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Renewable energy driven non-thermal chemistry: Plasma chemistry as the special case

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The worldwide energy crisis and environmental issues have greatly driven the current research on exploring and efficiently utilizing the environmentally-friendly and sustainable energy sources. Most sustainable sources such as solar and wind energy are in principle scalable and able to meet the global energy demand. Nevertheless, they are intermittent and require new concepts of conversion and storage of electricity. Chemical feedstock, i.e. storing energy in form of the binding energy of molecules, is an economically feasible option for long term (seasonal) storage. However, the main challenge is how to address the problem of developing an effective and economical process for converting electrical energy into molecules of high energy for chemical feedstock.

In a circular CO2 neutral society, where the use of dense energy carriers based on carbon will still be needed, the re-use of (air captured) carbon dioxide is required. These dense energy carriers can be utilized to mitigate intermittency of renewable energy sources by providing seasonal storage, as feedstock for the chemical industry to replace fossil based feedstock and as green synthetic fuels for long haul and air transport. Also in this context, nitrogen fixation is unquestionably one of the most important chemical conversion process since it converts atmospheric nitrogen (low energy molecule) into molecules of high energy (e.g. NH3, NO). The use of electrons, from renewable electricity, or photons, directly from the sun, provide scientific and technological opportunities to develop novel pathways for chemical conversion.

In this talk, after an introduction to the challenges facing the world in the next decades, I will discuss the opportunities of using plasmas, powered by renewable electricity, for scalable gas conversion of key molecules such as CO2 and N2. In particular I will address the use of microwave plasma to dissociate CO2 into CO and O2, and the possible, often claimed, role of nonequilibrium vibrational kinetics. The separation of the products CO2/O2/CO will discussed briefly. Inspired by this approach, I will present a unique hybrid type reactor consisting of a plasma reactor and solid state water electrolysers with oxygen ion or proton conducting membranes. One aided benefit of this proposed approach is that both technologies, i.e. water electrolyser and plasma activation, utilize base molecules (N2 and H2O) and can be directly powered by renewable electricity. Such a scheme may be a stepping stone to zero carbon footprint processes. Moreover, the advantages of proposed approach will be also compared to conventional plasma catalysis or pure plasma processes.