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Renewable Synthesis of Chemical Feedstock and Specialties Employing Low Temperature Electrochemical Reduction of CO_2

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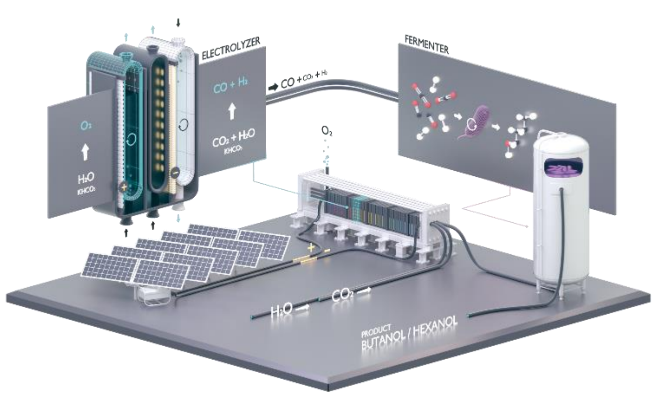
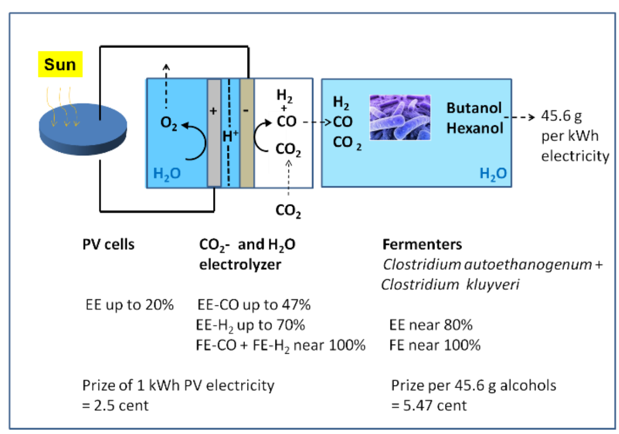
Graphical Abstract

The left artist picture shows a representation of the so-called "Technical photosynthesis". H_2 and CO are produced from H_2O, CO_2 and renewable energy (solar, wind) by electrolyzes, which can be used as molecular feed for an anaerobic bacteria mixture. Final products are butanol and hexanol. A back-of-the envelope calculation on the right shows the potential for economic viability **[1]**.





Abstract

Profitable renewable synthesis of chemicals and fuels is a prerequisite for its implementation into current economics. Boundary conditions for the synthesis sequence are the availability of renewable energy in sufficient quantities and its intermittent character. Profitability is difficult when considering the low fossil energy carrier prices and the physical efficiency limitations of the processes.

In the presentation, two options employing electrochemical reduction of CO_2 are discussed:

The closest to industrial application process consists of two major components: Firstly, electricity from wind or solar is stored by electrolysis into energy carriers like hydrogen (H_2) or carbon monoxide

(CO). Current density, Faradaic and electrical efficiency and endurance of this upstream process will be discussed. Secondly downstream, a flexible mixture of CO, CO_2 and H_2 is supplied to a multistep anaerobic fermentation process, whereas they are initially converted to acetic acid and ethanol with high carbon efficiency and thus almost without any undesired by-products. The today's economic value is obtained by further condensation of the C2 products to C4 and C6 special chemicals (carboxylates and alcohols). Eventually, finally scaled into the hundreds megawatt range the molecules can be used as fuels.

In the talk a potential solution is addressed by using a commercially available silver-based gas diffusion electrode (used in industrial-scale chlorine–alkaline electrolysis) as the cathode in the CO_2 electrolyser. Electric current densities up to 300 mA cm² were demonstrated for more than 1,200 hours with continuous operation. Faradaic efficiency of the anaerobic fermentation processes was almost quantitative **[1]**. Evonik and Siemens have decided to bring the technology toward an industrial scale. The project is named Rheticus **[2]**. Generally, such an approach is called artificial or technical photosynthesis.

Still in research state is the single step direct electrochemical reduction of CO_2 to hydrocarbons, such as ethylene or ethanol. A series of the newly developed electrocatalysts based on the copper mineral paramelaconite will be introduced. The product distribution can be tuned by substituting copper by silver atoms and using the crystallographic arrangement as nano-template.

Keywords: Technical photosynthesis, direct electrochemical reduction of CO_2, anaerobic fermentation, nano-template electrocatalyst.

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Biography of Presenting Author

Günter Schmid is a Principal Key Expert Research Scientist in the newly founded Spin-off Siemens Energy in the unit New Energy Businesses in the department Technology and Products. He earned his PhD degree from the University of Ulm (Germany) in 1993 in organometallic chemistry and crystallography. Later, he joined 1994 Texas A&M University (USA) for a postdoctoral position. Since 1996 he is working within the industrial framework of Siemens companies like Siemens Energy, Siemens AG, Infineon AG and Osram in various positions.

He started his carrier in silicon semiconductor industry developing high temperature stable photosensitive dielectrics for chip applications, which are now wildly employed in consumer electronics. Doping of organic semiconductor materials was applied to organic field effect transistors and organic light emitting diodes. Around 2010 he started to work on energy storage materials and electrochemical synthesis. His main interest is the single step electrochemical reduction of CO_2 with its industrial process integration. Focus areas are electro catalysts, gas-diffusion electrodes, industrial electrochemical cell design and operation conditions. Recently, degradation issues on Megawatt PEM electrolysers found his attention.

G. Schmid received fellowships from the "Studienstiftung des Deutschen Volkes" and the "Humboldt Stiftung". He is a member of the German Chemical Society (GDCH) and Electrical Engineering Society (VDE). In 2004 he received the GMM award and in 2009 he became inventor of the year within Siemens. He has authored and co-authored 300 patent applications and contributed to around 100 peer-reviewed papers and keynotes.

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