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Gliding arc plasma for CO_2 conversion: better insights by a combined experimental and modelling approach

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Highlights

- A two dimensional self-consistent model is developed and validated by the direct experiment.
- Gliding arc shows a strong non-equilibrium character of the conversion process, explaining the higher values of conversion and energy efficiency than thermal process.
- A chemical kinetics analysis shows that the CO_2 vibrational levels significantly contribute to the CO_2 dissociation.
- Promoting the vibrational kinetics, reducing the recombination of CO with O_2 and increasing the CO_2 fraction treated by the arc can further improve the conversion and energy efficiency.

Abstract

A gliding arc plasma is a potential way to convert CO_2 into CO and O_2, due to its non-equilibrium character, but little is known about the underlying mechanisms. In this paper, a self-consistent two-dimensional (2D) gliding arc model is developed, with a detailed non-equilibrium CO_2 plasma chemistry, and validated with experiments. Our calculated values of the electron number density in the plasma, the CO_2 conversion and energy efficiency show reasonable agreement with the experiments, indicating that the model can provide a realistic picture of the plasma chemistry. Comparison of the results with classical thermal conversion, as well as other plasma-based technologies for CO_2 conversion reported in literature, demonstrates the non-equilibrium character of the gliding arc, and indicates that the gliding arc is a promising plasma reactor for CO_2 conversion. However, some process modifications should be exploited to further improve its performance. As the model provides a realistic picture of the plasma behaviour, we use it first to investigate the plasma characteristics in a whole gliding arc cycle, which is necessary to understand the underlying mechanisms. Subsequently, we perform a chemical kinetics analysis, to investigate the different pathways for CO_2 loss and formation. Based on the revealed discharge properties and the underlying CO_2 plasma chemistry, the model allows us to propose solutions on how to further improve the CO_2 conversion and energy efficiency by a gliding arc plasma.

Keywords: CO_2 conversion, gliding arc, non-equilibrium plasma, plasma chemistry, splitting mechanisms, breakdown

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