33rd EPS Conference on Plasma Phys. Rome, 19 - 23 June 2006 ECA Vol.**30I**, P-2.086 (2006)

Characteristics of VOC treatment using secondary emission electron gun

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1. INTRODUCTION

It is well known that the emission of volatile organic compounds (VOCs) is a serious environmental problem. Due to more stringent limits imposed on VOCs emission, the development and characterization of VOCs control technologies has become an important issue. Various types of plasma devices have been employed for decomposition of VOCs. Recently, non-thermal plasma processes including pulsed corona discharge, dielectric barrier discharge, DC discharge and electron beam processes have offered an innovative approach[1]. The basic principle of these technologies is to produce plasma that introduces electron-impact dissociation and ionization of the background gaseous molecules. The free radicals and additional electrons caused by energetic electrons are useful to oxidize or reduce pollutant molecules. This process is in contrast to the use of thermal or catalytic oxidation and several chemical techniques which can treat lower concentration VOC streams.

We have developed a low-energy secondary emission electron gun (SEEG) using wire ion plasma source (WIPS)[2] for gaseous pollutant treatment. The devise has some inherentadvantages such as compact in size, wide and uniform electron beam. In present study, we studied characteristics of secondary electron beam in order to achieve main objective, which is to increase removal efficiency of VOCs using SEEG.

2. EXPERIMENT

Figure 1 shows schematic drawing of SEEG. This type of design is referred to as a side extraction type. The electron window is kept on the side orthogonal to the ion extraction window. Different from the conventional design, it can avoid the interaction between the electron beam and WIPS, also provide high quality beam during the operation. The advantage of SEEG is that simply configuring parameters of the pulse generator at WIPS discharge circuit easily modulates the pulse width and the repetition rate of the output electron beam. The pulsed power system is capable of delivering an output discharge

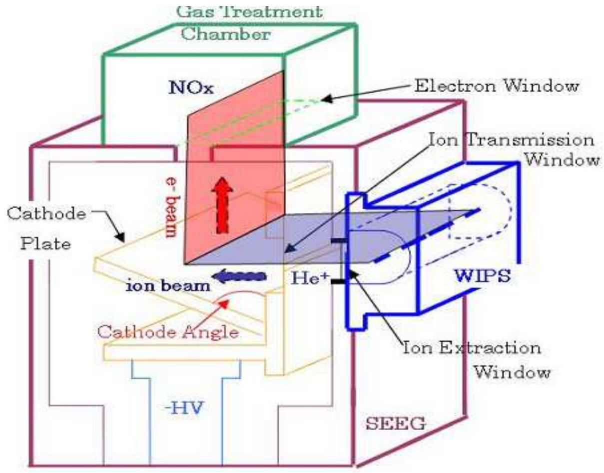

Fig. 1. Schematic diagram of SEEG

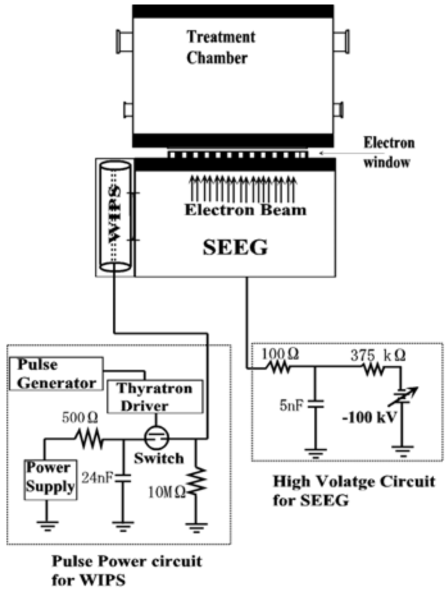

Fig. 2. Schematic diagram of power systems

voltage at 10 kV with pulse width of microsecond order at the repetition frequency up to 10 Hz in a continuous mode. Electron gun uses continuous negative biasing. A DC high voltage of negative polarity is applied to the cathode of the electron gun. Through the experiments, both WIPS and SEEG chambers were evacuated to a base pressure of under 0.026 Pa by vacuum system which consists of a rotary pump and a turbo molecular pump. They were then backfilled with 5 % of argon balanced helium gas until the pressure of both devices reaches 3×10-4 Pa. The gas pressure introduced to the gas treatment chamber is maintained at 1 atmospheric pressure during the process. Electron beam window takes a role as a vacuum seal which is located between SEEG and the gas treatment chamber. The aluminum honeycomb was placed over the electron window and below the silicon coated polyethylene polymer foil. The films used in this experiment were Gafchromic® Dosimetry Media, Type HD-810 produced by ISP Technologies INC. Exposure to ionizing radiation causes Gafchromic® dosimetry film to immediately change color and darken.

3. RESULTS AND DISCUSSION

An experiment to investigate the divergence of electron beam inside the chamber was set as showed below in Fig. 3. Figure 4 shows the electron beam energy density distribution along y axis as a function of distance from the window. As can be seen in Fig. 4, the divergence of electron beam increases first and gradually decreases when it is getting far

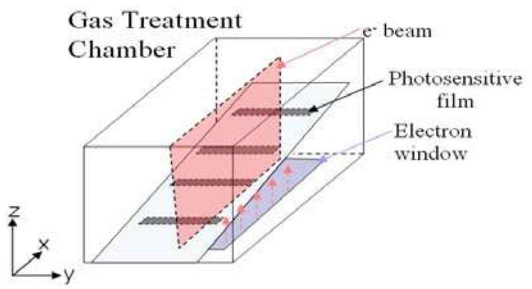

Fig. 3. Experimental setup to investigate divergence of electron beam

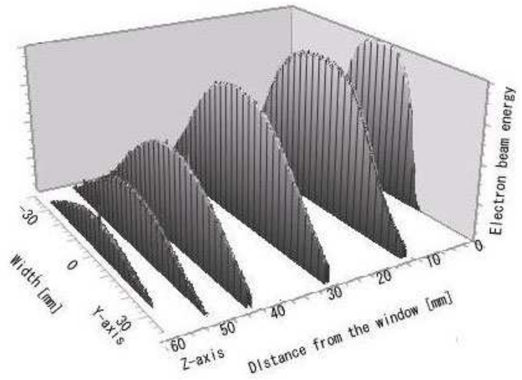

Fig.4. Electron beam energy divergence at applied voltage of 95 kV

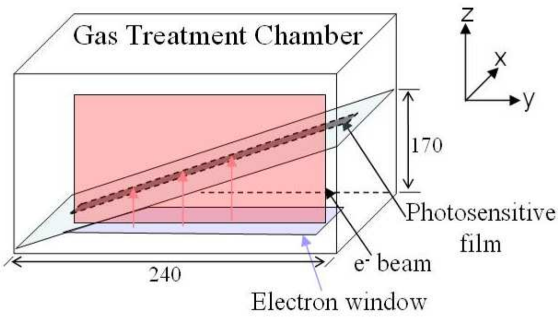

Fig. 5. Experimental setup to investigate penetration depth of electron beam

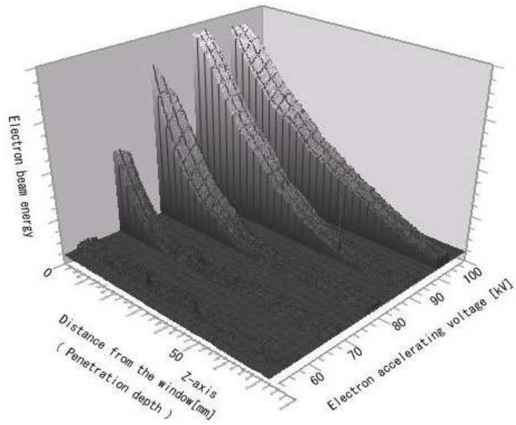

Fig. 6. Penetration depth of electron beam energy at applied electron accelerating voltage

from the electron window. Figure 4 may indicate that the electron beam energy concentrates near the central part of the beam.

An experiment was conducted to measure clearly the penetration depth of electron beam that occurred inside the gas treatment chamber during the treatment. The experimental setup for investigating penetration depth of electron beam is showed in Fig. 5. The experiment is operated at atmospheric pressure with 1 pulse of electron beam for each applied voltage from 60 to 100 kV. In this experiment, a photosensitive film was used for each applied voltage. The film was put on a board just above the electron window so that when irradiation of electron beam took place, it would hit the film effectively. The data of the electron beam energy from the film was then analyzed by Digital Array Viewer software.

The results are showed in Fig. 6. Electron beam filtered in through the electron window at 70kV and we cannot find a remarkable difference between the results at 90 kV and 100 kV compared to the difference between those at 80 kV and 90 kV. Therefore, energy loss at 100 kV is expected to be small.

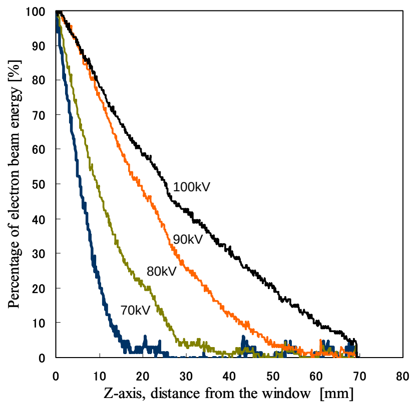

Fig. 7. Relationship of percentage of electron beam energy with penetration depth at various electron accelerating voltages

Figure 7 shows the percentage of electron beam energy as a function of penetration depth at various electron accelerating voltage from 70 to 100 kV. At 70 kV of electron accelerating voltage, the electron beam reaches the distance as high as 15 mm from electron window, and at 80 kV it achieves the distance of 30 mm from electron window, while at the electron beam energy of 90 kV and 100 kV, the penetration depth reaches 60 mm and 70 mm, respectively.

4. CONCLUSIONS

The penetration depth and divergence of electron beam were examined. Electron beam filtered in through the electron window at 70kV and it is expected that operating with electron accelerating voltage of 100 kV will decrease the energy losses in gas treatment chamber. In order to applied this device to VOCs treatment, it is necessary to examine more detailed energy distributions and to investigate the well-optimized parameters such as gun voltage, gas flow rate and chamber dimension.

ACKNOWLEDGMENT

This work is partly supported by Ministry of Education, Culture, Sports, Science and Technology, Grant-in-Aid for Scientific Research (B).

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