16th International Conference on Surfaces,
Coatings and Nanostructured Materials
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ABSTRACT:

Thermally and electrically conductive structured catalysts to enable distributed and decarbonized H_2 production.

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Chemical and catalytic processes are expected to play a significant role in the energy transition, enabling to provide clean solution for hard-to-abate sectors. A paradigm shift will be required since, up to now, chemical processes were developed to serve centralized production scheme, with highly optimized solutions run typically steady state.

The necessity to couple chemical processes with a decarbonized energy production system that relies on volatile renewable energy production, the rise of a distributed demand of different chemicals and energy vectors on the territory and the compelling requirement to decrease of the carbon footprint calls for new solutions that need to be developed in the next decades.

Chemical reaction engineering and process intensification can provide useful solutions for modular, small scale and intermittent systems that solve this task. Thermally conductive internals have been proposed as an alternative to conventional packed beds to overcome heat transfer limitations that hinder the scale down of several catalytic processes [1]. As an example, copper open cell foams have been successfully used for small scale H_2 production through methane reforming allowing therefore potential valorization of small scale reservoirs or use of alternative low carbon feedstocks s biogas for hydrogen production [2].

Electrification has emerged in the last years as an enabling solution for short-term production of low-carbon H_2 by transforming conventional methane steam reforming process and providing an alternative path to H_2O electrolysis that still suffers from low efficiency and high energy demand. Systems based on Joule heating are able to transform completely the electric power in high temperature heat and allow for a direct cut of process emissions, and, at the same time can provide additional advantages such as a simplified process layout, optimized use of the catalyst within the reactor tube and savings in terms of footprint and raw materials [3]. Electrified reactors may also play a significant role in reconversion of H_2 carriers, in a decarbonization scheme that exploits centralized energy and H_2 generation, conversion in a

suitable molecule that can be easily transported and then converted back to H_2 in small scale reactors without net emissions of CO_2. Examples such as electrified ammonia cracking and MCH dehydrogenation will be also presented.

[1] Freek Kapteijn, Jacob A. Moulijn Structured catalysts and reactors – Perspectives for demanding applications, Catalysis Today 383, 2022, 5-14
[2] F. Zaio, M. Ambrosetti, C. Tregambe, A. Beretta, G. Groppi, E Tronconi, Intensification of methane steam reforming by Cu-foams packed with Rh-Al2O3 catalyst: A pilot-scale assessment CHERD 215 2025, 98-107
[3] Lei Zheng, Matteo Ambrosetti, Enrico Tronconi, Joule-Heated Catalytic Reactors toward Decarbonization and Process Intensification: A Review, ACS Engineering Au 4, 2024, 4-21