Mixed Protonic-Electronic Membrane Reactors;
Converting Hydrocarbon Resources and CO_2 to Fuels

Membrane reactor technology holds the promise to circumvent thermodynamic equilibrium limitations by *in-situ* removal of product species, resulting in improved chemical yields. Recent advances in mixed-conducting oxide-membrane technology present the possibility for a dramatic reduction in the cost of converting petroleum, coal and biomass derived feed stocks to hydrogen and other "value added" hydrocarbons. We have developed novel membrane reactor technology, based on high temperature proton conductors, that can convert a wide range of hydrocarbons to pure H_2, and syngas for synthesis of liquid fuels and chemical feed stocks. By simultaneous H_2 permeation and catalysis, we have demonstrated the ability to increase water gas shift yields >70% over thermodynamic limitations. Similarly, we have demonstrated increases in steam reforming yields, and the ability to reform CH_4 with CO_2.

More recently we have developed single-step gas to liquid reactors that convert natural gas to C_{2+} products with high yields and no unwanted oxidation byproducts. The direct utilization of CH_4 and CO_2 to simultaneously produce C_{2+} hydrocarbons (C_2 and aromatics) and syngas (CO and H_2) on opposite sides of a mixed protonic-electronic conducting $SrCe_{0.7}Zr_{0.2}Eu_{0.1}O_{3-\delta}$ membrane reactor is demonstrated. On one side (interior) of the membrane reactor, direct non-oxidative methane conversion (DNMC) over an iron/silica catalyst produces C_{2+} hydrocarbons and H_2. On the other side (outer surface) of the membrane, permeated H_2 (driving the DNMC reaction) reacts with a CO_2 sweep gas to form CO and water via the reverse water gas shift (RWGS) reaction. This novel single H_2-permeable membrane reactor simultaneously addresses both reduction of greenhouse gas (CO_2 and CH_4) emissions as well as production of value-added hydrocarbon products (C_{2+}, CO, and H_2) with *in situ* gas separation.