SUMMARY OF FINDINGS - STRIVE Report No. 101

Flow Photochemistry – A GREEN technology with a bright future

**Authors: Kieran Nolan, Alexander Yavorskyy,
Michael Oelgemöller, Oksana Shvydkiv**

Lead Organisation: Dublin City University (DCU), Ireland

Brief Abstract The overall research goal is a more efficient use of resources - water, energy and materials. This project **Flow Photochemistry – A GREEN technology with a bright future** has allowed for the development of new technologies that not only addresses environmental needs by reducing water & energy requirements, but also offers a chemical manufacturer substantial process cost savings and improved product yield outputs potentially leading to higher profit margins. This is a truly win/win. The new technology developed makes photochemistry a far more attractive and green tool because:

i) high energy lamps are no longer used
ii) water as a coolant is eliminated
iii) high atom efficiency is guaranteed thereby reducing waste by-products.

All three of these achievements are in line with the resource use policy outlined in Europe 2020 and the EPA 2020 Vision document.

Key Words Resource efficiency, Green Chemistry, Sustainable growth, Microphotochemistry, Water savings, Waste savings, Industrial application, low carbon economy, Europe 2020.

Background The production of a chemical product, such as a typical pharmaceutical compound, relies to a large degree on chemical processes and involves the synthesis of the active ingredient as well as formulation and analytical quality control. All these individual processes produce significant amounts of waste and consume vast amounts of energy. As an example, it is estimated that between 25 and 100 kg of waste is generated for every 1 kg of active pharmaceutical product synthesised. In addition, the handling and storing of large quantities of hazardous materials requires strict safety precautions to avoid contamination of soil, water or air. In Europe, the flagship Europe 2020 Policy supports the shift towards a resource-efficient, low-carbon economy to achieve sustainable growth. The new technology developed in this project makes photochemistry a far more attractive, resource efficient, cost effective and GREEN tool.

Key Points & Findings

- Microphotochemistry can be considered to be an innovative 'green' methodology, contributing to the rapidly expanding field of Green Chemistry, by reducing the volume of waste, improving energy efficiency and product selectivity.
- The project established a high-profile international photochemistry research cluster centred at DCU with partners at the Leibniz Institute for Catalysis, Rostock, Germany (Dr Klaus Jaehnisch) and James Cook University, Australia (Prof Michael Oelgemöller).

- The researchers are now applying the discoveries made in this project to both the preparation of new materials (application of silica and magnetic nanoparticles in photooygenations) and further reactor development.

Recommendations

- The next and final stage for this chemistry is **industrial application.** The new technology developed in this project makes photochemistry a far more attractive and GREEN tool.
- Presently there are companies in Ireland that are interested in peroxides (for polymerization) that are prepared from renewable feed-stocks.
- The work we report here demonstrates that not only can we can achieve this goal, but we have **a ready-made Green technology** that can be adapted to industrial process needs.

For Further Information Contact: Dr Kieran Nolan (Department of Chemistry, Dublin City University, Glasnevin, Dublin 9, Ireland.)

Project Website http://www.dcu.ie/chemistry/m-PCC/

This report is published as part of the EPA Science, Technology, Research and Innovation for the Environment (STRIVE) Programme 2007–2013. The full report is published by the EPA and is available from http://www.epa.ie/pubs/reports/research/tech/strivereport101.html#.UpNIulKHuCg

Some publications connected to this work – more available in STRIVE 101

1) *Parallel Microflow Photochemistry: Process Optimization, Scale-up, and Library Synthesis*, Alexander Yavorskyy, Oksana Shvydkiv, Norbert Hoffmann, Kieran Nolan, Michael Oelgemöller, *Organic Letters*, **2012**, 14, 4342-4345.
2) *Synthesis of Juglone (5-hydroxy-1,4-naphthoquinone) in a Falling Film Microreactor,* Oksana Shvydkiv , Michael Oelgemöller, Kieran Nolan, *Journal of Flow Chemistry*, **2012,** 2, 52 – 55
3) *Green Photooxygenations in a bubble column reactor* , Alexander Yavorskyy, Oksana Shvydkiv, Carolin Limburg, Kieran Nolan, Yan M. C. Delauré, Michael Oelgemöller, *Green Chemistry*, **2012**, 14, 888-892.
4) *Microphotochemistry – a reactor comparison study using the photosensitized addition of isopropanol to furanones as a model reaction,* Oksana Shvydkiv, Alexander Yavorskyy, Su Bee Tan, Kieran Nolan, Norbert Hoffmann, Ali Youssef and Michael Oelgemöller, *Photochem. Photobiol. Sci*., **2011**, 10, 1399 – 1404.
5) *Microphotochemistry:4,4'-Dimethoxybenzophenonemediated photodecarboxylation reactions involving phthalimides*, Oksana Shvydkiv, Kieran Nolan and Michael Oelgemöller, *Beilstein J. Org. Chem.* **2011,** *7,* 1055–1063.