Hydrogen and carbon black production from cracking in molten media (HAMMER)

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Abstract
The HAMMER project is a PRIN PNRR 2022 initiative carried out in collaboration between the Department of Chemical Engineering at Sapienza University of Rome, the Department of Chemistry, Materials and Chemical Engineering, and the Department of Energy at Politecnico di Milano.
Methane cracking is considered one of the alternatives for the production of clean hydrogen and and valuable carbon materials. At high temperature, CH4 is broken into solid carbon and H2 through an endothermic pyrolysis process. The elemental carbon can be stored or valorized by targeting its properties to high value products, driving lower H2 price and improving the overall economics of the process. However, the high temperatures needed to reach high conversions and the formation of solid carbon brings up technological challenges for stable continuous reactor operation, making the industrial scale up complicated. Molten metal methane cracking (MMMC) is a viable solution to overcome the main issues of this technology. The continuity of the process is guaranteed by the floatation of carbon on the metal surface. Nevertheless, a deep knowledge of the occurring kinetic/fluid-dynamic is missing and application is still largely limited to empirical lab-scale approaches. The lack of detailed experimental data on the reaction intermediates and carbon precursors, on bubbles motion in the molten media and on solid carbon characterization inhibits the development of reactor models, hindering a careful assessment of the impact of operating conditions for design and optimization purposes.
The aim of the project is to improves the understanding of the chemistry and fluid-dynamics of CH4 cracking in molten metals, thus enabling a widespread adoption. The overall objective will be pursued by synergistically 1) developing a lab-scale bubble reactor and a methodological procedure for decoupling chemistry and fluid-dynamics (UNIROMA1) and 2) producing, assessing and validating a multiscale bubble reactor model which can serve as tool for design and optimization of larger scale reactors (POLIMI). Parametric exploration of operating regimes and conditions will provide evidence of key process features and validation targets for both the chemical kinetics and fluid-dynamic models.