Ozone Generation Characteristics of Xenon Excimer Lamp

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Abstract: In this study, ozone generation characteristics of xenon excimer lamp has been investigated. Power consumption per unit of ozone generation at 0 % R.H and 100 % R.H were 14.9 kWh/kg and 30.7 kWh/kg, respectively. Power consumption per unit of ozone generation at 21 % O_2 in N_2 and 100 % O_2 were observed to be 14.6 kWh/kg and 11.0 kWh/kg, respectively. It suggested that water vapour and N_2 existence has influence on ozone generation efficiency by xenon excimer lamp.

Keywords: Xenon-Excimer-Lamp, Dielectric discharge, Vacuum-Ultra-Violet, Ozone.

1. Introduction

Ozone has usually been generated by atmospheric air discharge in large scale industrial application [1]. Although, Pressure-Swing-Adsorption (PSA) oxygen condensation is needed to prevent NOx generation [2], but PSA equipment takes high initial cost. Thus, atmospheric air discharge is not always stable for small scale and distributed ozone generator.

In this study, Xenon-Excimer-Lamp (XEL) was utilized for ozone generator. It emits Vacuum-Ultra-Violet (VUV), and ozone could be generated by VUV irradiation to the oxygen molecule without NOx production [3, 4]. To aim odor treatment by ozone catalytic oxidation, influence of relative humidity (R.H) and oxygen concentration on ozone generation characteristics of XEL was investigated.

2. Experimental Setup

Fig. 1 shows the schematic image of the XEL (Ushio Inc., UXFL95-172F). Xenon gas was enclosed in a quartz glass, and the electrodes were designated on both sides of the outer surface of the quartz glass. Applying pulsed high voltage using a power supply (Ushio Inc., PXZ170I20-E), a dielectric barrier discharge plasma was generated along with emission of VUV light. As shown in equations (1) – (3) [5], ozone was generated by irradiation of VUV light to the oxygen molecule.

$$\mathrm{O_2} + h\nu\ (172\ \mathrm{nm}) \rightarrow \mathrm{O}(^1\mathrm{D}) + \mathrm{O}(^3\mathrm{P}) \cdots (1)$$

$$\mathrm{O}(^1\mathrm{D}) + \mathrm{M} \rightarrow \mathrm{O}(^3\mathrm{P}) + \mathrm{M} \cdots (2)$$

$$\mathrm{O}(^3\mathrm{P}) + \mathrm{O_2} + \mathrm{M} \rightarrow \mathrm{O_3} + \mathrm{M} \cdots (3)$$

Fig. 2 shows the schematic image of experimental setup. XEL was stored in a Stainless-Use Steel (SUS) chamber. Distance between XEL and SUS chamber was 15 mm. Flow rate was set at 1.5 L/min, and ozone concentration was measured by ozone monitor (Ebara jitsugyo, EG3000B). Power consumption of XEL was measured by a high-voltage probe (Tektronix, P6015A), a current probe (Tektronix, P6021) and a digital oscilloscope (Tektronix, TDS2024B). Power consumption of XEL was set at 130 mW, to avoid surface temperature rising.

Specific power consumption was defined as energy consumption of XEL per ozone generation amount, and its unit is kWh/kg. Equation (4) shows calculation formula of specific power consumption E [kWh/kg] [6]. Room temperature; T = 25 [℃], power consumption of XEL; P = 0.13 [W], flow rate; Q = 1.5 [L/min], and ozone concentration C [ppm].

$$E\ [\mathrm{kWh/kg}] = \frac{273 + T}{3.51 \times 10^{-2}} \times \frac{P}{QC} \cdots (4)$$

To investigate influence of water vapour on ozone generation characteristics of XEL, specific power consumption was measured with varying relative humidity of air. Relative humidity was controlled by mixing dry air and wet air. Wet air was generated by dry air passing though distilled water.

The influence of oxygen concentration on ozone generation characteristics of XEL were observed. Specific power consumption was also investigated with varying oxygen concentration. Oxygen concentration was controlled by mixing pure oxygen and pure nitrogen. Relative humidity was set at 0 %.

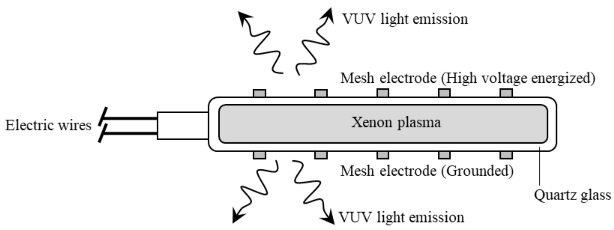

Fig. 1. The schematic image of the XEL.

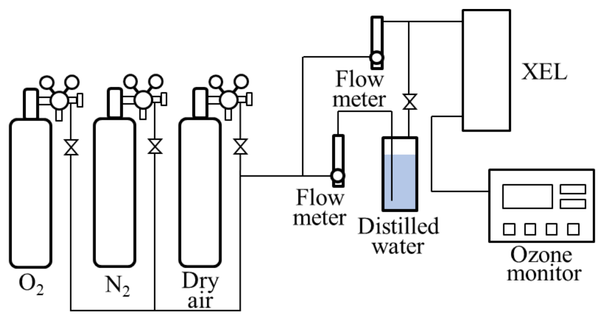

Fig. 2. The schematic image of experimental setup.

3. Results and Discussions

Fig. 3 shows specific power consumption versus relative humidity. When relative humidity was 0 % and 90 %, specific power consumptions were 14.9 kWh/kg and 30.7 kWh/kg, respectively. As shown in equations (5) - (8) [7], OH radical is generated by VUV irradiation to water vapour. And, OH radical decompose ozone. Thus, high relative humidity causes high specific power consumption.

$$H_2O + h\nu\ (172\ \mathrm{nm})\ \rightarrow \dot{O}H + \dot{H} \cdots (5)$$

$$\dot{H} + O_2 + M\ \rightarrow H\dot{O}_2 + M \cdots (6)$$

$$O_3 + \dot{O}H\ \rightarrow H\dot{O}_2 + O_2 \cdots (7)$$

$$O_3 + H\dot{O}_2\ \rightarrow \dot{O}H + O_2 \cdots (8)$$

Fig. 4 shows specific power consumption versus oxygen concentration. When oxygen concentrations were 21 % and 100 %, specific power consumptions were 14.6 kWh/kg and 11.0 kWh/kg, respectively.

As shown in equations (9) – (12) [8], oxygen atom, generated by VUV irradiation to the Oxygen molecule was captured by nitrogen molecule. And NO was decomposed by VUV irradiation. Finally, nitrogen atom is return to Nitrogen molecule. Thus, high oxygen concentration causes low specific power consumption.

$$O(\,^3P) + N_2\ \rightarrow NO + N(\,^4S) \cdots (9)$$

$$NO + h\nu\ (172\ \mathrm{nm})\ \rightarrow\ N(\,^4S) + O(\,^3P) \cdots (10)$$

$$N(\,^4S) + N(\,^4S) + M\ \rightarrow\ N_2 + M \cdots (11)$$

$$N(\,^4S) + NO\ \rightarrow\ N_2 + O(\,^3P) \cdots (12)$$

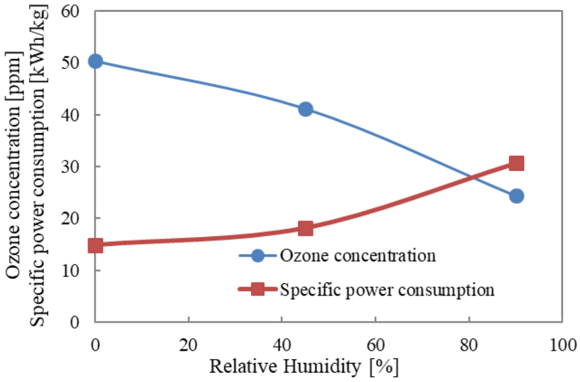

Fig. 3. Specific power consumption versus relative humidity.

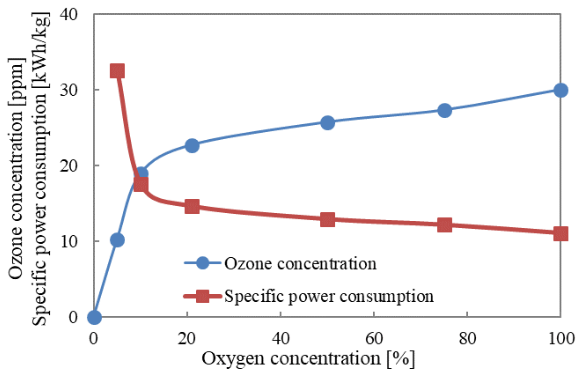

Fig. 4. Specific power consumption versus oxygen concentration.

4. Conclusions

By conducting series of experiments about ozone generation characteristics of xenon excimer, the following conclusions were obtained.

(1) When relative humidity was 0 % and 90 %, specific power consumptions were 14.9 kWh/kg and 30.7 kWh/kg, respectively. Water vapour disturb ozone generation because of VUV adsorption to the water vapour, and ozone decomposition due to OR radical.

(2) When oxygen concentrations were 21 % and 100 %, specific power consumptions were 14.6 kWh/kg and 11.0 kWh/kg, respectively. Nitrogen molecules disturb ozone generation because oxygen atom react with nitrogen molecule.

For small scale and distributed ozone generator, PSA oxygen condensation would not be cost-effective due to its initial cost. Dehumidifier such as desiccant would be cost-effective for XEL ozone generation.

5. References

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