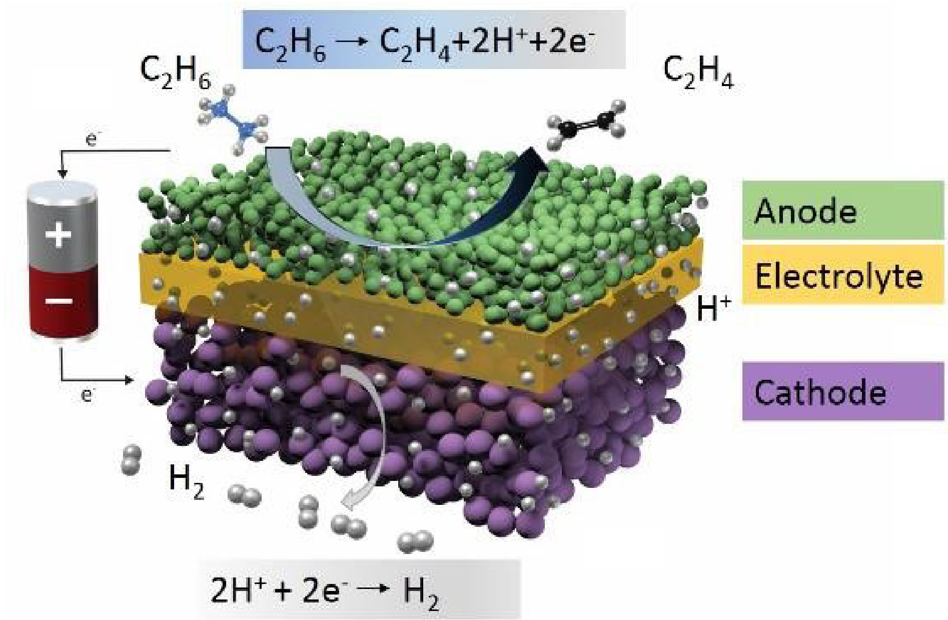
U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Low-Temperature Electrical Activation of Ethane for Co-Production of Chemicals/Fuels and Hydrogen



Depiction of the proposed electrochemical cell in the low-temperature production of ethylene and hydrogen from ethane. *Graphic image courtesy of Idaho National Laboratory*

The abundance of shale gas resources in the United States has created a vast supply of low-cost methane and ethane that can be further processed into valuable chemicals, polymers, and liquid fuels. To produce these commodities, ethane is converted to ethylene—a high-value intermediate—through high-temperature thermal steam cracking. Thermal steam cracking for ethylene production is the single most energy-consuming process in the chemical industry and is estimated to account for 60% of the product cost. However, viable alternatives to steam cracking at an industrial scale are lacking.

This project is expected to advance a breakthrough, reduced-temperature electrochemical technology that converts ethane into ethylene, synthetic fuels, and pure co-product hydrogen with improved energy and cost efficiency. New electrocatalysts will be developed and incorporated into electrochemical cells to carry out the conversion reactions at significantly lower process temperatures (300°-500°C) compared to those of steam cracking (typically at ~ 850°C). The process will oxidize ethane into ethylene and protons, and the ethylene will be coupled into high-value products—such as butylene, gasoline, or diesel. Hydrogen gas will be formed as protons migrate through an electrolyte and combine with electrons. Successful completion of this project will validate the technology in a laboratory environment and attract support for further development.

Benefits for Our Industry and Our Nation

This technology will enable the chemicals industry to take advantage of ethane's low cost as a feedstock and greatly reduce the energy required to produce high-demand commodities and chemicals. These advantages will enable the U.S. chemicals industry to secure its global competitive edge over other producers that typically use more expensive feedstocks, such as naphtha. Other benefits include the following:

- Improved process efficiency by at least 65%
- Reduced process emissions to near zero, with further potential to reduce the carbon footprint by using electricity generated from renewables
- Reduced production cost by at least 25%

Applications in Our Nation's Industry

This technology will have vast applicability in industry due to the broad use of ethylene-derived products. Ethylene is the primary building block for the majority of plastics produced in a growing market for low- and high- density polyethylene (LDPE, HDPE), polyethylene terephthalate (PET), and others. In addition, scientific concepts from this project could advance other electrochemical manufacturing technologies, such as hydrogen production from water electrolysis, high-efficiency power generation from intermediate temperature solid oxide fuel cells, and others.

Project Description

The objective of the project is to demonstrate proof of concept for the co-production of chemicals/fuels and hydrogen from ethane by means of non-oxidative electrochemical deprotonation at intermediate temperatures. This transformational, low-thermal budget, non-oxidative process could have pronounced impact on natural gas/natural gas liquids upgrade for ethylene production.

The core component of the technology is a non-oxidative electrochemical cell incorporating a super protonic conductor electrolyte and electrodes made of heterogeneous electrocatalysts. This technology will be optimized to verify co-production of ethylene and hydrogen with a reduction of process energy by at least 65% and carbon dioxide emissions by 70% compared to steam cracking.

Barriers

- Ability to fabricate electrode membranes with desired functionalities and stability, and produce in a cost-effective manner
- Ability to achieve ethylene yields of at least 90% along with the desired performance improvements to validate the process

Pathways

This project will pursue three main thrusts. The first thrust will develop and test the electrochemical cells, electrolytes and electrodes, and super protonic conductors to improve conductivity of the cells. These components will also be tested for performance and low temperature operation.

The second thrust will focus on developing electrocatalysts for ethane deprotonation, and advanced heterogeneous catalysts for ethylene coupling. The heterogeneous catalysts will be integrated into the electrocatalyst to create a bi-functional catalyst.

The third thrust will apply modeling and advanced characterization to optimize the catalysts, determine the durability and integrity of the cell components, and validate the technology. The analysis will enable the project team to optimize electrolyte/catalyst compositions.

Milestones

This two-year project began in May 2018.

- Synthesize electrochemical cell components and electrolyte, electrocatalyst for ethane oxidation, and advanced catalyst for ethylene coupling (2019)
- Complete computational modeling and structure characterization (2020)
- Assemble cells and integrate catalysts to validate bi-functionality (2020)

Technology Transition

Idaho National Laboratory has formed a strategic partnership with the University of Wyoming and the Massachusetts Institute of Technology to provide the multi-faceted capabilities needed for project success. This project will play a critical role in validating that the project goals are attainable and will attract industrial partners for product development and subsequent commercialization. Project partners will also seek to establish strategic industrial partnerships to support advancement of the technology and its eventual commercialization.

Project Partners

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