Impact Objectives

- Develop innovative multifunctional catalytic membrane reactors (CMRs) based on new nano-architectured catalysts and selective membranes materials
- Improve the performance, durability, cost-effectiveness and sustainability of CMRs
- Establish the proof of concept of these novel CMRs

Advancing catalytic membrane reactors

With outstanding potential to intensify industrial processes whilst at the same time minimising environmental impacts, it is not surprising that chemical engineering of membranes is attracting so much global attention. Here, through extracts from project newsletters, we survey the progress being made in the area of catalytic membrane reactors (CMRs) by the DEMCAMER project managed by ***Dr José-Luis Viviente***

Can you briefly explain what the DEMCAMER project is?

DEMCAMER stands for the Design and Manufacturing of Catalytic Membrane Reactors, by developing new nano-architectured catalytic and selective membrane materials. It is an EU-funded collaborative project on membrane reactors where 18 partners work together to design and demonstrate new membranes reactors for four reactions. The DEMCAMER project proposes an answer to the paradigm set by the European Chemical Industry: increase the production rate while keeping the same product quality and reducing both production costs and environmental impacts. This involves the implementation of a novel process intensification approach that combines reaction and separation in a single CMR unit.

What parts of process intensification is this project aiming to improve?

The project has addressed the development of innovative multifunctional CMRs based on new nano-architectured catalysts and selective membranes materials to improve their performance, cost-effectiveness (such as reducing the number of steps) and sustainability (lower environmental impact and use of new raw materials) over four selected chemical processes: autothermal reforming (ATR), water gas shift (WGS), Fischer-Tropsch synthesis (FTS) and oxidative coupling of methane (OCM) for pure hydrogen, liquid hydrocarbons and ethylene production.

After your first two years of research and development, what kind of results did you start to see?

The first two years of the project were devoted to the development of new membranes and catalysts for the four reaction systems selected for demonstration of the membrane reactor technology. Exciting results have been obtained for the new catalysts for all the reaction systems, surpassing or very nearly meeting the targets set in the project. As far as membranes are concerned, we have

achieved stable O2 membranes for which a high temperature sealing procedure has been developed. For the hydrogen membranes, we reached the targets set for selectivity/permeation while the research is now devoted to improving sealing and lifetimes.

What do you see as some of the highlights of your efforts?

Many advances have been made since we started the project. New stable and active catalysts have been produced and tested. As far as membranes are concerned, the first generation of membranes has been produced and interesting preliminary results in terms of flux and selectivities have been obtained. The membranes are now ready for integration into membrane reactors and further testing. In the meantime, different reactor concepts have been studied theoretically, designed and constructed. Collaboration has been established with other major EU projects on membrane reactors and joint seminars have been planned. Personally, I think that one of the biggest steps forward has been to set up the framework for the collaboration between the partners, integrating knowledge and know-how from many parts of the value chain.

Communicating the science to a broader audience is always important in these highly technical projects. Can you tell us ways you have shared the results of this project?

Dissemination and collaboration with other major EU projects have been a major point for the DEMCAMER project. More than 150 publications and/or conference participations have been presented by the DEMCAMER consortium. A joint seminar with other three EU projects was held in November 2014 in order to share experiences in the field of membranes and membrane reactors. The package of presentations together with the interactive discussion gave a very clear picture of the status of palladium membrane technology and the critical issues to be addressed in the near future. The final dissemination and exploitation event took place at the International Conference on Catalysis in Membrane Reactors on 22–25 June 2015.

Greening chemical processes

The DEMCAMER consortium is making serious inroads into developing innovative technologies with their improved, more cost-effective catalysts and membranes in an effort to create cleaner, more energy efficient industrial processes

The European Commission's Directorate-General for Research and Innovation believes sustainable chemistry – the designing and manufacturing of more environmentally friendly products and processes – is a catalyst for changing the way the world manages and uses its resources: 'The overall idea is to produce in a more efficient and safe manner, exploiting and integrating advances in nanosciences, biotechnologies, materials technologies and new engineering concepts.' At the very heart of this is the concept of process intensification which, through novel chemical engineering principles and methods, supports the sustainable manufacturing of products. The US Department of Energy describes process intensification as targeting dramatic improvements in manufacturing and processing by 'rethinking existing operation schemes into ones that are both more precise and efficient than existing operations'. While process intensification technologies have been commercially applied since the 1970s, it is only recently that their true potential to create cleaner, more energy efficient technologies has been recognised.

Europe is certainly well aware of the potential that lies in process intensification technologies, in terms of the major benefits that can be achieved through improved product life cycle efficiencies, reduced capital and operating expenses, and reduced waste. The European Commission, in its publication *Rejuvenating the European Chemical Sector*, states that the 'only alternative to safer and cleaner production appears to be the route of Sustainable Chemistry', noting that innovative chemical engineering methods are needed to increase production whilst using less resources, thus achieving all of the four pillars of sustainable development for the region. One example of novel chemical engineering is developing the ability to store electricity using hydrogen which could make wind and solar power a secure energy source. As part of the EU's driver to develop more efficient manufacturing and engineering processes whilst minimising environmental impacts, a project known as DEMCAMER (Design and Manufacturing of Catalytic Membrane Reactors) has been delving into the different technologies of membrane reactors with the aim of developing new nano-architectured catalytic and selective membrane materials.

MEMBRANE REACTOR TECHNOLOGY

Dr José-Luis Viviente, DEMCAMER Project Manager, considers that the project will provide some important answers for industry: 'DEMCAMER proposes an answer to the paradigm set by the European Chemical Industry: increase the production rate while keeping the same product quality and reducing both production costs and environmental impacts.' Currently, the majority of catalytic industrial processes rely on conventional reactors, thus with innovative catalytic concepts vast improvements in intensification can be made. The technology of a membrane reactor plays an important role in process intensification, which is based on a device combining a membrane-based separation and a catalytic chemical reaction in one unit. Therefore reaction and separation in a single unit CMR is the DEMCAMER team's main target in order to develop an innovative process intensification approach.

This is a large project with a consortium of 18 partners from 10 different countries, including eight research centres and universities, four SMEs and five large

“One of the biggest steps forward has been to set up the framework for the collaboration between the partners, integrating knowledge and know-how from many parts of the value chain”

enterprises. These organisations and institutions enable the meeting of minds with significant multidisciplinary expertise in material development, catalyst synthesis, catalytic membranes development, chemical and process engineering, modelling, life cycle assessment, and industrial risk study. Viviente considers that this consortium, and the experience all the partners bring to the table, has been a very positive outcome of the work: ‘It has been very encouraging to see how well the DEMCAMER partners have been interacting and collaborating together, as well as taking up their responsibilities with great enthusiasm and dedication.’ These partners have been essential in determining how the project progresses, particularly in terms of potential applications from the results. For example, the industrial partners helped define the industrial requirements for each of the reactions to be carried out in the membrane reactors.

SUPPORTING THE ENTIRE PRODUCT CHAIN

The work plan of this project includes experiments that are connected across the whole product chain, including the development of materials right through to a stage where four semi-CMR prototypes have been validated. In addition, there is research being completed on the environmental and health and safety issues of the new processes being developed. ‘Besides, designs of the pilot prototypes and the initial assessment of the health, safety and environmental impact of the four CMRs have been also carried out’, says Viviente. The four prototype reactors revolve around different chemical processes. Autothermal reforming and Fischer-Tropsch synthesis are based on palladium-supported membranes, and water gas shift and oxidative coupling of methane are based on mixed ionic–electronic conducting membranes. Modelling and simulation was used to support the design of the membranes, catalysts and CMRs.

After four years of intensive research by the consortium the results speak for themselves. The DEMCAMER final report states that the team has produced improved, more cost-effective catalysts and membranes for all four of these processes: ‘The final catalysts for each of the pilot-scale CMRs all demonstrate superior activity, selectivity and stability compared to the current state of the art’. Essentially, explains Viviente, the outcomes from this project mean that improved performance, cost-effectiveness and sustainability of the industrial processes that rely on catalytic reactions can be achieved through the CMRs developed: ‘Many advances have been made, especially in the development of the catalysts, membranes and lab-scale validation of the reactors as well as in modelling and simulation, such as ab initio calculation for membranes and catalysts, transport in membranes, CMR simulation, and process design and simulation.’

Communication of results has been an important part of this project, as well as training of young researchers through the different activities at the partner institutions and organisations. Newsletters provided regular updates to the consortium and wider audiences. Contributions are being made to a number of international and national conferences to share the results, and links with related projects fostered. In addition, a number of papers on the project have been published in highly regarded industry journals and publications. The final results were shared with the research and industrial community at the International Conference on Catalysis in Membrane Reactors in 2015. It was here that the DEMCAMER partners revealed some of the technologies developed by the project, such as membranes, lab-scale reactors and test modules, as well as the overall process developments. The team are continuing to impart results through different international conferences and workshops to ensure that the technologies can have a real and practical impact on process intensification for EU sectors that are reliant on industrial chemical processes.

Project Insights

FUNDING

European Union Seventh Framework Programme (FP7)

PARTNERS

Institut National De L Environnement Et Des Risques Ineris • Guascor Ingenieria S.A. • Total Petrochemicals France Sa • Agencia Estatal Consejo Superior De Investigaciones Cientificas • Abengoa Bioenergia Nuevas Tecnologias Sa • Hygear B.V. • Fraunhofer-Gesellschaft Zur Foerderung Der Angewandten Forschung E.V • Quantis Sàrl • Höganäs Ab • Hybrid Catalysis Bv • Universita Della Calabria • Boreskov Institute Of Catalysis, Siberian Branch Of Russian Academy Of Sciences • Total Petrochemicals Research Feluy • Technische Universiteit Eindhoven • Vlaamse Instelling Voor Technologisch Onderzoek N.V. • Total S.A. • Ceramic Powder Technology As • Rauschert Kloster Veilsdorf Gmbh

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SEVENTH FRAMEWORK PROGRAMME

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DEMCAMER
Catalytic Membrane Reactors