + \tau} \quad (9)$$

### 3. The Process of Generate Ozone Gas

Air has 79% nitrogen to be the main factor ( $N_2$ ) and apporximatly 21% of oxygen ( $O_2$ ). The rest is innurse and steam. Ozone is the gas that is consisted of 3 atoms. Oxygen in unstable status, easily disperse up to the environmental condition and the density of the quantity of production. The procedures of production is consisted of the producing oxygen's free atom process, from oxygen's machine in the air. After that these free atoms will be together with oxygen molecule until causing ozone ( $O_3$ ) which is brought to use in industrial cured system. The occurring ozone process forms from 2 processes — ionization process and dissociation process. The spreading of the gas, ionization is the decreasing of electron avalance leading to breaking down in passive which electric current is considered through the line. The late occurance is the heat since the current flows from the occurred breaking down causing the low related energy ozone disintegrating. So the ozone production should not be breaking down. That electron energy is received from power field should have less power than ionization energy but enough power to separate the oxygen atoms.

### 4. Design and Construction of Ozonize Mini Air Cleaner by Applied Electric Field

#### 4.1 Ionization Part and Dust Collector Part

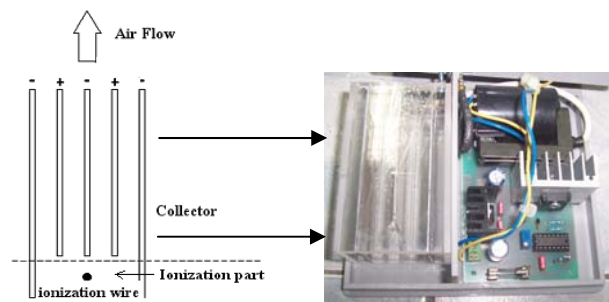


Fig. 2 Ionization part and collector part.

#### 4.2 The Calculation of Energy for Generate Ozone Gas (Ozonize)

Energy using ozone gas generation

$$W = \frac{1}{2} \int \epsilon E^2 dv \quad (10)$$

$$E = \sqrt{\frac{2W}{\epsilon V}} \quad (11)$$

$$E = 16.27 \text{ kV/cm}$$

$$E = 19.129 \text{ kV/cm}$$

From Eq. (1),  $d = 0.5 \text{ cm}$ ,  $\eta^* = 20\%$

$$V_i = E_i \times d \times \eta^*$$

$$E_{\max} = 16.27 \text{ kV/cm}$$

$$V_i = 16.27 \text{ kV} \times 0.5 \times 0.2$$

$$V_i = 1.627 \text{ kV}$$

$$E_{\max} = 19.129 \text{ kV/cm}$$

$$V_i = 19.27 \text{ kV} \times 0.5 \times 0.2$$

$$V_i = 1.927 \text{ kV}$$

#### 4.3 Design and Construction of High Voltage DC Switching Power Supply Using Flyback Converter

The erection of high voltage DC switching power supply using IC#TL494 to erect pulse width modulation (PWM) to be the circuit of controller the switching device that use IGBT#MGW12N120D to be the equipment in conducting which has the speed of switch about 10 kHz. At last, the flyback transformer is passed to cause directed current high voltage as needed by erecting 1 level of 10 kV<sub>dc</sub>.

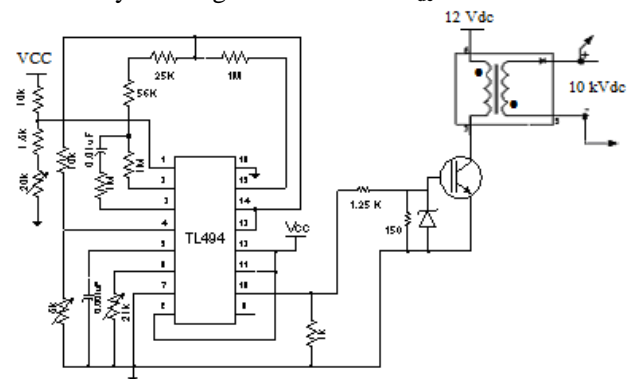
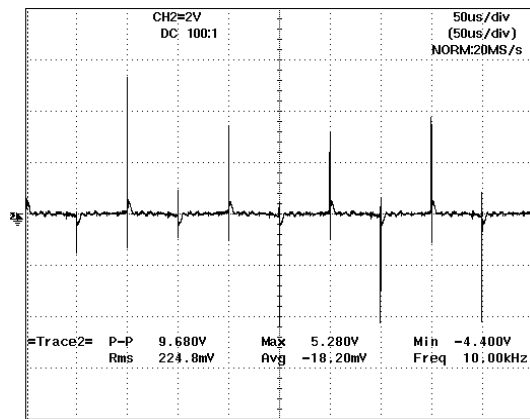


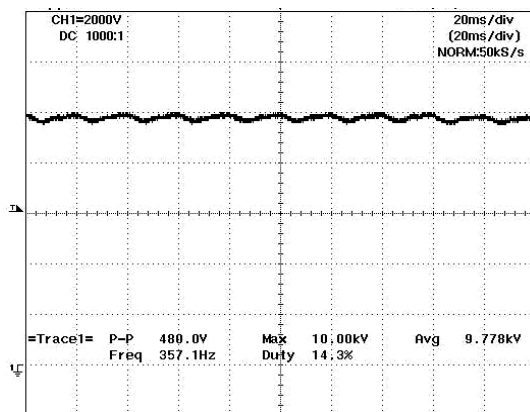
Fig. 3 DC high voltage switching power supply using flyback converter.

### 5. The Testing of Ozonize Mini Air Cleaner

#### 5.1 The Testing of High Voltage DC Switching Power Supply Using Flyback Converter



(a)



(b)

**Fig. 4** (a)  $I_G$  of IGBT and (b)  $V_{OUT}$  of flyback transformer at 10 kV<sub>dc</sub>.

### 5.2 The Testing Result of Ozonize Mini Air Cleaner

#### 5.2.1 The Testing of Function on Mass of Dust Collector

For studying and testing the function on mass of dust collector using atom of powder in about 0.3 micron in testing, and adjust wind velocity 95 cubic metre per hour

the testing equipment

- (1) 10 grams of powder
- (2) Digital weight ozone gas air cleaner
- (3) Ozone gas air cleaner

the steps of testing for the mass efficiency of dust collector part

- (1) Clean the dust collector part before testing
- (2) Weigh the powder for 10 grams
- (3) Spray the powder in to the dust collector part while the small air cleaner is operating

(4) Knock the dust collector part for weighing the powder from the dust collector part

(5) Repeat testing as step 1 to 4 until 10 times

From the result of the testing as Table 2, the value of average mass efficiency of dust collector part is  $(95.7+92.3+99.1+97.2+94.8+96.1+97.5+98.4+99.3+97.9)/10 = 96.8\%$ .

#### 5.2.2 The Testing of the Value of Efficiency of Dust Collector Part Using Handy Laser Partical Counter (CLL)

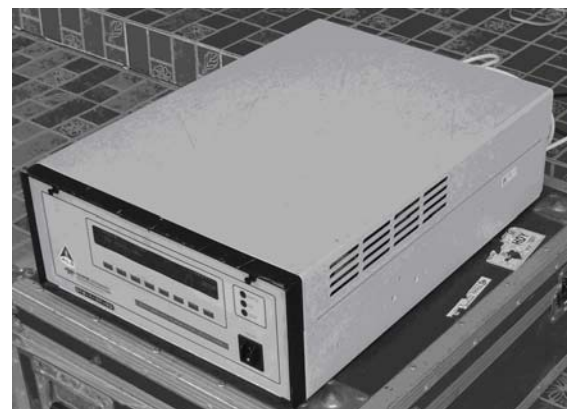
**Table 2** The result of testing for mass efficiency of dust collector part.

Order	Weight before fixing to dust collector (g)	Weight after fixing to dust collector (g)	Efficiency (%)
1	10.0	9.57	95.7
2	10.0	9.23	92.3
3	10.0	9.91	99.1
4	10.0	9.72	97.2
5	10.0	9.48	94.8
6	10.0	9.61	96.1
7	10.0	9.75	97.5
8	10.0	9.84	98.4
9	10.0	9.93	99.3
10	10.0	9.79	97.9

From the handy laser partical counter (CLL), the value of efficiency of dust collector part is 97.5%.

#### 5.3 The Result of the Testing of Generate Ozone Gas Quantity

Ozone gas quantity generation in ionization part at 10 kHz is 85 mgO<sub>3</sub>/hr



**Fig. 5** Ozone gas quantity analyzer.





Fig. 6 Ozonize mini air cleaner by applied electric field.



(a)



(b)

Fig. 7 (a) Probe x 1000 for high voltage measurement and (b) Handy Laser Partical Counter.

The testing of Ozone gas quantity analysis using Photometric O<sub>3</sub> Analyzer–Model 400E by ALS

Laboratory Group (Thailand) Co., Ltd as shown in Fig. 7.

## 6. Conclusion

Ozonize mini air cleaner enables to catch the dust in 0.3 micron which is the very tiny atom by mass efficiency is 96.8% and 97.5% using the handy laser partical counter) CLL) for dust measurement. Ionization part enables electric changing to the dust and ozone gas generation is 25 mgO<sub>3</sub>/hr. Switching circuit that controls the high voltage of flyback transformer#FB015, can use the duty cycle for adjusting the size of the high voltage as needed. There is a switch for discharging in electrostatic of dust collector part using magnetic contactor to prevent the danger from electric current for the user.

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