

In the process industry, down-stream processes are the most resource and energy consuming industrial operation steps. Moreover, the integration of new processes often requires a large portion of CAPEX and OPEX. To enhance the competitiveness of the European process industry and to contribute to Europe's goal of a clean and liveable environment, a broadly applicable concept for efficient integration of downstream operations in the overall process chain is highly desired.

*The MACBETH consortium provides a **breakthrough technology by combining catalytic synthesis reaction with the corresponding separation units** in a single highly efficient **Catalytic Membrane Reactor (CMR)**. With this disruptive technology a **reduction of greenhouse gas emissions (GHG)** and an **increase in resource and energy efficiency** of large volume industrial processes can be achieved. The revolutionary new reactor design will guarantee substantially smaller and safer production plants and thus **reduce operational and investment costs**.*



MACBETH
Membranes And Catalysts Beyond
Economic and Technological Hurdles

Topics

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Consortium News

Modelta and its first activities

Modelta B.V. – a spin-off of MACBETH has become a technical start-up company specialized in providing modelling services and consultancy around membrane- and membrane reactor technology.

In months following its creation, Modelta has started participation in several project including a first big European project on membrane technology "MEASURED - Membrane Scale Up for Chemical Industries" which has started on January 01, 2023. It is funded by from the European Union's Horizon Europe research and innovation programme under grant agreement No 101091887. MEASURED's main objective is

to provide a quantum leap in the development of membrane technologies for pervaporation, gas separation and membrane distillation, setting the basis for future commercialization of greener technological pathways all along the value chain.

The interdisciplinary consortium is composed of 2 SMEs, 7 industries and 8 Universities/research centers, which will comprehensively study the development of advanced materials, reactor design and process configuration to identify the most sustainable options from a demonstration, techno-economic and environmental point of view.

Within MEASURED, Modelta is responsible for Work Package 6 – Modelling.

Project Information

Project No.:

GA 869896

Call (ID) Identifier:

H2020-NMBP-SPIRE-2019

Topic:

CE-SPIRE-04-2019
Efficient integrated
downstream processes (IA)

Project Duration:

54 (+6) months
Nov 2019 – Oct 2024

Project Budget:

20,7 M€



MEASURED

Its objective is to aid the development of the aforementioned technologies through multi-scale modelling, LCAs, techno-economic assessments, and market readiness assessments. More information you can find on www.measured-project.eu.

Additionally, the Modelta team created an own website and defined service portfolio. On www.modelta.nl you can find Modelta's main services, relevant sectors, its history, the team, and relevant news. The main provided services are highlighted below:

1. Membrane- & Membrane Reactor Modelling

Modelling of membranes and membrane reactor units to optimize performance, tackling problems such as suitable membrane materials, membrane sizing, operating conditions

2. Process Design & Upscaling

Focusing on implementation

of the technology on a process scale, sizing and upscaling the units to the process, techno-economic analyses and process sensitivity studies

3. Customized Models Development

Development of custom models for specific processes and systems for issues like unusual geometries, special reactions and separations,

4. Consultancy on Membrane Processes

General consultancy on membrane related processes and systems.

For more information, you can visit their website or their [LinkedIn](#) page. And if you have any questions or want to know what Modelta can do for you, you can also contact them directly at info@modelta.nl.

Review Report

We got the official review report based on the virtual review meeting with Mrs. Jühr in November 2022. Overall, it is very positive with some remarks. We will address the issues at our project meeting in May 2023 in Frankfurt. The next review meeting will be taking place in November 2023.

In particular, the following innovations were highlighted:

- New disruptive process for propylene production from Propane DeHydrogenation (PDH) by means of Catalytic Membrane Reactor (CMR) concept
- Tailored polymer membranes for membrane reactors
- Heterogenized rhodium catalysts for hydroformylation of olefins
- MODELTA B.V., a spin-off company focused on modelling
- New disruptive process for omega-3 enrichment in fish oil by means of Catalytic Membrane Reactor (CMR) concept

In the following months we will present these in more detail.

Dr. Marco Haumann is professor at the FAU

Dr. Marco Haumann from Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) has been awarded an extraordinary professorship for his outstanding achievements in research and teaching.

Prof. Dr. Marco Haumann is internationally known as one of the pioneers in the field of the so-called Supported Ionic Liquid Phase (SILP) technology, with the help of which homogeneous catalysis can be carried out in fixed bed reactors.



PROJECT PROGRESS

As outlined above, the MACBETH consortium provides a breakthrough technology combining catalytic synthesis reaction with the corresponding separation units in a single highly efficient catalytic membrane reactor (CMR). In the

project, this technology is applied to four highly relevant large-scale processes: Hydroformylation (HYFO), hydrogen production (H₂), propane dehydrogenation (PDH) and bio catalytical oil cleavage (BOC). In the following, an update on

the project progress achieved for each of these four cases is provided.

HYFO - Hydroformylation

Preparation for the demonstration phase of the Hydroformylation (HYFO) case are in full swing.

With the knowledge gained in the past years of the MACBETH project, a final structure for the monolithic support, which retains the catalytic phase and holds the membrane, has been fixed for the demonstration phase. The production of the membrane coated monoliths has already started. A close cooperation of the partners and quality checks will ensure consistent quality and timely delivery of the monoliths for the installation in the demonstrator in this reparation for the demonstration phase of the Hydroformylation (HYFO) case are in full swing.

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membrane, has been fixed for the demonstration phase. The production of the membrane coated monoliths has already started. A close cooperation of the partners and quality checks will ensure consistent quality and timely delivery of the monoliths for the installation in the demonstrator in this upcoming summer.

The detail engineering phase of the demonstrator is ongoing and well on track. The construction of the HyFo demonstrator units will start in the upcoming month. It will be built in a modular fashion, which allows construction outside the plant premises and transportation and integration into the plant after cold start-up. "Modularization enables minimal disruption of production routines and speeds up the construction phase. Furthermore, the demonstrator can be transported and used at any other production facility, which will allow testing it for

other applications", explains Dr. Frank Stenger, modularization specialist at Evonik.

Besides construction and engineering work research activities are still ongoing. Currently, one major focus lies in ensuring a stable reactor performance even under non-optimal operation conditions. "There will be times, when an unplanned event in the production plant may require a sudden shutdown of our demonstrator. Thus, we have to develop strategies to protect our catalytic system and restart our reactors without performance losses", says Thomas Diehl, process engineer at Evonik's Process Technology department.

With this the Hydroformylation (HYFO) case is taking large steps towards the goal to integrate a catalytic membrane reactor for the heterogenized hydroformylation into a production environment.

H₂ - Hydrogen Production

In the Hydrogen line, two systems are being developed for pure hydrogen production through membrane reactors. One prototype is based on steam reforming, and H₂Site (Spain) is responsible its development, which is now finalized and is currently operating initial tests, producing hydrogen from

methane using both catalyst and membrane. The second prototype is based on autothermal reforming of biogas and ICI Caldaie (Italy) is finalizing the assembly phase. For both reactors, the membranes production has been finalized by Tecnalia. The catalyst production is accomplished for the steam reforming plant,

while is under finalization for the autothermal reforming one. In the meantime, catalyst formulation is being optimized by JM with the modelling support of POLIMI and TUE.

Furthermore, the sites for the testing of the two systems are being prepared to receive the set-ups.

Finally, new membranes are successfully being developed in the hydrogen line, based on cheap metallic supports that are being modified to be used as Pd supports. TUE is carrying out membrane

preparation at lab-scale, with the support of Tecnalia. This family of membranes will also be involved and tested in the demonstration campaign.

Several results of this line will be presented as oral

presentations at the International Conference on Catalysis in Membrane Reactors in October 2023 in San Sebastian, Spain.

PDH - Propane Dehydrogenation

The PDH case is in a crucial and critical phase: after detailed engineering task 5.1.2 completion, due to budget problems (mostly caused by Covid19 pandemic and Ukraine war) it is not possible to proceed with procurement and construction task 5.1.3 for pilot unit at TRL7.

Therefore the PDH partners are collaborating to submit an amendment to the EC Project

Officer to demonstrate the line at lower TRL in a different location.

In the meantime, pilot scale up (KT) and modelling (POLIMI/UNIBS) activities are in progress.

The Business Plan and Exploitation activities are also in progress: the focus is in particular on the definition of exploitation plans with the aim of identifying the commercial

strategy for the novel PDH technology deployment.

Finally, the activities for the LCA are progressing too, with the collection of general information on the benchmark process and on novel PDH process to outline the framework for data collection and the impact assessment methodology.

BOC - Bio Catalytical Oil Cleavage

The BOC case advances in several areas. Long-term reaction trials have been performed in the labs of Chiralvision and Enzymicals. Critical process parameter for ensuring the longevity of the enzyme catalyst were identified. This led to an updated version of the P&ID of the demonstration plant. HAZOP analysis has been

conducted and detailed engineering was finalized by Microinnova. At the moment, the procurement process is ongoing and construction of the demo plant can begin on schedule. In the meanwhile, the lab spaces for the plant were prepared both on Enzymicals as well as on Solutex site. Also, process

optimization experiments have been performed by VITO. POLIMI and UNIBS finalized the modeling activities for the membrane and also for the enzymatic reaction part. Scaling of the membrane process and construction of the pilot plant are the next milestones that will be achieved in the first half of 2023.

EVENTS

Consortium Meetings

The 8th MACBETH Consortium Meeting will take place from 10th to 12th of May 2023 in Frankfurt (Germany).

In case-wise workshops, recent results & technological progress will be discussed and presented in plenary sessions to the consortium. Additionally, communication, dissemination, and exploitation activities will be coordinated for the next project period. In the evening before, all project members will meet for a get-together for

socializing. We are glad that the next locations for project meetings are already set (subject to change). Thanks a lot at the project members for the willingness to host.

Fall 2023 (review meeting) - Rome (hosted by KT)

Spring 2024 - Izmit, near Istanbul (hosted by Tupras)

Fall 2024 (EAB and final meeting) - Marl (hosted by Evonik)

We are very excited to meet in person again!

Conference Participations

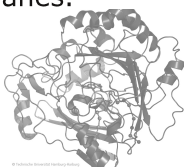
We have been present in conferences all over Europe in the last months. Some of the conferences we attended are presented in the following.

Nordic Symposium on Catalysis: On June 06-08, 2022, Mahtab Madani (DTU) presented the topic "Gas-phase Hydroformylation of 1-Butene using Monolithic Supported Liquid-Phase (SLP) Catalyst" on the Nordic Symposium on Catalysis in Espoo, Finland.

ICCMR15: The MACBETH consortium successfully participated in the 15. International Conference on Catalysis in Membrane Reactors during July 31th to August 4th 2022 in Tokyo, Japan. MACBETH was represented by 8 individual presentations.



BIOCAT 2022: Rob Schoevaart (CHIVI) participated in BIOCAT 2022 from 28. August till 01. September in Hamburg, Germany with his presentation about the biocatalytical ethanolsis of edible oils with CaLA immobilized on acrylic beads and membranes.



Meet MACBETH

Are you interested to meet our partners and learn more about the project?

Upcoming Events:

August 27 – September, 2023

Europacat23

<https://www.europacat2023.cz/>

September 17 – 21, 2023

ECCEAB23

<https://ecce-ecab2023.eu/>

November 05 – 10, 2023

2023 AIChE Annual Meeting

<https://www.aiche.org/conferences/aiche-annual-meeting/2023>

CEHC-2: On March 29. – 31. 2022, DTU participated in the Cutting-Edge Homogeneous Catalysis in Leipzig, Germany. Leonhard Schill showed attendees the progress in moving gas phase hydroformylation towards industrial application which was made possible by catalyst phase optimization and the use of a membrane reactor.

ILSEPT: On February 05-08, 2023, FAU participated as Keynote Speaker in the 5. International Conference on Ionic Liquids in Separation and Purification Technology in Scottsdale, Arizona, USA. Marco Haumann gave a presentation on "Supported ionic liquid phase (SILP) materials in catalysis and separation application".



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