Bench-Scale Development of Facilitated Transport Membranes for Bio-Syngas Cleanup

Yang Han (PI) and Winston Ho (Co-PI), The Ohio State University (OSU)

The objectives of this bench-scale project are to develop a cost-effective design and fabrication process for transformational facilitated transport membranes (FTMs) and membrane modules to improve the energy efficiency in H₂S and CO₂ removal from biomass-derived syngas (bio-syngas). By implementing the membrane-based H₂S removal vs. the conventional wet scrubbing and ZnO bed, we aim to reduce the carbon emissions in bio-syngas cleanup and retain the H₂ and CO at the high pressure for the downstream Fischer-Tropsch (FT) synthesis. The membrane process also has an added benefit of partially capturing biogenic CO₂, resulting in an even lower carbon footprint of the biofuel production. The R&D goals are to (1) synthesize new FTMs, (2) validate the FTM module performance with simulated bio-syngas, and (3) demonstrate the membrane process using an integrated bench skid with actual bio-syngas (TRL 5 upon project completion).

Based on our advanced understanding of the amine carrier–CO₂ reaction chemistry, we will synthesize transformational FTMs with (1) >1000 GPU H₂S permeance and >200 GPU CO₂ permeance and (2) >600 H₂S/H₂ and >5 H₂S/CO₂ selectivities at bio-syngas conditions. Optimization of the FTMs, scale-up of the membrane to a prototype size of 21 inches wide in continuous roll-to-roll fabrication, and fabrication of spiral-wound (SW) membrane modules will be performed. For the design of this membrane, we use a cost-effective nanoporous polymer support and coat a thin top layer of the membrane. The simplicity of this membrane design offers a low cost for the membrane element in commercial SW configuration (lower than $5.00/ft²).

An innovative single-stage membrane process has been designed to replace the conventional H₂S removal (i.e., liquid redox wet scrubber followed by ZnO bed) to reduce the H₂S concentration in the bio-syngas from 200 to 1 ppm, while capturing 8% of the biogenic CO₂. Preliminary techno-economic analysis (TEA) shows that the membrane process reduces the biofuel production cost from $35.8/GJ to $29.2/GJ biofuel. A cradle-to-gate life cycle assessment (LCA) also indicates an overall CO₂ emission reduction of 70% vs. petroleum fuels, owing to the more energy-efficient H₂S removal and the co-benefit of biogenic CO₂ capture.

For the 3-year project in 3 budget periods (BPs) each for 1 year, we will synthesize the transformational FTMs, characterize them, and validate the membrane formation methods in BP1. In BP2, we will scale up the optimized membrane to the prototype width of 21” (21 inches) in continuous roll-to-roll fabrication and fabricate prototype SW membrane modules. In BP3, we will test the membrane module in a single-stage membrane system to demonstrate the H₂S removal process using a simulated bio-syngas and an actual bio-syngas. Aside from OSU, the project team also include Trimeric Corporation for the TEA and LCA, the University of Kentucky as the test site, and Zenith Purification LLC for membrane QA/QC.