Green Chemistry Centre of Excellence

Clean Synthesis
CLEAN SYNTHESIS

The Clean Synthesis Technology Platform (CSTP) in the Green Chemistry Centre of Excellence (GCCE) promotes the application of green and sustainable technologies, particularly those that can be used to deliver products that meet consumer and legislation requirements.

Developing cleaner synthetic routes and processes makes the production of a range of chemicals possible in a manner which maximises efficiency and minimising waste. Our diverse expertise supports the development of biorefineries, both by demonstrating the valuable products that can be produced sustainably and providing the key enabling technologies to bring about the required synthesise.

Platform Molecules

The CSTP undertakes research into both the synthesis and use of bio-based platform molecules. They are typically small, relatively simple molecules of low cost and ideally high production volumes, and are seen as the bio-based equivalent to crude-oil derived base chemicals.

Platform molecules typically contain significantly more heteroatom content than traditional crude-oil derived base chemicals, and therefore most of our research focuses on maximising the use of this inherent increased chemical functionality.

We have prepared a range of key derivative chemicals from platform molecules, these being precursors to a range of products that include solvents, monomers, polymers, surfactants, antioxidants, metal chelators and catalysts.

![Figure 1. The use platform molecules as demonstrated in the CSTP](image)

Bio-Based Polymers

We work extensively in the development and application of new bio-based monomers and polymers. Two major research projects support our activities in this area:

- EPSRC project studying the formation of various polymer classes using bio-derived platform molecules and waste carbon dioxide.
- BBSRC/IUK investigating the use of new bio-based monomers for the synthesis of polymers via enzymatic catalysis, and the influence of this on the physical properties and bio-degradability of the resultant plastics.
HETEROGENEOUS CATALYSIS

Heterogeneous catalysis represents one of the key technologies in cleaner synthesis. Facile recovery and reuse of heterogeneous catalysts means that their application can often reduce the environmental damage caused by traditional chemical processes and reactions. We are active in the development of new heterogeneous catalysts, in applying them in reaction involving platform molecules and in their characterisation via a range of available analytical tools.

For example, we have shown that a porous lignin-derived solid support can be easily recovered during the biorefinery process for converting polysaccharides in lignocellulose into CMF. This recovered solid support can have its textural and polar properties fine-tuned through thermal treatment and can be easily sulfonated to produce a reusable solid acid catalyst.

We have previously demonstrated that simply lab-grade K60 silica can be thermally treated and result in an effective catalyst for the direct formation of amides from aniline and a range of carboxylic acids. This was further extended to show that mesoporous silicas reduce the overall catalyst loading required and also that the system operates effectively in flow. Recently we have demonstrated how computational modeling allows for prediction of reagent solubility and product precipitation, meaning a recirculating system is effective and that high boiling point (and therefore lower VOC releasing) solvents such as p-cymene can be used.

Bio-Based Solvents

Solvents are used in many processes throughout the chemical industry. At present, most are petroleum-derived, many are toxic and some cause damage to the atmosphere.

Using bio-based platform molecules and clean synthetic methodologies, such as flow chemistry, heterogeneous catalysis and enzymatic catalysis, new bio-based solvents can be designed and manufactured. These solvents can be subsequently used for the production of chemical intermediates, polymers and materials.
ENZYMATIC CATALYSIS

The polymer industry is under pressure to mitigate the environmental cost of oil-derived plastics. Biotechnologies contribute to the gradual replacement of petrol-based chemistry and the development of new renewable products, leading to the closure of carbon circle. An array of bio-based building blocks are already available on an industrial scale and is boosting the development of new generations of sustainable and functionally competitive polymers. Biocatalysts add higher value to bio-based polymers by catalyzing not only their selective modification, but also their synthesis under mild and controlled conditions. The ultimate aim is the introduction of chemical functionalities thus enlarging the spectrum of advanced applications.

The enzymatic catalysis team main research interests are:

- Enzymatic synthesis of polymers carrying lateral functionalities
- Chemo-enzymatic post-polymerization functionalisations
- Biodegradation and surface functionalisation of polymers
- Biocatalyst immobilisation, optimisation and characterisation

Figure 3. Enzymatic circle for the synthesis, functionalization, modification, and hydrolysis of bio-based polyesters (From: Pellis et al. 2016, Trends Biotechnol., 34, 316-328)