EXPERIMENTAL STUDY OF DIELECTRIC BARRIER DISCHARGE IN MIXTURES OF CARBON DIOXIDE AND OXYGEN

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Carbon dioxide decomposition in mixtures of CO_2 and O_2 has been experimentally investigated using dielectric barrier discharge, with special interest on O_3 and CO productions. Experiments have been conducted at different frequencies and operating voltages, and the concentration of O_3 and CO have been measured by means of absorption spectroscopy in the UV and in the IR regions. According to the observations, the production of both species can be substantially increased by adding molecular oxygen to carbon dioxide, even in small proportions.

Keywords: dielectric barrier discharge (DBD); carbon dioxide; oxygen; carbon monoxide; ozone.

1 Introduction

Carbon dioxide emissions constitute a great concern because of its implications for the global temperature rise of Earth. Therefore, member countries of the Intergovernmental Panel on Climate Change (IPCC) have agreed to impose more stringent restrictions on CO_2 emissions to the atmosphere in the coming year. In this scenario, reprocessing of CO_2 emissions by plasma treatment can help to mitigate this problem, while producing valuable chemicals for the industry, such as ozone and carbon monoxide [1-3]. However, direct production of ozone from carbon dioxide gives poor results, due to the absence of enough molecular oxygen in the background gas. Therefore, in this work we explore the possibility of increasing ozone production by mixing carbon dioxide with small amounts of oxygen.

2 Experimental

The DBD reactor consisted of two stainless steel circular electrodes, 20 mm in diameter, covered with fused silica glasses of 1 mm of thickness. The gap between the two dielectrics was fixed at 2 mm. High purity CO_2 (99.995%) and O_2 (99.995%) were used to prepare the gas mixture, and the total gas flow was kept constant (Q = 100 cm^3/min) with the help of digital mass flow controllers (Alicat). High voltage (20 kVpp to 24 kVpp) was applied to one of the electrodes using a high voltage amplifier (Trek 20-20C-HS). The frequency of the AC voltage was varied in the range 50-500 Hz. The other electrode was connected to a monitor capacitor (C_m = 1 μF), and the voltage drop across the capacitor was measured using a digital oscilloscope (Tektronix DPO7254). The concentration of ozone and carbon monoxide in the effluent gas was sampled periodically using UV/VIS and IR spectrophotometers (Thermo Evolution 300, Bruker Vertex 70).

2 Results and Discussion

Figures 1 and 2 show the measurements corresponding to ozone and carbon monoxide productions as a function of the averaged energy density, P/Q, where P is the averaged

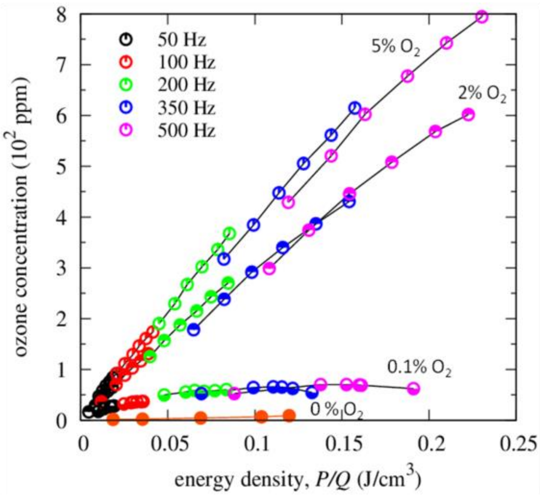

Fig. 1: Ozone concentration as a function of the energy density for different ratios of O_2/CO_2 in the gas mixture.

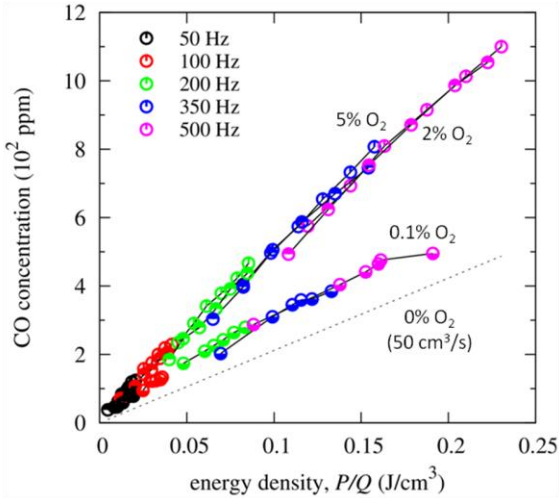

Fig. 2: CO concentration as a function of the energy density for different ratios of O_2/CO_2 in the gas mixture.

electrical power and Q is the gas flow rate. Regarding ozone (Fig. 1), the admixture of oxygen boosts importantly ozone production with respect to the case of using 100% CO_2, even with admixtures of oxygen of the order of 5% or lower. Moreover, ozone production increases steadily with the augmentation of the energy density, except for very low oxygen admixtures (< 0.1 O_2) for which a saturation is observed. It is also interesting to compare the production of ozone in a mixture of CO_2 and O_2 with the one obtain in pure O_2: for a gas flow rate of 200 cm^3/min and using the same experimental set-up, it was found that ozone production in pure O_2 increases linearly with the energy density at a rate of 2×10^4 ppm/(J/cm^3). Therefore, using a mixture with 5% of O_2, the direct production of ozone due to the presence of O_2 can be estimated to be 10^3 ppm/(J/cm^3). However, according to the results shown in Fig. 1, the measured rate of ozone production is more than 3.5 times the expected value, due to the contribution of CO_2. Similarly to ozone, the addition of O_2 also favors production of carbon monoxide (Fig. 2) by, at least, a factor of two. Its concentration increases very linearly with the energy density and no saturation was observed in the range of tested energy densities.

4 Conclusion

The decomposition of CO_2 using DBD can be substantially increased by mixing CO_2 with O_2 in small percentages. In mixtures with 2-5% of O_2, the production of CO was doubled, as compared with pure CO_2. Moreover, the production of O_3 was three times higher than the one expected according to the proportion of O_2 in the gas mixture.

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