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Carbon Nanostructure Based Heterogeneous Catalysts

Heterogeneous nanocatalysis is essential for conversion of sustainable and renewable feedstocks into transportation fuels and high value chemicals. However, there are still a number of significant challenges to overcome including the limited stability of catalysts at high temperatures, issues with controlling the selectivity of reactions and also significant scalability problems due to the sheer volumes of material involved. Carbon nanostructures (CNS), including carbon nanotubes (NTs), graphitised carbon nanofibres (GNFs) and graphitised mesoporous carbon (GMCs) all contain nanosized features, well-defined channels and/or pores, which can be tailored to encapsulate molecular and nanoparticulate catalysts.[1,2] The dimensions of these pores and channels in CNS, 1-50 nm, are also ideal sterically confined environments for performing controlled chemical reactions with the extreme confinement imposed directing the formation of new materials and causing changes in selectivity for established reactions.

This project aims to utilise the internal channels and pores of NTs to act as both template and stabilising layer for the formation of uncoated metal nanoparticles (MNPs) from metal complex precursors (Figure 1). The size and shape of the pores within CNS stabilises the unprotected nanoparticles which prevents sintering of the metal, leading to increased stability and thus longer catalytic lifetimes. Composites using the catalytically important group 8 (Fe and Ru) and group 10 (Ni, Pd and Pt) metals will be targeted, with particular emphasis on making sustainable Fe and Ni catalysts, supported inside narrow carbon nanotubes (internal d_{NT} = 1-5 nm). Characterisation of catalyst performance in potentially industrially-valuable biomass transformations e.g. furfural reduction, will be carried out initially in test scale, batch reactions and then within packed-bed continuous flow reactors[3] in order to facilitate rapid reaction optimization using design of experiment techniques to explore the full potential of these exciting new materials.

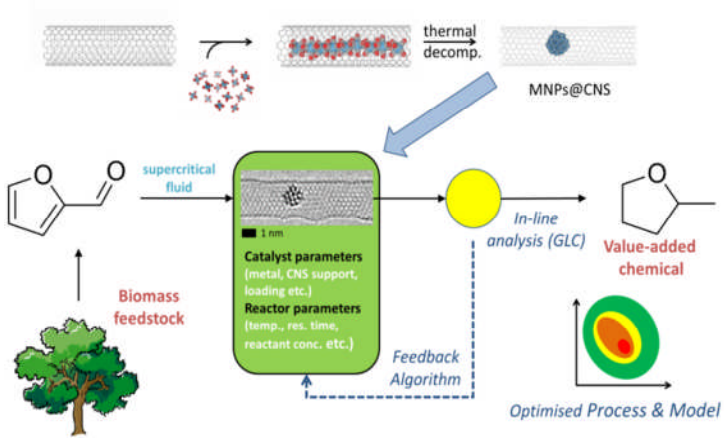

Figure 1. Schematic of the universal method for MNPs@CNS fabrication in which the CNS (shown as a NT in this example) acts as the template for the thermally induced decomposition of an encapsulated metal complex precursor. Integration of the CNS stabilised MNP catalysts within high throughput, self-optimising flow reactors allows rapid evaluation of catalyst performance.

Different projects are available in this area, for example in: (i) fabrication and structural characterisation of novel metallic, bimetallic and mixed metal oxide catalysts supported in CNS; (ii) development of rapid solid state nanocatalyst formation and screening methodologies for integration into self-optimising reaction systems; (iii) reaction optimisation using packed-bed continuous flow reactors. Project work will involve *solid state catalyst fabrication*; *structural characterisation of catalyst materials* including transmission electron microscopy, powder X-ray diffraction, X-ray spectroscopies including XANES[4] and EXAFS and other solid state techniques; and *synthetic organic chemistry* including flow chemistry.

References

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