Non-thermal Plasma—Nanometer TiO_2 Photocatalysis for Formaldehyde Decomposition

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Abstract: In non-thermal plasma—nanometer TiO_2 photocatalysis, the techniques of photocatalysis and plasma are combined, and do not need ultraviolet light. It can make use of some kinds of energy in the process of decomposing, while at the same time producing much free hydroxide and improving the efficiency of decomposing. It is regarded as one of the most promising technologies in air cleaning.

A non-thermal plasma—nanometer TiO_2 photocatalysis purifier was placed in a stimulant air conditioning room, followed by pumping in a mixture of formaldehyde and air. The purifier was then turned on to carry on the static state experiment of decomposing formaldehyde. The INTERSCAN4160 analysis instrument was adapted to analyze the variety of the formaldehyde density in the room. The fan was turned on in the room to keep the diffusion circulating in the room and alter the velocity of the air and the density for the experiment.

The experiment shows that the efficiency of the decomposing formaldehyde in static state increased up to 90% after the Non-thermal Plasma—Nanometer TiO_2 Photocatalysis process. In an air-conditioned room, the purifier can decrease the density of formaldehyde effectively. The concentration increasing effect of decomposing is more promising.

Key words: Air cleaning Techonlogy; Non-thermal Plasma; TiO_2 Photocatalysis

1. INTRODUCTION

The volatile organic matter (VOCs) [1]is the main pollution source of indoor air, also the toxicity is extremely big, can lead to the unusual function of the central nervous system, the respiratory system, the reproductive system ,circulatory system and the immunity system. The formaldehyde belongs to VOCs .It is of great toxicity, and has been referred as the abnormal matter for the carcinogenicity, the allergy source which is commonly recognized, and one of the latent sudden-change leading matters by the World Health Organization. Therefore, indoor pollutant purification is imperative.

At present, the indoor pollutant purification includes: gas adsorption, gas filter, anion purifies, the low temperature plasma purifies, and the catalyzed purification and so on. But the sole purification technology has respective limitation [2~5], this article uses the low temperature plasma-nanometer TiO_2 photochemical catalysis and purification technology, which made the effective union of photochemical catalysis technology and the plasma effect, did not need the ultraviolet photo source, could use each kind of energy produced in the electric discharge process, at the same time produced the massive hydroxyl free radical, enhanced the degeneration efficiency.

2. PURIFICATION MECHANISM

The process of low temperature plasma -nanometer TiO_2 photochemical catalysis and purification of VOCs include: Plasma chemical reaction process, photochemical catalysis reaction process, plasma and photochemical catalysis synergism process.

The interior high-energy electron of low temperature plasma has non-elastic collision with the VOCs gas molecules, converts the energy into the internal energy of ground state molecules, has the process of stimulation, dissociation and ionization, enables the gas molecular to form high-activity granule: Ion, electron, excited state atom, molecule and free radical. This active granule's energy is higher than the key energy of the gas molecule. They have the frequent collision with the volatile organic matter molecules to cause the gas molecule breaking the chemistry key, dissociation until the volatile organic matter is directly resolved into harmless molecules. Because when active ion and free radical gaseous discharge ,some high energy stimulation granules can produce the ultraviolet light while jumping downward, but the TiO2 energy gap is 3.2eV, the corresponding light absorption wave length threshold value is 387.5nm, when the ultraviolet light wave length was equal to or is smaller than 387.5nm, electron on the TiO2 semiconductor valence band can be stimulated, to cross the forbidden band and enter the conduction band, at the same time produces the corresponding hole on the valence band. The conduction band electron and the valence band hole produced by photo excitation (also called light- sending electron and light- sending hole) has enough life before compounding. The light- sending hole has the very strong electronic ability, but the light- sending electron has strong reducibility. The pollutant in the catalyst surface unites with the free electron or the hole union, has the redox reaction, produces hydroxyl free radical ·OH of greater oxidization to oxidize pollutant into CO_2 and H_2O, thus to remove it, at the same time can effectively kill the bacterium virus. The low temperature plasma -nanometer TiO_2 photochemical catalysis and purification process is the technology of air purification ,which is under the united function of hydroxyl free radical, plasma, ultraviolet radiation. Compared with the pure nanometer TiO_2 photochemical catalysis, it does not need the ultraviolet photosource, can use each kind of energy produced in the electric discharge process, at the same time it produces massive hydroxyl free radical, enhances the degeneration efficiency. [6 ~ 12]

3. RESPONSE INSTALLMENTS

There are many kinds of low temperature plasma and the catalyst compound reactor .According to the mechanism structure, they can be divided into: packed bed type, line plate type, and compound -in type and so on. [13] This article uses self-made compounding reactor of the plate-type counter-structure, like chart 1 shows:

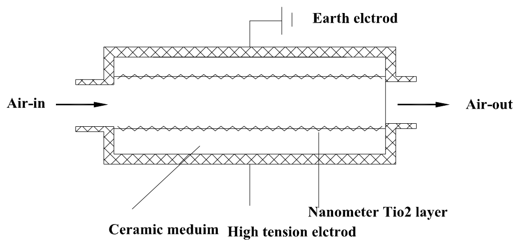

Fig. 1 The experiment equipment of purifier

The reactor uses the form of medium prevention electric discharge, covers the ceramic medium between the two electrodes, the ceramics act as the medium of electricity between the two electrodes, which enables the reactor to work under the high peak voltage but has not been penetrated. Using the method of soaking and the porosity on the ceramic surface to take the carrier,to spread nanometer TiO_2 in ceramics dielectric surface. The power output parameters used in the experiment are: voltage peak value 0 ~ 30KV, frequency 5 ~ 30kHz, electric discharge gap 10mm, effective discharge length 15cm.

4. EXPERIMENTAL METHODS AND RESULTS

4.1 Experimental materials

The self-made low temperature plasma -nanometer TiO2 photochemical catalysis purifier, the INTERSCAN4160 formaldehyde cryoscope, the closed casing body simulation air conditioning room which is of $6.75m^3$ (room temperature is 19 ~ 25 ℃, relative humidity is 65%), in the room lays aside a ventilator, a typhoon machine at the leaving air grille.

4.2 Testing methods

In this article, the low temperature plasma -nanometer TiO_2 photochemical catalysis purifier is put in a 1.5m×1.5m×3m simulation air conditioned room, where some mixture of the formaldehyde and the air is input in. Make sure the air in the room is even with the ventilator. Measure the initial density of the formaldehyde with the formaldehyde cryoscopy. Start the purifier, and measure the density of formaldehyde every 5 minutes. Compute purification efficiency according to formula (1).

$$\eta = \frac{C_0 - C_1}{C_0} \times 100\% \quad (1)$$

In the formula:

η —purification efficiency;

C_0 —initial gas density before purification;

C_1 —gas density after purification.

Start the air blower, change the formaldehyde gas velosity, the initial density, then measure the gas density after purification.

4.3 Results analyses

The peak voltage is 20KV, Input the formaldehyde gas, of which the initial density is 55mg/ m^3, close the air blower, start the ventilator to make the gas in the room to be even , then close the ventilator. Start the purifier, carries on the formaldehyde static state degeneration experiment; record the formaldehyde density change in the room with the INTERSCAN4160 formaldehyde analyzer. The purification efficiency of the formaldehyde gas changes with time under the low temperature plasma and the nanometer TiO_2 photochemical catalysis compound purification, which is showed by the curve in chart 2:

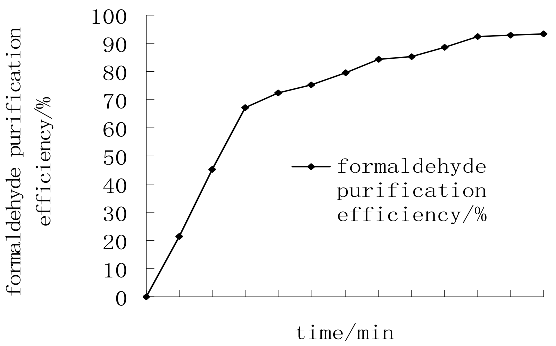

Fig. 2 Indoor static purification effect of formaldehyde

We can see from the picture that the purification efficiency basically tend to be stable 25 minutes later, and the finally purification rate may reach above 90%. Obviously, this technology has a good purification effect to the formaldehyde gas.

Start the air blower, change the air velocity in the room. Chart 3 shows the purification effect of formaldehyde under the density to be 55mg/ m3 and different air velocity:

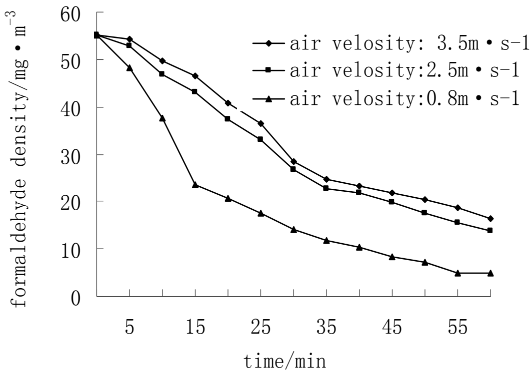

Fig. 3 Purification effect of formaldehyde gas under different wind speed

Like chart3 shows, the formaldehyde gas purification effect is weaken with the wind speed increased, mainly because the wind speed increases, the time of gas pauses in the purifier shortens, therefore in unit time, unit area the molecular number increases, while when U is assigned, the number of the high energy electronic and active grain of fraction produced by plasma is certain, the number of formaldehyde molecular which could be degraded achieves saturated, therefore the purification efficiency will decrease with the gas velocity increased.

The peak voltage is 20kV, start the air blower, when the wind speed is 0.8m/ s, change the initial density of formaldehyde gas. The changing rate of the gas purification efficiency with the time like the chart below shows.

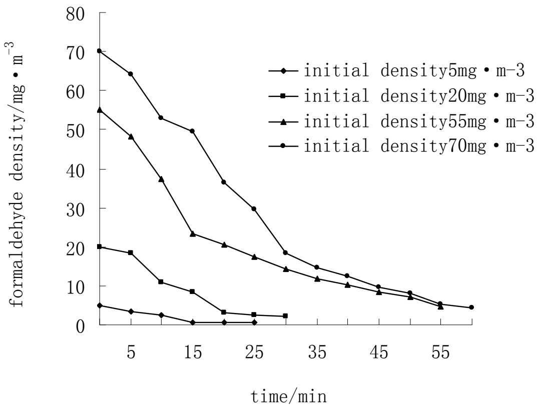

Fig. 4 The formaldehyde gas purification effect under different initial densities

We can see from the chart that, the low temperature plasma -nanometer TiO2 photochemical catalysis may effectively degrade the dynamic formaldehyde gas.

5. CONCLUSIONS

After the function of plasma -nanometer TiO2 photochemical catalysis, the static formaldehyde degeneration rate reaches above 90%; In the air conditioning room, this purifier can effectively degrade the mobile formaldehyde gas, and with the air velocity increasing, the formaldehyde degeneration rate reduces gradually.

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