Design of Bifunctional Structured Fischer-Tropsch Catalysts with Improved Heat Conductivity for Modular Small-Scale Reactor Applications

This project aimed to develop new structured Fischer-Tropsch catalysts with improved heat conductivity and higher selectivity for forming long-chain hydrocarbon products. There were three specific objectives for this project. 1) Synthesis of Fe and FeCo nanoparticles supported on 3D Ti skeleton and acid-functionalized TiO$_2$ nanotube arrays; 2) Synthesis of core-shell Fe and FeCo nanoparticles inside an acid-functionalized carbon shell; and 3) Characterization and catalytic testing of bifunctional, thermally conductive catalysts in Fischer-Tropsch synthesis.

Models for 3D printing of the Ti and polymer structures. These designs were chosen to maintain structural stability during the 3D printing process and to allow for heat transfer through the structure.
Accomplishments:
In this work, new structured catalysts, fabricated via 3D printing, were applied to FTS. The catalysts consisted of a 3D printed support material with Fe and FeCo nanoparticles immobilized to the support material. Using a Ti alloy, Ti64, Ti structures were successfully printed and then TiO2 nanotubes were grown from the Ti surface using a two-step anodization procedure. The sequence of Ti annealing and anodization was investigated, and it was discovered that annealing the materials after the formation of TiO$_2$ nanotubes creates the best TiO$_2$ structures with minimal quantities of impurities. This project produced the first example of TiO$_2$ nanotubes grown from DMLM 3D printed Ti64 alloy. The performance of catalytic materials was evaluated through measurements of the temperature gradients, selectivity, conversion, olefin/paraffin ratio, and carbon distribution. The 3D printed catalysts were compared to the catalysts which used unstructured support materials such as activated carbon or P25 TiO$_2$. This work produced the first 3D printed catalytic materials applied to FTS. It was observed that the 3D printed catalysts had a higher olefin/paraffin ratio but at the expense of higher methane selectivity. There are many opportunities for optimization of these catalysts, and this work provided a foundation for future improvements.

NETL Collaboration:
NETL videoconferences were held every month or two to discuss the current project’s results and future work. The researchers benefitted from NETL’s guidance and suggestions and future collaboration is planned.

Relevant Presentation:

Benefits:
The resulting 3D-printed materials can be deployed into modular reactor systems for coal and biomass gasification to produce fuels and other platform chemicals. The catalysts can also provide environmentally responsible chemical pathways for the valorization of coal and biomass to products that are poised to have measurable positive economic impacts on both the local and national levels.