University of Birmingham

# Dr Gary Leeke AMIChemE FHEA MRSC

Reader in Low Carbon Technologies

**School of Chemical Engineering (/schools/chemical-engineering/index.aspx)**

## Contact details

**Telephone** +44 (0) 121 414 5351 (tel:+44 121 414 5351)

**Email** g.a.leeke@bham.ac.uk (mailto:g.a.leeke@bham.ac.uk)

School of Chemical Engineering
University of Birmingham
Edgbaston
Birmingham
B15 2TT
UK

## About

Gary has published over 100 papers in journals and conference proceedings on the use of sub and supercritical fluids (water, CO2 and alcohols). His research covers both fundamentals and industrial applications and he is inventor on two patents. He has received funding awards from UK Research Councils, the Technology Strategy Board, the European Union and local government together with money from industrial sources to finance the research.

He has communicated his work through invited talks, international conferences and with existing and potential industrial collaborators.

## Qualifications

- PG Cert in Learning and Teaching in HE, 2011
- PhD Chemical Engineering, 2000
- BSc(Hons) Applied Chemistry, 1996

## Biography

Gary received his PhD under the direction of the late Michael King from the University of Birmingham in 2000. His research focused on high pressure phase equilibria and mass transfer. After his PhD he took up a post-doctoral post researcher and then spent a spell in industry where he worked for a company which executed process systems for the oil, gas and water industries. He then returned to Birmingham to undertake further post-doctoral research and was awarded a lectureship in March 2006.

## Teaching

- Chemical and Biochemical Processes
- Fluid Flow, Thermodynamics and Heat Transfer
- Process Engineering Fundamentals
- Petrochemical Engineering

## Postgraduate supervision

Gary is interested in supervising doctoral students in the following areas:

- Polymer processing
- Supercritical Water Gasification and Biorefining
- Hydrogen and fuel generation from biomass
- Chemical Engineering of Flow Chemistry processes
- Production of particles by supercritical techniques
- High pressure phase equilibria

If you are interesting in studying any of these subject areas please contact Gary on the contact details above, or for any general doctoral research enquiries, please email: **dr@contacts.bham.ac.uk (mailto:dr@contacts.bham.ac.uk)**

## Research

He has a research portfolio in the development of processes based on environmental and energy efficient principles that utilise sub and supercritical fluids. The research is largely multi-disciplinary and covers reaction engineering of catalytic flow processes, separation of natural products, bio-refining of biomass, manufacture of biofuels, processing of polymers and production of nanoparticles from rapid crystallisation techniques using water, alcohols and $CO_2$ as solvents.

A supercritical fluid (SCF) is a fluid above its critical temperature and pressure. SCFs possess low viscosity and high diffusivity, and their density and solvent power are readily tunable by changing the temperature or pressure. Advantages of SCFs manifest themselves through product quality, environmentally acceptable processing and the manipulation of process conditions to control product characteristics.

The most commonly used SCF is carbon dioxide ($scCO_2$), because of its low critical conditions and high availability.

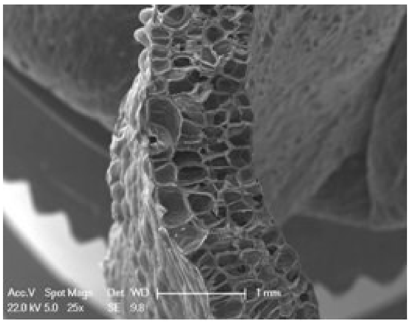
**Polymer Processing**

He is interested in the processing of biodegradable and engineering polymers for medical and food packaging applications. He has received funding from the European Union to undertake research in these areas. He is currently PI on an EU FP7 project (PLA-FOAM, SME-2008-1 232145) and has recently completed a FP6 project (PROTEC, STREP 517070) on which he was Co-I. The FP6 project involved the Universities of Twente and Lodz and polymer processors, Trexel, Germany, Matgas, Spain and Smithers Rapra. The FP7 project involves partners in Sweden (YKI), Switzerland (Maillefer), Belgium (Omniform), Italy (CIB and Boscarol) and the UK (Pera and Biopac).

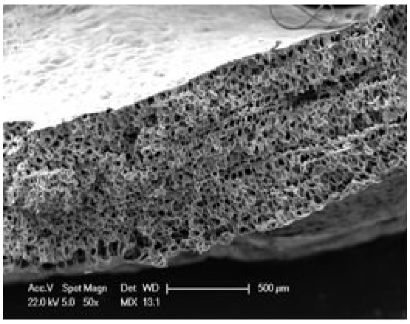
Thermally sensitive polymers such as polylactic acid (PLA) and polyglutamic acid can be processed at temperatures below their melt in the presence of carbon dioxide and therefore avoids their degradation. The common problem with extruding such polymers is that the polymer needs to be heated above its melt temperature to form the melt seal in the extruder. He is part of a consortium developing an extrusion process where the polymer can be introduced into the extruder at temperatures below the ambient melt but still manages to form a melt seal in the extruder therefore minimising degradation.

He is also interested in coating PEEK onto surfaces for medical applications.

The images below show PLA sheets foamed by supercritical $CO_2$.




Natureworks PLA 3051 D, processed at 140°C, 150 bar, 2 min soak. The product has 28% crystallinity and a density of 375 kg/m3




Natureworks PLA 4060 D, processed at 70°C, 150 bar, 5 min soak. The product has 0% crystallinity and a density of 205 kg/m3

**Particle Formation**

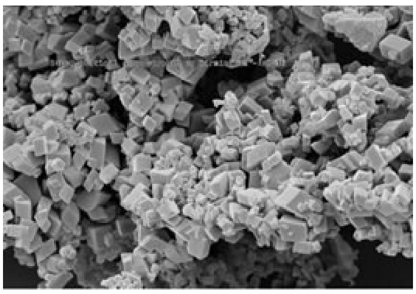
He is interested in the production of particles for pharmaceutical, medical, catalytic and personal health care applications. Several techniques have been developed in which nano- and microparticles are produced using SCFs (particularly $CO_2$).

These methods can be more attractive than many conventional particle production techniques because:

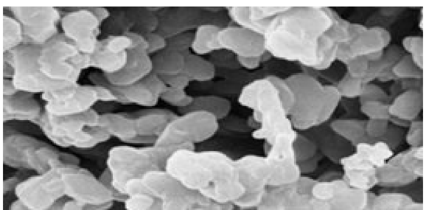
- Micro and nanoparticles with a narrow size distribution can be produced in one step
- The use of organic solvents can be eliminated or greatly reduced
- The processes can be less damaging to labile substances
- The processes may produce polymorphs that are not obtainable by other means

There are a number of supercritical particle production techniques available and their selection largely depends on the solubility of the active in the supercritical fluid. At Birmingham he has projects that use CO2 as a solvent and anti-solvent. He also uses the PGSS method where particles are produced from a melt phase, which is useful for producing polymeric particles for encapsulation applications.

The ability of supercritical fluid particle formation techniques to produce different morphologies is demonstrated in the images below:



Prismatic particles produced using a methanol modified-RESS process



Platelet particles produced using an acetone-modified RESS process

He currently holds an EPRSC grant (EP/F0373228/1) on particle formation on which he is Co-I. This project is in conjunction with the University of Warwick. The research is developing a supercritical fluidisation process to capture nanoparticles directly from SCF precipitation processes and incorporating them into a readily processable form. Processing in this way retains the unique properties of the particles in formulation and is currently in the early stages of a patent application. This technology has important applications in the food and pharmaceutical industries.

He was Co-I on another EPSRC project that ended in 2008 (EP/C515943/1). The research was investigating the scale out of rapid crystallisation techniques to manufacture catalytic nanoparticles. This project included the Universities of Cardiff and Liverpool and Johnson Matthey.

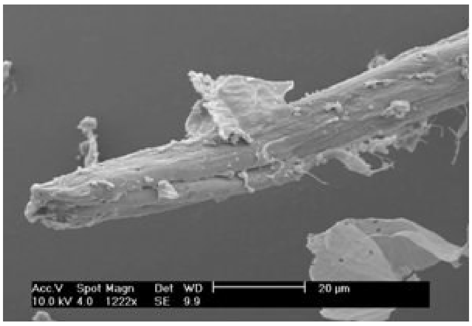
**Reaction Engineering of Flow Processes**

He is interested in the development of flow processes for pharmaceutical, wastewater, gasification, biofuel and biorefining applications that use sub and supercritical water and CO2 as solvents/reaction media. These processes are developed from a thorough understanding of kinetic, hydrodynamic and phase equilibria properties. He is one of only a handful of groups worldwide that are working on the phase behaviour (experimental and modelling) of biorefinery and gasification products. Data from which are fundamental to the take-up of this technology by industry. He also has a long history in studying the phase equilibria of CO2 and other non-ideal mixtures.

A number of reactions have been investigated in supercritical CO2 – ranging from palladium carbon-carbon coupling reactions, diaryl ether synthesis and Friedel-Crafts alkylation. He was visiting researcher at the University of Melbourne 2006-07, working with Andrew Holmes's (FRS) group developing reactions under flow conditions in CO2; a collaboration which is still active. Other collaborators in this area include AstraZeneca, and the Universities of Cornell, Melbourne, Leeds, and CSIRO, Australia. An extension of this work is the use of CO2/water emulsions to undertake synthetic reactions in a totally clean environment (EPSRC grant: EP/H007784/1). Proof of principle reactions have demonstrated this approach to yield unique benefits.

He is researching the production of hydrogen and syngas from biomass for conversion into fuels (bioethanol). Other projects include the manufacture of biodiesel in flow at sub and supercritical conditions. In collaboration with an industrial partner (WRK Ltd) they have demonstrated that very high yields of biodiesel can be produced in a new reactor that produces incredibly high rates of mass transfer in less than 10 minutes at room temperature. The photo below shows the supercritical water gasification rig used at Birmingham.

He is also working on the biorefining of biomass to target valuable chemicals. Depending on process conditions these chemicals can either be used as feedstocks for fermentation processes to produce $H_2$ or as an alternative source to fossil based chemicals or as a natural source of compounds. Collaborators include Boots and Scottish and Newcastle. The image below shows an intact cellulose fibre following delignification using a mixture of subcritical water ethanol:$CO_2$




For more details of Birmingham's work into hydrogen and energy visit our **Research and Commercial Services (http://www.rcs.bham.ac.uk/hydrogenproject/index.shtml)** microsite and **Birmingham Science City. (http://www.birminghamsciencecity.co.uk/)**

Also see the **World Renewable Energy Congress / Network (http://www.wrenuk.co.uk/)** for the upcoming World Renewable Energy Forum 2012 in Denver, USA for which Gary is on the Technical Committee.

## Other activities

Editorial board member for:

- Renewable Energy
- Open Catalysis Journal

Peer reviewer for:

- Renewable Energy
- Biomacromolecules
- Ind. Eng. Chem. Res
- Fuel
- Powder Tech
- J. Chem Eng Data
- J. Supercritical Fluids
- Review of Scientific Instruments
- J. Microencapsulation
- International Journal of Molecular Sciences
- Food and Bioproducts Processing

Committee Member of the **West Midlands Chemistry Teachers' Centre (http://www.wmctc.co.uk/)**.

## Publications

**Recent publications:**

Baig, M.N., Leeke, G.A., P.J. Hammond, P.J., Santos, R.C.D., (2011), Modelling the extraction of soil contaminants with supercritical carbon dioxide, Environmental Pollution, 159, 1802-1809.

Shah, A., Fishwick, R.P., Leeke, G.A., Wood, J., Rigby, S.P., Greaves, M., (2011), Experimental Optimization of Catalytic Process In-Situ for Heavy Oil and Bitumen Upgrading, J. Can. Pet. Tech., accepted.

Smith, K., Bridson, R.H., Leeke, G.A., (2011), Solubilities of Pharmaceutical Compounds in Ionic Liquids, J. Chem. Eng. Data, 56, 2039-2043.

Smith K.B.; Bridson R.H.; Leeke, G. A., (2010), Crystallisation of APIs from Ionic Liquids J. Pharm. Pharmac., 62, 1412-1413.

Shah, A., Fishwick, R., Wood, J. A, Leeke, G.A., Rigby, S., Greaves, M., (2010), A review of novel techniques for heavy oil and bitumen extraction and upgrading, Energy and Environmental Science, 3, 700–714.

Alenezi, R., Leeke, G.A.; Santos, R.C.D.; Khan, A.R., (2010), Esterification Kinetics of Free Fatty Acids with Supercritical Methanol for Biodiesel Production, Energy Conversion and Management, 51, 1055-59.

Collins, N.J. Bridson, R.H. Leeke, G.A. Grover, L.M., (2010), Particle Seeding Enhances Interconnectivity in Polymeric Tissue Engineering Scaffolds Foamed using Supercritical CO2, Acta Biomaterialia, 6, 1055-1060.

Alenezi, R.; Santos, R.C.D.; Baig, M.; Leeke, G.A., (2010), Continuous Flow Hydrolysis of Sunflower Oil as a Route to Fatty Acid Intermediates for Biodiesel Production, Energy Sources Part A, 32, 460.

Alenezi, R., Leeke, G.A.; Santos, R.C.D.; Khan, A.R., (2009), Hydrolysis Kinetics in Supercritical Water, Chem. Eng. Res. Des., 87, 867-873.

Angeles, M.J.; Leeke, G.A., Santos, R.C.D., (2009), Catalytic Supercritical Water Oxidation for the Destruction of Quinoline Over MnO2/CuO mixed catalyst, Ind. Eng. Chem. Res., 48, 1208-1214.

Lu, T.; Blackburn, S.; Dickinson, C.; Rosseinsky, M.; Hutchings, G.; Axon, S.; Leeke, G.A., (2009), Production of Titania Nanoparticles by a Green Processing Route, Powder Tech., 188, 264–271.

Nalawade, S., Westerman, D., Leeke, G.A., Santos, R.C.D., Grijpma, D., Feijen, J., (2008), Preparation of porous poly(trimethylene carbonate) structures for controlled release applications using high pressure CO2, J. Controlled Release, 132, 3, e73-e75.

Lee, J-K.; Fuchter, M.J.; Williamson, R.M.; Leeke, G.A.; Bush, E.J.; McConvey, I.F.; Saubern, S.; Ryan, J.H.; Holmes, A.B., (2008), Diaryl Ether Synthesis in Supercritical Carbon Dioxide in Batch and Continuous Flow Mode, Chem. Comm., 38, 4780-4782.

Collins, N. J.; Leeke, G.A.; Bridson, R. H.; Hassan, F.; Grover, L.M., (2008), The influence of silica on pore diameter and distribution in PLA scaffolds produced using supercritical CO2, J. Mat. Sci., 19, 1497-1502.