Newcastle University
School of Engineering

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pig MONTHLY

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New Project: HE Toolbox

Several members of the PIG are part of a collaborative project that has recently been awarded an **ULTSEC Strategic Innovation Fund** for the ***Development of a Physical Computing Higher Education Toolbox***.

Raspberry Pi microcomputers, microcontrollers (e.g. Arduino) and 3D printing have great potential to engage students and provide innovative teaching of computer programming under constructive pedagogy. This allows students to test algorithms by interacting with the physical world through moving parts and sensors. The aim of this project is to develop a HE Physical Computing L&T Toolbox for science and engineering. This will be achieved by cross-disciplinary collaboration between computer science and other science and engineering students. Activities will comprise development of learning and teaching materials, workshops, makers competition and STEM activities, supplemented by prototyping projects to showcase the potential of the technology. The activities will be open to UG, PGT, PGR and staff, so we look forward to seeing many PIG members involved!

The project is a collaboration between the schools of Engineering, Sciences and Computing and it involves a series of academics and students:

School of Engineering:

- *Staff:* Fernando Russo Abegao, Chris O'Malley, Jon Goss, Matthew Dyson, Richard Law, Rosemary Norman, Sharon Joyce
- *Students:* Harry Middleton (UG), Peter Wrixon (UG)

School of Computing:

- *Staff:* Marie Devlin
- *Students:* Anna Vasilchenko (PGR), Megan Venn-Wycherley (PGR)

School of Sciences:

- *Staff:* Helen Adamson
- *Student:* Adam Rodgers (PGT)

Upcoming Conferences

- **25th International Symposium on Chemical Reaction Engineering, ISCRE25** (20-23 May 2018, Florence, Italy)
- **European Symposium on Computer Aided Process Engineering, ESCAPE28** (10-13 June 2018, Graz, Austria). Registration Deadline: 1st June 2018
- **22nd Annual Green Chemistry & Engineering Conference** (18-20 June 2018, Portland, Oregon, US). Early Registration Deadline: 30th April 2018
- **16th International Heat Transfer Conference** (10-15 August 2018, Beijing, China). Registration Deadline: 30th June 2018
- **6th International Congress on Green Process Engineering (GPE)** (3-6 June 2018, Toulouse, France). Early Registration Deadline: 9th April
- **16th European Conference on Mixing** (9-12 Sept 2018, Toulouse, France). Final Abstract Submission Deadline: 15th April 2018
- **6th International Conference on Micro and Nano Flows, MNF2018** (9-12 Sep 2018, Atlanta, Georgia, US). Extended Abstract Deadline: 30th April 2018
- **2018 *AIChE* Annual Meeting** (28 Oct-2 Nov 2018, Pittsburgh, PA, US). Abstract Deadline: 18th April 2018
- **International Symposium on Green Chemistry, ISGC2019** (13-17 May 2019, La Rochelle, France). Abstract Deadline: 15th April 2019

PIG News

- The PIG would like to welcome the following new PhD students:
  - **Usman Dahiru** (working with Prof Adam Harvey) | Investigating the use of non-thermal plasma for the decomposition of volatile organic compounds
  - **Abubakar Halidu** (working with Dr Anh Phan) | Production of bio-hydrogen from agricultural residual (Spelt Husk) using gasification process
- Dr Valentine Eze is now working with Prof Adam Harvey on the ***Sustainable Polymers*** project
- Dr Richard Law has accepted an invitation to become a member of the **UK National Heat Transfer Committee** (www.uknhtc.org), where he will join his Colleague, Professor David Reay, a long-standing member. Immediate activities include bidding for the 2026 International Heat Transfer Conference, assisting with the organisation of the 2019 UK National Heat Transfer Conference to be held at Nottingham University, and liaising with the (Heat Transfer Society), of which Professor Reay is a Past President, in order to foster closer ties between groups in each that are active in industry and academia. Making academics and students here aware of the substantial research prizes available will be one activity we will be championing!
- Congratulations to Dr Chris O'Malley, Prof David Reay, and Dr Kamelia Boodhoo who have all been nominated for the NUSU Teaching Excellence Awards (TEA). Kamelia and Chris were nominated in the category of "**Outstanding Contribution to Student Employability**", whilst David was nominated for "**Research Supervisor of the Year**".
- Congratulations to **Safaa Ahmed** who was presented with an award for best presentation at ChemEngDayUK2018 hosted at Leeds University

Fully Funded PhD CASE Project

Industrial Cooperative Awards in Science & Technology (CASE) provide PhD studentship funding through the EPSRC, where businesses take the lead in arranging projects with an academic partner of their choice. There is currently three years of funding available from this scheme for the following project: "***Next generation loop heat pipe wick technology for thermal management of Space and Terrestrial Applications***", a summary of which can be found here. This project will involve working at both Newcastle University and Aavid Thermacore (situated in Ashington, ~30 miles north of Newcastle). The project will be supervised at Newcastle University by Dr Richard Law and Prof David Reay, while Dr Ryan McGlen will supervise the work at Thermacore. Anyone interested in applying should contact Richard directly: richard.law2@ncl.ac.uk.

PIN & HEXAG Meetings

The next HEXAG and PIN Meetings will be held in The Research Beehive at Newcastle University on 15th and 16th May respectively. Wide-ranging agendas involving UK and overseas speakers have been put together and these will be circulated to HEXAG and PIN members within the next two weeks (around Mon 16th April).

There will be opportunities for some *impromptu* talks in both meetings - these may be indicated when you submit the Reply Form to David Reay.

Intensified by Design® (IbD)

General Meeting, Eindhoven, NL, 21-22 March 2018

Intensified by Design®, an EU-SPIRE funded project for the intensification of processes involving solids handling, involves a consortium of 22 partners across Europe. Newcastle University, represented in the project by Dr Kamelia Boodhoo, Dr Anh Phan, Dr Vladimir Zivkovic and Dr Ahmad Mustaffar, have been working on the development and incorporation of several PI modules within the IbD Platform (http://ibd-project.eu/) in close collaboration with Prof David Reay and Dr Richard Law from David Reay and Associates.

The penultimate General Meeting of the IbD project took place on 21-22 March 2018 in Eindhoven, NL where the main focus was on the achievements to date in 6 industrial Case Studies covering the pharmaceutical, mineral, ceramic and chemical processing sectors.

Other Information

- Full contact details and research profiles for the PI group members can be found at the website: *http://pig.ncl.ac.uk*
- For enquires about collaborations or PhD study, see the website: *http://pig.ncl.ac.uk*
- If anyone would like to contribute any articles, or if anyone has any ideas regarding the newsletter please contact Jonathan McDonough: jonathan.mcdonough@ncl.ac.uk

MatSub Meeting

Faiz, Valentine and Abdul recently attended the MatSub meeting in York on the 19th March. The following results from the ***Sustainable Polymers*** project were presented:

Epoxidation (Faiz)

Kinetic study of pinene epoxidation

- Experiments were performed to determine the order of reaction w.r.t pinene, H_2O_2 and catalyst concentration
- A typical first-order behaviour was observed for all parameters tested
- The kinetic study was performed following a series of process parameter optimisation steps to avoid the formation of multiple oxidative by-products from α-pinene epoxidation

Limonene epoxidation in continuous meso-OBR

- A mixing study was performed at different oscillation conditions and residence times using various baffle geometries
- Three different baffles were tested: Helical, integral and single orifice. A comparison of initial reaction rates showed that the helical baffle performed significantly better than the other baffles due to the increased plug flow created by the helical baffle
- A new 'sieve' baffle was designed to increase the edge of the baffle and further increase plug flow. It was "3D-printed" and experiments are currently being conducted to evaluate the performance of the new baffle in order to compare it with the helical baffle

Cyclic carbonate synthesis (Abdul)

- The synthesis of styrene carbonate from styrene oxide and CO_2 was carried out in the presence of an acid-base heterogeneous silica-supported alkylaminopyridinium halide catalyst
- To study the kinetics of the reactions, and understand the reaction mechanism, a series of experiments were performed to determine the reaction order w.r.t. CO_2, epoxide and catalyst
- The activation energy of styrene carbonate synthesis has been calculated by performing experiments under solvent free conditions from 100-160 °C (i.e. 60.42 kJ/mol)
- The effect of using $ZnBr_2$ as co-catalyst along with heterogeneous silica-supported alkylaminopyridinium halide has been studied. The rate of the reaction increased by ~ 2.62 times
- A decrease in activation energy required for styrene carbonate synthesis was due to the addition of $ZnBr_2$ as a co-catalyst and has been determined to be 46.65 kJ/mol
- The heterogeneous catalyst will be characterized using the following techniques:
  - Elemental analysis | Solid state NMR | XRD | SEM

Ongoing Work

- Evaluate the performance of newly-designed baffles in terms of reaction rates, induction time and residence-time distributions
- Perform limonene epoxidation in the Heat-Pipe OBR to study the passive isothermalisation of a solvent free operation
- Continuous pinene epoxidation using meso-OBR
- Determine purification techniques for limonene bis-exposide
- Synthesis of limonene carbonate from limonene oxide and CO_2 using heterogeneous silica-supported alkylaminopyridinium halide catalyst
- Stereoselective epoxidation of limonene using bromine water for the bromination step
- Synthesis of non-isocyanate polyurethanes (NIPUs) from limonene bis-carbonate and poly functional amines
- Comparison of NIPU qualities when using bio-based

World Water Day 2018

As part of Dr Velasquez-Orta's research project, which aims to investigate new technologies for wastewater treatment using microalgae, a series of presentations took place on the 22nd and 23rd of March, 2018. In the World Water Day several events are planned around the world to increase public awareness on the conservation of water (http://worldwaterday.org/). Water is a natural resource significantly affected in terms of quantity and quality by our damaged ecosystems. Currently, it is estimated that 2.1 billion people live without safe drinking water at home; affecting their health, education and livelihoods. For this reason, new engineering concepts for sustainable wastewater treatment must emerge, and, most importantly, be proven! A way to increase sustainability could be through the use of biological intensified processes that use microalgae.

The project is funded by British Council, UK and CONACyT, and Mexico aims to contribute to the Sustainable Development Goals set up for 2030. It involves researching innovative wastewater treatment technologies that can contribute to facilitating "**access to safe water**" by reducing pollution and recycling water. The project, on the UK side, has been supported by Dr Valentine Eze and Laura Walls. Currently, Laura Walls along with Edward Peacock are working on their MEng projects at the Institute of Engineering in UNAM, Mexico, plus enjoying the sunshine!

- Eze, V.C., Velasquez-Orta, S.B., Hernández-García, A., Monje-Ramírez, I. and Orta-Ledesma, M.T. Kinetic modelling of microalgae cultivation for wastewater treatment and carbon dioxide sequestration. Algal Research 32 (2018) 131-141
- World Water Day seminars: https://www.youtube.com/watch?v=rAeml3-18Fo&t=151s

1. Official UN poster | 2. Poster used to announce the event and workshop | 3. Dr. Sharon Velasquez-Orta during her presentation | 4. Left to right: Gonzalo Figueroa (MEng student from Manchester University), Dr Sharon Velasquez-Orta, Edward Peacock (MEng student), Laura Walls (MEng student), Dr Teresa Orta from the Institute of Engineering, UNAM.

Upcoming PIG Seminars

- Friday 6th April
  Ben Dannatt
  "Biomass flue gas filtration optimization—Industrial case study"
- Friday 13th April
  David Okot
  TBD
- Friday 20th April
  Toluanimi Kolawole
  TBD
- Friday 27th April
  Ahmed Al-Hatrooshi
  TBD
- Friday 4th May
  Jonathan Harris
  TBD
- Friday 11th May
  James Hockaday
  TBD

Recent PIG Seminars

- ***Dr Valentine Eze*** | 9th Feb
  "Phytoremediation of Arsenic Contaminated Soil and Recovery of Valuable Arsenic Products"
- ***Abdul Rehman*** | 23rd Feb
  "Cyclic carbonate synthesis in the presence of silica-supported aminpyridinium halide catalyst"
- ***Dr Jonathan McDonough*** | 2nd Mar
  "Intensified Carbon Capture using Adsorption: Hydrodynamic Map ping of Small-Scale Fluidized Beds"
- ***Muayad Al-Karawi*** | 9th Mar
  "Hydrothermal liquefaction (HTL) of microalgae harvested by foam flotation column"
- ***Safaa Ahmed*** | 16th Mar
  "Developing a Scale-Up Correlation for Oscillatory Baffled Reactors based on Mass Transfer Coefficient"

New Publications

- L.S. Diaz-Silvarrey, K. Zhang, A.N. Phan. Monomer recovery through advanced pyrolysis of waste high density polyethylene (HDPE). Green Chemistry (2018) Article In-press
- V.C. Eze, A.N. Phan, A.P. Harvey. Intensified one-step biodiesel production from high water and free fatty acid waste cooling oils. Fuel 220 (2018) 567-574
- V.C. Eze, S.B. Velasquez-Orta, A. Hernandez-Garcia, I. Monje-Ramirez, M.T. Orta-Ledesma. Kinetic modelling of microalgae cultivation for wastewater treatment and carbon dioxide sequestration. Algal Research 32 (2018) 131-141
- T Horie, S. Shiota, T. Akagi, N. Ohmura, S. Wang, V. Eze, A. Harvey, Y. Hirata. Intensification of hollow fiber membrane cross-flow filtration by the combination of helical baffle and oscillatory flow. Journal of Membrane Science 554 (2018) 134-139
- R. Law, S. Ahmed, N. Tang, A.N. Phan, A. Harvey. Development of a more robust correlation for predicting heat transfer performance in oscillatory baffled reactors. Chemical Engineering & Processing: Process Intensification 125 (2018) 133-138
- D.K. Okot, P.E. Bilsborrow, A.N. Phan. Effects of operating parameters on maize COB briquette quality. Biomass and Bioenergy 112 (2018) 61-72
- A. Rehman, A.M. López Fernández, M.F.M. Gunam Resul, A. Harvey. Kinetic investigations of styrene carbonate synthesis from styrene oxide and CO_2 using a continuous flow tube-in-tube gas-liquid reactor. Journal of CO_2 Utilization 24 (2018) 341-349
- S.B. Velasquez-Orta, O. Heidrich, K. Black, D. Graham. Retrofitting options for wastewater networks to achieve climate change reduction targets. Applied Energy 218 (2018) 430-441

Training on the production of novel algal biocomposites at North Carolina State University

Dr Thea Ekins-Coward, Dr Sharon Velasquez-Orta, Dr Kamelia Boodhoo

Prof Michael Flickinger and his research group at North Carolina State Univeristy (NC State) have been pioneering advancements in the creation of novel biocomposite materials for over 20 years. Biocomposites concentrate immobilised microoganisms on a substrate material, often utilising an adhesive or a latex binder to stabilize the living cells to essentially create an environmental biocatalyst. Biocomposites have a wide range of potential uses such as rapid degradation of pollutants, solar energy harvesting, carbon recycling and gas-cleaning [1].

Photosynthetic microorganisms are among the most productive biological systems for capturing carbon. However, large volumes of liquid media required for the growth of cells in suspension, poor gas-liquid mass transfer, and small biomass concentration of reactive cells relative to the volume of liquid (low biomass to liquid ratio) are a significant disadvantage to the use of these microorganisms on an industrial scale. The Flickinger group has demonstrated biocomposites are able to reduce footprint and increase volumetric reactivity, and that photosynthetic biocomposites can enhance CO2 uptake rates of up to a factor of ten when compared to suspended cultures, and are able to remain active for hundreds of hours [2].

Prof Flickinger spent a year at Newcastle University in 2015, becoming a member of the Process Intensification Group. While in Newcastle he developed a number of collaborations, one of which is the recently started project "Scalable engineering approaches for exploiting a novel biocomposite material applied to light-driven CO_2 absorption and utilization", led by Dr Kamelia Boodhoo and Dr Sharon Velasquez-Orta. This is a proof of concept project, funded by BBSRC NIBB (Networks in Industrial Biotechnology and Bioenergy) via C1Net (http://www.c1net.co.uk/). It seeks to combine the PI of biocomposites with two PI technologies: 1) a spinning disc reactor (SDR), and 2) electrochemical processing. As part of the project I recently visited NC State for four weeks to learn the skills for creating biocomposites and develop methods for our specific applications.

The thin film flow on a spinning surface offers short path lengths and very high surface areas. Intensified mass transfer rates could be achieved in this so-called spinning disc bioreactor (SDBR). However, the complexity is to create a biocomposite that is reactive, viable for long periods of time, and strong enough to withstand the high shear of the SDR. Biocomposites have been previously tested in falling film reactors [3] and in raceway assays up to 400 rmp, however, the SDR can run up to 2500rpm. Working alongside Prof Flickinger, Dr Ryan Barton, and PhD student Adam Wallace it was decided that a biocoating (cells in a latex coating

applied in a thin uniform layer to a support) would be unlikely to withstand the shear of a SDR. We therefore developed a biocomposite paper, using a combination of hard wood, soft-wood, and microfibrillar cellulose (MFC) pulps to integrate the cells into the paper matrix. MFC has been shown to have the capability to retain high concentrations of viable microorganisms as part of the matrix while preserving viability and reactivity. Pictured below is the paper we developed while I was at NC State. The algal biocomposite paper was tested for reactivity by monitoring the gas consumption over 130 hours and strength by creating a model mini SDR. The paper proved to have consistent reactivity, whereas cells in suspension plateaued over a similar time period. The paper was also strong enough to withstand the shear of a continuous liquid film at high rpms (>1500 rpm). The four weeks at NC State were useful for developing the biocomposite type for our proof of concept applications. Now back in Newcastle, I shall be optimising the paper via the range of variables such as MFC content, cell loading, paper thickness, and chitosan levels and applying them to the SDR and electrochemical processing technologies.

Thank you to Prof Flickinger, Dr Ryan Barton and Adam Wallace for their help, support, and guidance during my visit.

Thea

Left: High concentrations of the algae *Chlorella Vulgaris* integrated into a paper biocomposite. **Right:** (from left to right) Dr Sharon Velasquez-Orta, Dr Thea Ekins-Coward, Prof Michael Flickinger, PhD student Adam Wallace, and Dr Ryan Barton during a meeting hosted at Golden LEAF Biomanufacturing Training and Education Centre (BTEC), North Carolina State University.

1. Cortez, S., *et al.*, *Biocoatings: A new challenge for environmental biotechnology*. Biochemical Engineering Journal, 2017. **121**: p. 25-37
2. Bernal, O.I., C.B. Mooney, and M.C. Flickinger, *Specific photosynthetic rate enhancement by cyanobacteria coated onto paper enables engineering of highly reactive cellular biocomposite "leaves"*. Biotechnology and Bioengineering, 2014. **111**(10): p. 1993-2008
3. Schulte, M.J., *et al.*, *A high gas fraction, reduced power, syngas bioprocessing method demonstrated with a Clostridium ljungdahlii OTA1 paper biocomposite*. Biotechnology and Bioengineering, 2016. **113**(9): p. 1913-1923