the ENERGY lab

R&D FACTS

Separations and Fuels Processing

Non-Thermal Plasma for Fossil Energy Related Applications

Background

The U.S. Department of Energy is investigating various non-thermal plasma technologies for their catalytic properties related to fossil energy conversion and carbon dioxide decomposition. Non-thermal plasma is an ionized gas comprised of a mixture of charged particles (electrons, ions), active chemical radicals (O_3, O, OH), and highly excited species that are known to accelerate reforming reactions in similar ways to traditional metal-based catalysts. Plasmas have several advantages over traditional catalytic systems in that they do not suffer from catalyst poisoning problems and their performance does not decline over time. The specific energy requirement to incorporate non-thermal plasmas into reforming systems is typically low, with less than 5% of the reformate energy consumed to generate the plasma. The detailed mechanisms of plasma-stimulated catalysis are not completely known and it is our goal to develop in-house expertise in this area. It is expected that future efforts using optical diagnostics and modeling and simulation techniques will allow DOE researchers to identify the critical species and kinetic routes responsible for the observed catalytic effects. Such efforts will allow for the optimization of plasma systems so that they may be incorporated into a broad range of transportation and industrial-scale reforming technologies.

Objective

Evaluate the performance of gliding arc plasma technology for the conversion of logistic fuels (Diesel) into hydrogen-rich synthesis gas with 100% conversion to $<C_3$ hydrocarbons and minimal soot formation. The syngas reformate will be used as fuel for solid oxide fuel cells developed in the Solid State Energy Conversion Alliance (SECA) program.

Investigate the effectiveness of Dielectric Barrier Discharge (DBD) plasma for CO_2 decomposition and conversion into value-added chemicals. Optical emission and laser absorption spectral diagnostics will be used to identify the active species and their concentrations generated by the plasma and quantify the level of CO_2 conversion. Efforts will also combine traditional catalysts with DBD plasma to evaluate synergistic effects of using combined systems. Future investigations may include the plasma-assisted conversion of coal in a CO_2-rich environment.

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Accomplishments

A vortex-based gliding arc plasma reformer was developed and has yielded promising results for the partial oxidation of heavy hydrocarbon fuels with conversion efficiencies >80%, which is close to thermodynamic equilibrium predictions. The results from initial trials showed evidence of little or no soot formation and syngas yields that contained up to 4-5% methane, which has been shown to be beneficial for the thermal management of SOFCs. An additional 1-2% of C_2 hydrocarbons (C_2H_4, C_2H_2) were also detected in preliminary trials and future efforts are focused on understanding the mechanisms of C_2-hydrocarbon formation, finding optimal plasma conditions to mitigate these hydrocarbons, and increasing syngas yields to even higher levels.

A Versatile Atmospheric Dielectric Barrier Discharge Experimental Reactor (VADER) has been developed in conjunction with the West Virginia University (WVU) Department of Physics to investigate plasma-assisted CO_2 decomposition. The VADER system is highly flexible with capabilities including a wide operating pressure range 10^{-3}- 2 atm, variable plasma frequencies of 0-10 kHz, adjustable electrode distances up to 2 cm, and optical access ports for plasma diagnostics. Experiments to quantify CO_2 decomposition and the application of optical diagnostics to identify plasma parameters such as electron and neutral species temperatures are currently in progress.

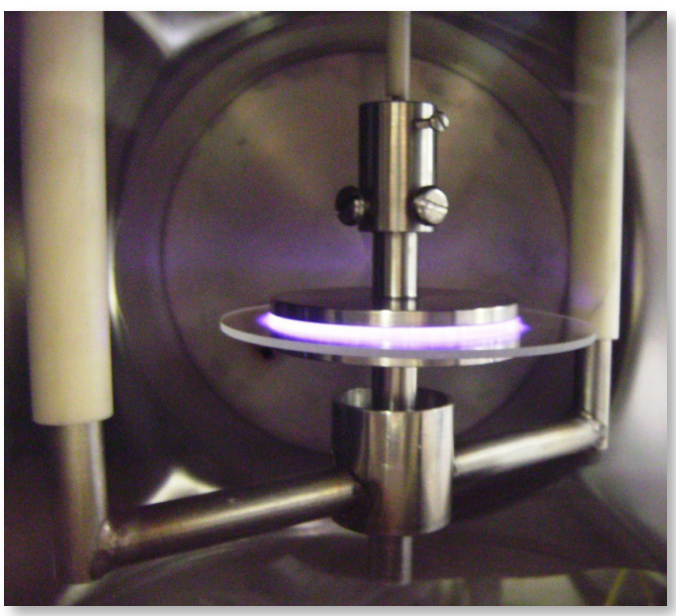

Figure 1. VADER system developed in conjunction with West Virginia University which uses a DBD plasma for CO_2 decomposition.

Benefits

Non-thermal plasma has several advantages over traditional catalysis in hydrocarbon reforming systems due to its fast start time, low preheating requirements, low electrical power consumption, and inability to be poisoned or deactivated. Various types of non-thermal plasmas are well suited for reforming systems because they have relatively low gas temperatures (near room temperature) and therefore the electrical energy used to generate the plasma is selectively channeled into creating active chemical species that can influence and accelerate reforming reactions. The detailed mechanism by which the plasma catalysis effect is realized in fuel-rich syngas production systems is currently being investigated. Advances in our fundamental understanding of plasma phenomenon will lead to the optimization of plasma systems to further enhance performance and make it a more attractive technology with a wider range of applications.

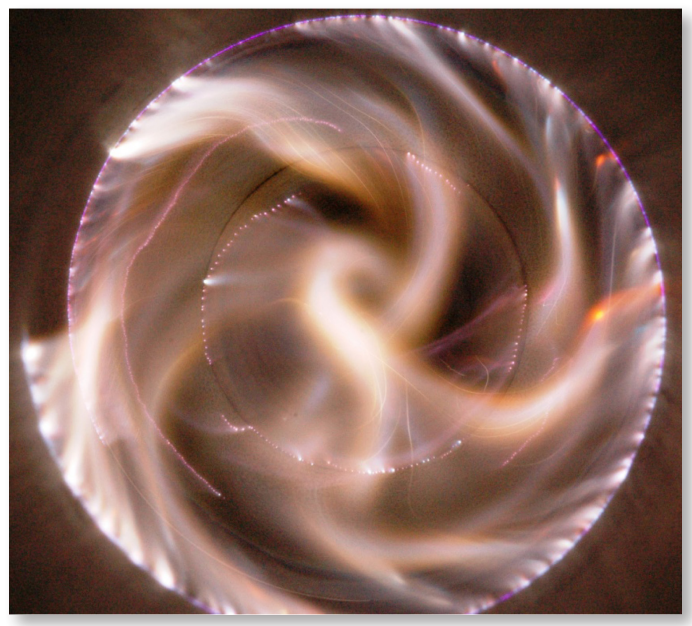

Figure 2. Top view of the gliding arc plasma rotating in a vortex flow reactor.