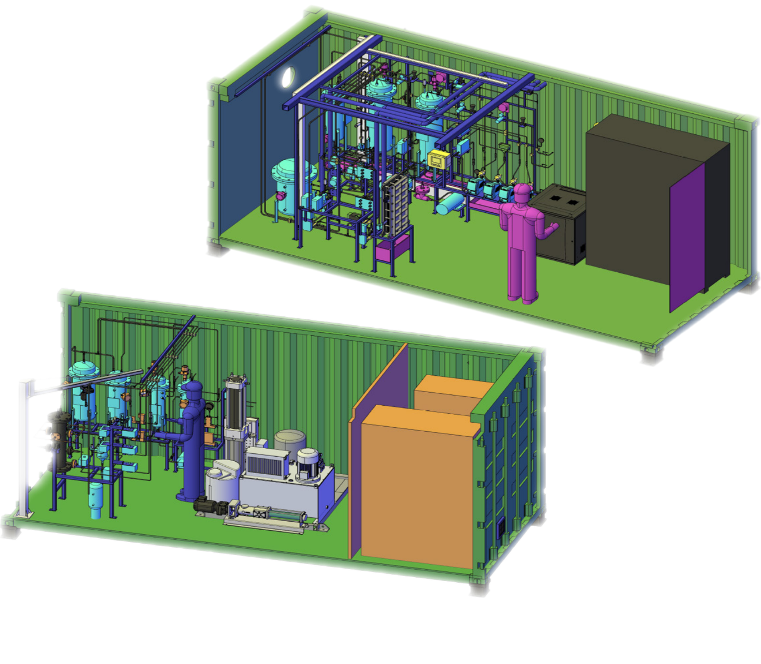
Electrocatalytic conversion of CO_2

a step towards a CO_2 circular economy



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Background

To take the circular approach, the captured and purified CO_2 of the cement industry is converted to acid additives for cement formulations. To meet future challenges in terms of energy sources for industrial processes, electrochemical synthesis routes are targeted. Due to the significant cost impact of electricity, high Faradaic efficiencies are needed. High added-value products are coupled with high enough revenues for the company when the ratio of electrons needed per carbon atom is low.

Technology

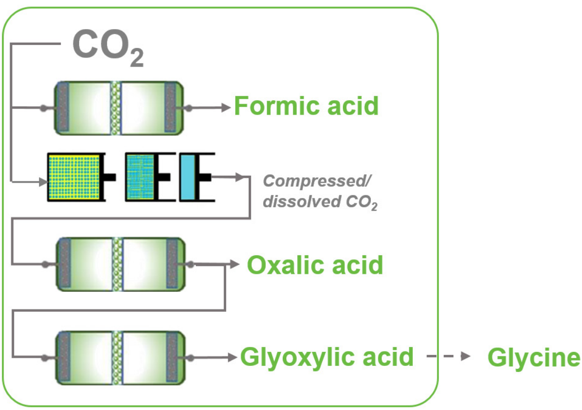
The chemicals produced for re-use within the cement plant are formate, oxalate and glyoxylic acid. The basis of an efficient electrochemical synthesis are the key functional materials such as catalysts and electrodes. The development was carried out by Academia and SMEs which lead to the design of different electrochemical units. In addition, a new process for the combined gas compression and dissolution was developed. A scale-up of all sub-processes lead to a pre-pilot scale demonstration of the different products.

For the synthesis of formate, CO_2 is directly reduced using Avantium's novel gas diffusion electrode technology and a highly selective electrocatalyst developed by the University of Groningen (NLD).

In parallel, the purified CO_2 stream is compressed and dissolved into a non-aqueous electrolyte which is fed to the electrochemical unit where the CO_2 reduction to oxalate takes place. The dissolution system resembles a conventional compressor in which liquid is injected. The simultaneous compression and dissolution enables a nearly isothermal and thereby energy efficient operation.

Oxalic acid – derived from oxalate – is reduced to glyoxylic acid through electrochemical reduction. This reaction is tested in the same unit as formate synthesis which is possible due to the fact that both reactions are carried out in aqueous electrolytes with the same oxygen evolution reaction. One of the container units is designed as a flexible dual nature reactor that is used for testing the two electrochemical processes. This concept brings technological innovation in terms of process and electrochemical cell design.

The compression-dissolution system was developed by Karlsruhe Institute of Technology (GER) and built by Cubogas (ITA). The electrochemical reactors were developed by Avantium (NLD). Hysytech (ITA) assembled all components in two containerized demonstration plants.



Facts

- Development of electrocatalytic routes with high Faradaic efficiency
- Formate production by electroreduction of CO_2: Faradaic efficiency > 90% at > 100 mA/cm^2
- Oxalate production by electroreduction of CO_2: Faradaic efficiency > 90% at > 50 mA/cm^2
- Development of an energy efficient system for the simultaneous compression and dissolution of CO_2 in the electrolyte solution
- Flexible dual pre-pilot scale unit able to produce 0.5 kg/h of formate or glyoxylic acid

Demo-unit for the production of 0.5 kg/h of formate and glyoxylic acid

Project

The Recode project answers the question how the cement industry can lower their carbon footprint: by enabling a circular-economy-approach. The CO_2 produced by cement manufacturing is re-used in significant part within the plant to produce better cement-related products entailing less energy intensity and reduction of CO_2 emissions. Moreover, CO_2 is used in various synthesis routes. Through electrocatalytic and catalytic pathways, formic acid, oxalic acid and glycine are produced to be used as hardening acceleration promoters or grinding aids.

For the past five years, the project consortium investigated all necessary sub-processes and scaled them up to technically relevant size. Dedicated pilot plants were developed for all technologies and are demonstrated within a TRL 6 integrated system campaign at Kamari cement plant in Greece.

avantium

Electochemical Synthesis

HYSYTECH

Engineering Construction

CUBO GAS

Compression Dissolution

Academical partners

KIT Karlsruhe Institute of Technology

Compression Dissolution

university of groningen

Electrochemical Synthesis

ERIC European Research Institute of Catalysis

Electrochemical Synthesis

iit Istituto Italiano di Tecnologia

Project Coordination