A compact portable power supply-driven dielectric barrier discharge and spark discharge plasma-assisted CO_2 conversion

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The utilization of greenhouse gas is of great significance for mitigating climate change and achieving the carbon neutrality goal. Direct dissociation of CO_2 into CO and O_2 is one of the important routes for producing value-added chemical products, in which the CO can be utilized for fuel synthesis while the O_2 can be used in some special situations such as submarine oxygen supply[1] and in-situ resource utilization on Mars[2].

In this regard, the non-thermal plasma (NTP) process which can activate stable CO_2 molecules under mild conditions, is considered a promising alternative to traditional routes. However, plasma power supplies commonly have problems such as complex structure, high cost and short operating time[3-4], which hinder their integration and distributed-scale utilization.

Therefore, in this study, a series of commercial compact portable neon transformers (HB-C06/C10/11010) were modified and used to drive two forms of NTP for CO_2 dissociation, including dielectric barrier discharge (DBD) and spark discharge. Based on the in-situ characterization methods (digital oscilloscope, on-line gas chromatography, optical emission spectroscopy) and numerical simulation methods (computational fluid dynamics, CFD), the relationship between reactor configuration parameters (gap distance and shape of the electrodes) and dissociation performance (conversion rate and energy efficiency) was studied.

The results show that the neon transformer can drive plasma CO_2 dissociation discharge stably and efficiently. For the DBD plasma, a conversion rate of 17.4% and an energy efficiency of 17.6 MJ/mol were achieved at a 4 mm gap. And as for spark discharge, the asymmetric electrode structure (including needle-plate and hemisphere-plate) had an optimal discharge gap, and the highest conversion rate was 10.3%, with a corresponding energy efficiency of 8.2 MJ/mol. The CO_2 conversion rate of the symmetric plate-plate electrode decreased with the increase of gap distance. The advantage of energy efficiency of asymmetric electrode structure in spark discharge was verified by the vibration-rotation temperature obtained by fitting emission spectroscopy and CFD simulation.

References

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