Converting CO₂ and Methane to Fuels by Enhanced Plasmonic Effects in a Nanotemplated Catalyst Plasma Reactor

The primary objective of this research was to develop and demonstrate low temperature operation of a novel hybrid plasma catalysis reactor that is characterized by an intensive and uniform discharge to achieve efficient conversion of CO₂ and methane to chemicals or fuels. Another objective was to address the most significant challenge in the plasma catalysis hybrid system, which is to achieve the strongest synergistic interaction between the plasma and catalyst and to increase the selectivity for producing methanol and alkanes/alkenes.

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Project Description:
Rising atmospheric concentration of CO₂ is forecasted to have potentially disastrous effects on the climate from its role in global warming and ocean acidification. To alleviate atmospheric CO₂ levels, significant cuts in emissions and active removal of CO₂ from the atmosphere are necessary. A catalytic process that utilizes CO₂ as a feedstock to make valuable oxygenates and hydrocarbons is considered to be more desirable than sequestration. An approach utilizing plasma-enhanced catalytic conversion at low temperature to reform methane into high value chemicals and fuels in a one-step process involving the conversion of CO₂ has potential for great impact on the environment and energy/fuel production. In this project, the researchers developed a novel nanodischarge reactor with enhanced plasmonic effects from a nanotemplated catalyst structure to achieve highly efficient plasma-enhanced low temperature conversion of CO₂ and methane (from natural gas) to chemicals or fuels.

Project Funding:
$199,631

Project Duration:
10/01/2016 - 12/31/2018
**Accomplishments:**
The researchers successfully built and operated two types of dielectric barrier discharge (DBD) reactors, with a coaxial tube and parallel plates, that were used to screen catalytic effects of different catalytic metal surfaces and supported catalysts. Results obtained from this work contribute to a better understanding of selectivity and efficiency in plasma promoted process for converting methane and CO$_2$ to fuels. The work on the catalytic trends of metal and metal alloys in contact with nonequilibrium plasma also contributes to a better understanding of the role of the catalyst in the plasma catalysis field. The team discovered strong synergistic effects between nonequilibrium plasma and catalysts for both the methane coupling reaction and NH$_3$ synthesis. Furthermore, supported bimetallic catalysts were found to have large impact on activity.

The development of a nanosecond and DC hybrid discharge provides a new capability to optimize the plasma discharge for efficient fuel reforming. In addition, the researchers developed a Thomson scattering method to quantify the electron number density and temperature in the plasma discharge. Diagnostics for the electric field and electron temperature provided insights for understanding the physics and chemistry of non-equilibrium plasma. The results of plasma property measurements such as electron temperature, number density, and O(1D) reactions with fuels provide valuable data to develop experiments validated kinetic modeling tools for plasma assisted fuel reforming. The time resolved plasma electric field measurement provides critical electric field strength to quantitatively model the plasma kinetics and to understand the plasma physics.

**NETL Collaboration:**
The team planned to supply catalysts to NETL scientists for further testing reactor and catalyst performance in the larger scale microwave reactor facility at NETL once they successfully demonstrated promising results for their plasma reactor and found high performance catalysts and parameters for the RF discharge conditions. However, the grant period of performance expired before collaboration with NETL scientists or use of NETL facilities occurred.

**Relevant Publication:**

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