

pig MONTHLY

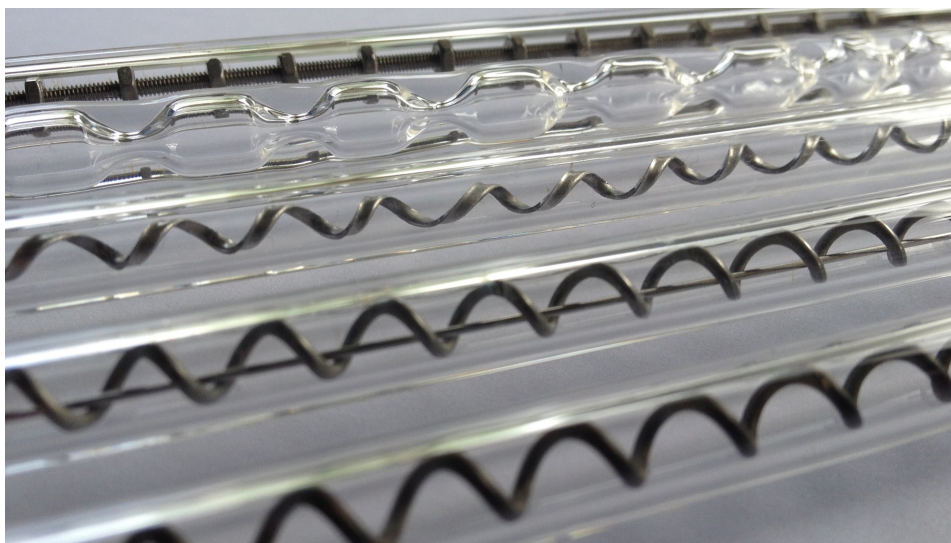
process intensification group | www.pig.ncl.ac.uk | www.pinetwork.org

Introduction

Process Intensification (PI) is the strategy of dramatically reducing the size of process equipment or improving the performance of unit operations in order to achieve given production objectives. Through the adoption and exploration of novel technologies, and through process hybridisation, the Process Intensification Group (PIG) at Newcastle University has achieved significant improvements in applications including: fine chemicals, polymers, food, bio-medical, medical, offshore, pharmaceuticals, electronics, transport and energy.

The purpose of this newsletter is to better disseminate the group's research activities and also provide useful information for upcoming events and conferences of interest. In this inaugural issue, an overview of the group is presented, covering research areas and associated academics/RAs/students, and current funded projects. Additionally, a breakdown of the facilities available in the group is highlighted, and a summary of group news and recent research activity is presented. Future issues will also aim to provide a spotlight for areas of research in the group.

Process Intensification (PI) is definable in a number of ways. Typically, PI is associated with enhanced transport rates and uniform processing, leading to improved reaction control (less waste, improved selectivity, etc), higher efficiency, reduced capital costs and reduced inventory (smaller footprint, improved intrinsic safety, etc).



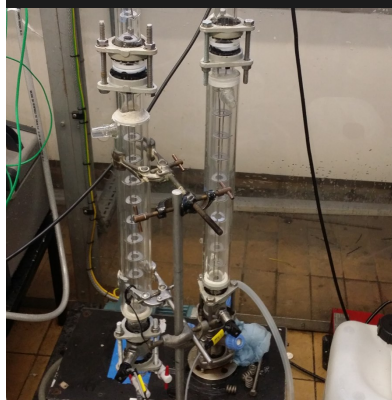
Mesoscale Oscillatory Baffled Reactors. One example of intensified reactor used in the group.

In This Issue

- Introduction to research areas
- Highlight of current funded projects
- List of facilities
- PIG news
- Research activity
- Upcoming events



Pilot-Scale Rotating Packed Bed



Pilot-Scale Oscillatory Baffled Reactor



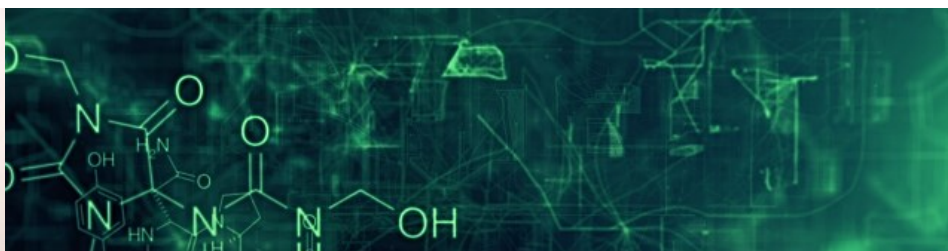
Spinning Disc Reactor



Micro-Fluidic Membrane



Foam Column for Algae Separations



Active Research Areas & People

Algae Processing

- Dr Jon Lee
- Dr Sharon Velasquez Orta
- Prof Adam Harvey
- Muayad Al-Karawi
- Auwal Aliyu
- James Hockaday
- Abbas Umar

Biodiesel/Biofuels

- Prof Adam Harvey
- Dr Jon Lee
- Dr Sharon Velasquez Orta
- Dr Anh Phan
- Dr Fernando Russo Abegao
- Ahmed Al-Hatrooshi
- Luma Al-Saadi
- Auwal Aliyu
- Akeem Babatunde
- Salihu Musa
- Malik Musthofa

Bioelectrochemical Processes

- Dr Sharon Velasquez Orta
- Xenia Christodoulou
- Tobechi Okoroafor

Catalysis

- Dr Fernando Russo Abegao
- Prof Adam Harvey
- Auwal Aliyu

Fluidics (Oscillators)

- Prof Adam Harvey
- Dr Richard Law
- Jonathan McDonough

Foam Column Separation

- Dr Jon Lee
- Muayad Al-Karawi
- Salihu Musa
- Abbas Umar

In-Situ Product Recovery

- Prof Adam Harvey
- Dr Jon Lee
- Victoria Outram

Membranes

- Dr Takafumi Horie

Microfluidised Beds/Torbed

- Dr Vladimir Zivkovic
- Prof David Reay

- Dr Richard Law
- Orlando do Nascimento

Oscillatory Baffled Reactors

- Prof Adam Harvey
- Dr Anh Phan
- Dr Ana Lopez
- Dr Richard Law
- Safaa Ahmed
- Luma Al-Saadi
- Mohamad Gunam Resul
- James Hockaday
- Jonathan McDonough

Particulate Matter

- Dr Steven Wang

Plasma, Pyrolysis and Gasification

- Dr Anh Phan
- Dr Kui Zhang
- Prof Adam Harvey
- Laura Diaz Silvarrey
- Jonathan Harris
- Teuku Mukhriza
- David Okot
- Ha Phan
- Phuet Prasertcharoensuk
- Faisal Saleem

Polymers

- Prof Adam Harvey
- Dr Kamelia Boodhoo
- Dr Ana Lopez
- Mohamad Gunam Resul
- Abdul Rehman

Rotating Packed Beds (& CO₂ Capture)

- Dr Jon Lee
- Dr Pierrot Attidekou
- Toluanimi Kolawole

Spinning Disc Reactors (Crystallization)

- Dr Kamelia Boodhoo
- Sahr Sana

Stranded Natural Gas Utilization

- Dr Jon Lee
- Chukwuma Anyigor

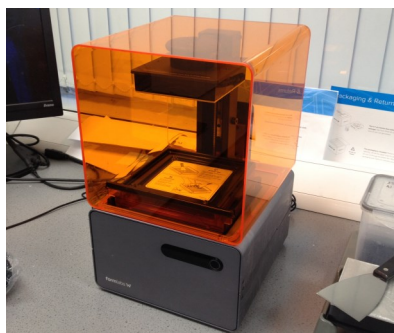
Water/Wastewater Treatment

- Dr Sharon Velasquez Orta
- Prof Adam Harvey
- James Hockaday

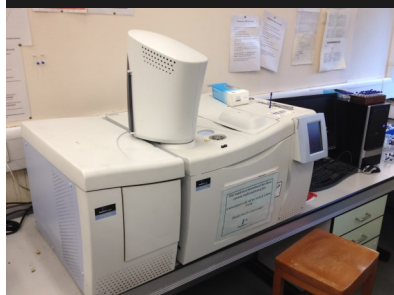
Current Funded Projects

<i>Live Project</i>	<i>Investigators</i>	<i>Duration</i>	<i>Value (£K)</i>	<i>Awarding Body</i>
<i>Conversion of biomass into superior electrode materials for energy storage applications</i>	A Phan F Russo Abegao	Oct 2016—Jul 2017	10	International Partnership Fund
<i>Novel adsorbents applied to integrated energy-efficient industrial CO₂ capture</i>	DA Reay V Zivkovic	2016—2019	985	EPSRC
<i>Process intensification of biodiesel production from microalgae</i>	F Russo Abegao JGM Lee	Aug 2016—Jan 2017	30 (Total: £50k)	Share Sandpit Award, SuperGen Bioenergy
<i>Rational Catalyst Development</i>	M von Stosch F Russo Abegao	2016 (6 months)	10	IfS, Newcastle University
<i>Development of New Cooling Technologies for High Power Electronics</i>	R Law	2016 (6 months)	10	IfS, Newcastle University
<i>IbD: Intensified by Design</i>	KVK Boodhoo DA Reay	2015—2018	€639 (Total: €10 million)	EU (Horizon 2020)
<i>Sustainable Polymers</i>	AP Harvey	2014—2019	412 (Total: £2.9 million)	EPSRC
<i>Cleaning Land for Wealth (CL4W)</i>	AP Harvey	2013—2016	400	EPSRC
<i>Evaluation of PI on early development or retrofitting existing processes for green & sustainability benefits</i>	KVK Boodhoo	2013—2016	115	EDB (Singapore) GSK (Singapore)
<i>Supergen Bioenergy</i>	AP Harvey	2012—2017	286	EPSRC

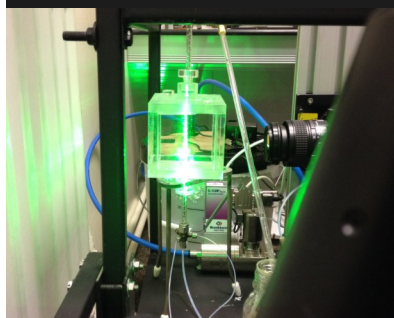




3D Printer (Form1+)



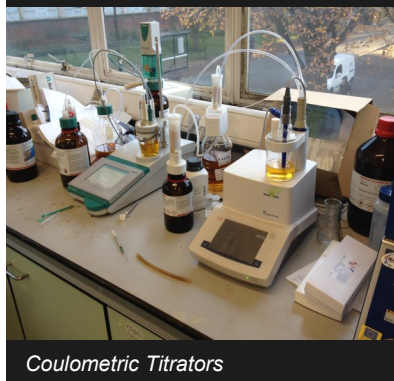
GC-MS (with autosampler)



PIV Measurements in a meso-OBR



High Speed Camera



Coulometric Titrators



Main PI Lab, C113 Merz Court

List of Available Facilities

The PI group has amassed a large array of research equipment through various projects. For example the group currently has working reaction platforms operating from milli-scales ($\mu\text{L/mL}$) to pilot-scale (L), numerous analytical equipment (such as FTIR, UV-VIS, GC, etc), large amounts of general-purpose labware (e.g. glassware, separation units, furnaces, etc) and has access to resources such as high-speed camera imaging and PIV. The list below summarizes some of the available facilities to the group and preliminary contacts/current users. It is intended in due course that full specifications for each facility as well as points of contact will be available on the group's website (www.pig.ncl.ac.uk).

Labs (Located in Merz Court)

- C12 | *Dr Anh Phan or Dr Kui Zhang*
- C18 | *Dr Anh Phan or Dr Vladimir Zivkovic*
- C113 | *Prof Adam Harvey or Dr Valentine Eze*
- C122 | *Prof Adam Harvey or Dr Ana Lopez*
- C123 | *Prof Adam Harvey or Dr Richard Law*

Intensified Reactors/Separators

- Spinning Disc Reactors | *Dr Kamelia Boodhoo*
- Oscillatory Baffled Reactors (5—80 mm diameter) | *Prof Adam Harvey*
- Pilot-Scale Rotating Packed Beds for CO_2 Capture | *Dr Jon Lee*
- Plasma Reactor | *Dr Anh Phan or Dr Kui Zhang*
- Heat Pipe-Extruder | *Dr Ahmad Mustaffar or Dr Anh Phan*
- Taylor-Couette Reactor | *Dr Haoyu Wang or Dr Kamelia Boodhoo*
- Micro Fluidized Beds | *Dr Vladimir Zivkovic*
- Foam Flotation Column | *Dr Jon Lee, Muayad Al-Karawi or Abbas Umar*

Analytical Equipment

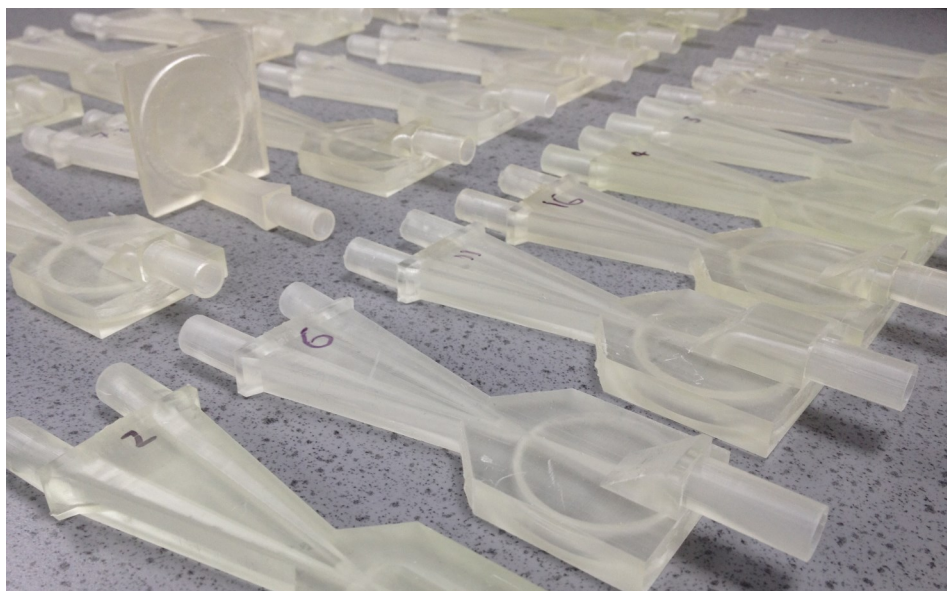
- UV/Vis Spectrophotometer | *Dr Kamelia Boodhoo*
- FTIR Spectrometers | *Jonathan McDonough or Dr Ana Lopez*
- HPLC | *Jonathan Harris*
- GC & GCMS with automated samplers | *Dr Valentine Eze*
- Calorimeter | *Jonathan Harris*
- Coulometric Titration | *Dr Valentine Eze or Jonathan Harris*
- Gel Permeation Chromatography | *Dr Kamelia Boodhoo*
- DO Probes | *Safaa Ahmed*
- Conductivity Probes | *Jonathan McDonough or Safaa Ahmed*
- Viscosity Measurement | *Dr Kamelia Boodhoo*

General Equipment

- Syringe Pumps | *Jonathan McDonough or Dr Valentine Eze*
- Potentiostats | *Dr Sharon Velasquez Orta*
- Heating/Stirring Plates
- Rotary Evaporator | *Jonathan McDonough or Dr Ana Lopez*
- Vacuum Oven | *Dr Valentine Eze*
- Oven
- Furnace | *Malik Musthofa*
- Vibrating Sieve | *David Okot or Akeem Babatunde*
- Heated/Cooled Recirculating Baths | *Jonathan McDonough, Dr Richard Law or Dr Ana Lopez*
- Extraction Column | *Akeem Babatunde*
- Glassware (condensers, flasks, etc)

Other Resources Available

- Digital Microscope | *Dr Sharon Velasquez Orta*
- Water/Wastewater Characterization | *Dr Sharon Velasquez Orta*
- PIV and Stereo PIV | *Jonathan McDonough or Safaa Ahmed*
- High Speed Camera | *Dr Jon Lee*
- 3D Printer | *Jonathan McDonough or Dr Richard Law*



Examples of 3D Printed Fluidic Oscillators

PIG News

- The PIG would like to welcome the following new group members:
 - Dr Steven Wang, *Lecturer*
 - James Hockaday, *Postgraduate Student* (supervised by Dr Velasquez Orta and Prof Harvey)
 - Ha Phan, *Postgraduate Student* (supervised by Dr Phan and Dr Fernando Russo Abegao)
- Congratulations to Xenia Christodoulou, who passed her viva on 1st November with corrections. Her PhD thesis was titled: "Economic and Empirical Investigation of Bioelectrochemical Systems for CO₂ Utilization".
- Congratulations to Dr Richard Law for his promotion to the position of Lecturer. Richard is currently working with Vlad and David on a CO₂ capture project, and will officially begin the new role in August 2017.
- Congratulations to Jonathan McDonough who has accepted a Research Assistant position working with Prof Harvey. The project (running from Nov 2016-Aug 2017) aims to investigate the use of fluidic oscillators (see picture above) in a variety of applications relevant to process intensification.
- Congratulations to Dr Steven Wang (in collaboration with Prof Harvey) for securing an IfS grant. The project is titled: "*Learning from trees: study of PM capture mechanism, and development of a new bioinspired approach to solve emission problems*"

Upcoming Conferences

- International Symposium on Green Chemistry, *ISGC* (16-19 May 2017, La Rochelle, France)
- International Conference on Fluid Mechanics, *ICFM* (26-27 Feb 2017, Barcelona, Spain)
- ChemEngDayUK (27-28 March 2017, University of Birmingham). Abstract Submission Deadline: 16 Dec 2016
- WCCE10+ECCE11+ECAB4 (1-5 Oct 2017, Barcelona, Spain). Abstract Submission Deadline: 30th Jan 2017
- European Process Intensification Conference, *EPIC* (1-5 Oct 2017, Barcelona, Spain). Abstract Submission Deadline: 30th Jan 2017
- 4th International Conference on Heat Transfer and Fluid Flow, *HTFF* (8-10 June 2017, Rome, Italy). Extended Abstract Deadline: 1 March 2017
- Global Biotechnology Congress (10-13 July 2017, Boston, US). Abstract Submission Deadline: 10th June 2017
- 15th UK Heat Transfer Conference (4-5 Sep 2017, Brunel University, London). Extended Abstract Submission Deadline (2 Pages): 16 June 2017
- UK Fluids Conference (6-8 Sep 2017). Abstract Submission Opening: 16 January 2017
- 2017 AIChE Annual Meeting (Oct 29-Nov 3 2017, Minneapolis, US). Abstract Submission Opening: 16 January 2017

Upcoming Events

- PIG Seminar, Fri 2nd Dec 2016, 12:00-13:00 (Buttery). Toluwanimi Kolawole: "Pilot-plant scale post-combustion CO₂ capture using a rotating packed bed: Mass transfer studies and CO₂-loading analysis method development"
- CEAM Seminar, Tues 6th Dec 2016, 13:00-14:00 (L201). Prof Oscar Ces: "Microfluidic technologies for the bottom-up construction of artificial cells"

Other Information

- Full contact details and research profiles for the PI group members can be found at the website: www.pig.ncl.ac.uk
- For enquires about collaborations or PhD study, see the website: www.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

Research Activity

Recent Publications (October and November)

- McDonough JR, Law R, Kraemer J, Harvey AP. Effect of geometrical parameters on flow-switching frequencies in 3D printed fluidic oscillators containing different liquids. *Chemical Engineering Research and Design* 117 (2017) 228-239
- McDonough JR, Phan AN, Reay DA, Harvey AP. Passive isothermalisation of an exothermic reaction in flow using a novel "Heat Pipe Oscillatory Baffled Reactor (HPOBR)". *Chemical Engineering and Processing* 110 (2016) 201-213
- Outram V, Lalander CA, Lee JGM, David ET, Harvey AP. A comparison of the energy use of *in situ* product recovery techniques for the Acetone Butanol Ethanol fermentation. *Bioresource Technology* 220 (2016) 590-600
- Salam KA, Velasquez-Orta SB, Harvey AP. A sustainable integrated in situ transesterification of microalgae for biodiesel production and associated co-products—A review. *Renewable and Sustainable Energy Reviews* 65 (2016) 1179-1198

Recent Books (September)

- Hesselgreaves JE, Law R, DA Reay. *Compact Heat Exchangers*, 2nd Edition. Butterworth-Heinemann. ISBN: 978-0-08-100305-3

Attended Conferences/Events

- Prof Harvey, Dr Ana Lopez, Mohamad Gunam Resul and Abdul Rehman recently attended the Materials Substitution/Industrial Advisory Board Meeting from 22nd-23rd November as part of the Sustainable Polymers project. The meeting was hosted at the Green Chemistry Centre of Excellence at the University of York. The following presentations were given to the attending industrial advisory board (Lotte, Unilever and Eonic) and collaborators (University of York, Imperial College London and University of Oxford):
 - "Limonene epoxidation in microwave vs conventional heating. Continuous limonene epoxidation using novel microwave irradiated meso-OBR" (Dr Ana Lopez)
 - "Continued optimization of the epoxidation of terpenes in Oscillatory Baffled Reactors (OBRs) and batch reactor" (Mohamad Gunam Resul)
 - "Synthesis of cyclic carbonates in batch and continuous FlowSyn reactor using limonene oxide and styrene oxide" (Abdul Rehman)
 - "Process development and intensification of terpene epoxidation and the synthesis of cyclic carbonates" (Prof Adam Harvey)
- Prof Harvey and Dr Zhang attended the Supergen Bioenergy Conference in Sheffield on 17th November
- Safaa Ahmed attended the 2016 AIChE annual meeting in San Francisco (13th-18th November). Safaa presented two talks:
 - "Scale up of oscillatory baffled reactors (OBRs)"
 - "Mass transfer enhancement as a function of the oscillatory baffled reactor design"

Research Activity (cont'd)

PIG Seminars

- Dr Ana Lopez. "Sustainable Polymers: Process Intensification of Terpene Epoxidation". 18 Nov
- Abdul Rehman. "Cyclic Carbonates Synthesis from Epoxides and CO₂: Batch to Continuous
- Dr Pierrot Attidekou. "Non Destructive Technique (NDT) for Lithium Ion Battery (LiB) Assessment". 28 Oct
- Xenia Christodoulou. "Economic and empirical investigation of bioelectrochemical systems for CO₂ Utilization". 21st Oct
- Dr Brian Ray. "Synchrotron radiation used to probe a working reactor bed in-situ via X-Ray diffraction". 14th Oct
- Prof Glen McHale. "Liquid adventures with smart surfaces". 7th Oct

