Influence of humidity on ozone concentration in negative corona discharge fed by oxygen

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Abstract

The ozone generation in negative DC corona discharge fed by pure oxygen has been investigated. The gas was flowing through the reactor at flow rate of 100cm^3/min. The influence of discharge power and humidity on the ozone concentration was studied. We have investigated the effect of large values of humidity on ozone concentration before and after the critical value of Becker parameter. Furthermore, the influence of the humidity on the current-voltage characteristics was studied too. The ozone concentration was measured by UV transmittance measurements.

Introduction

Corona discharge has been proven to be a reliable ion source for charging objects, such as particles or surfaces in electrostatic precipitators, photocopiers, and laser printers [1]. The production of ozone in the corona discharge is attributed to a series of gas-phase reactions driven by the energetic electrons created in the thin corona plasma layer [2], [3]. Numerous experimental studies by many researchers have examined the dependence of ozone production on the discharge polarity, current level, discharge electrode size, feed gas temperature, velocity, and relative humidity to seek methods to reduce the ozone production [4]–[10].

Experiments indicated that the electrical characteristics of negative coronas change with relative humidity [5] and the production of ozone decreases with increasing humidity [5], [9]. The underlying reasons for the reduction of ozone in the presence of water vapour are not clear.

Experimental apparatus

The experimental apparatus is shown in Figure 1. Discharge tube containing coaxial cylindrical electrode systems (a stainless steel inner electrode of diameter 125 μm and a brass outer electrode of diameter 16 mm) was used in these experiments. The active part length of the discharge tube was 6.5 cm. A regulator of humidity was placed between the discharge tubes and the oxygen-fed bottle. A DC corona discharge was generated in the discharge tubes. The same gas was closed in the comparative cell of the Shimadzu UV spectrometer, which was used to measure the optical transmittance of the gas contained in the discharge. The transmittance was recorded simultaneously with discharge voltage and current. In order to identify ozone produced in the discharge the UV spectrum of the discharge was monitored and ozone identified through the characteristic Hartley Band (centred at 254nm), ozone concentrations can then be derived using the well known Beer-Lambert formula. The ozone concentration was measured as a function of Beckers's parameter for different levels of humidity. The flow rate of the gas was maintained by mass flow controller at the level 100 cm^3/min. A Glassman high voltage power supply unit was used to provide power to the discharge electrodes. The discharge current and the voltage applied to the electrodes were monitored by two multimeters and recorded by computer. The current-voltage characteristics (CV) were measured. For each voltage value the transmittance of UV light (T) was registered. The experiments were carried out at atmospheric pressure. The O_2 of technical purity has been used in the experiments.

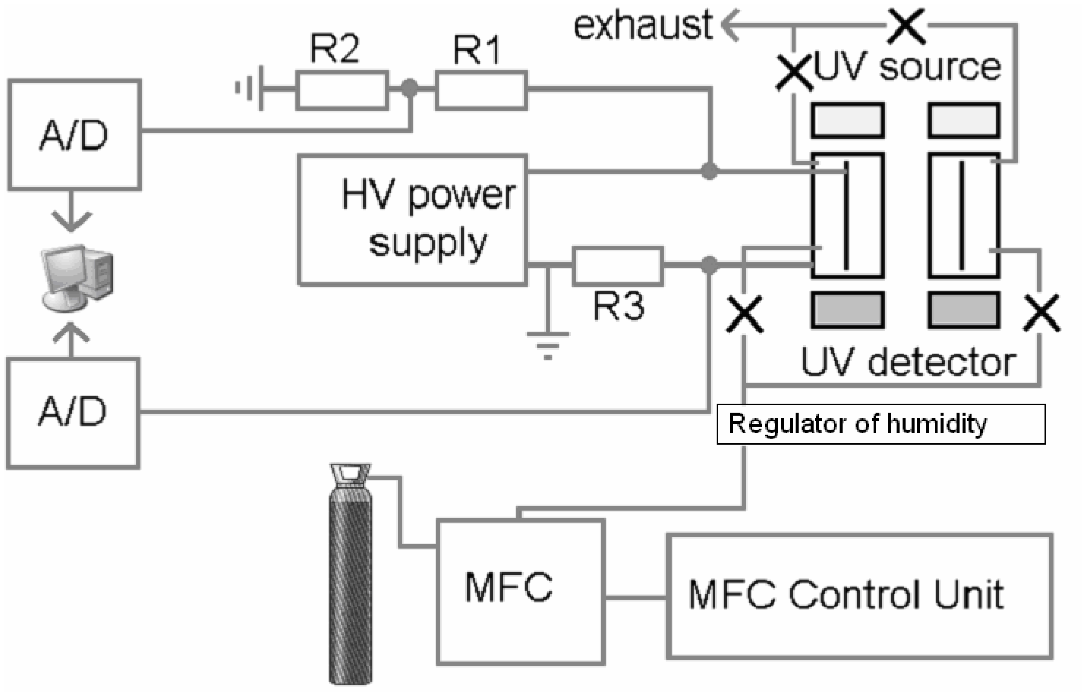

Fig. 1. Simplified scheme of the experimental apparatus.

Experimental results and discussion

The ozone generation in the discharge fed by pure oxygen is relatively simple two-step process. First, the diatomic oxygen is dissociated to the atomic oxygen in a dissociative electron attachment process

$$e + O_2 \rightarrow O^- + O. \quad (1)$$

The produced oxygen atom combines with oxygen molecules in a three-body process during which the ozone molecule is created and stabilized

$$O + O_2 + M \rightarrow O_3 + M. \quad (2)$$

The third body *M*, can be any species including a solid surfaces, such as the discharge electrode. The rate of reaction (1) depends on the reduced intensity of electric field *E/N*. The efficiency of reaction (2) is affected by the discharge parameters which can cause the decomposition of ozone molecules. Ozone dissociates according the reactions

$$O_3 \rightarrow O_2 + O \quad (3)$$
$$O + O_3 \rightarrow 2O_2. \quad (4)$$

Humidity also affects the ozone concentration, both by reacting with ozone molecules as well as by competing for the atomic oxygen radicals, thereby reducing the rate of generation. The presence of water vapour can dissociate ozone according to [9]:

$$O + H_2O \rightarrow 2OH^* \quad (5)$$
$$OH + O_3 \rightarrow HO_2 + O_2 \quad (6)$$
$$HO_2 + O_3 \rightarrow OH^* + 2O_2 \quad (7)$$

Where OH* is a highly unstable intermediate species.

In the Figure 2 there are dependences of ozone concentration on the Becker parameter for different water vapour concentration shown. The Becker parameter is the amount of energy put by the discharge into the gas volume and was calculated according to the formula

$$\eta = \frac{I.U}{Q} = \frac{P}{Q} \quad \{1\}$$

where I is total discharge current, U is voltage applied on the electrodes and Q is the gas flow rate. As it is shown in Figure 2, in our measurement the minimum ozone production was at the water concentration of 3000 ppm and with increasing humidity the ozone concentration increased, which is in contradiction with experimentally and theoretically obtained results of other authors [5,9], according which the production of ozone decreases with increasing humidity. Moreover, after a critical value of Becker parameter the ozone concentration begins to increase in case of all measured humidity.

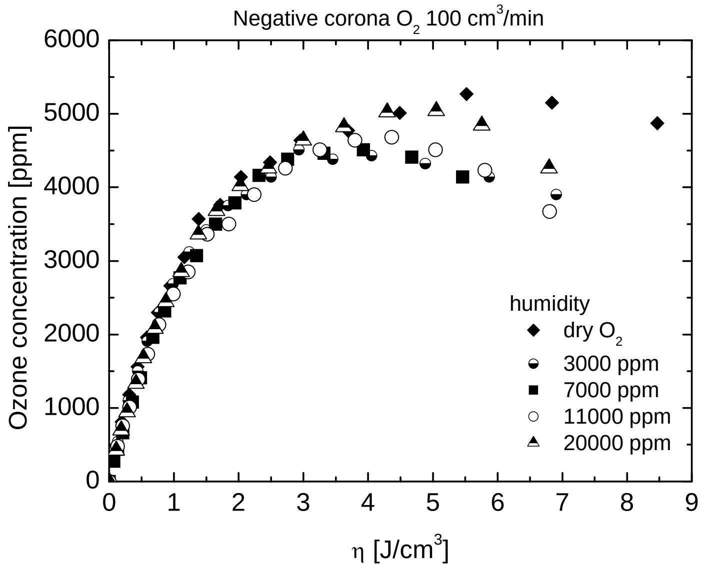

Fig. 2. Dependence of ozone concentration on Becker parameter in dry and humid oxygen.

In the Figure 3 there are the dependencies of discharge current on the applied voltage for different concentrations of water vapour. As it is shown, with increasing content of water vapour the discharge current is lower at the same voltages. It seems that the electron attachment increases with the humidity.

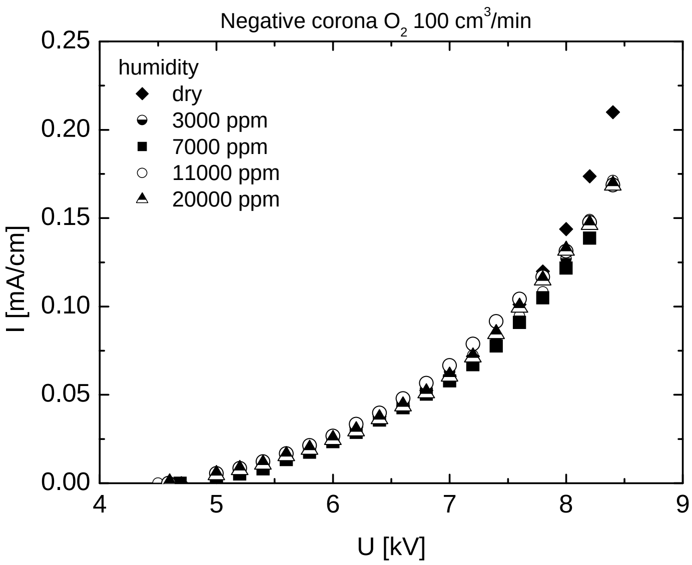

Fig. 3. Current-voltage characteristics for different contents of water vapour.

Conclusion

The ozone generation in negative corona discharge fed by oxygen for different contents of water vapour has been investigated. The influence of the humidity on the ozone production and decomposition was emphasized.

The finding of the other authors that ozone generation generally decreases with increasing humidity it was not confirmed. The ozone generation is most efficient in dry oxygen, at water concentration of 3000 ppm the ozone concentration decreased but with additional increasing of humidity the ozone begins to increase. The reasons of this behaviour of ozone generation in discharge fed by oxygen are not clear yet. There is necessary to carry out more experiments in wide scale of humidity to understand these processes.

Acknowledgments

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