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Hydrogen production from natural gas thermal cracking: design and test of a pilot-scale solar chemical reactor

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Solar methane decarbonization aims at dissociating methane into two valuable products: hydrogen and carbon black.

After the operation of a 10 kW solar reactor, a 50 kW reactor was designed, built and tested at the 1 MW solar furnace of the laboratory. The indirect heating reactor is composed of a graphite cavity (approaching the black-body behaviour) crossed by seven single graphite tubes (80 cm length). The cavity is separated from the ambient oxidizing atmosphere by a domed quartz window. A filter bag permits to separate carbon particles from the gaseous products.

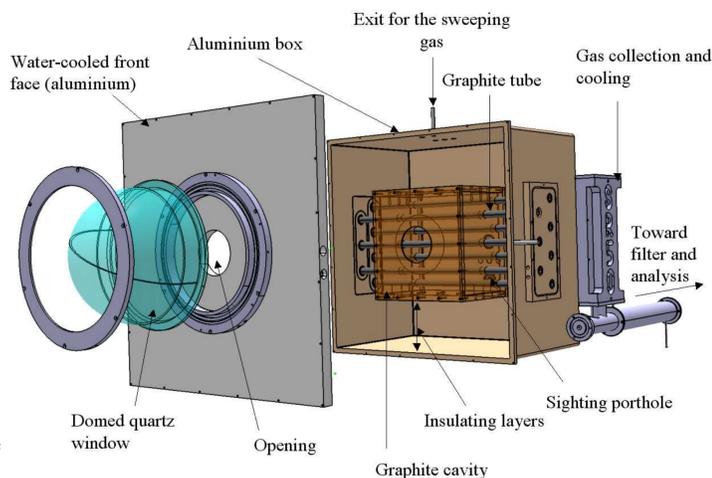
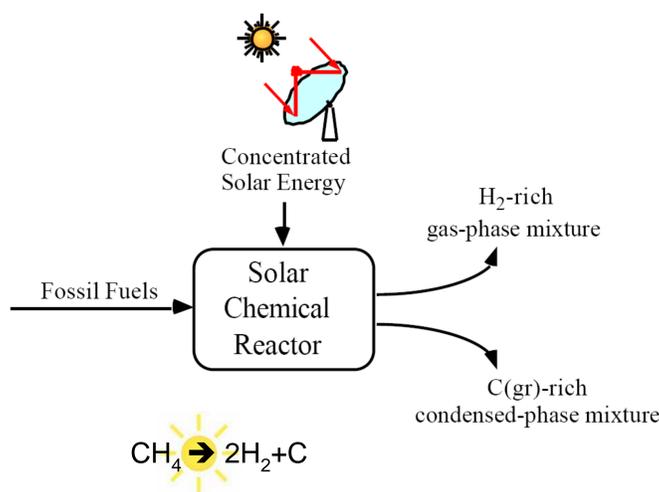


Figure 1: 50 kW solar reactor

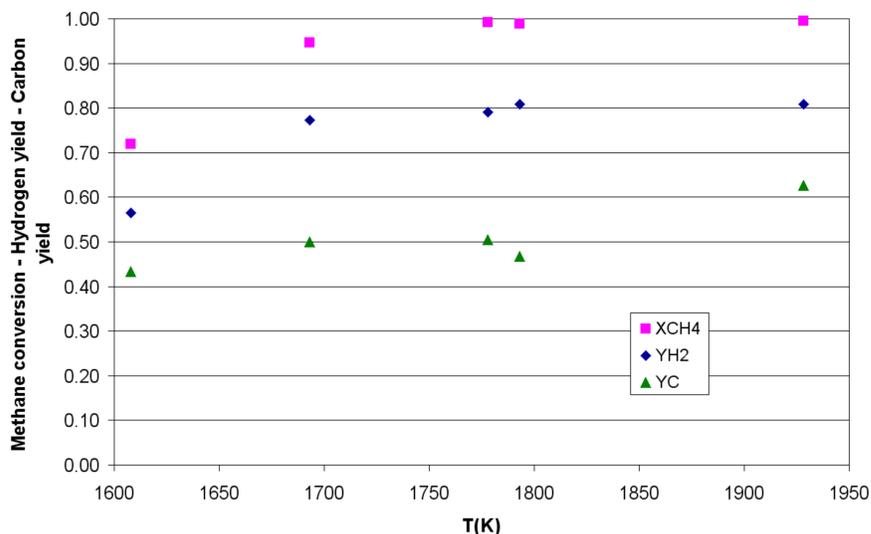


Figure 2: CH₄ conversion, H₂ yield, and C yield versus temperature for the first experimental series (Ar: 31.5 NL/min, CH₄: 10.5 NL/min)

Results show the strong influence of temperature and residence time on the chemical conversion, C₂H₂ is the main by-product. Significant quantities of carbon black were recovered and analysed: the higher the temperature, the higher the specific surface area.

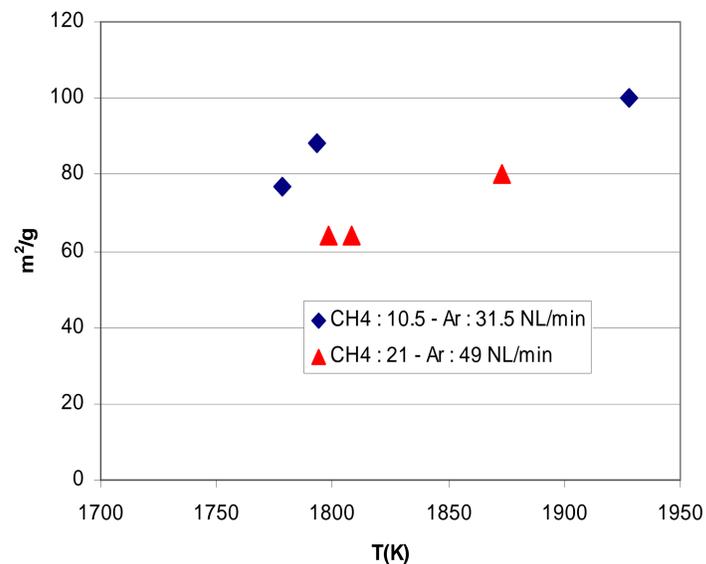


Figure 3: Carbon black specific surface area versus temperature

For 900 g/h of CH₄ injected (50% molar, the rest being argon) at 1800K, this reactor produced 200 g/h H₂ (88% H₂ yield), 330 g/h CB (49% C yield) and 340 g/h C₂H₂ with a thermal efficiency of 15%. A 2D thermal model of the reactor was developed. It showed that the design of the reactor front face could be drastically improved to lower thermal losses. The optimized design could reach 77% of the ideal black-body absorption efficiency (86% at 1800K), i.e. 66%. A preliminar economic analysis at 55 MW scale shows that this process can be competitive with the conventional process of hydrogen production that is to say, the steam methane reforming.

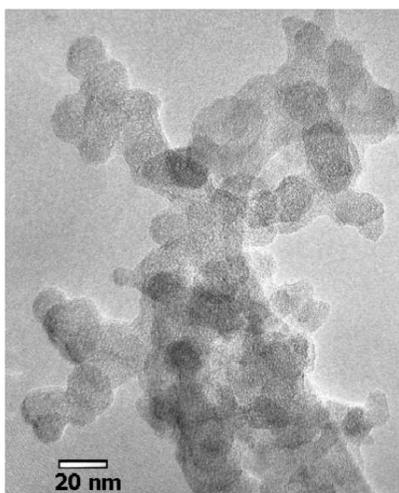


Figure 4: TEM image (APT, Greece) of a carbon black sample (CNRS, France)

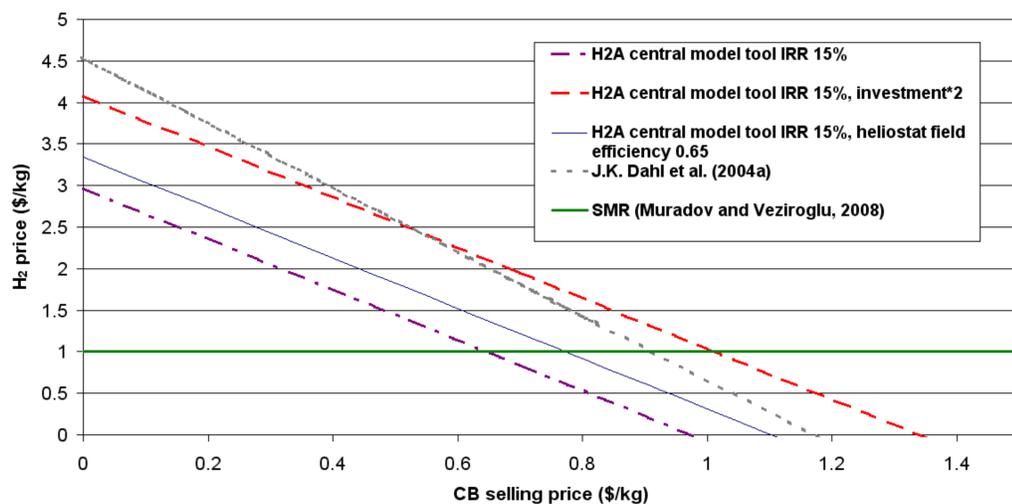


Figure 5: Economic analysis (Hydrogen production price vs carbon black selling price)



Projected total cost: 3.2 m€
Maximum EC contribution: 1.9 m€
Co-ordinator's e-mail address: Flamant@promes.cnrs.fr
Project web site - URL address:
<http://www.promes.cnrs.fr/ACTIONS/Europeenes/solhy carb.htm>
Duration: March 2006- February 2010 (4 years)