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Editorial Note

Membrane Reactors: A Way to Increase Efficiency

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Editor

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In general, Process Intensification (PI), is defined as "any chemical engineering development that leads to a substantially smaller, cleaner, safer and more energy efficient technology" [1], and is always referred to as the next revolution of the chemical industry. There is consensus on the contribution that PI can give to the chemical industry in terms of improved energy efficiency.

The chemistry and related sectors have already recognized the benefits of PI and estimate a potential for energy saving of about 1000 ktoe/y using these processes.

PI is however a very broad field and, in many cases, it is just a new and nicer name for practices that were already carried out in chemical industries. PI is not just about debottlenecking processes already working at industrial level, but rather strategies that can open new process windows not available with conventional systems.

Several authors have reported reviews and books on process intensification, and an interested reader is referred to these works for more information [2-4].

The most interesting concepts can be summarized in the Figure 1. The strategies adopted are divided in 4 categories, where the PI will be achieved either in one or more of the domains.

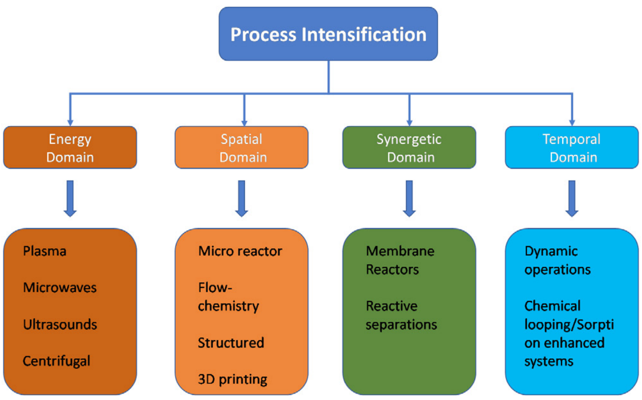

Fig. 1. Summary of the process intensification strategies.

One interesting strategy is achieved in the synergy domains, where functions are integrated in single units. Generally, the functions integrated are reaction and separation or reaction and heat management. The integration of functions promises to decrease the capital costs and operating costs compared to typical systems where these functions are separated.

One of these "novel" concepts is the membrane reactor concept, in which membrane separation is integrated with reaction.

The systems where membrane reactors can give clear benefits (see Figure 2) are reaction systems in which the conversion/yields are either limited by thermodynamic equilibrium or by consecutive/parallel reactions. In these cases, removal of the product (or feeding of a reactant) can give great benefits in terms of product yields.

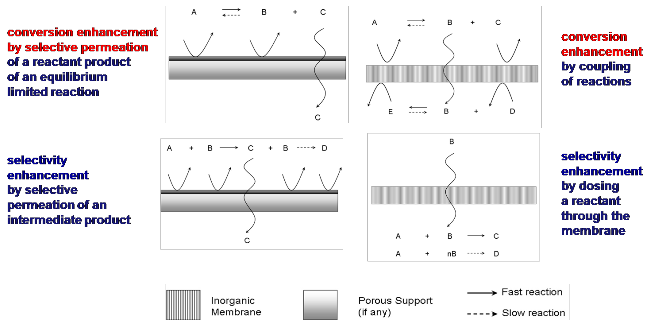

Fig. 2. Main application possibilities of (inorganic) membrane reactors.

Probably the only membrane reactor that has found large application in industry is the membrane bio-reactor, where gas is fed into the reactor through membranes immersed in the liquid to be treated. However, most of the benefits for the chemical industry can be achieved when using membrane reactors to drive equilibrium reactions, so that the removal of one of the products shifts the equilibrium toward higher yields. There are numerous reports on the benefits of membrane reactors for those reactions compared to conventional reactors. At European level, several projects have been granted and are running on membrane reactors. From very fundamental projects to high technology readiness level projects (like BIONICO or the newly granted MACBETH project), the membrane reactors have been brought a step closer to industry.

What is really missing and is hampering the application of membrane reactors to industry is a real proof that membrane reactors are stable and produce high value products for a long time on stream. For many types of membrane reactors (see for instance hydrogen production membrane reactors) it is not a matter of scientific breakthrough anymore (already reported by many authors [5-10], but rather a demonstration in real environment that is required. For this kind of reactors, we should expect more papers on proof-of-concept and long-term demonstration, while additional papers on the production of more selective and high flux membranes for hydrogen could be submitted.

For other applications of membrane reactors, still we could expect more fundamental studies on the integration of reaction and separation,

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interaction between catalyst and membranes, membrane stability under reactive conditions (see for example high temperature partial oxidations with oxygen selective membranes), as well as on electro-driven membrane separations in combination with reaction.

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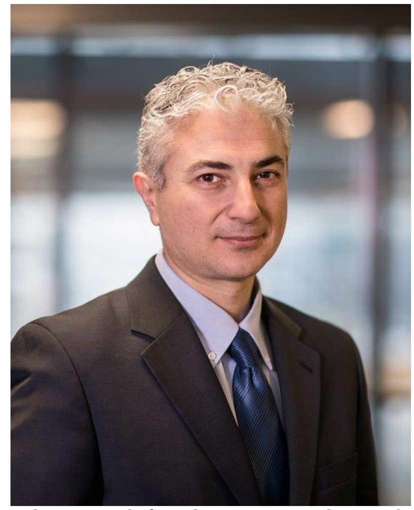

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Fausto Gallucci studied Chemical Engineering at the University of Calabria (UNICAL, Arcavacata di Rende, Italy) where he obtained his MSc (2001) and PhD (2006) degrees. He performed his PhD research on hydrogen production from methanol in membrane reactors. In 2007, after having held a position as a postdoctoral researcher at the Research Institute on Membrane Technology (ITM-CNR, at the UNICAL campus), Gallucci moved to the research group Fundamentals of Chemical Reaction Engineering at the University of Twente (Enschede, The Netherlands). In 2009 he was appointed Assistant Professor (tenure track) there. The following year, Gallucci moved to the Chemical Process Intensification laboratory at Eindhoven University of Technology (TU/e, The Netherlands) where he was appointed Associate Professor in 2015, leading the Multiphase Reactors research effort. In 2018 he was appointed full Professor at the chair 'Inorganic Membranes and Membrane Reactors'.