1999 International Symposium on Electrical Discharge and Plasma (ISEDP 99)

Effect of the Change in Electrode Construction for the Improvement of Ozone Characteristic of a Superposed Discharge Type Ozonizer

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Abstract

In this paper a new discharge type ozonizer comprising the superpose operation of silent and surface discharge is presented. The ozonizer consists of two concentric glass tubes with three types of discharge electrodes : the external electrode(EE), the internal electrode(IE) and the central electrode(CE). By varying the structure of IE and materials of CE, we analyzed the characteristics of ozone related different parameters including O_{3con} , O_{3g}, and O_{3Y} . Using Cu made CE it was found that O_{3con} is higher with Cu tape than that with Cu coil wound IE. At Q = 1[l /min] the values of O_{3con} were found as 3000[ppm] with Cu tape wound IE and 1898[ppm] with Cu coil wound IE . Then using SUS wire made CE with Cu tape wound IE at Q=1[l /min] the maximum value of O_{3con} was found as 5632[ppm]. It was observed that both O_{3con} and O_{3Y} are higher with SUS made CE than that with Cu made CE. The maximum values of O_{3Y} were found as 79[g/kWh] with Cu made CE and 170[g/kWh] with SUS wire made CE.

1. Introduction

The main contributors to the environmental problems facing the world, such as acid rain, global warming, and smog are SOx, NOx, CO_2 and volatile organic compounds (VOC's) [1]. For water treatment such as sterilization, decolorization, deodorization, ozone is very useful. Ozone is one of the strongest oxidizing agents and it's important property is that it decays without residues that can be harmful to the environment. Also since the online production of ozone requires only air and electricity, there is no transport of potentially dangerous chemicals in the application of ozone. So, the fields of ozone applications are going on in increasing day by day. The researchers have been trying to design a large varieties of ozonizers [2~6].

The efficiency of a hybrid type ozonizer is higher in compared to that of a conventional ozonizer [7~8]. Considering all the above mentioned points we tried to develope a superpose discharge type ozonizer(SDO). When high voltage is applied between IE and EE with CE connected to ground, silent discharge is occurred in the space between the two tubes and surface discharge on the surface of the internal tube. The same types of discharges (silent and surface) are occurred if we apply high voltage between CE and IE with EE connected to ground. The combined effect of the two discharges causes higher performance of the device. O_2 was used as the source gas. Using SUS made CE with Cu tape wound IE, the maximum values of O_{3con} , O_{3Y} and O_{3g} were found as 5632[ppm] 170[g/kWh] and 753[mg/h] respectively. The corresponding values with Cu made CE were found as 3000[ppm], 79[g/kWh] and

471[mg/h] respectively. Fig. 1 shows the block diagram representation of the over all measurement process. Commercial oxygen gas

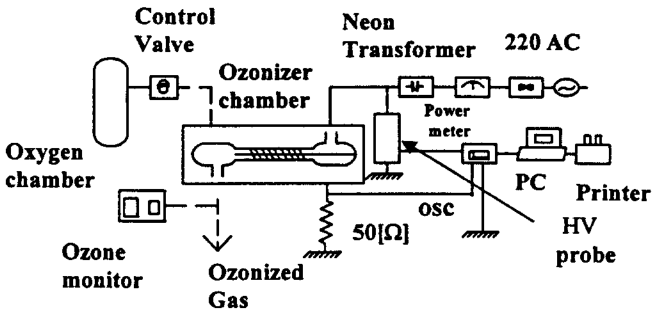

Fig. 1 Schematic diagram of the experiment process.

of 99.99[%] purity was used as supplied gas. The discharge voltage, Vd and discharge current, Id were measured by means of digital storage oscilloscope (500[MHz], 1[Gs/s]). The quantity of supplied gas was controlled by a flow meter [0 -24[ℓ/min]]. The ozone concentration of ozonized gas for gaseous phase was measured by using ozone monitor (0 - 110,000[ppm]). O_{3g} is calculated by using O_{3con} and Q. O_{3Y} is calculated by using O_{3g} and the discharge power W_d. Experiments were carried out by applying HV to IE and EE with CE connected to ground.

2. Theoretical Analysis

2.1 Ozone formation

When an electron is propelled to a high velocity and contains energy of 6~7[eV], an interaction between the electron and the oxygen molecule can take place to dissociate the oxygen molecule into two oxygen atoms. The rate of oxygen dissociation by electron impact depends on the energy distribution in the discharge region.

$$O_2 + \text{High energy electron} \rightarrow 2O + \text{Low energy electron} \quad \text{.....................(2.1)}$$

$$O + O_2 \rightarrow O_3 \quad \text{.............(2.2)}$$

$$K = 1.06 \times 10^{-34} \exp\left(\frac{510}{T}\right) \; [cm^3/s]$$

$$O + O_3 \rightarrow 2O_2 \quad \cdots\cdots (2.3)$$

$$K = 1.9 \times 10^{-11} \exp\left(\frac{-2300}{T}\right) \; [cm^3/s]$$

The oxygen molecule generated by ionization by electron collision in equation (2.1) reacts with other oxygen molecule to form ozone as shown in equation (2.2). Here the high speed reaction of equation (2.2) yields ozone concentration and ozone generation according to the current flowing in the microdischarge channel. If the reaction time of the oxygen atom in the discharge region of a silent discharge type ozonizer is lengthened, in spite of the increase in ozone concentration, ozone atom dissociates at a higher rate by either ionizing electron or oxygen atom similar to that shown in equations (2.5) & (2.6). This results in a saturation of ozone generation.

In the silent discharge operation ozone generation takes place mainly in the form of equation represented by

$$O + O_2 + M \rightarrow O_3 + M \quad \cdots\cdots (2.4)$$

Where M is the third collision partner.

2.2 Ozone decomposition

The decomposition reaction of ozone are mostly represented by the equations (2.5) and (2.6) as shown below.

$$e + O_3 \rightarrow e + O + O_2 \quad \cdots\cdots (2.5)$$

$$O_3 + M \rightarrow O + O_2 + M \quad \cdots\cdots (2.6)$$

3. Experimental Results and Discussions

Fig. 2 to 5 show the different characteristics of the ozonizer. Fig. 2(a) shows the comparison of O_{3con} and O_{3g} characteristics between Cu coil wound IE and Cu tape wound IE for Q=1[ℓ/min] while fig. 2(b) shows the same for Q = 2[ℓ/min]. At Q = 1[ℓ/min] as V_2 increases from 5.5 to 15[kV] O_{3con} rises from 133 to 1898[ppm] for Cu coil wound IE and from 325 to 3000[ppm] for Cu tape wound IE. At Q = 2[ℓ/min] with the same amount of voltage increase O_{3con} increases from 130 to 1516[ppm] with

Cu coil wound IE and from 191 to 2000[ppm] with Cu tape wound IE. The maximum values of O_{3g} were found as 357[mg/h] and 471[mg/h] for the two cases. Fig. 3 shows

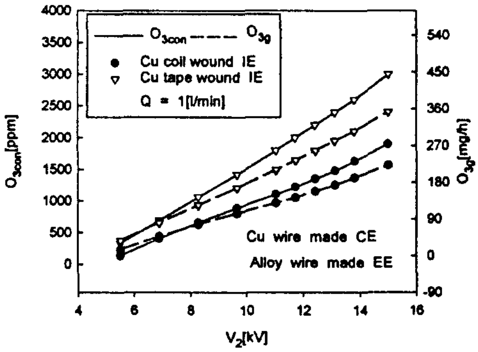

Fig. 2(a) O_{3con}-O_{3g} comparison for Cu coil and Cu tape wound IE for Q = 1[ℓ/min].

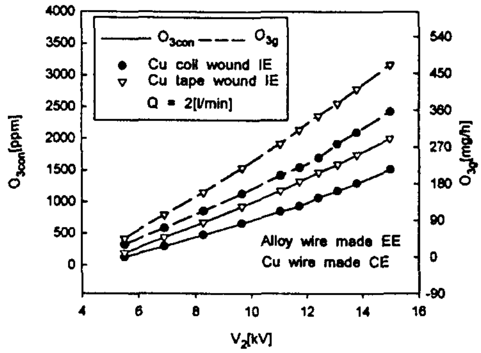

Fig. 2(b) O_{3con}-O_{3g} comparison for Cu coil and Cu tape wound IE for Q = 2[ℓ/min].

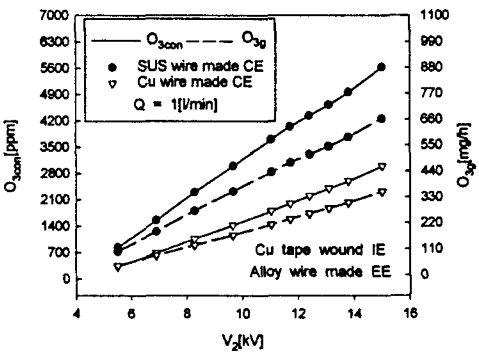

Fig. 4.(a) O_{3con}-O_{3g} comparison for Cu and SUS made CE for Q = 1[ℓ/min].

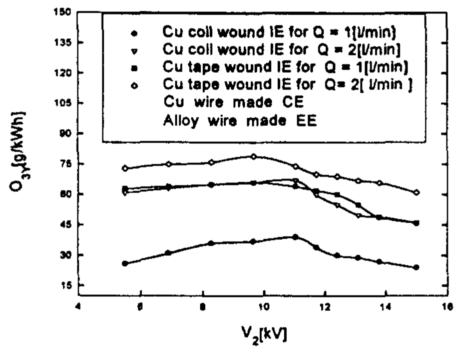

Fig. 3 O_{3Y} for Cu tape and Cu coil wound IE.

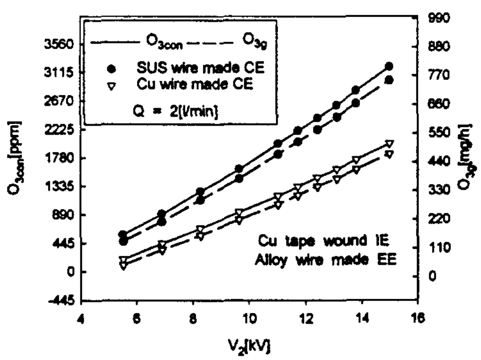

Fig. 4.(b) O_{3con}-O_{3g} comparison for Cu and SUS made CE for Q = 2[ℓ/min].

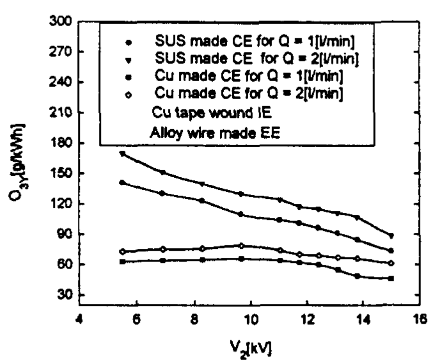

Fig. 5 O_{3Y} for SUS and Cu made CE.

the ozone yield characteristics for the two cases stated above. The maximum values of O_{3Y} were found as 67[g/kWh] with Cu coil wound IE and 79[g/kWh] with Cu tape wound IE. Fig. 4(a) and 4(b) show the comparison of O_{3con}-O_{3g} characteristics between the Cu made CE and SUS made CE for Q = 1 and 2[ℓ/min] respectively. With SUS made CE as V_2 increases from 5.5 to 15[kV] O_{3con} rises from 840 to 5632[ppm] for Q = 1[ℓ/min] and from 578 to 3200[ppm] for Q = 2[ℓ/min].Whereas with Cu made CE O_{3con} rises from 325 to 3000[ppm] for Q = 1[ℓ/min] and from 191 to 2000[ppm] for Q = 2[ℓ/min]. The maximum value of O_{3g} with SUS made CE was 753[mg/h]. Fig. 5 shows the ozone yield characteristics for the two cases. The maximum values of O_{3Y} were found as 170[g/kWh] with SUS made CE and 79[g/kWh] with Cu made CE.

4. Conclusion

1. Under the same condition of CE and EE the value of O_{3con} with Cu tape wound IE is higher than that with Cu coil wound IE. The maximum value of O_{3con} was found as 1898[ppm] for Cu coil wound IE and 3000[ppm] for Cu tape wound IE.
2. The value of O_{3con} with SUS made CE is higher than that with Cu made CE. The maximum value of O_{3con} was found as 5632[ppm] with SUS made CE and 3000[ppm] with Cu made CE.
3. The maximum values of O_{3Y} were found as 170[g/kWh] for SUS made CE and 79[g/kWh] for Cu made CE.
4. The maximum values of O_{3g} were found as 471[mg/h] for Cu made CE and 753 [mg/h] for SUS made CE.

Acknowledgement

The authors sincerely thank to the president of yeungnam university, Dr. Dong-In Lee and Dr. Kwang-Sik Lee for their assistance in obtaining the experimental data reported herein. Discussion with Dr. Hyun-Jig Song was helpful and appreciated

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