Novel reaction concepts for synthesis of chemicals in modular plants using ultrafast pulsation of microwave plasmas.

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Abstract: Building on severl years of experience on microwave and reaction engineering, KIT started activities connected to the application of plasmas for chemical synthesis as part of the Helmholtz program “Materials and Technologies for the Energy Transition” in the topic “Chemical Energy Carriers”. Here we present the novel reactor concepts developed at KIT for modular reaction systems.

Keywords: CO_2 conversion, Modular Plants, Fluidized bed, Hydrogen Peroxide.

1. Need of modular technologies for chemical conversion

As part of the transition to Net Zero by 2050 in the European Union, the chemical industry is exploring ways to incorporate more renewable energy and electrify its activities[1, 2]. Therefore, research that supports progrees in this direction is needed.

The Helmholtz program "Materials and Technologies for the Energy Transition” explores opportunities for the development of innovative materials and scalable technologies for the future energy infrastructure in Germany and other connected regions. As part of this initiative KIT has contributed with several of these developments in the area of “Chemical Energy Carriers” using unique infrastructure such the Energy Lab 2.0 and developments in the area of efficient, compact reactors powered by renewable energy.

Fig. 1. Sketch of the e-XPlore transportable research platform, which is jointly provided and operated by KIT and DLR

One example is the e-XPlore container based platform (Fig. 1). e-XPlore is a transportable research platform for new electrically generated low-emission synthetic fuels, which is jointly provided and operated by KIT and DLR. The aim of this platform is to validate selected options for electricity-based synthetic gas production from carbon dioxide and water in combination with selected utilization pathways for the conversion of the produced synthetic gas into high-value fuels and chemicals.

This platform is designed to work with three interchangeable process lines:

1- Fuel synthesis (Fischer-Tropsch route)
2- Syntthesis of oxygenates
3- Plasma based CO_2 conversion**.**

2. Approach for plasma based converiosn in KIT

The activities on the use of plasma activated chemical proceses started five years ago in KIT. Two institutes, IHM and IMVT joined forces in order to overcome the mentioned cahllenges from a multidisciplinarty perspective. As a result of this we have developed the first nanaosecond pulsate microwave plasma [3, 4]. This route allows to control the delivery of energy and progress of the reactions at atmospheric pressure.

In order to take advantage of this new approach, novel suitable reaction approaches are being developed. Two examples will be highlighted:

- The activation of CO_2 in fluidized beds at atmospheric pressure(Fig. 2) .
- The synthesis of hydroge peroxide (Fig.3).

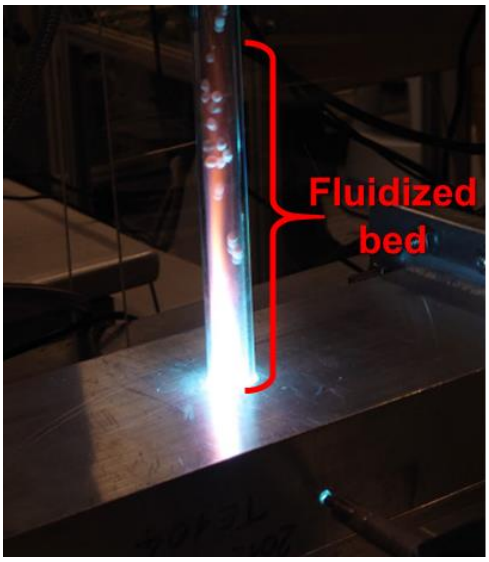

Fig. 2. CO_2 splitting in a microwave plasma activated fluidized bed.

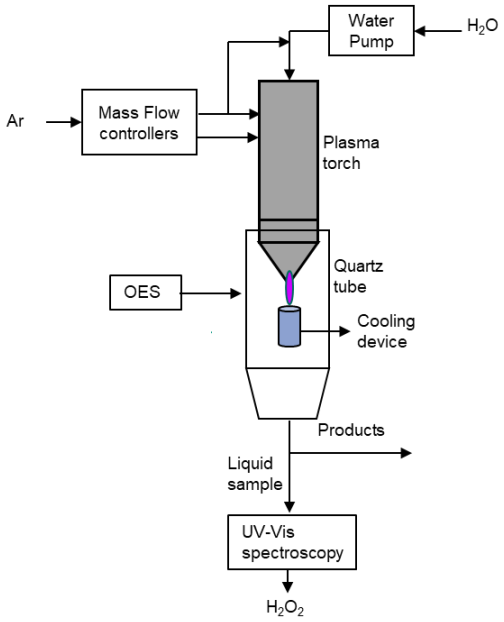

Fig. 3. Microwave plasma torch illustration for the synthesis of H_2O_2 from argon and water at atmospheric pressure. Optical Emission Spectroscopy (OES) is used here as a tool to understand the mechanism of the reaction.

3. Acknowledgements

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4. References

[1] SABIC chemical plant to become first of its kind to operate on 100% renewable power. Series SABIC chemical plant to become first of its kind to operate on 100% renewable power 2020; Available from: https://packagingeurope.com/sabic-chemical-plant-to-become-first-of-its-kind-to-operate-on-100-renewable-power/5313.article.

[2] BASF bundles renewable energy activities in new subsidiary BASF Renewable Energy GmbH. Series BASF bundles renewable energy activities in new subsidiary BASF Renewable Energy GmbH 2021; Available from: https://www.basf.com/global/en/media/news-releases/2021/11/p-21-383.html.

[3] Soldatov, S., et al., Time-Resolved Optical Emission Spectroscopy Reveals Nonequilibrium Conditions for CO2 Splitting in Atmospheric Plasma Sustained with Ultrafast Microwave Pulsation. ACS Energy Letters, 2021. 6(1): p. 124-130.

[4] Soldatov, S., et al., Efficiency of a compact CO2 coaxial plasma torch driven by ultrafast microwave power pulsing: Stability and plasma gas flow dynamics. Journal of CO2 Utilization, 2022. 58: p. 101916.