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Gliding arc plasma-assisted CO_2 conversion: Efforts on improving the efficiency

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The conversion of CO_2 into value-added chemicals or fuels has been considered as one of the attractive solutions for CO_2 reduction. However, CO_2 is a highly stable molecule and its activation remains a challenge as a large amount of energy is required for CO_2 conversion in a traditional thermal process. In this regard, non-thermal plasma has emerged as an attractive alternative solution as it enables this thermodynamically unfavourable reaction (i.e., CO_2 activation) to proceed with a reduced energy cost under mild conditions. Also, the compactness (high specific productivity) and flexibility (high reaction rate, instantaneous 'on-and-off') of it offers a promising solution to the imbalance between energy production and consumption by intermittent renewable sources, creating a carbon-neutral network. Various non-thermal plasma systems have been reported for direct dissociation of CO_2, among which gliding arc discharge is one of the most promising ones because it offers the possibility to operate at atmospheric pressure and simultaneously reach a non-equilibrium state that is strong enough to stimulate the most efficient dissociation of CO_2 through vibrational excitation. Nevertheless, efforts on simultaneously improving the reactant conversion and energy efficiency in gliding arc assisted CO_2 activation systems are urgently needed.

Our recent efforts show that the efficiency of CO_2 conversion in gliding arc plasma can be promisingly improved by optimizing the reactor design, coupling catalysis with plasma, as well as introducing a carbon bed into CO_2 plasma, in addition to optimizing the experimental conditions. By enhancing the gas treatment in the plasma area, e.g., via optimization of the injector nozzle, use of a quadrangular cover, and development of a magnetically enhanced gliding arc, the CO_2 conversion and energy efficiency can be both improved to some extent [1-2]. Furthermore, for the first time, we experimentally demonstrate the existence and detrimental effect of the recombination reaction ($CO+O_2 \rightarrow CO_2$) in plasma-assisted CO_2 splitting reaction. Significant enhancement in the performance is then achieved by inhibiting the recombination reaction, through e.g., cooling the reactor and introduction of biochar to allow for the reverse Boudouard reaction ($CO_2+C \rightarrow 2CO$) [3-4]. Also, we propose a plasma TiO_2 photocatalytic strategy that produces a strong plasma-catalysis synergy for CO_2 splitting (only in the in-plasma catalysis mode), improving remarkably the reaction performance [5]. These efforts provide critical clues for further enhancement of CO_2 activation in the promising plasma processes.

References
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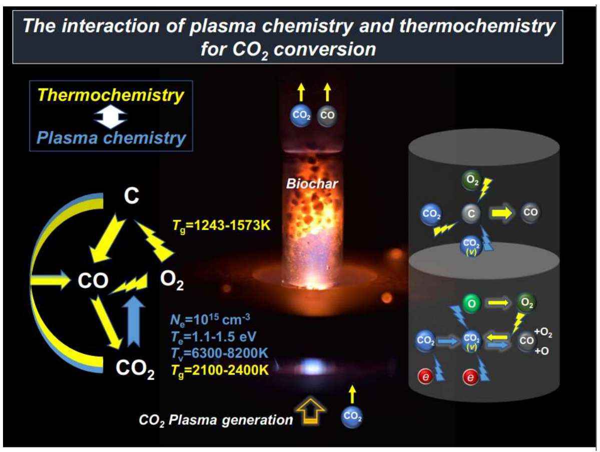

Figure 1 Reaction scheme of the plasmatron-assisted CO_2 reaction with biochar along the reactor [4].

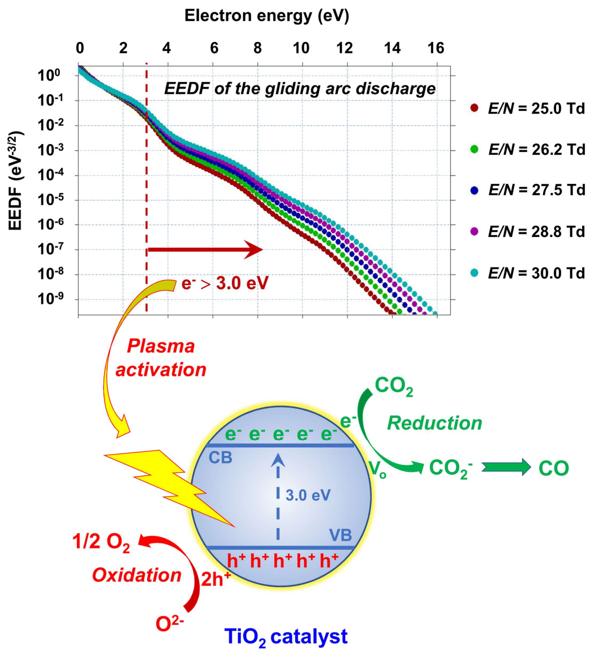

Figure 2 Electron energy distribution function (EEDF) of the gliding arc discharge and the possible reaction mechanisms of the plasma photocatalytic CO_2 dissociation process [5]