Alternative Nickel-based catalysts for the high-temperature H_2O/CO_2 co-electrolysis

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Motivation / Strategy

By opting for ambitious ''Energiewende", Germany government decided to substitute nuclear energy plants by renewable energy sources such as biomass, wind and solar farms and at the same time to drastically reduced CO_2 emission into the atmosphere. Power plants such as wind mills and solar energy plants, however, are subjected to unforeseeable seasonal climatic fluctuations that can destabilize electricity supply. To face this crucial issue, innovative strategies are required when e.g. electricity production surpass the demand but also when production is insufficient like on sunless and windless periods. In that context, German Ministry for research and education has founded four project proposals in the frame of Kopernikus program axed on (i) improvement of electricity grid infrastructure (ENSURE), (ii) energy reduction in industrial processes (SynErgie), (iii) systems integration (ENavi) and (iv) chemical storage of excess electricity (P2X). "Power-to-X" project strategy aims at evaluating innovative for storing surplus electricity in form of gas such as H_2 or syngas via electrolysis (Power-to-Gas) and eventually for transforming it into fuels such as alcohol, hydrocarbons or/and chemicals (Power-to-Liquid) (see Fig. 1). In the first project period, 6 research clusters (FC) composed of 18 research institutions, 27 companies and 3 associations will work closely together but also compete to develop innovative technologies for sustainable transition from fossil-based economy to sustainable CO_2-neutral one. The most promising ones will be selected for validation and demonstration periods.

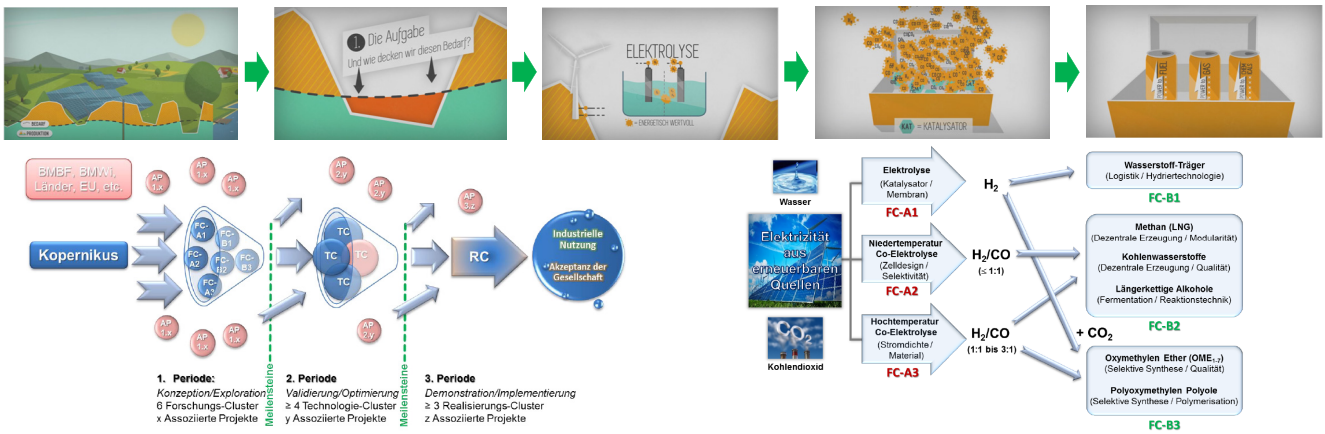

Fig. 1: (Top) illustration of P2X concept (source "Tricklabor FZ Jülich"(https://www.youtube.com/watch?v=Eoip2nMapz0); (bottom) P2X roadmap & cluster networking

State-of-the-art & challenges of HT co-electrolysis

Ni-cermets are the state-of-the-art cathode material for steam electrolysis. However, addition of up to 10% H_2 or CO is required to avoid Ni oxidation [1}. Alternative materials such Rh, Ru, Pt, Pd and Ir on CeO_2 and Al_2O_3 that have been investigated for CO_2 reduction and dry CH_4 reforming [2,3] may be taken into consideration for this project as well as LSCM/GDC that was tested as SOEC cathode for 200h [4, 5]. Electrode reactions are shown in Figure 2.

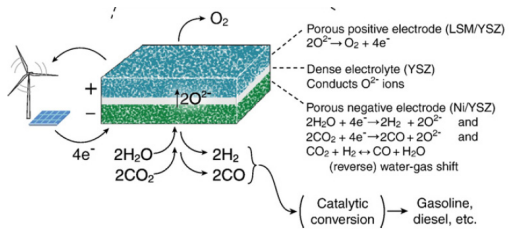

Fig. 2: Typical co-electrolysis set up with common electrode reaction from [1]

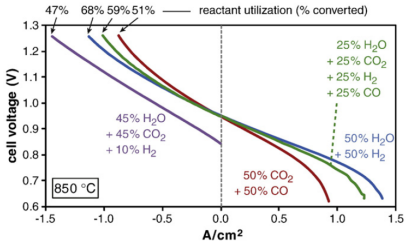

Fig. 3: DC polarization (curves for oxidation and reduction of chosen mixtures of H2, H2O, CO, and CO2 in SOFC and SOEC mode [1].

Feasibility of power-to-fuel concept was demonstrated by Sunfire company (160L gasoline per day) by combining SOEC with Fischer-Tropsch process [6].

[1] C. Graves ; Sol. State Ionics 192 (2011) 398
[2] C. de Leitenburg et al., J. of Catalysis 166 (1997) 98–107
[3] A.T. Ashcroft et al., Nature 352 , 18 July 1991, 225
[4] X. Yue et al., Electrochem. Solid-State Lett. 15(3) (2012) B31
[5] X. Yue., J.T.S. Irvine , Solid State Ionics 225 (2012) 131
[6] http://www.sunfire.de/de/anwendungen/kraftstoffe

DFI contribution to FC-A3 cluster

In FC-A3 cluster, HT co-electrolysis of H_2O & CO_2 will be developed for syngas production. Main challenges are related to activity and more especially to stability of Ni-based catalyst in presence of large amount of water vapor, and to carbon formation that can lead to metal dusting.

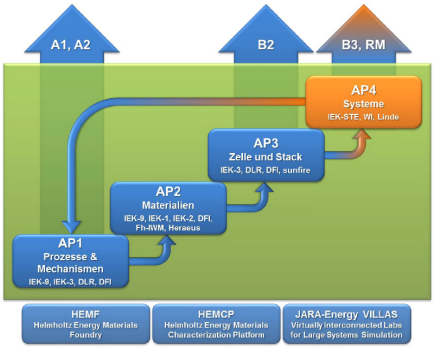

Fig. 4: Organigram of FC-A3 working packages (AP) and links with other research clusters and organizations within Kopernikus program.

DFI tasks focus principally on the development and characterization of coking-resistant Ni-based cathode materials as follows:

- AP1: Evaluation of catalytic activity and selectivity of powder materials for H_2O/CO_2 reduction to H_2/CO in function of mass ratio in glass tube reactor at 850°C by means of GC analysis.
- AP2: Synthesis of Ni_3Sn_2 intermetallic phase by different routes to get optimal powder morphology for coating process.
- AP3: Fabrication of electrolyte-supported button cell and test under electrochemical SOEC conditions.

Acknowledgements

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