Integrated Reactive Catalytic Fast Pyrolysis System for Advanced Hydrocarbon Biofuels
Area of Interest 4: Systems Research of Hydrocarbon Biofuel Technologies

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The development of a cost-competitive technology for advanced biofuel is largely dependent on product yields. The key technical challenge associated with direct biomass liquefaction technologies is maximizing the carbon efficiency of the integrated process by optimizing the biomass thermochemical conversion step to maximize bio-crude intermediate yield and quality simultaneously. Bio-crude quality is often simply defined by the oxygen content of the liquid intermediate. Catalysts in the thermochemical conversion step are applied to enhance deoxygenation of the pyrolysis vapors to produce a low oxygen content, thermally stable bio-crude intermediate that can be effectively and efficiently upgraded into advanced hydrocarbon biofuels. Unfortunately, the oxygen content in bio-crude is inversely proportional to yield in catalytic biomass pyrolysis, so, ideally, the catalyst should promote deoxygenation of the pyrolysis vapors while minimizing carbon loss to light gases, char, and coke.

RTI International has been developing a novel direct biomass liquefaction technology referred to as reactive catalytic fast pyrolysis (RCFP) and incorporates atmospheric pressure hydrogen and an in-situ catalyst provided by our partners at Haldor Topsoe. Hydrogen in the pyrolysis reactor improves bio-crude yield by reducing char and coke formation and improves bio-crude quality by eliminating reactive oxygenates. Catalyst screening in a lab-scale bubbling fluidized bed reactor system was used to identify a suitable RCFP catalyst for enhanced hydrodeoxygenation while optimizing process conditions (H_2 partial pressure, temperature, and space time) improved carbon efficiency.

A focus of the proposed project is to design, fabricate, and operate a reactor system that can continuously regenerate and reduce the RCFP catalyst to maintain steady state hydro-deoxygenation activity while meeting the hydrogen demand of the RCFP process. With this proposed system, enough low oxygen content RCFP bio-crude will be produced to support extensive upgrading studies. The chemical composition of RCFP bio-crude is quite different compared to CFP bio-crude or fast biomass pyrolysis oil because hydrodeoxygenation occurs during conversion. Consequently, hydrotreating RCFP bio-crudes will contribute to a more general understanding of how the oxygen content, and more importantly the oxygen speciation, in bio-crudes affects hydroprocessing.

The outcome of the proposed project is to improve the technical feasibility of the integrated RCFP/upgrading process by producing 100 gallons of a renewable blendstock that meets ASTM D975 specifications. The proposed project goal is to verify at engineering scale the developed RCFP technology to attain the goal of 50 mole %C yield in the bio-crude intermediate. The quality of the RCFP bio-crude, defined by the oxygen content (target less than 10 wt%), will enable continuous upgrading to a renewable diesel blendstock for commercially relevant times on stream. The integrated conversion and upgrading unit operations can be optimized collectively to maximize biofuel yield while minimizing hydrogen consumption. Techno-economic analysis, based on experimental results collected during the proposed project, will substantiate the economic viability of a fully integrated process design to produce a finished diesel blendstock that can sell for $3/GGE through robust system optimization and integration.