Novel Carbon Dioxide-Free Hydrocarbon Conversion Processes and Reactor Technologies for Solid Carbon and Hydrogen Production

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OTHER INFORMATION

KEYWORDS

hydrocarbon, hydrogen, hydrocarbon feedstocks, carbon, hydrogen production, hydrocarbon decomposition, batteries, battery, chemical, fuel, plasma, feedstocks

CATEGORIZED AS

- **Energy**
  - Other
  - Storage/Battery
- **Materials & Chemicals**
  - Chemicals

RELATED CASES

2022-984-0

BACKGROUND

Producing a hydrogen product without carbon dioxide remains a substantial challenge. The pyrolysis of low-cost hydrocarbon feedstocks including petroleum and natural gas produces molecular hydrogen and solid carbon. In the absence of a catalyst, the reaction requires high temperatures (T > 1000 °C), which presents technical and economic challenges. To date there have been no significant commercial processes using pyrolysis to produce hydrogen as a primary product. Plasma use in molecular hydrogen production has also been limited; production is restricted to gas phase processes at relatively low pressures.

DESCRIPTION

Researchers at the University of California, Santa Barbara have developed several technologies that introduce novel reactors, catalysts, and processes to produce both hydrogen and carbon products from fossil hydrocarbon decomposition. Unique reactor designs facilitate efficient heat transfer into high temperature reactors and solid carbon management, while alternative configurations enable heat addition and product management within the reaction environment. The integrated processes can eliminate net carbon dioxide emissions by focusing conversion on solid carbon and hydrogen-based products. High quality graphitic carbon can be produced suitable for use in batteries. Collectively, these technologies represent potential advances in producing low-cost, low-emission hydrogen for use in the chemical and fuel industries.

Inert Media Enhanced Catalytic Pyrolysis of Hydrocarbons

UC Case No. 2023-99K

Enhanced production of molecular hydrogen from decomposition hydrocarbon gases, such as methane, in a stratified circulating fluidized bed reactor using an iron-ore based catalyst and inert media (e.g. sand). The circulating inert can be heated by combustion gases or electricity to maintain the high temperature reaction environment eliminating the major barrier of methane pyrolysis. High yields of hydrogen and carbon have been demonstrated. The system operating conditions can be employed to regenerate the catalyst activity or to dispose of the catalyst within the solid carbon product. The use of a low-cost, long-lifetime catalyst enables a low-cost process for hydrocarbon conversion into hydrogen and solid carbon, and the use of pyrolysis represents a breakthrough in hydrogen production.

- Publication
- Patent application

Production of Chemicals by Direct Plasma Conversion of Liquid Feedstocks

UC Case No. 2024-852

An innovative reaction system to produce chemicals from liquid feedstocks through the generation of plasma between two or more electrodes within a liquid phase has been developed. This technology enables direct conversion of liquefied natural gas (LNG) and other low-value liquid hydrocarbon mixtures into valuable products, including hydrogen, acetylene, and ethylene. While plasma-based processes have previously been employed to drive chemical transformations in both gases and liquids, their application for producing molecular hydrogen and light hydrocarbons has largely been confined to gas-phase systems operating at relatively low pressures. In contrast, this new reactor system operates within a liquid phase, offering a novel pathway for high-efficiency chemical conversion. The system comprises a liquid medium containing one or more reactants—such as LNG or other liquid hydrocarbons—and an electrode assembly designed to generate a high-voltage, pulsed plasma discharge. Incorporation of conductive agents (e.g., catalysts, salts, or similar additives), along with tuning of plasma pulsing characteristics, allows precise control over the liquid's conductivity, breakdown voltage, and reaction timescales, enabling modulation of reaction rates and product selectivity. Overall, this technology represents a significant advancement in chemical processing, with the potential to lower economic barriers in the transition away from fossil fuels. By enabling direct, electricity-driven production of hydrogen without CO_2 emissions, it offers a promising route toward more sustainable energy and chemical manufacturing systems.

- Publication
- Patent application

Improved Processes, Reactors, and Catalysts for Hydrocarbon Pyrolysis

UC Case No. 2024-881

An extension of UC Case No. 2023-99K (above) introduces a method for operating the reactor system under autothermal conditions the novel low temperature process converts hydrocarbons (like natural gas and petroleum) to solid carbon and hydrogen gas without the net co-production of carbon dioxide. Unique reactor and process configurations are outlined designed to provide solid carbon management and heat exchange within the reactor. This process overcomes the major challenge of heat transfer for methane pyrolysis. Crucially, this process provides an avenue to produce low-cost hydrogen with lower emissions.

- Patent application

Halogen Mediated Production of Hydrogen and Carbon from Hydrocarbons

UC Case No. 2022-984

A novel method of facilitating hydrogen production from decomposition of hydrocarbon feedstocks using halogens. Traditional hydrocarbon decomposition requires significant energy inputs and high temperatures, complicating reactor and process design. By operating in a limited halogen regime to produce both molecular hydrogen and hydrogen halides, little or no heat needs to be added to the reactor, and the process energy input is shifted to regeneration of the halogen. This innovative method has the potential to critically impact both the chemical and clean fuel industries, through its low-cost, low-emission process.

- Publication
- Patent application

ADVANTAGES

- Production of hydrogen with low-cost catalysts
- Eliminates carbon dioxide co-production during hydrocarbon conversion
- Efficient solid carbon management and product separation
- Enhanced heat exchange for improved process efficiency
- Flexible reactor configurations to optimize reaction conditions
- Produces valuable hydrogen and solid carbon chemical products

APPLICATIONS

- Clean hydrogen production for energy and industrial use
- Manufacture of solid carbon materials for industrial applications
- Sustainable chemical manufacturing from fossil and renewable hydrocarbons
- Environmental technologies focused on reducing CO_2 emissions
- Energy sectors aiming to decarbonize fossil fuel utilization

PATENT STATUS

Country	Type	Number	Dated	Case
Patent Cooperation Treaty	Reference for National Filings	WO 2023/220731	11/16/2023	2022-984

Patent Pending

ADDITIONAL TECHNOLOGIES BY THESE INVENTORS

- Halide-Free Gas Phase Methanol Carbonylation for Environmentally Friendly Acetic Acid Production
- Molten Salt Chemical Looping Process for Efficient Chlorine Production from HCl
- Multi-Junction Artificial Photosynthetic Cell With Enhanced Photovoltages

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