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CO_2 utilisation focused on market relevant dimethyl ether production, via 3D printed reactor and solid oxide cell based technologies

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1. Introduction

This presentation will showcase a newly started project, CO2Fokus (www.CO2Fokus.eu), that brings together six research organisations and six industrial partners. The goal of the project is to develop cutting-edge technology able to convert industrial CO_2 into DME, a valuable gas extensively used in the chemical and energy sectors fostering an alternative to fossil fuel derived feedstock (see the overall concept presented in Figure 1). Currently, DME is commercially produced through an indirect, two-step process involving the production of methanol and its subsequent dehydration. This process is energy intensive and requires substantial capital and infrastructure investments. The project will contribute towards the transition to a low-carbon society by demonstrating that DME can directly be produced in an efficient way from CO_2 captured at large industrial point sources, such as energy intensive processes in the petrochemical sector.

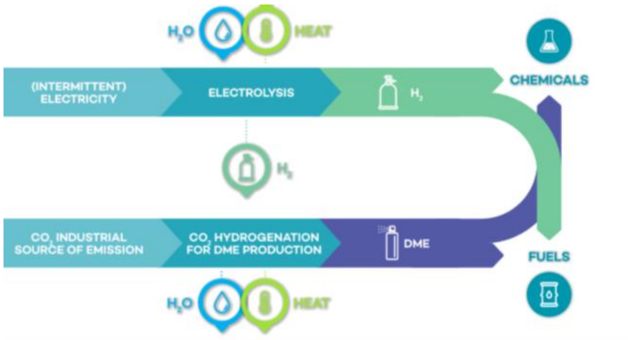

Figure 1. Flow diagram illustrating approach and methodology for carbon dioxide hydrogenation to DME

2. Methods

To this end, innovative 3D printed multichannel catalytic reactors and solid oxide electrolyser cells are being developed and tested at lab scale and at pilot scale in an industrial environment of large industrial CO_2 point sources. Key considerations will be given with respect to the thermodynamic aspects controlling DME production from CO_2 underpinned by innovative catalytic reactor and solid oxide electrolyte systems.[1] Structured multi-channel reactors (Figure 2) are designed to accommodate the DME production process and provide tailored heat and mass transfer to the catalytic reaction zone. Their design can be realised using emerging 3D printing technologies to lay down functional material with high fidelity and near exact repeatability.[2] The use of finessed catalyst materials within bespoke reactors represents a step change in chemical engineering. A unit based on co-electrolysis cells (co-SOEC) developed by Solid Power will be used to convert CO_2 and H_2O to a mixture of CO, H_2 (and unconverted CO_2 and H_2O) suitable to synthetise DME in the catalytic reactor.

3. Results and discussion

Active catalyst materials (such as Cu-ZnO-Al_2O_3 and similar, novel composites) are directly 3D printed and integrated within structured supports and the internal engineering of multi-channel catalytic reactors to produce DME in an efficient way.[3-5] A highly defined three-dimensional network is designed to offer an exact control of flow dynamics and mixing. For innovative 3D printed multichannel catalytic reactors comprising 30 or more tubes and operating at 1500 N L/h CO_2/H_2 feed, at least 30 % CO_2 conversion is expected.

Regarding the solid oxide cell technology, aspects crucial to the stack design that will further advance the technology, are good catalytic activity of the electrolysis catalyst (the cathode catalyst layer), resistance to carbon deposition and degradation, heat transfer and good overall performance of the stack. SOEC is being optimised in order to allow the operation at high CO_2/H_2O ratios, while preventing the carbon deposition on the fuel electrode. Optimised solid oxide electrolyser cells with a power consumption of up to 3.5 kW operated in the co-electrolysis mode are expected to achieve 50 % conversion.

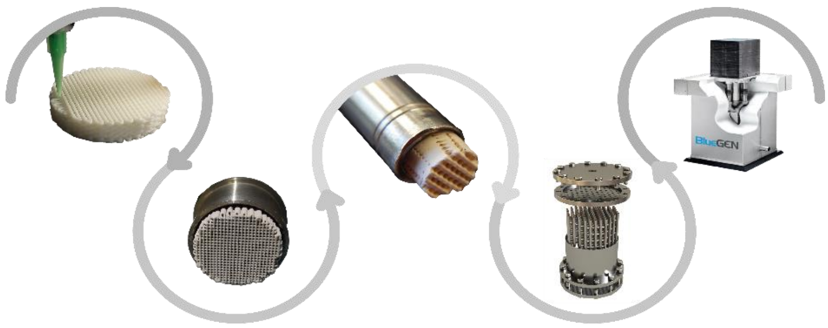

Figure 2. 3D co-printing of catalysts at VITO employed for manufacturing different formulations and architectures of pre-defined patterns and size, inserted in a single reactor tube and TECNALIA's millichannel reactor scaled up from 16 to 68 channels; Solid Power's SOEC stack operating at > 1 kW and 0.5 A/cm^2

4. Conclusions

The production of DME in a single-step process by direct catalytic and electrochemical conversion of CO_2 and H_2 can offer to meet the ever-increasing demand for alternative, carbon-neutral, environmentally-friendly fuels and chemical and energy carriers.

References

[1] E. Catizzone, G. Bonura, M. Migliori, F. Frusteri, G. Giordano, CO_2 Recycling to dimethyl ether: state-of-the-art and perspectives, Molecules, 23 (2018) 31

[2] V. Middelkoop, A. Vamvakeros, D. De Wit, S. Jacques, S. Danaci, C. Jacquot, Y. De Vos, D. Matras, S. Price, A. Beale, 3D printed Ni/Al2O3 based catalysts for CO_2 methanation - a comparative and operando XRD-CT study, Journal of CO_2 Utilization, 33 (2019) 478-487

[3] G. Bonura, M. Migliori, L. Frusteri, C. Cannilla, E. Catizzone, G. Giordano, F. Frusteri, Acidity control of zeolite functionality on activity and stability of hybrid catalysts during DME production via CO_2 hydrogenation, Journal of CO_2 Utilization 24 (2018) 398-406

[4] G. Bonura, C. Cannilla, L. Frusteri, F. Frusteri, The influence of different promoter oxides on the functionality of hybrid CuZn-ferrierite systems for the production of DME from CO_2-H_2 mixtures. Applied Catalysis A: General 544C (2017) 21-29.

[5] G. Bonura, C. Cannilla, L. Frusteri, A. Mezzapica, F. Frusteri, DME production by CO2 hydrogenation: Key factors affecting the behaviour of CuZnZr/ferrierite catalysts. Catalysis Today 281 (2017) 337–344.