Fabrication and Joining of Proton Conducting Cell Assemblies for Dehydrogenation of Alkanes

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Abstract

Satisfying the ever-increasing global demand for energy and material goods while achieving the ambitious CO_2 emissions targets of the EU for 2030 on climate change requires the utilization of renewable resources (e.g. wind, solar) in the fuels and chemical industries. The project AMAZING (Additive Manufacturing for Zero-emission Innovative Green Chemistry) directly addresses this by replacing large-scale high-temperature cracking processes (e.g. steam cracking) with electrically driven thermo-catalytic activation of alkanes to produce chemical building blocks allowing significant reduction in the CO_2 emissions associated with energy-intensive cracking reactions (Figure 1).

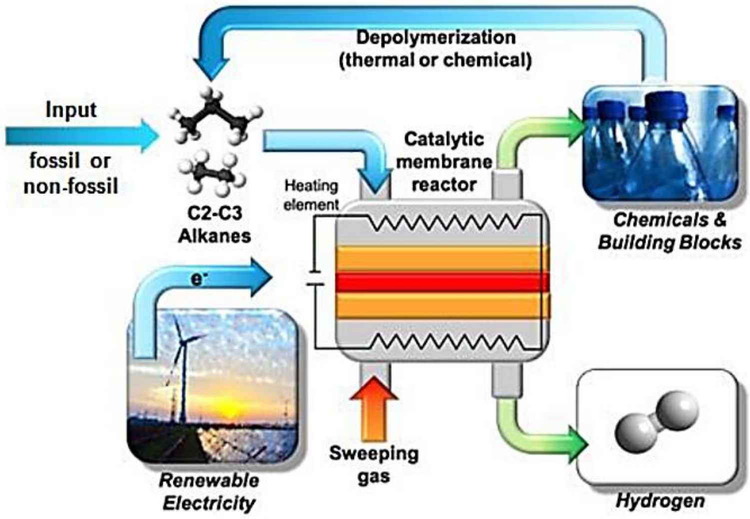

Figure 1: Schematic overview of the AMAZING project concept.

The core of the cell assembly is a ceramic membrane made from mixed proton and electron conducting $La_{6-x}WO_{12-\delta}$. To increase the electronic conductivity of the material Mo as doping element is used to form $La_{6-x}W_{0.8}Mo_{0.2}O_{12-\delta}$ (LWO-Mo20). The powder is in-house produced and the particle size, specific surface area and chemical composition is determined before the ceramic layers are formed. Therefore, three different fabrication techniques are used in this work. The first one is sequential tape-casting and lamination to fabricate an asymmetric structure of a dense membrane layer (thickness ≈ 25 µm) and a porous support (thickness ≈ 500 µm). Furthermore 3D-printing techniques are implemented to achieve defined support structures. Firstly, a combination of tape casting and material extrusion (MEX) is introduced, where the support structure is printed directly on a tape-cast membrane layer. This technique allows a good membrane quality but suffers during the co-firing of the final layers. Secondly, a pure 3D-printing approach is introduced, which utilizes 3D-screen printing. With this technique both, membrane and support layer, are formed subsequently in one machine allowing good membrane quality and precise support structures.
After co-firing all membrane components undergo a quality testing procedure, which includes He-leakage determination and white-light topography. The next step is the joining of the ceramic membrane into a metal frame to

form a membrane module, which can easily be built in a test reactor and quickly exchanged for multiple tests. The joining procedure takes place in a furnace at 850 °C applying load on the sealing area. Glass sealant is used to connect the ceramic and metal part. After joining, another He-leakage test is performed to assure the joining quality. With this procedure large amounts of lab-scale membrane modules can be fabricated for further performance tests.

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