

Pyrolysis of methane by thermal plasma: a 30+ year journey and start of an industrial adventure

Speaker

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In this conference, we'll report a 30+ year research journey on thermal plasma pyrolysis of methane which has led to the emergence of a new, environmentally-friendly, and disruptive process to produce decarbonized hydrogen and carbon black. After a brief introduction stating the benefits of plasma methane pyrolysis in the energy transition context and history, a discussion on the state of the art, scientific challenges and main achievements will be given.

Introduction: The most common current method of hydrogen production on an industrial scale (SMR) is accompanied by more than 10 tons of CO₂eq per ton of hydrogen. Water electrolysis holds promise as a source of "decarbonized" hydrogen. Now, water dissociation is extremely energy-intensive, and the cost of H₂ from electrolysis remains very high. An emerging pathway for H₂ production is based on the pyrolysis of methane to produce solid carbon and H₂

$\text{CH}_4 \rightarrow \text{C} + 2\text{H}_2$

The main advantage of this method is that it allows low CO₂ production of hydrogen and solid carbon while being thermodynamically much less energy-intensive than water electrolysis for H₂ production, requiring about seven times less energy per mass (or mole) of hydrogen (38 kJ vs 285 kJ per mole H₂). Additionally, this process can co-produce two valuable products: hydrogen and high-value carbon. The principle of this process is illustrated on Figure 1.

History: Commercialization of thermal plasma for hydrocarbon processing has been attempted for over 100 years (Rose 1920). From 1920 to 1990, many carbon black companies followed in the footsteps of the original thermal plasma process patent. From 1993 onwards, our group initiated research based on a three-phase AC plasma technology [1]. Since 2012, research continued with MONOLITH Materials, who in parallel constructed a pilot plant in California. After using this pilot facility to demonstrate technical feasibility and economic viability, MONOLITH then constructed a commercial scale facility in Nebraska (termed OC1) which began construction in 2016 and was complete and operational in 2020.

Results and Discussion: This presentation gives an overview of plasma processing of hydrocarbons through different experimental and modeling conditions and approaches carried out over decades with a special focus on: (i) gas phase chemistry of methane pyrolysis, solid carbon nucleation and growth; (ii) technology and modelling challenges; life cycle analysis; and (iii) future challenges and opportunities for the plasma scientific community [2].

Conclusion: After a long journey, thermal plasma methane pyrolysis technology is now mature and can offer a new, economically viable, environmental-friendly, and disruptive process to produce decarbonized hydrogen and carbon black that may have a huge impact in the context of decarbonization.

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References:

- [1] L. Fulcheri et al. Int. J. H. E. Vol. 20, No. 3, pp. 197- 202, (1995).
- [2] E. Dames et al. Ad. in Chem. Eng. Vol. 61, pp 253-317 (2023).

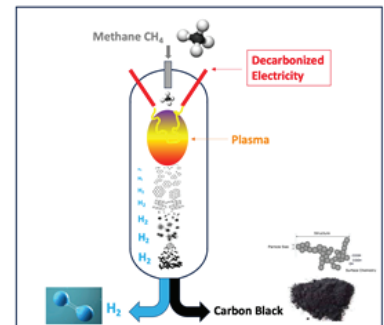


Figure 1: Schematic of the plasma methane pyrolysis

Laurent Fulcheri was graduated from École Nationale Supérieure des Arts et Métiers (ENSAM-ParisTech) in 1983, he got a DEA (2nd master degree) at INP-Grenoble (Physics&Energy) in 1984, a PhD and Habilitation degree in 1989 and 2003 respectively.

He joined École des Mines de Paris (PSL-University) at the end of his PhD in 1989 as Assistant Professor. He created in 1995 a new research group on Plasma Processing. He was appointed Senior Researcher in 2007, then Research Director (Full Professor) in 2013. He was appointed Honorary Professor at the School of Engineering at the University of KwaZulu-Natal, Howard College Campus in Durban (South Africa) in 2016.

Laurent Fulcheri published 100+ articles in international peer review scientific journals. He supervised 20 PhD students, filed 12 patents, 7 of which have been internationally extended.

His research activities focus on the development of thermal and non-thermal plasma processes in the context of Energy Transition.

Laurent Fulcheri has been working for more than 30 years on the Plasma Pyrolysis of Methane for the co-production of decarbonized hydrogen and nanostructured solid carbon (he obtained in 2003, his habilitation degree on this field). He contributed in 2012 to the creation of the start-up MONOLITH Materials in the USA. Since then, he has been accompanying the development of MONOLITH with continuous R&D efforts. He was awarded the "Laurent Fulcheri prize" for transformative innovation by MONOLITH Materials' CEO, Rob Hanson in 2021 and the "Carnot prize" in 2023



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