

# New life for

The Fischer-Tropsch reaction may offer an economical way to produce third generation biofuels from agricultural waste. Derek Atkinson, Business Development Director at Oxford Catalysts, UK, reports

Oil and liquid hydrocarbon fuels are still the mainstay of the energy economy, but change is in the air. World demand for petroleum is continually increasing, while oil production has reached a plateau. This, along with factors such as high oil prices and concern about fuel security and climate change is encouraging the development of alternative fuels.

As a result, interest has been revived in the Fischer-Tropsch (FT) reaction, a process first developed by Franz Fischer and Hans Tropsch in Germany in the 1920s and 1930s to produce fuel via a coal to liquid (CTL) process (see also *Materials World*, June 2008, pp31-33).

## Conversion through catalysts

In the FT process, synthesis gas, composed of a mixture of carbon monoxide (CO) and hydrogen (H<sub>2</sub>), is converted into various forms of liquid hydrocarbons over a catalyst at elevated temperatures and pressures via reactions such as  $(2n+1)H_2 + nCO \rightarrow C_n H_{(2n+2)} + nH_2O$ , where  $n$  is a positive integer.

Conventional FT catalysts are typically based on cobalt and require precious metal promoters in order to obtain the desired activity. Because they do

not contain aromatics or sulphur-containing contaminants, the liquid fuels produced are typically of higher quality and burn cleaner than petroleum-based diesel and jet fuels. This results in lower emissions of nitrogen oxides and harmful particulates.

In theory, any source of carbon can be used to generate synthesis gas. There are seven FT plants worldwide producing liquid fuels, lubricant feedstocks and industrial waxes from coal or natural gas on a large scale. The growing interest in FT is because of its potential role in producing biofuels via biomass to liquid.

## Optimising options

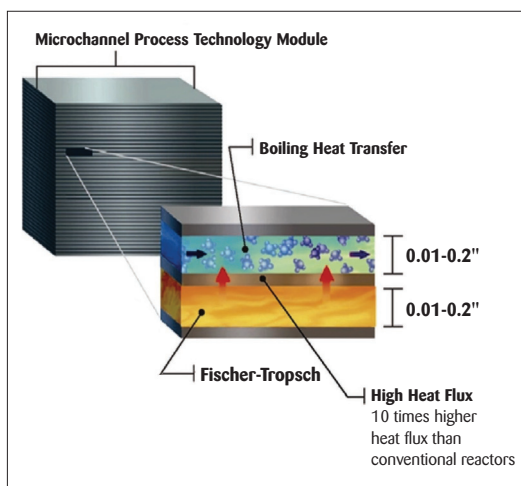
Work is taking place to develop more active catalysts and improved reactors to enable gas to liquid to become an environmentally friendly and sustainable proposition.

The two conventional reactor types used for FT processes are fixed bed and slurry bed reactors. Each has its drawbacks. Fixed bed reactors are comparable to the shell and tube heat exchangers that are common in the process industries. In these the catalyst, in the form of cylindrical pellets, is contained in 2.5 to five-centimetre tubes that are oriented vertically within a large vessel. However, the performance of these reactors is limited by heat transfer – a particular drawback for FT applications as they are exothermic and strongly affected by temperature.

In slurry bed reactors, the FT catalysts take the form of small particulates (~50µm in diameter) that are suspended in the liquid wax produced by the reaction. Although the liquid slurry is efficient at heat removal, the liquid film surrounding the catalyst blocks the reactants (H<sub>2</sub> and CO) from quickly reaching catalytic sites. This mass transfer problem limits their performance.

Another challenge facing both reactor types is finding ways to adapt them so that they work efficiently on the small scale. Existing FT reactors are

In a microchannel reactor, a single reactor module consists of hundreds of rows of microchannels, each containing large numbers of parallel microchannels. The orientation and size of the channels within each row is determined by the application. Adjacent rows of channels potentially have different duties. Diagram courtesy of Velocys Inc



# an old reaction

designed to operate efficiently at production rates between 30,000-140,000 barrels/day, but because the biomass feedstock is not dense (on average it takes one tonne of biomass to produce one barrel of liquid fuel) it makes more sense, both in economic and environmental terms, to produce biofuels on a distributed basis. This would involve setting up a series of small-scale plants near the waste sources that are capable of efficient and economical biofuel production at the scale of 500-2,000bn barrels/day.

From a cost viewpoint, fixed bed and slurry bed reactors do not scale down efficiently, so reactor designers are exploring the use of new microchannel reactors.

## Thinking small

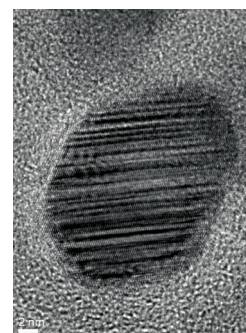
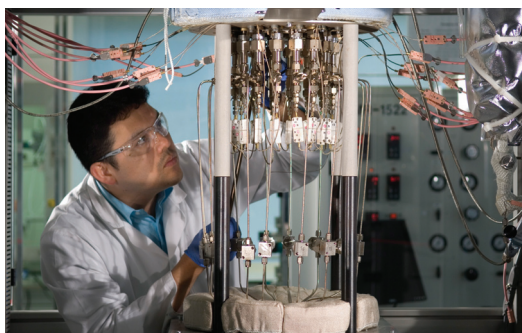
Microchannel reactors take advantage of the microchannel process, a developing field of chemical processing that exploits rapid reaction rates by minimising heat and mass transport limitations. This is achieved by reducing the dimensions of the reactor systems to parallel arrays of microchannels, each with typical dimensions between 0.1 and five millimetres (see image left). This modular structure is flexible and offers advantages when it comes to reducing the size and cost of the chemical processing hardware. For example, the capacity of plants can be increased by 'numbering up' – or simply adding more reactors of the same proven dimensions – rather than increasing the size of each reactor unit.

Performance success comes from the design of the microchannel reactors, which enables efficient and precise temperature control, leading to higher throughput and conversion. Another factor lies in the need for new highly active FT catalysts optimised for use in this reactor design.

## Catalysing success

The level of catalyst activity is related to its surface area. This, in turn, is related to crystal size, so producing catalysts with the optimal crystal size for a given application is a key goal. The challenge lies in achieving the right balance between catalyst activity and stability.

Developing improved FT catalysts requires a good theoretical understanding of the properties needed, along with much experimentation. However, thanks to newly developed catalyst production



methods such as organic matrix preparation (OMX) – a technique patented by Oxford Catalysts – it is possible to produce a catalyst crystal size that is just right to ensure the desired levels of activity and stability. This method generates FT catalysts that have higher levels of activity and greater stability than traditional versions. These are being optimised for use in microchannel reactor designs. In recent trials carried out in 2008 in Ohio, USA, by Velocys Inc, a member of the Oxford Catalysts Group, a microchannel reactor using a highly active FT catalyst achieved productivities of over 1,500kg/m<sup>3</sup>/h (kilograms of product per metre cubed of catalyst per hour) – a major advance over the 100kg/m<sup>3</sup>/h of fixed bed reactors, or the productivities of around 200kg/m<sup>3</sup>/h for slurry bed reactors.

Taking advantage of FT to produce environmentally friendly and sustainable second and third generation biofuels economically, and on a small distributed scale, presents many challenges. Some experts believe it may be five to 10 years before commercial production becomes viable. However, new catalysts may make it a viable economic reality and a practical way to reduce carbon emissions, much sooner.

**Above: Transmission electron microscope picture of the Fischer-Tropsch catalyst produced using the organic matrix preparation method. Image courtesy of Oxford Catalysts.**

**Above left: The use of high throughput experimentation rigs enables catalyst developers to run up to 16 different experiments at once, speeding up the catalyst development process. Image courtesy of Oxford Catalysts**

### Further information

Derek Atkinson is the Business Development Director responsible for the petroleum and petrochemical markets at Oxford Catalysts, 115e Milton Park, Oxford, OX14 4RZ, UK. Tel: +44 (0)1235 841700.

E-mail: [derek.atkinson@oxfordcatalysts.com](mailto:derek.atkinson@oxfordcatalysts.com).

Website: [www.oxfordcatalysts.com](http://www.oxfordcatalysts.com).