# HYDROGEN AND $CO_2$ CAPTURE

Andreas ZÜTTEL[1,2], Philippe MAURON[1,2], Elsa CALLINI[1,2], Shunsuke KATO[1,2], Marco HOLZER[1,2], Jianmei HUANG[1,2]

[1)] Laboratory of Materials for Renewable Energy (LMER), Institute of Chemical Sciences and Engineering (ISIC), École polytechnique fédérale de Lausanne, EPFL Valais/Wallis, Switzerland, [2)] EMPA Materials Science and Technology, Dübendorf, Switzerland

Hydrogen is produced from water by means of electrolysis with renewable energy. $CO_2$ is abundant in the atmosphere at a concentration of 400 ppm. The extraction of $CO_2$ and reduction with hydrogen to hydrocarbons leads to synthetic and $CO_2$ neutral fuels. Furthermore, the controlled reaction to a specific product like $C_{10}H_{22}$ would allows to store large quantities of renewable energy in easy way based on established technology for diesel. Two major challanges have to be overcome: 1) energy efficient extraction of $CO_2$ from the atmosphere and concentration to pure $CO_2$ at 1 bar, and to develop new reaction pathways which allow to reduce $CO_2$ to a specific product.

## $CO_2$ FROM THE ATMOSPHERE

The extraction of $CO_2$ from the atmosphere (400 ppm = 0.04%) to 1 bar pure $CO_2$ requires the Gibbs free enthalpy $\Delta G$ = 20 kJ/mol which corresponds to 0.126 kWh/kg$CO_2$. However, with the today known adsorption processes approximately 1.5 to 2 kWh/kg$CO_2$ of heat are necessary in order to concentrate $CO_2$ [1]. Therefore, new processes working close to the thermodynamic limit have to be developed.

## $CO_2$ REDUCTION WITH HYDROGEN

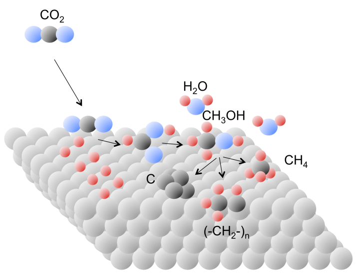


Fig. 1. Schematig representation of the various reduction paths of $CO_2$ on a surface with adsorbed H.

The reduction path of $CO_2$ on a surface depends on the reaction conditions e.g. temperature, hydrogen partial pressure, and on the surface composition as well as the local surface structure. $CO_2$ is reduced to methane ($CH_4$) on Ni and C-C coupling ($C_2H_4$) was only found on Cu [2].

Thermodynamically the reduction of $CO_2$ follows the established paths of the reversed water gas shift reaction, Fisch-Tropsch synthesis or the Sabatier reaction.

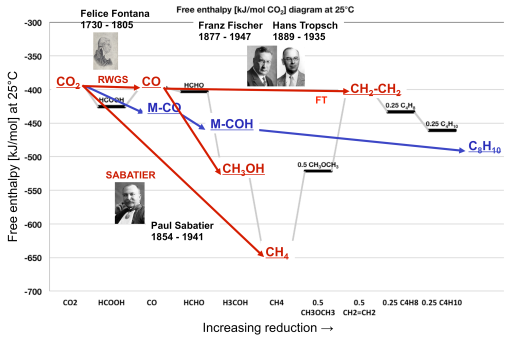


Fig. 2. Free enthalpy of the $CO_2$ reduction along the established reaction paths (red). The new controlled reaction path (blue) will be investigated.

## References

[1] http://www.climeworks.com/co2-capture-plants.html

[2] Y. Hori, Modern Aspects of Electrochemistry 42, (2008), pp 89-189. Electrochemical $CO_2$ Reduction on Metal Electrodes.

Andreas ZÜTTEL

Born 22. 8. **1963** in Bern, Switzerland. **1985** Engineering Degree in Chemistry, Burgdorf, Switzerland. **1990** Diploma in Physics from the Unversity of Fribourg (UniFR), Switzerland. **1993** Dr. rer. nat. from the science faculty UniFR. **1994** Post doc "Amorphous hydrides and optical films" with AT&T Bell Labs in Murray Hill, New Jersey, USA. **1997** Lecturer at the Physics Department UniFR. **2003** External professor at the Vrije Universiteit Amsterdam, Netherlands. **2004** Habilitation in experimental physics at the science faculty UniFR. President of the Swiss Hydrogen Association „HYDROPOLE". **2006** Head of the section "Hydrogen & Energy" at EMPA. Prof. tit. in the Physics department UniFR. **2009** Guest Professor at IMR, Tohoku University in Sendai, Japan. **2012** Visiting Professor at Delft Technical University, The Netherlands. **2014** Full Prof. in Physical Chemistry and head of the Laboratory of Materials for Renewable Energy (LMER), Institute of Chemical Sciences and Engineering (ISIC), École polytechnique fédérale de Lausanne, EPFL Valais/Wallis, Switzerland

Corresponding author: Andreas ZÜTTEL, email: andreas.zuettel@epfl.ch, Tel. +41 79 484 2553