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(I) Atmospheric pressure synthesis of chemical fuels by high frequency plasmas: an outlook

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Chemical synthesis of fuels using sustainable energies is one of the main challenges for the development of a circular economy. In recent years, because of their flexibility and capability of not using any rare earth materials or noble metals, atmospheric pressure plasmas have been the focus of intense research activities for the reduction of stable molecules such as CO2 and N2. In this contribution, we will discuss the current status of plasmas for synthesis of chemicals and some of the main challenges ahead. To compare the potential of plasma technology with other technologies such as electrochemical and thermochemical reduction methods, many aspects need to be taken into account. This contribution focuses, as an example, on the reduction of CO2 using high frequency discharges (namely radio-frequency and microwave plasmas).

Depending on plasma parameters such as the electron density and temperature, the gas and vibrational temperatures, the dissociation and recombination pathways of molecules are completely different in atmospheric pressure plasmas. To enhance the energy and conversion efficiencies , the experimentalist has a number of tools to achieve this goal, mainly while controlling the reduced electric field and deposited power density, both through the applied frequency and applicator geometry, and via the input gas flow.

Energy efficiency is currently the main metric used for assessing the performance of the CO2 dissociation (plasma) process. It is however required to consider also the separation step to have pure CO and, the lower the initial CO yield, the higher is the energy cost per kg of produced CO. Although non-equilibrium plasmas are inherently attractive due to higher energy efficiencies (when achievable), their typically low conversion yields are detrimental for any industrial upscaling. Thermal plasmas, when energy recycling is possible, may prove to be a better alternative. Also, the power coupling efficiency as well as the energy losses due to transformers should be accounted. Such parameters, together with the assessment of employed materials, the reactor compactness, its flexibility to handle fluctuating renewable energy supplies and its integrability into a process chain need to be considered while considering new technologies for chemical synthesis of fuels.

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