Plasma technology for electrification of chemical reactions

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Plasma technology is gaining increasing interest for various gas conversion applications, such as CO_2 and CH_4 conversion into value-added compounds, and N_2 fixation for fertilizer applications, i.e., more in general: electrification of chemical reactions. Indeed, there is a strong need for electrification in the chemical industry, to reduce greenhouse gas emissions. Plasma technology is a promising candidate, because plasmas are created by applying electricity. Moreover, in gas discharge plasmas, the electrons are mainly heated by the applied electric field, due to their small mass, and they activate the gas molecules by electron impact ionization, excitation and dissociation, creating new ions, excited species and radicals. These are very reactive, so they can easily produce new products. Hence, thermodynamically or kinetically limited reactions can proceed at mild conditions of gas temperature and pressure, because the gas activation is accomplished by the electrons. Typically, plasma reactors operate at atmospheric pressure and the gas is introduced at room temperature. Plasma technology has low CAPEX costs. Finally, the plasma reactors can quickly be switched on/off, and because they operate with electricity, they are very suitable to be combined with (fluctuating) renewable electricity, and thus, for electrification of chemical reactions.

To improve this application in terms of conversion, energy efficiency and product formation, a good insight in the underlying mechanisms is desirable. We try to obtain this by computer modelling, supported by experiments.

I will first give a brief explanation about different types of plasma reactors used for electrification of chemical reactions (green chemistry applications), i.e., mainly gliding arc, microwave plasmas and dielectric barrier discharges, but also atmospheric pressure glow discharges, spark discharges and ns-pulsed discharges. This will be followed by an overview of the state-of-the-art in plasma-based CO_2 and CH_4 conversion, as well as N_2 fixation, with these different types of plasma reactors, and a brief discussion of the opportunities and main challenges. Subsequently, I will present recent results obtained in our group in this domain, including experiments and modelling, for plasma chemistry, plasma reactor design and plasma-catalyst interactions, with the aim to gain a better understanding of the underlying mechanisms.