Preheating in 915 MHz CO2 Microwave Plasma: Looking into Heat Recycling in Plasma Systems

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Abstract: In this work we present an investigation of the influence of heated input flows on a CO_2 microwave discharge. Effluent composition, plasma size, thermal losses and plasma temperatures were investigated. Measurements show a significant increase in conversion efficiency with increasing injection temperature up to 700 K. Spectroscopic measurements show that the increase in efficiency is due to an increase in plasma volume.

1. Introduction

Microwave (MW) plasmas offer a promising approach for splitting CO_2 with high efficiencies, approaching the thermal limit of ~50% [1,2]. In these reactors the CO_2 is rapidly heated to temperatures of >3500 K dissociating the CO_2. A large part of the energy, not utilized in the dissociation process, is lost as heat energy in the effluent due to overheating of the CO_2 [3]. Recuperation of heat using a heat exchanger is a well-known method to increase process efficiency in industry, leading to the question whether or not there is a benefit in heat recycling in CO_2 plasma reactors.

2. Methods

Experiments took place in a 915 MHz MW plasma reactor equipped with WR975 waveguide components. An FeCrAl spiral heater was used to preheat the injection flow to temperatures up to 850 K. Conversion efficiencies were determined using gas chromatography. Plasma sizes were determined using the atomic oxygen 777 nm emission profile. Plasma temperatures were determined using optical emission spectroscopy, utilizing the C_2 Swan band. Thermal losses were measured using IR thermography.

3. Results and Discussion

Figure 1 shows energy efficiencies for 1172 W, 10 slm CO_2 plasmas at different pressures and injection temperatures, showing relative increases of 35 % at 500 K and 54 % at 700 K injection temperature when compared to room temperature injection. CCD imaging shows that the plasma tends to contract in the axial direction whilst growing in the radial direction when increasing the injection temperature with an overall increase in plasma volume, showing that the area of high temperature where dissociation can take place is likely increasing whilst the residence time decreases with higher injection temperatures. Spectroscopic measurements confirm that the area of conversion increases in the radial direction, giving an explanation of the increased conversions at higher pressures. Experiments injecting CO_2 at 850 K show lower conversion gains than experiments performed at 700 K, showing that there is diminishing returns as the peripheral flow heats up to beyond the point where it can effectively quench the hot central flow.

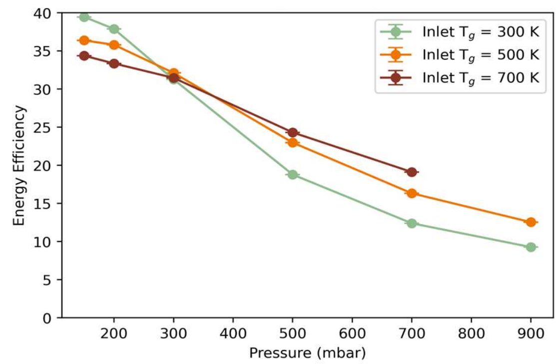

Fig. 1. Energy efficiencies for an 1172 W, 10 slm CO_2 plasma at different injection temperatures vs pressure.

4. Conclusion

This work presents results of a preheated 915 MHz CO_2 plasma reactor, showing increased energy efficiencies as a function of injection temperature. CCD imaging and spectroscopic measurements show that this increased energy efficiency is likely caused by an increase in area of conversion. Present work shows that heat recycling in CO_2 plasma reactors is a viable strategy for increasing the system level efficiency of these types of reactors.

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References

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