



Producing Hydrogen by Plasma Pyrolysis of Methane

Plasma pyrolysis offers several advantages over traditional catalytic pyrolysis.

Marshall Space Flight Center, Alabama

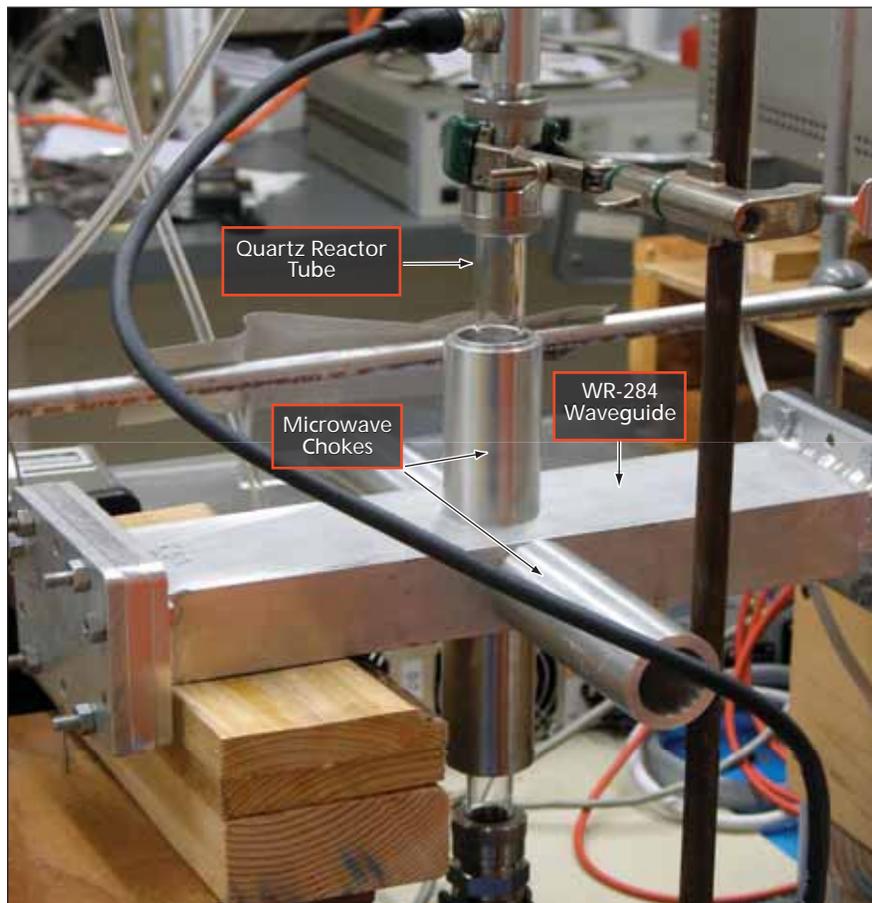
Plasma pyrolysis of methane has been investigated for utility as a process for producing hydrogen. This process was conceived as a means of recovering hydrogen from methane produced as a byproduct of operation of a life-support system aboard a spacecraft. On Earth, this process, when fully developed, could be a means of producing hydrogen (for use as a fuel) from methane in natural gas.

The most closely related prior competing process — catalytic pyrolysis of methane — has several disadvantages:

- The reactor used in the process is highly susceptible to fouling and deactivation of the catalyst by carbon deposits, necessitating frequent regeneration or replacement of the catalyst.
- The reactor is highly susceptible to plugging by deposition of carbon within fixed beds, with consequent channeling of flow, high pressure drops, and severe limitations on mass transfer, all contributing to reductions in reactor efficiency.
- Reaction rates are intrinsically low.
- The energy demand of the process is high.

In contrast, because the plasma pyrolysis process does not involve either a catalyst or fixed beds, it is inherently amenable to long-term, continuous operation without fouling of a catalyst or plugging of beds. Also, because this process involves only minimal heating of non-reactive components, it offers potential advantages of operation at relatively low power with high energy efficiency, plus enhanced safety (because of lower power levels and fewer hot surfaces).

The apparatus used in the investigation includes a 0.75-in. (1.9-cm)-diameter quartz reactor tube that contains the methane feed gas. Part of the length of the reactor tube lies in a horizontal WR-284 rectangular waveguide (see figure), through which microwave power is supplied to excite the methane to the plasma state. The reactor tube is inserted vertically through the middle of the horizontal waveguide via vertical



The **Quartz Reactor Tube** is inserted vertically through the middle of the horizontal WR-284 waveguide. In the portion of the tube that lies inside the waveguide, methane contained in the tube is excited to plasma by microwave power.

metal tubes, attached to the waveguide, that serve as microwave chokes. Apertures defined by two additional, horizontally oriented microwave chokes enable direct visual observation of the plasma. The microwave system delivers variable microwave power levels, monitors delivered and reflected power, and enables matching of microwave-source, waveguide, and load impedances (the main load being the plasma) for maximum power-transmission efficiency. The microwave source is a water-cooled magnetron that operates at the fixed frequency of 2.45 GHz and can deliver between 100 and 1,200 Watts of power under manual or computer control. Re-

flected microwave power not absorbed by the plasma is absorbed by a circulating-water load.

In operation, a process gas that consists of or includes methane is fed into the reactor through a mass flow controller that has a range from 0 to 1,000 standard cubic centimeters per minute. The microwave plasma is created and confined within the portion of the quartz tube that lies inside the waveguide. Early experiments were conducted using a 1:9 methane:argon feed-gas mixture, followed by experiments using pure methane. Operating conditions were identified under which methane-to-hydrogen conversion efficiencies ap-

proached 100 percent. Long-term tests were conducted to demonstrate continuous production of hydrogen without loss of reactor efficiency. Chemical analyses of the reaction products revealed that generation of hydrogen through decomposition of methane is accompanied by a

combination of cracking, oligomerization, and aromatization reactions, which tend to minimize the formation of elemental carbon. Further research is planned to refine understanding of these reactions and to determine whether and how they might be exploited.

This work was done by James Atwater, James Akse, and Richard Wheeler of Umpqua Research Co. for Marshall Space Flight Center. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32539-1.

Self-Deployable Membrane Structures

These support structures can be used as portable shelters, camping tents, and thermal insulation.

NASA's Jet Propulsion Laboratory, Pasadena, California

Currently existing approaches for deployment of large, ultra-lightweight gossamer structures in space rely typically upon electromechanical mechanisms and mechanically expandable or inflatable booms for deployment and to maintain them in a fully deployed, operational configuration. These support structures, with the associated deployment mechanisms, launch restraints, inflation systems, and controls, can comprise more than 90 percent of the total mass budget. In addition, they significantly increase the stowage volume, cost, and complexity.

A CHEM (cold hibernated elastic memory) membrane structure without any deployable mechanism and support booms/structure is deployed by using shape memory and elastic recovery. The use of CHEM micro-foams reinforced with carbon nanotubes is considered for thin-membrane structure applications. In this advanced structural concept, the CHEM membrane structure is warmed up to allow packaging and stowing prior to launch, and then cooled to induce hibernation of the internal restoring forces. In space, the membrane remembers its original shape and size when warmed up. After the internal restoring forces deploy the structure, it is then cooled to achieve rigidization. For this

type of structure, the solar radiation could be utilized as the heat energy used for deployment and space ambient temperature for rigidization.

The overall simplicity of the CHEM self-deployable membrane is one of its greatest assets. In present approaches to space-deployable structures, the stowage and deployment are difficult and challenging, and introduce a significant risk, heavy mass, and high cost. Simple procedures provided by CHEM membrane greatly simplify the overall end-to-end process for designing, fabricating, deploying, and rigidizing large structures. The CHEM membrane avoids the complexities associated with other methods for deploying and rigidizing structures by eliminating deployable booms, deployment mechanisms, and inflation and control systems that can use up the majority of the mass budget.

In addition, highly integrated multi-functional CHEM membranes with embedded thin-film electronics, sensors, actuators, and power sources could be used to perform other spacecraft functions such as a communication, navigation, science gathering, and power generation.

This advanced membrane concept represents the introduction of a new generation of self-deployable structures.

This technology will introduce a new paradigm for defining configurations for space-based structures and for defining future mission architectures. It will provide new standards for fabricating, stowing, deploying, and rigidizing large deployable structures in a simple, straightforward process.

A number of deployable structures are used for space robotics and other support deployable structures for solar sails, telecommunication, power, sensing, thermal control, impact, and radiation protection systems. A self-deployable membrane structure could be used on some of these space applications with a big improvement.

Although the space community is the major beneficiary, potential commercial applications are foreseen for this technology. It could be applied to deployable shelters, storage places, and camping tents. Other potential applications are seen in self-deployable house construction, thermal insulation, automotive, packaging, and biomedical.

This work was done by Witold M. Sokolowski and Paul B. Willis of Caltech and Seng C. Tan of Wright Materials Research Co. for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-41759

Reactivation of a Tin-Oxide-Containing Catalyst

This technique extends the lifetime of a catalyst in a laser discharge.

Langley Research Center, Hampton, Virginia

The electrons in electric-discharge CO₂ lasers cause dissociation of some CO₂ into O₂ and CO, and attach themselves to electronegative molecules such as O₂, forming negative O₂ ions, as well as larger negative ion clusters by colli-

sions with CO or other molecules. The decrease in CO₂ concentration due to dissociation into CO and O₂ will reduce the average repetitively pulsed or continuous wave laser power, even if no disruptive negative ion instabilities occur. Ac-

cordingly, it is the primary object of this invention to extend the lifetime of a catalyst used to combine the CO and O₂ products formed in a laser discharge.

A promising low-temperature catalyst for combining CO and O₂ is platinum