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Direct plasma NOx reduction using single surface dielectric barrier discharge

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NO_x reduction using direct atmospheric barrier discharge in air-NO mixture at different voltages and flow rates is inversigated. Reduction rate of 80% is achieved at 3.18 W/cm^2 power density and gas mixture of 20 slm air and 0.006 slm NO. The ozone for NO reduction is produced by a honeycomb structured DBD with a total surface of 12.56 cm^2. The reduction process is investigated by FTIR spectroscopy, chemiluminsecence, mass spectrometry and optical emission spectroscopy.

Due to the negative impact of industrial NO_x emission through acidic rains on human health, several technologies have been developed in the last decades to reduce the amount of these harmful gases [1]. Among these technologies, non-thermal atmospheric pressure discharges and specifically, dielectric barrier discharges (DBDs) have received many interests due to their low operating costs, flexibility and modularity in terms of scale up possibility or combination with other techniques [2]. DBDs have been studied for NO_x treatment either as ozone production source in indirect NO reduction or direct plasma treatment. However, using direct plasma still requires more investigations to understand the process of NO_x reduction [2, 3]. This work investigates ozone production in a novel configuration of a single surface DBD reactor for different levels of input power as well as gas flow rates. The results of direct plasma treatment of NO are discussed.

The experimental setup includes a seven-meter long reactor designed in a serpentine configuration with several gas sampling ports for FTIR spectroscopy, mass spectroscopy, chemiluminscence measurements and ozone monitoring [4]. The reactor has a flexible and exchangeable mixing zone which enables flue gas treatment either by feeding ozone gas from the ozonizer or by direct plasma treatment. In the latter case, the required ozone for NO reduction is produced by air DBD in the mixing zone. The mixing zone, which is connected to the reactor is schematically shown in Fig 1. The DBD cell is produced by Kyocera and consists of two perforated parallel electrodes (honey comb configuration) with 40 mm diameter (1256 mm^2) and 615.8 mm^2 total opening. One of the electrodes is completely embedded in a ceramic dielectric. The dielectric thickness between electrodes is 0.6 mm. The electrodes are connected to an AC power supply which delivers up to 13 kV at 15.5 kHz.

The plasma is generated close to the uncovered electrode and extends approximately 1mm in front of the electrode surface. Due to the transverse flowing gases in this configuration, there is no

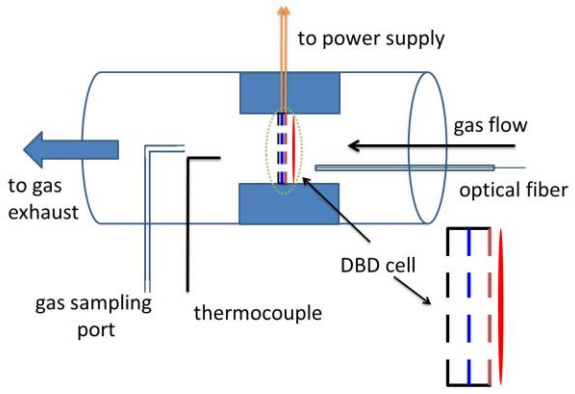

Fig. 1: The experimental setup for ozone generation and NO reduction.

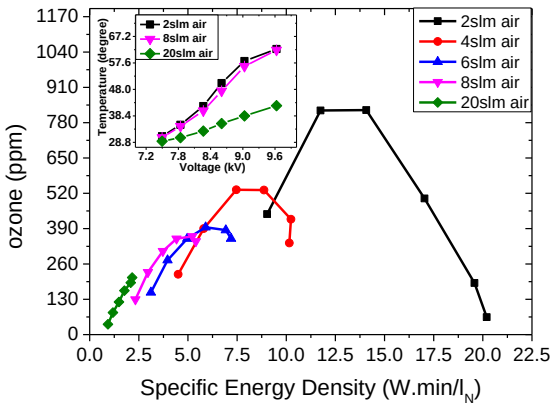

Fig. 2: Produced ozone for different flow rate vs specific energy density. The measured gas temperature is shown in the insert figure.

possibility for direct cooling, which is a disadvantage for operation at low flows but a big advantage for treating flue gases with large particles, as in the case of biomass power plants.

The measurements were carried out at the sampling port located 70 cm away from the discharge zone. The ozone concentration is measured by BMT ® ozone sensors. NO and NO_2 are measured using a chemiluminiscence device (CLD 62 manufactured by Eco Physics ®). The output gas composition is monitored by FTIR model MB-100 from BOMEM.

Fig. 2 shows the evolution of produced ozone at different air flow rates with respect to the specific input energy (SIE) which represents the energy per molecule and calculated by power/flowrate [5]. The experiemantal results show that at a fixed flow rate, the ozone concentration increases with SIE increases. More increase in the SIE, especially for lower flow rates results in a decrease in the ozone concentartion. This effect is attributed to the temperature rise which is confirmed by temperature ascent with respect to voltage increase (shown in the insert figure). These effects led to an increase in the ozone decomposition and nitrogen oxides formation [5]. Additionally, the cooling effect of the flowing air is prominent for higher flow rates. For instance, increasing the voltage from 7.5kV to 9.6kV results in 12 and 32 degrees temperature differences at 20slm and 2slm airflow, respectively.

As reported in [3] a reduction rate higher than 95% can be achieved for a molar ratio of O_3:NOx slightly below 2. Therefore we choose a ratio O_3:NO of approximately 2. As it can be seen from Fig. 2, applying 8.5 kV results in 200 ppm ozone at 20 slm flow rate. We obtained 72 ppm of NO and 160 ppm of NO_x at the sampling port located at 70 cm away from DBD cell with the gas mixture of 0.006 slm NO and 20 slm air. Fig. 3 shows the time evolution of NO at voltages of 7.5 kV and 8.5 kV from an initial NO level of 72 ppm. As expected, due to the quick reaction oxidation of NO to NO_2, the NO level declines quickly to 57 ppm and 24 ppm at 7.5kV and 8.6kV respectively.

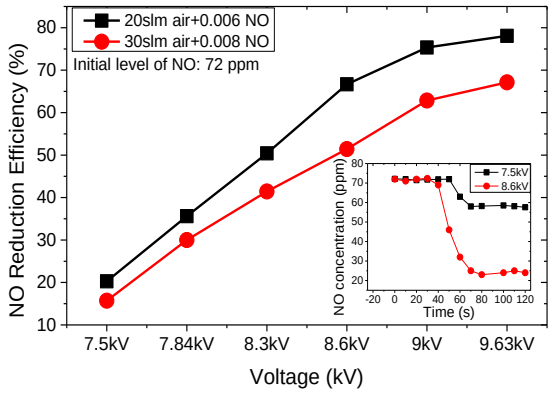

Fig. 3: NO reduction efficiency with respect to peak to peak voltage. The insert figure shows the time evolution of NO concentration at discharge voltages of 8.6 and 7.5kV.

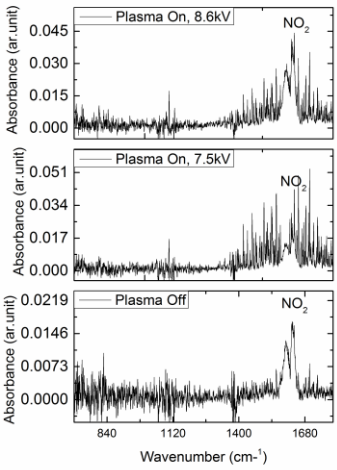

Fig. 4: FTIR spectrum before and after plasma operation.

Fig. 3 shows that the NO reduction efficiency increases as the peak-to-peak voltage decreases. This is attributed to higher initial level of produced ozone leading to a higher value of NO_2. The FTIR spectroscopy results (Fig. 4) confirm NO conversion to NO_2.

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