

Greenhouse and acid gas conversion by electrothermal catalysis

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Introduction

Mitigating CO₂ emissions becomes a continuously more pressing challenge. An important reason for the slow progress in this respect lies in the composition of CO₂ containing streams. Typical waste gases not only include CO₂, but also other acid gases, such as H₂S, a combination known as sour gas. Conventional removal technologies rely on separation and independent conversion of these components, which is inefficient, from the economical perspective as well as from the environmental one.

The Horizon Europe project e-CODUCT (<https://e-coduct.eu/>) tackles the environmental challenge of reducing both acid gases through a novel two-step technology (Figure 1a). The simultaneous presence of CO₂ and H₂S is turned into an opportunity by having them react into COS and water, followed by decomposition of COS into industrially valuable CO and elemental sulphur (S). For the latter conversion, an ElectroThermally Fluidized Bed reactor (ETFB), powered by renewable energy sources, is foreseen. The ultimate goal is to develop a breakthrough technology with a 50% reduced reactor size and energy demand, that enables the simultaneous reduction of CO₂ and H₂S for the production of marketable green end products in the form of fuels and useful chemicals (CO, S and CH₃OH).

Materials and Methods

Nine European partners team up to tackle the ambitious project goal, each taking on one or more of following objectives:

- Development of stable, sulphur-resistant catalysts for COS synthesis;
- Lab-scale investigation of thermal COS decomposition;
- Design and construction of an ETFB pilot plant, powered by renewable energy, for conversion of COS into CO and S; a technology readiness level (TRL) of 6 is aimed for with an annual production capacity amounting to 16 tonnes of CO;
- Multi-scale (micro)kinetic, reactor and process modelling to describe the interplay of all relevant elementary phenomena;
- Optimization of renewable energy supply for a chemical plant.

Results and Discussion

As alternative to the conventional Claus process for H₂S abatement, COS synthesis was realized at lab-scale over a 13X zeolite under a CO₂:H₂S feed ratio of 1:1, at 45°C and atmospheric pressure. The effects of temperature and water were assessed, showing slow deactivation of the zeolite by water poisoning.

COS thermal decomposition was examined at lab-scale in a tubular flow reactor with systematic variation of COS feed concentrations, residence times and catalysts. For an inlet COS concentration of 4.5 mol% and residence time of 5 s, the COS conversion in an empty Hastelloy X reactor exceeded 99% with CO as major component in the gas phase (>99%) at temperatures above 950°C.

The ETFB reactor for COS decomposition to CO and S requires temperatures up to 800-1200°C. These will be achieved through Joule heating of the fluidized bed between two electrodes (Figure 1b). Currently, the ETFB pilot is under construction in a demonstration hall at the Institute Jožef Stefan (IJS, Slovenia).

Parameter estimates for the COS synthesis kinetics, based on a Langmuir-Hinshelwood-Hougen-Watson (LHHW) mechanism, properly predict the experimental data from the transient fixed-bed reactor, including breakthrough, rollup and pseudo-steady state of the CO₂, H₂S and COS components. The ETFB reactor is also being modelled, based on co-axial and end-to-end resistors. In combination with microkinetic simulation of the reaction rates, the multi-scale modelling approach will eventually enable optimization of the catalytic materials, the reactor configuration, as well as the operating conditions.

In parallel, techno-economic assessment (TEA) and life-cycle analysis (LCA) modelling are performed to demonstrate the techno-economic and environmental performance of the developed e-CODUCT process. Given the use of renewable sources like solar and wind, intermittent by nature, energy fluctuations will be managed by means of a battery buffer connected to the grid as backup, in view of energy-efficient e-CODUCT process operation.

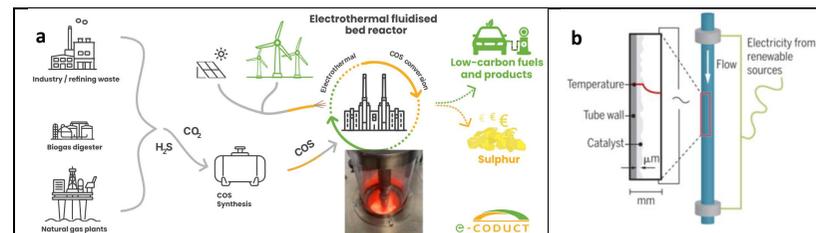


Figure 1. a: scheme of the e-CODUCT process and b: concept of the ETFB reactor.

Significance

The novel e-CODUCT technology contributes to simultaneous reduction of H₂S and CO₂, both produced as by-products in refineries and petrochemical industry. The mixture of gases is converted into COS, and further into platform molecule CO and marketable S. The entire technology relies on electrification as major driver to make chemical industry more sustainable.

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