Basic Research on carbon fiber in Discharge State

Yang Peng*

Department of Micro-Nano Electronics, School of Electronic Information and Electrical Engineering, Shanghai Jiao Tong University

*Corresponding author

Abstract. In order to solve the oxidation problem of the inner electrode in the pipeline reactor during decontamination, this paper proposes that carbon fiber was used as the pipeline structure of the inner electrode for plasma decontamination. The research results show that the reactor with carbon fiber as internal electrode can work for a long time and the decontamination effect will be enhanced. The decontamination efficiency of the experimental device by using ethyl acetate can reach 91%, and the experimental device was characterized by discharge state of discharge voltage and frequency in argon atmosphere, thus describing the process of discharge energy enhancement.

Keywords: Carbon fiber; Plasma; Positive feedback; Dielectric barrier discharge.

1. Introduction

As an example, gas incident on Tokyo subway [1], it was extremely high hidden, sudden and dangerous that released of toxic VOCs in densely populated enclosed public Spaces. Compared with traditional wet chemical decontamination [2], plasma washing has attracted extensive attention due to its high efficiency, rapidity and greenness. At present, low-temperature plasma technology is widely used in environmental protection. Dielectric Barrier Corona discharge (DBCD) is an important means to produce low temperature plasma at atmospheric pressure [3]. Dielectric barrier discharge (DBD) refers to the insertion of a solid insulating medium into the discharge space to suppress arcing [4], thereby forming a stable discharge in the air gap. The dielectric barrier corona discharge (DBCD) in a wire tube electrode configuration. In the traditional DCBD device, considering the conductivity characteristics of the electrode and the coaxial fixing problem, researchers choose all the metal electrodes [5], such as stainless steel, tungsten, copper, etc., at the same time, it was found that the wire tube structure would produce a large number of active groups in the space between the inner electrode and the insulating medium, and would produce solid oxides on the surface of the metal electrode, which could greatly affect the later Decontamination rate. Therefore, this paper proposes to use carbon fiber as the inner electrode of the wire tube structure, and studies its discharge state under different voltage and frequency.

2. Decontamination Test

The reactor which is mainly composed of a quartz tube and a stainless steel mesh is a wire tube structure. The quartz tube as the insulating medium layer has an inner diameter of 9mm, an outer diameter of 13mm and a length of 300mm. The 120 mesh steel mesh is evenly wrapped with quartz and connected with the ground wire. A 12K carbon fiber passes through the quartz tube, both ends of which are fixed by the copper tube in a clockwise rotation and connected to the high-pressure end. The effective discharge area of the reactor is determined by the external electrode to 200mm.

As shown in figure 1, the experimental device is powered by trek power supply, and the gas distribution system passes a mixture of pure air and ethyl acetate in a ratio of 4: 1 to the reaction chamber at a speed of 1
L/min. The GC (gas chromatography, GC) was used to detect the concentration of ethyl acetate in the air inlet and its air outlet to calculate the decontamination efficiency of the reactor.

Figure 1. Decontamination device.

Within the range of the power supply, using a voltage of 16.5kV and a frequency of 6.5kHz for a long-term decontamination test, the discharge decontamination effect will not only decline, but also will become stronger as the discharge time increases, as shown in figure 2. The maximum decontamination efficiency obtained was 91% and was as theoretically expected. The reason for the enhanced discharge may be that a single carbon fiber was burned out, resulting in a new tip that enhanced the effect of the discharge.

Figure 2. Long-term decontamination test.

3. Test of Discharge State under Argon Atmosphere
For VOCs that are difficult to dissolve, people will mix argon into the air to achieve the effect of combustion. The more the argon content, the greater the increase in spectral intensity. In order to investigate the discharge state of carbon fiber under different voltages and different frequencies, this article will pass 1L/min argon in the reactor, and use high-speed camera recording to characterize it. The test device is shown in figure 3.

Argon gas was fed into the reactor through the buck valve to reduce the flow rate to 1L/min with a constant frequency of 3kHz. The voltage was increased from 4kV to 10kV, and the reactor was rotated 90 degrees to repeat the pressurization process. As shown in figure 4, is the discharge state of each group voltage after the front and rotation of 90 degrees.
Figure 3. Schematic diagram of discharge state test under argon atmosphere.

Figure 4. Discharge status at different voltages.

As can be seen from figure 5, the discharge state in argon atmosphere is Lingers discharge. With the increase of voltage, new Linger is generated and the original Linger is strengthened. In addition, it can be clearly observed that when the Linger bombards the surface of the dielectric layer, it will become the discharge filaments scattered on the surface of the dielectric layer. When the voltage reaches 10 kV, the discharge filaments almost cover the entire inner wall.

The flow rate of argon is reduced to 1L/min through the pressure reducing valve, and then it is fed into the reactor. The voltage is constant at 4kV, and the frequency is increased from 4kHz to 9kHz. Similarly, the reactor rotates 90 degrees, and the frequency conversion is repeated. The test results are shown in Figure 5, which are the discharge state of each group of voltage after the front and rotation of 90 degrees.
As shown in figure 5, with the increase of frequency, no new Linger will be generated, but the existing Lingers will be strengthened. It can be clearly observed that a large coverage area can be formed on the surface of a single Lingers bombarding the dielectric layer.

4. Discussion
The mechanism of low-temperature plasma to remove VOCS is complicated and involves many chemical reactions [6]. The plasma contains a large number of strong oxidizing active groups O *, OH *, etc. These active substances can completely mineralize VOCS molecules into CO2, H2O. Carbon fiber filament is an internal electrode that can work for a long time in the wire tube structure. It does not reduce the discharge intensity because of solid oxides on the electrode surface. The state of discharge will even be strengthened because the carbon fiber filaments burned out during the discharge process form new tip.

The phenomenon observed in Wei Heng's [7] experiment was directly proved by the decontamination experiment with argon. Why is the decontamination effectiveness with high frequency and low voltage only about half of that with high voltage and low frequency in the same reactor? The increase of voltage makes some points that could not meet the discharge conditions begin to discharge to enlarge the region for generating plasma in whole space, making the residence time of gas in the plasma region longer. VOCS gas molecules increase the probability of collision with the active substances in the plasma, increasing the degradation rate [8] . At the same time, the discharge filaments are increasing continuously, which also enhances the process. The ways of increase of discharge power and energy density in the discharge system were explained.

5. Conclusion
Carbon fiber is a feasible choice for internal electrode of wire-tube type. It can discharge for a long time without degrading its performance and has a positive feedback effect. The decontamination efficiency will gradually increase with time, with a maximum decontamination efficiency of 91%. The wire-tube structure and the process of discharge energy enhancement were observed by parametric sweep of voltage and frequency in argon atmosphere.

References
[1] Li Zhanguo, Hu Zhen. Prtection technology and protective equipment against the new chemical threat [J]. Chemical defense research, 2005(3): 54–58.
[2] A Yang Y C Baker J A Ward J R. Decontamination of chemical warfare agents [J]. Chem. Rev.1992 92(8) 1729–1743.
[3] Sun Y , Qiu Y , Yu F , et al. Application of DBD and DBCD in so2 removal[J]. Plasma Science and Technology, 2004, 6(6):2589-2592.
[4] Obradovi B M, Sretenovi G B, Kuraica M M. A dual-use of DBD plasma for simultaneous NOx
and SO2 removal from coal-combustion flue gas[J]. Journal of Hazardous Materials, 2011, 185(2-3):1280-1286.

[5] Jin Xinyu, Zhang Yu, Jiang Xuanzhen, Wang Rui. Analysis of electrode material effect on organic exhaust gas decomposition by pulse plasma [J]. China Environmental Science, 1998, 18(3):213-217.

[6] Dahiy a P, Mishra S, Veefkind A. Plasma chemical investigations for NOx and SO2 removal from flue gases[ J]. IEEE Trans on Plasma Science, 1993, 21(3):346-348.

[7] Wei Heng, Dong Xiaodan. Study on Removal of Ethyl Acetate by Dielectric Barrier Discharge (DBD) Low-temperature Plasma [C]. Shanghai Chemical Industry. 2018, 43(1):15-18.

[8] Guo Yufang, Ye Daiqi. Catalysis-assisted non-thermal plasma technique for exhaust gas control [J]. Techniques and Equipment for Environmental Pollution Control, 2003, 4(7):41-46.