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EPSRC
Engineering and Physical Sciences Research Council

EPSRC Centre for Doctoral Training in Sustainable Chemistry

Annual Report 2017

suschem-nottingham-cdt.ac.uk

Contents

Foreword

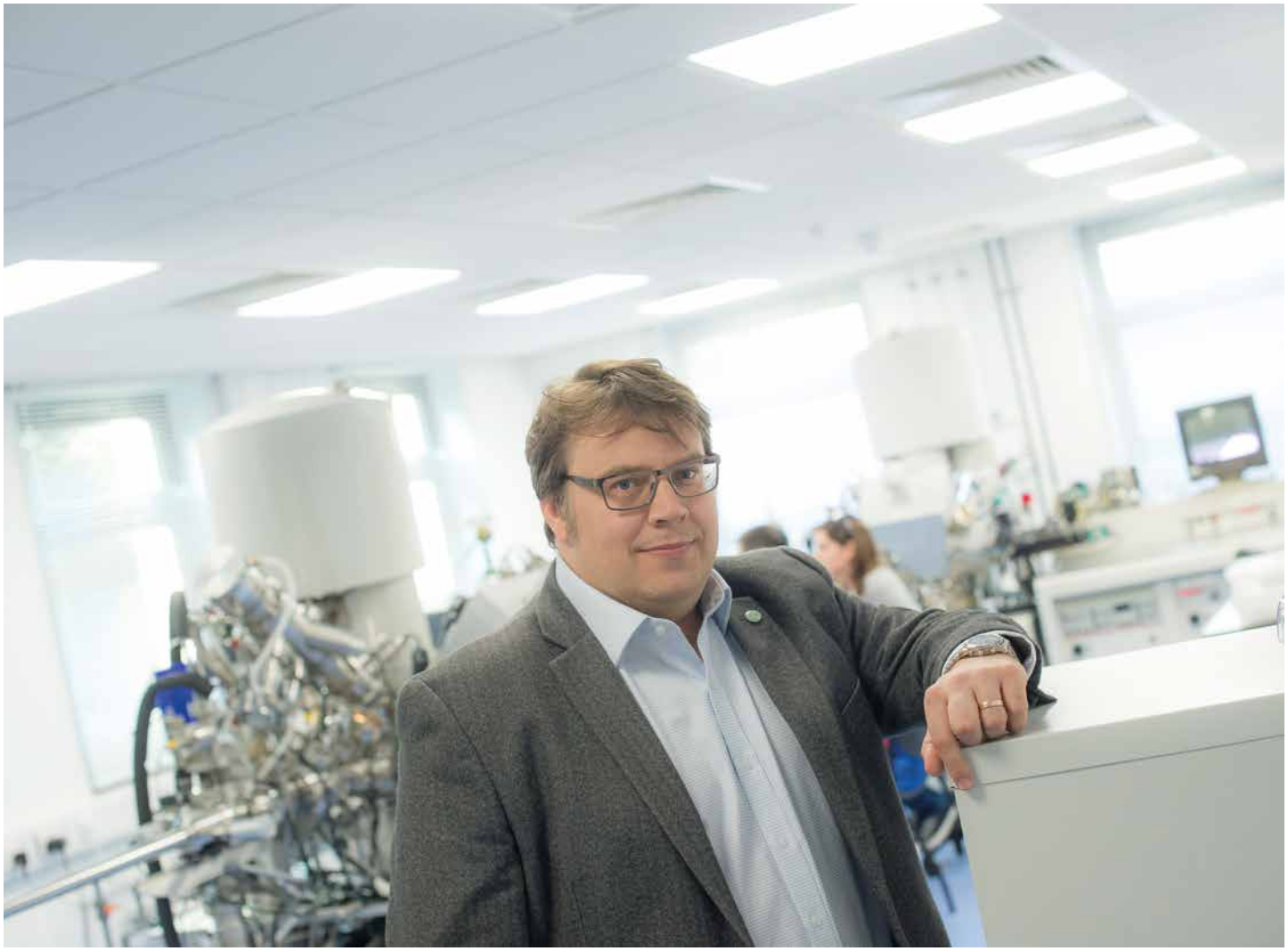
As Co-Director it gives me great pleasure to write a brief introduction to the Annual Report for our EPSRC Centre for Doctoral Training (CDT) in Sustainable Chemistry.

The academic year 2016/17 was a significant one in the lifecycle of our CDT. In September 2016 Cohort Three moved into its custom designed training suite located within the newly commissioned GSK Carbon Neutral Laboratories for Sustainable Chemistry (CNL). At last we have realised our vision to deliver a thought provoking and transformational training programme in a facility designed to ensure minimal environmental impact, whilst inspiring its occupants to "think differently".

The CNL project, and the broader aspects of Sustainable Chemistry at our University, were projected onto the world stage in September 2014, however, sadly for the wrong reason. The iconic CNL building was destroyed during its construction by a fire. The timing of this event could not have been worse, in fact it was just a handful of days before Cohort One joined our newly formed CDT. In reality the impact upon the operations of the CDT were not as great as one might imagine, alternative accommodation was provided on University Park and the hard work of building a bespoke, student focused training programme carried on.

So onwards to 2017, we have now recruited our fourth Cohort of 12 students drawn from a broad range of backgrounds spanning chemistry, life science and engineering. Interest in our CDT continues to grow with nearly 300 applicants so far. Cohort Four will join a thriving and vibrant learning environment where they will be challenged by opportunities to work on real-world problems that will impact on sustainability, many of which will be co-created with partners in industry. 2017 also marks an important milestone for Cohort One, who now enter the final year of our programme. We enthusiastically look forward to entering the final phases of Cohort One's journey through our CDT, and driving onwards with the next phases of the CDT programme, celebrating the successes of our co-workers whilst focussing on our strong desire to engage with industrial partners such that our science is applied and can generate benefits beyond our laboratories.

Prof Peter Licence
Co-Director
EPSRC CDT in Sustainable Chemistry



GSK Carbon Neutral Laboratories: A New Home for the EPSRC CDT in Sustainable Chemistry

At the time of writing this brief update for our Annual Report, we are just days away from celebrating the first anniversary of the completion of the spectacular GSK Carbon Neutral Laboratories for Sustainable Chemistry (CNL).

As we move through this anniversary we are actively working with the construction team to finalise a very small number of outstanding activities and snags. The first year has been a phenomenal experience, we have successfully equipped and occupied the laboratories, the CNL currently hosts eight academic research groups, our flagship undergraduate drug discovery project which is delivered jointly with GSK, and of course the EPSRC CDT in Sustainable Chemistry.

The CNL is unique in the world. Designed to ensure minimal environmental impact incorporating the latest developments in sustainable construction, this iconic facility will have a zero impact in terms of embedded and operational carbon over the 25 year projected lifetime of the building.

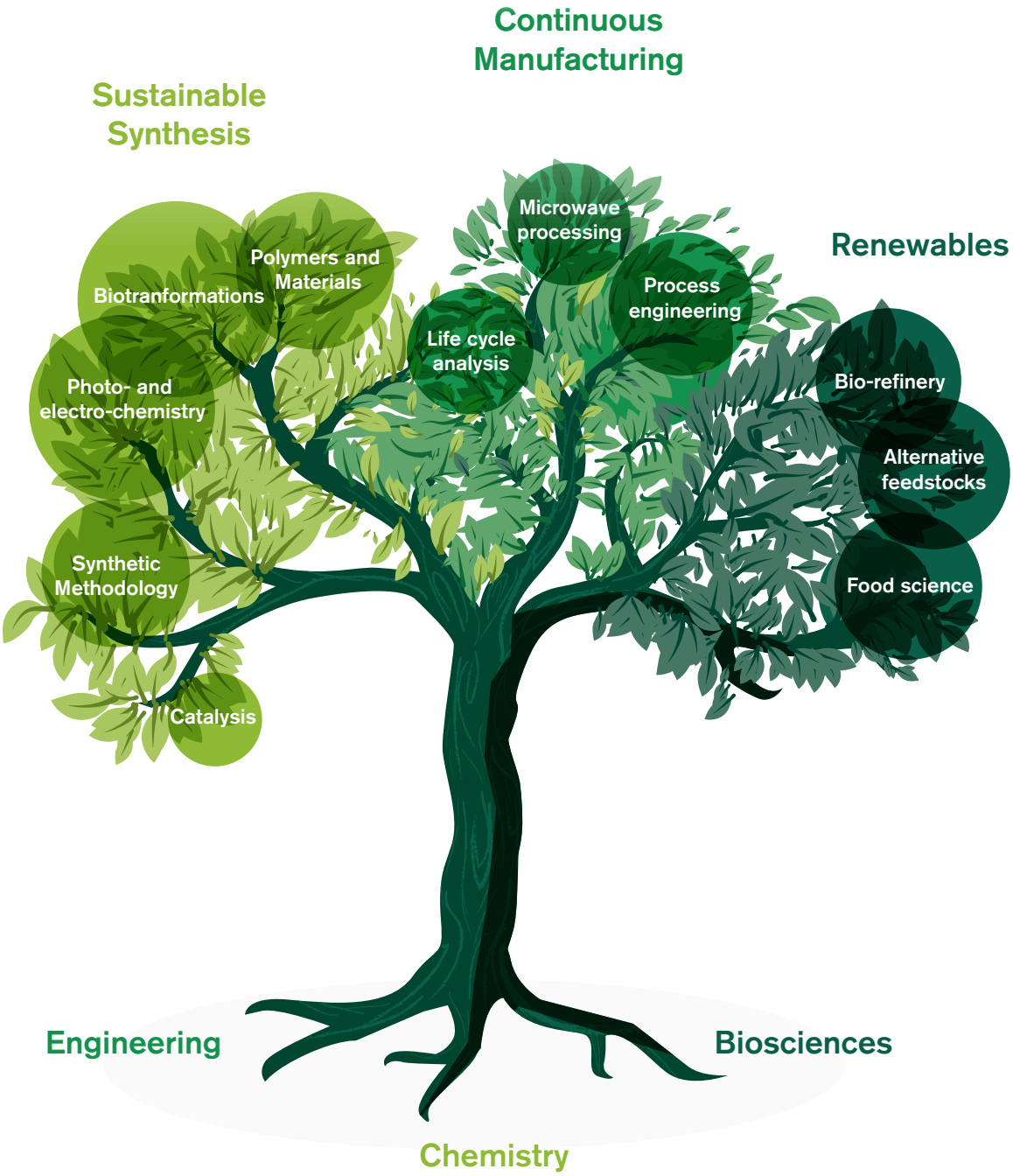
Our laboratories embrace energy efficiency and provide the spring board from which we can deploy sustainable chemistry solutions to some of society's most pressing needs, such as low cost anti-malarial medicines, next generation battery technologies and the crucially important interface with biology.

Architecturally, the CNL is striking; it has rapidly achieved "landmark" status within the University and the wider community. The building, with its elegant profile, rises from the brown field site of the former Raleigh cycle works which now hosts the University of Nottingham's Innovation Park.

In terms of architectural and infrastructural-based environmental recognition the CNL has achieved the highest levels of acknowledgment for its innovation and holistic approach towards sustainability. The facility has achieved **BREEAM Outstanding** and **LEED Platinum** status, and was recently awarded the S-Lab "Physical Sciences Building" prize for new build facilities. What better venue could we provide to inspire the next generation of thought leaders in the field of sustainable chemistry.


AVANCE III HD

EPSRC CDT in Sustainable Chemistry Research Themes



A taste of our students' research

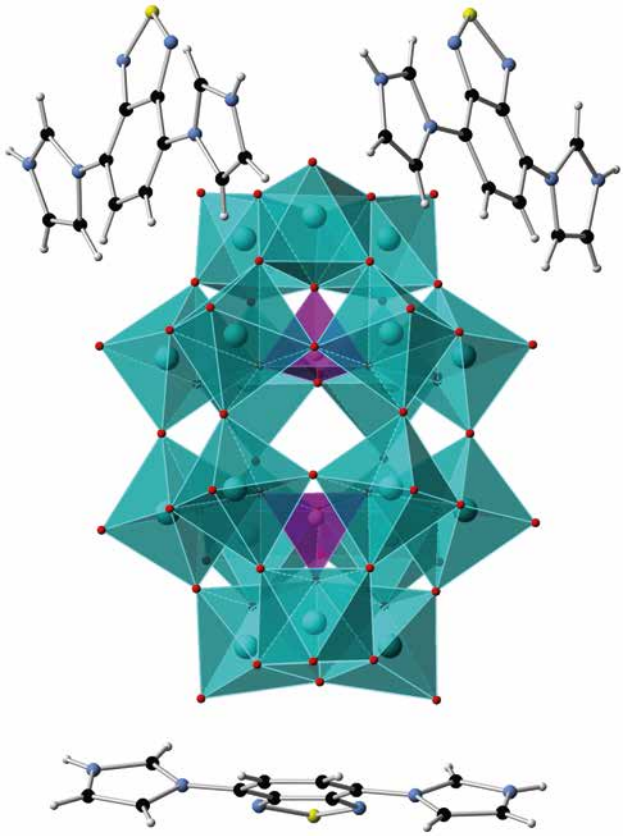
POM-IL hybrid systems for artificial photosynthesis

Alexander Kibler, School of Chemistry

This project is aimed at designing catalytic systems for artificial photosynthesis applications. The proposed components consist of polyoxometalates, which are capable of reversible multi-electron redox processes and ionic liquids, which are reputed for their unique solvent properties. The project aims, not only to exploit the wide solubility profile of ionic liquids to efficiently deliver the susbtrates to the catalyst, but also to utilise their unique solvent environment to activate the substrates towards catalytic transformations.

Specifically, the focus is on the Wells-Dawson polyoxotungstate structure as the catalyst as it has already demonstrated water oxidation capability in ionic liquids. This will be combined with ionic liquids featuring planar aromatic cations as these systems often have higher stabilities, conductivities and advanced liquid ordering which can act to stabilise reactive intermediates and template reaction pathways.

In addition, the aim is to promote the catalytic activity of the system through further functionalisation of both the polyoxometalate and the ionic liquid cation, this will allow modulation of the key physical and chemical properties resulting in a bespoke system for achieving concomitant water oxidation and carbon dioxide reduction.



Microwave pyrolysis of biomass in solvents to obtain fuels, sugars and high value chemicals

Benjamin Shepherd, Department of Chemical Engineering

The primary aim of this project is to produce bio-oil from biomass sources, such as wood, spent coffee grounds and seaweed, using microwaves in an inert atmosphere to prevent combustion. The process is known as pyrolysis, splitting the individual constituents of the biomass (cellulose, hemicellulose and lignin) into useful chemicals, such as 5-hydroxymethylfurfural. Microwave pyrolysis has the advantage over conventially heated pyrolysis in that the microwaves heat directly and volumetrically rather than by convection and conduction.

The novel theme of the project is that the pyrolysis process is being carried out in the presence of a solvent, such as cyclohexane, for superior temperature control compared to pyrolysis carried out in the presence of gas. The solvent also provides an intert atmosphere and no inert gas is required. The superior temperature control prevents what is known as cracking of the bio-oil produced, and therefore the oil is of a higher quality than that of conventional and gas-inerted microwave pyrolysis. Preliminary tests show that lignin breakdown is limited in solvent-inerted pyrolysis, which provides promise for fermentation of the bio-oil as few phenols (formed by the breakdown of lignin) will be present.

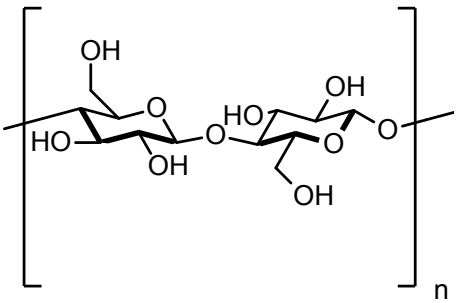


Figure 1 – Cellulose

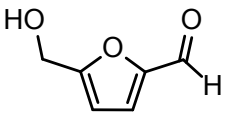


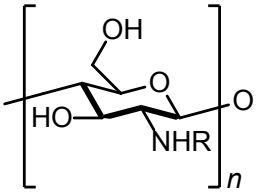
Figure 2 – 5-Hydroxymethylfurfural

Conservation of alum treated wooden artefacts

Jennifer Wakefield, School of Biosciences

Artefacts in the Viking Ship Museum in Oslo are at serious risk of being lost. In 1905, these artefacts were treated with alum, which maintained their structure but produced acid, which over time has hydrolysed the cellulose in the wood, and to a small extent the lignin. This has resulted in the artefacts becoming incredibly fragile, and concern over future degradation and eventual loss of these artefacts. Conservation methods currently available would either seriously alter the look of these artefacts or are unsuitable, as they are water-soluble. Water would dissolve the alum and in doing so, cause further damage to the most fragile artefacts. Some more robust artefacts may support a water-soluble based method(s) but the current options are limited and the acid and iron in the artefacts could cause problems with current methods.

The aim is to produce a sustainable consolidant similar to cellulose in natural wood. This will help to retain a natural appearance, avoid unnecessary use of fossil fuels as the main consolidant material would come from waste plants or crab shells (amino cellulose or chitosan), and help avoid unpredictable consequences of treatment due to similarity to natural components of wood. The aim is to make chitosan and/or amino cellulose soluble in an organic solvent so it can be applied to the wood. This is being done by changing functional groups on the backbone either through click chemistry or addition of silyl alkyl groups. Reductive amination is also being considered for adding a water-soluble chelating group to produce an alternative water-soluble option.



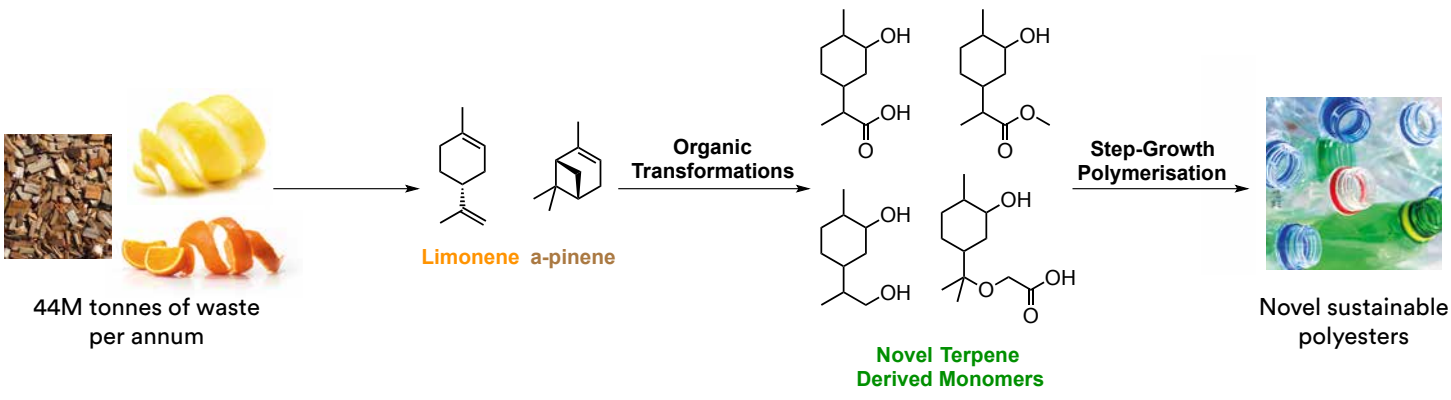
R = H or $COCH_3$

The sustainable functionalisation of biomass for the synthesis of novel polymers

Megan Thomsett, School of Chemistry

The development of macromolecular materials from renewable resources is currently an important area of research, which aims to successfully alleviate society's dependence on fossil fuels. Terpenes are a class of plant-based renewable molecules, which have been extensively studied for the production of renewable polymers and could potentially replace petroleum derived monomers.

This research aims to functionalise various terpenes in a sustainable manner that will not cause adverse effects on the environment. The monomers obtained could be used in step-growth polymerisations to produce potentially biodegradable polyesters. The overall objective of this research is to synthesise novel and useful polymers derived partly or entirely from abundant and cheap terpene feedstocks.

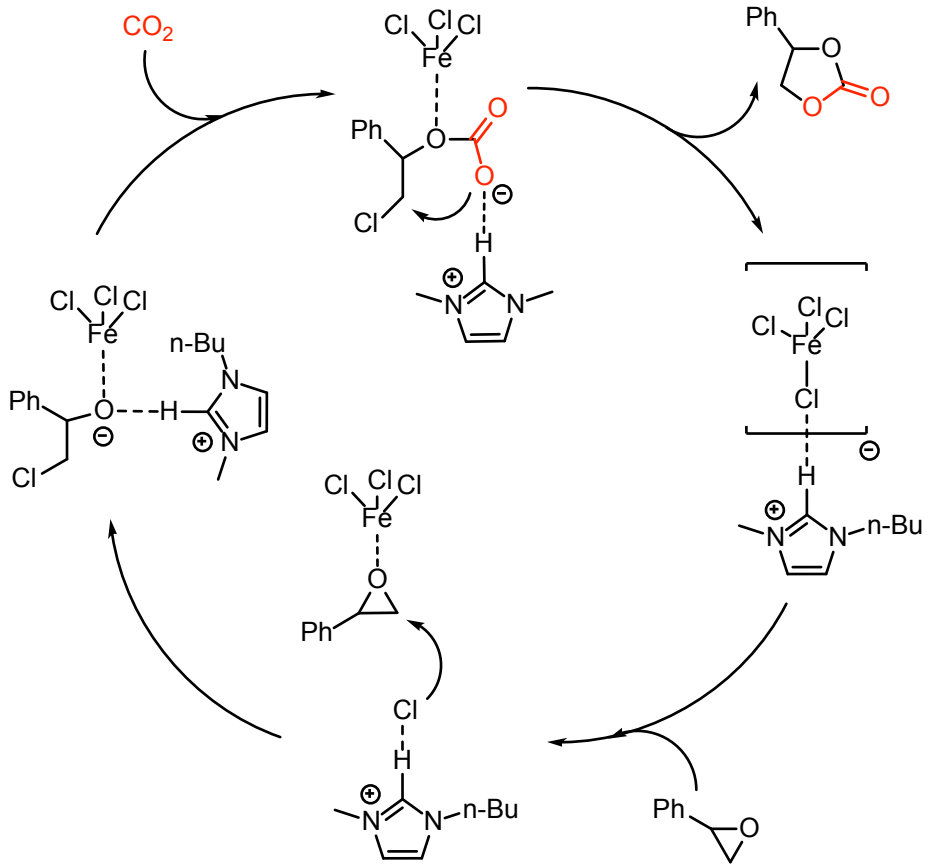


Catalytic magnetic materials in ionic liquids

Meike Leu, School of Chemistry

Most chemical processes require high temperature. In this context, traditional thermal heating is a non-sustainable expensive process and, due to heat loss, inefficient. The development of new methodologies for the heating of reactions in the chemical industry could significantly reduce the carbon footprint.

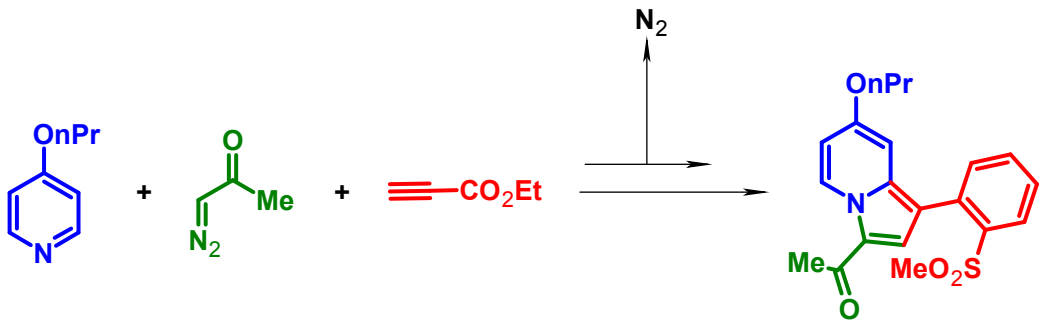
The use of CO_2 as a C1 building block in organic synthesis requires the employment of energy efficient processes, since CO_2 activation is a high-energy demanding transformation due to the stability of this molecule. This particular approach deals in the development of efficient transformations by magnetic heating catalytic systems based in magnetic ionic liquids (MIL). MILs with distinct magnetic properties are being synthesised and screened as catalysts for the formation of cyclic carbonates from epoxides and carbon dioxide.



Catalytic synthesis of N-heterocycles

Tim Douglas, Department of Chemical Engineering

Demand for sustainable manufacture of high value molecules continues. This research is developing new catalytic, multi-component reactions for efficient assembly of valuable, biologically active products from simple starting materials. These methods exploit the unique reactivity of diazo compounds and produce nitrogen as the only by-product, but these reagents are hazardous. The research is developing on-demand synthesis of diazo precursors from benign feedstocks in order to mitigate these risks. Development of these reactions for continuous manufacture in flow will facilitate up-scaling for commercial manufacture.



GSK2801
Bromodomain probe

Cohort Two student profiles

Jonathan Hunter

Background: MSci Medicinal and Biological Chemistry, University of Nottingham
Research area: Photochemistry in flow
Supervisor(s): Prof Sir Martyn Poliakoff, CBE, FRS and Prof Mike George

Following a completion of masters degree project, which focused on cobaloximes as water splitting catalysts, Jonathan worked as a research scientist for an SME based in Biocity, Nottingham - Haemostatix. Whilst in this position, he invented and developed new haemostatic agents for surgical and trauma wounds.

Jonathan is currently working on continuous flow photochemistry under the supervision of Prof Mike George and Prof Sir Martyn Poliakoff. The research aim is to develop methods for the manufacture of chemicals in a more environmentally benign way.

Meike Katharina Leu

Background: MSc Master of Science – Chemistry, Ruhr-Universitat Bochum-Germany
Research area: Magnetic nanoparticles based on Fe and use in catalysis
Supervisor(s): Prof Jairton Dupont and Prof Peter Licence

During the final year of her MSc, Meike worked on a project involving metal containing ionic liquids for gas absorption under the supervision of Prof Anja Verena Mudring and Prof Margarida Costa Gomes (Université Blaise Pascal, Clermont-Ferrand, France).

Meike's current project involves development of magnetic ionic liquids for catalysis, namely the development of iron-containing magnetic ionic liquids as catalysts for the use in a magnetically induced heating system.

Astrid Delorme

Background: MSci Chemistry with an International Study Year, University of Nottingham
Research area: 3-D printable polymers functionalised with ionic liquids
Supervisor(s): Prof Peter Licence, Dr Darren Walsh and Dr Victor Sans Sangorrin

During her masters degree project Astrid worked in Prof Peter Licence's group looking at ionic liquids with XPS using silver and aluminium sourced XPS. As a part of her course, she spent a year at the University of Melbourne.

Astrid is currently working with Prof Peter Licence, Dr Darren Walsh and Dr Victor Sans Sangorrin to develop sustainable systems for the oxidation of alcohols.

Sara Pérez Nieto

Background: MEng Chemical Engineering. University of Valladolid – Spain
Research area: Biomedical polymers; renewable source of trimethylene carbonate
Supervisor(s): Prof Steve Howdle

Sara completed her final masters degree project at the Technical University of Denmark, where she was working on the experimental analysis of solid and liquid split behaviour of promoted amines for CO_2 capture. After that, with an Erasmus internship she joined Prof Steve Howdle´s group at the University of Nottingham, where she started working on energy efficient polymerisations.

Sara's research interests include the development of more sustainable chemical processes and the use of green solvents. Sara is currently working in the synthesis of biodegradable polymers using supercritical CO_2.

Benjamin Shepherd

Background: MEng Chemical Engineering, University of Nottingham
Research area: Process engineering; scale up of microwave processing of biomass
Supervisor(s): Dr John Robinson and Dr Liam Ball

Having spent his third year between the University's two campuses in Nottingham and Malaysia, Benjamin spent his final year working under the supervision of Dr Ian Lowndes, designing the process components of a North Sea oil and gas platform and computationally modelling gas plume dispersion from the platform's flare stack, with a focus on measuring the effects on health and the environment, gas capture design and adhering to EU legislative bodies. This project raised his awareness of the need for sustainable process design and as such is the focus of his research.

Benjamin's research area is novel microwave processing, particularly the microwave pyrolysis of lignocellulosic biomass in solvents to produce fuels, sugars and high value chemicals.

Riccardo Di Sanza

Background: Laurea Specialistica Degree in Pharmaceutical Chemistry and Technology. Universita Degli Studi G. D'Annunzio, Italy
Research area: C-H activation reactions and mechanistic studies
Supervisor(s): Prof Hon Lam and Dr Liam Ball

Riccardo's final year project focused on the synthesis of natural alkaloids with dibrominated indolic framework. As a part of his degree in Pharmaceutical Chemistry, Riccardo spent one year as Erasmus student in Université de Reims Champagne-Ardenne, France where he undertook a research on the synthesis of potential antitumour drugs using Pd(0) catalysed reactions. He also spent a brief period at Haupt-Pharma in Italy as Quality Control Analyst and undertook a one-year research project at Imperial College London, working on the mechanistic studies of new asymmetric organocatalytic reactions.

Riccardo is currently working on the development of new sustainable C-H functionalisation methodologies using transition metal catalysts or electrochemistry.

José Jorge Pinto

Background: MSci Biotechnology, Faculdade de Ciencias e Technologia da Universidade Nova de Lisboa, Portugal
Research area: Farnesane as source of biofuels; selective hydrogenation. Industrial scale-up.
Supervisor(s): Prof Jairton Dupont and Dr Victor Sans Songorrin

Jose's masters degree dissertation was on development of an alternative route for the separation of menthol oils using biocatalysis and alternative solvents to create greener routes, under the supervision of Prof Susana Barreiros and Dr Alexandre Pavia.

Subsequently, he received a grant for a project on the production of molecularly imprinted polymers for the removal of genotoxic agents from active pharmaceutical ingredients, in a partnership between NOVA and Hovione.

Jose's research project involves working on production of a surrogate bio jet fuel based on terpenes that can be utilised in modern day aircraft. His project combines the utilisation of environmentally benign solvents, catalysis and engineering towards the creation of a sustainably acceptable process.

Teresa Ambrosio

Background: MSc Chemistry, La Sapienza, Italy
Research area: Biomimetic C-H activation (oxidation and halogenation)
Supervisor(s): Dr Liam Ball and Dr Christoph Loenarz

During the final year of her study Teresa worked under the supervision of Dr Stefano di Stefano and Prof Luigi Mandolini on the synthesis of novel catalysts, biologically inspired by the P450 enzyme, for the oxidation of hydrocarbons.

Teresa is currently developing novel and more sustainable methods for halogenation of unactivated C-H bonds with the ultimate objective of site-selective, late-stage halogenation of natural products and drugs.

Vlad Dinu

Background: MSc Applied Biomolecular Technology, University of Nottingham
Research area: Release of food volatiles; monitoring by mass spec; interaction of volatiles with proteins
Supervisor(s): Dr Ian Fisk, Prof Stephen Harding, Dr Garry Adams and Dr Nicole Yang

During his final research project and for his MSc placement project, Vlad worked under the supervision of Prof Stephen Harding at the National Centre of Macromolecular Hydrodynamics (NCMH) and gained experience in the field of biopolymer characterisation and modelling in aqueous solutions in scope of improving polysaccharide functionality in food and health applications.

Vlad's current work focuses on the use of natural polysaccharides as a route to maximise and extend the persistence of flavour compounds in food and health products. A large part of the work is carried out at the NCMH and is based around the study of mucin-biopolymer interactions.

Francesca Spagna

Background: Integrated Masters Pharmaceutical Chemistry and Technology, Universita degli Studi di Ferrara, Italy
Research area: Dehydrogenation of amines: Perspectives for protecting groups removal
Supervisor(s): Prof Chris Moody

During the final year of her masters course. Francesca worked under the supervision of Prof Vinicio Zanirato dealing with chiral auxiliaries. She spent a short period of time in industry and obtained a scholarship for a visiting researcher at the University of Portsmouth.

Francesca applied to the CDT as she had an interest in making organic synthesis more sustainable.

Francesca's interests in chemistry include development of new sustainable methodologies in catalysis and thermal dehydrogenation.

Daniel O'Connor

Background: MChem, University of Newcastle
Research area: Applying photoredox catalysis to carbocycle and heterocycle synthesis
Supervisor(s): Prof Rob Stockman

During his MChem course Daniel worked with Dr Michael Hall synthesising novel BODIPY dyes for application in biomedical imaging. His final project involved working on synthesising ionic functionalised polymers for application in catalysis. Daniel currently works with Prof Stockman looking at novel applications of photoredox chemistry and is currently investigating the applicability of chiral sulfur centres.

Alexander Kibler

Background: MSc Chemistry, University of Nottingham,
Research area: Polyoxometalate-ionic liquid systems as photocatalysts for artificial photosynthesis
Supervisor(s): Dr Graham Newton and Prof Jairton Dupont

Alexander has a keen interest in inorganic chemistry, especially the synthesis and behaviour of unusual transition metal complexes. During his masters degree project, he worked under the supervision of Dr Jon McMaster on the synthesis of structural analogues of the enzyme Ni-Fe hydrogenase.

Currently, Alexander is working with on the development of a system for artificial photosynthesis through the pairing of polyoxometalates with ionic liquids.

Christopher Peel

Background: MSci Chemistry, University of Nottingham
Research area: Developing methodology for transaminase catalysed cyclisations
Supervisor(s): Dr Elaine O'Reilly

Owing to his interest in organic chemistry and its biological applications, Christopher completed his final year working with Dr James Dowden on the development of selective inhibitors of protein arginine methyltransferases (PRMTs).

Christopher is currently working in the group of Dr Elaine O'Reilly on the development and application of transaminases for installing chiral amines into cheap biorenewable starting materials. Prior to his chemical career Chris has had experience in the electrical industry and pharmacy.

Jennifer Wakefield

Background: MSc in Biomedical and Forensic Studies in Egyptology, University of Manchester/ MSc in Drug Discovery and Development, University of Aberdeen
Research area: Conservation of Alum Treated Wooden Artefacts
Supervisor(s): Prof Stephen Harding, Dr Ian Fisk and Dr Garry Adams

Jennifer graduated from The University of Aberdeen in July 2011 with a BSc in Chemistry. During her summer holidays Jennifer attended various archaeological excavations in Bulgaria and Italy which included a restoration course. She then went on to complete an MSc in biomedical and forensic studies in Egyptology at The University of Manchester in 2012 reinforcing her interests in archaeology and conservation. Following this she obtained another MSc in drug discovery and development from The University of Aberdeen in 2014 (funded by the Scottish Government). Her interest lies in origins of life, natural product drug discovery, historical medicine, archaeological science and archaeological conservation.

Her current project is developing a consolidant from natural polymers that could be used to conserve wooden Viking artefacts in Oslo. It involves three parts: 1. AUC analysis of the polymer to determine molecular weight and interaction with lignin in the wood, 2. Chemical modification of polymers, and 3. Analysis of consolidation efficacy using techniques such as SEM, IR microscopy, pressure tests and humidity tests.

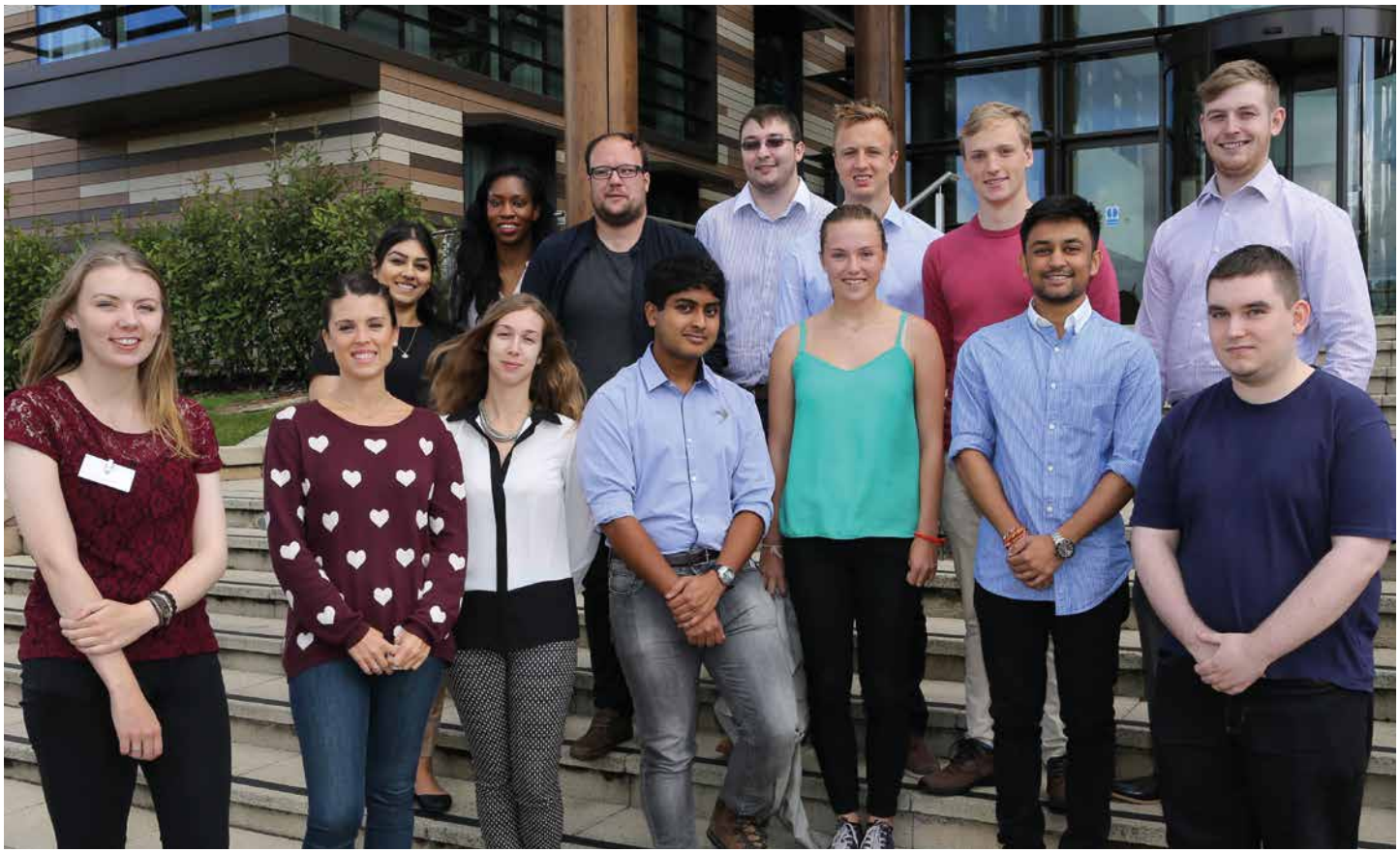
Industrial Partners

A number of industrial partners have already made significant contributions to the Centre by part-funding scholarships, attending our Induction or Industrial Showcase, hosting student visits or participating in Industrial Challenge workshops.

We are extremely grateful to the following companies for their valuable contribution to our CDT:

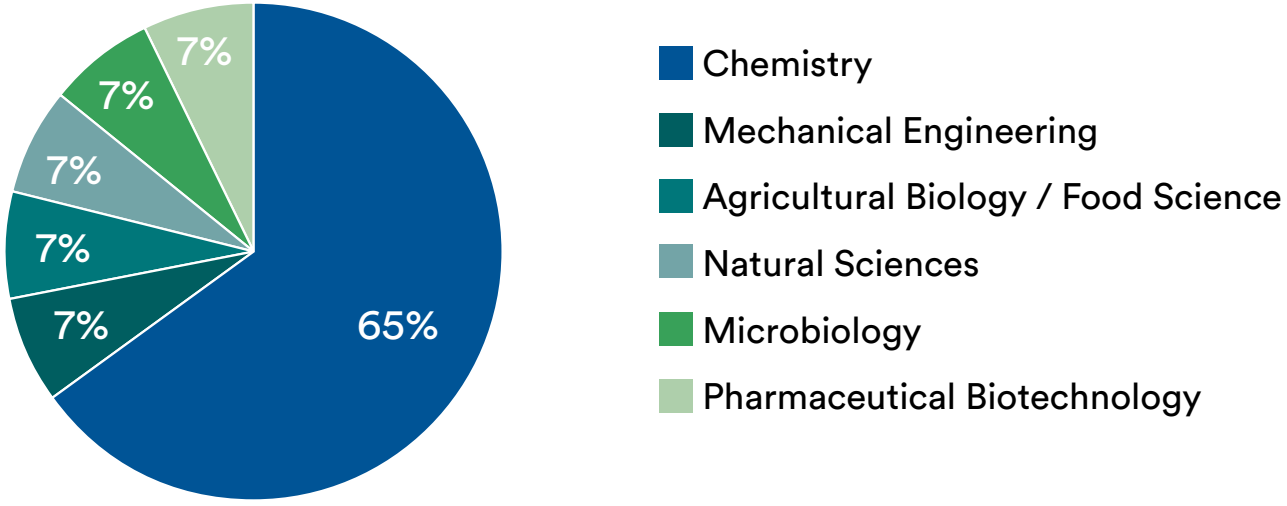
- Astra Zeneca
- Bruker
- Buhler
- Croda
- FCC Environment
- GlaxoSmithKline
- Lubrizol
- PepsiCo
- Sygnature Discovery
- Synthomer
- UCB Celltech
- Unilever

Welcome to Cohort Three



Back row from left to right: Neelam Mughal, Jennifer Okoye, Jack Jordan, Thomas Barber, Rhydian Beddoe, Patrick Morgan, John Ryan; **Front row from left to right**: Sarah Farthing, Lidia Delgado, Vera Salgado, Nafees Mujtaba, Rhona Savin, Sharad Amin and Samuel James Howe Gaughan.

Cohort Three educational background



Student case study: Laura Finney

Having completed my undergraduate masters degree at the University of Nottingham, I joined the CDT as a member of its first cohort in 2014. My vision of a PhD journey involved not just working on a research project but having ownership of the project while also developing additional professional skills - so the CDT programme was a natural route.

Opportunity to develop my own research project

Being able to develop my own project idea was something that was important when I chose my PhD and the support I have received has been excellent. The process of the development of my research proposal, from the literature review, developing ideas to writing and formally presenting the proposal was both challenging and rewarding and giving me the opportunity to further develop my critical analysis and problem solving skills.

Project presentation at the Dragons' Den event was a particular challenge. It required careful consideration of how a multidisciplinary audience would receive the information about my project, thinking of potential issues which might arise from the project and possible solutions as well as preparation for questions by a panel of multidisciplinary audience at the project presentation.

Developing my own project and presenting it to an expert audience at such an early stage of my doctoral studies helped me develop a confidence in my ability to reflect and evaluate my own work. I also had the opportunity to act as a panel member myself, ask questions and provide a constructive feedback for presentations by Cohorts 2 and 3 students.

Transferrable skills development

The CDT in Sustainable Chemistry has given me the opportunity to develop a whole range of other professional skills too. I have had the opportunity to help organise a student led event on Connecting Sustainability and Science Policy, chair the 'Towards Sustainable Future Symposium' involving prominent international speakers, present my work orally and by poster in CDT events such as Dragons' Den Event and Industrial Showcase. In addition, I have taken advantage of extensive CDT training which included training courses and workshops science communication, interview techniques and publishing.

Outreach activities

Outreach is a focus of the CDT and I have been able to work alongside other CDT colleagues to design and implement an A level master class. This has meant that I have been able to experience the entire process from experiment design and the research that must go into this type of event, all the way through to leading the delivery of these master classes and receiving feedback from the students. I also managed to put some of these skills to the test in the I'm a Scientist Get Me Out of Here scheme, where I was voted as a winner for the Catalyst category and was awarded a prize of £500 for further outreach projects.

Internship

I have been encouraged and supported to complete a science journalism placement at The Conversation, a non-partisan news organisation that commissions articles from academics and researchers. I have worked as part of the science, health and environment desks to communicate news and research, from academics, to the general public.

This experience has given me a good insight into the world of journalism and the editorial process. I gained valuable hands on experience in editing, developing article ideas, commissioning and seeing the completed articles through the process of publication. In addition, whilst at The Conversation, I wrote and published two articles.

Overall, it has been a great two and a half years so far, filled with many opportunities and invaluable experiences. I am excited to see what the next academic year will bring.

What our students say about us

We asked our students to tell us about their CDT experience so far:

Jonathan Hunter, Cohort Two student

What have you particularly enjoyed about studying at the CDT?

Studying with the CDT has many positive aspects. The one I enjoy the most is meeting interesting people through industrial engagements like the industrial showcase and afternoon challenges. This has opened my eyes to areas that I would not have I encountered otherwise.

Do you feel you have benefitted from being a part of a cohort of students, if so how?

Being in a cohort is extremely useful. You have a group of like-minded people around you who are going through the same events, doing the same activities and meeting the same deadlines, which is an excellent morale booster. Additionally, it gives you access to other areas of expertise, so you can usually find someone who can help in areas which you are less comfortable with.

What attracted you to applying for the CDT programme versus the 'traditional' PhD route?

I decided to apply to the CDT following a year spent working at a local SME. Whilst there I decided to complete a PhD but I wanted it to be industrially focused. The CDT was exactly what I needed as it has that focus but also allows you to develop your own ideas and project.

What advice would you give to a prospective postgraduate student interested in applying to the CDT in Sustainable Chemistry?

The first year is not easy but you get an array of excellent opportunities. Beyond the main events related to the research project development such as writing your literature review, presenting your proposal at the Dragons' Den event and working on a pilot project, you can access other training and outreach activities and conferences. If you're a hard worker and enjoy a challenge then the CDT is for you.

Riccardo Di Sanza, Cohort Two student

What have you particularly enjoyed about studying at the CDT?

Compared to a traditional PhD, we have freedom to choose and carry out our own projects and this is the thing I enjoyed the most. Freedom is really rare to find in a PhD and it can be really scary at the outset, but looking back I feel really proud of how this process has made me grow and develop my own ideas.

Do you feel you have benefitted from being a part of a cohort of students, if so how?

Being part of a cohort of students coming from different backgrounds is, without any doubt, beneficial. As an organic chemist, I have the opportunity to have regular discussions with people from engineering, biological and inorganic backgrounds who have a different point of view. This has helped to widen my awareness of sustainability and improve the development of my ideas.

What attracted you to applying for the CDT programme versus the 'traditional' PhD route?

Four years for a PhD might seem like a long time, but once you have started the course, the time goes very quickly and you need to make the most of it. For this reason I think that the intensive training prior to the lab-work could make me progress faster and, potentially, make a lot more out of my PhD.

What advice would you give to a prospective postgraduate student interested in applying to the CDT in Sustainable Chemistry?

My advice would be to choose the PhD topic they like the most. There will be tough times during the PhD, but if you choose what you like, those difficulties can be overcome fairly easily and, in my opinion, there is nothing more enjoyable than carrying out a project that you developed from your own idea.

Astrid Delorme, Cohort Two student

What have you particularly enjoyed about studying at the CDT?

I have enjoyed the diversity of the workshops, challenges and lectures that are offered by the CDT. This has allowed me to see how sustainability is treated from different perspectives, e.g. from a business, chemistry and engineering perspective.

Do you feel you have benefited from being a part of Cohort of students, if so how?

The projects in our cohort are very different from each other, which I think makes the discussions we have very useful. In our research update meetings, for example, we get questions from food scientists, engineers, biologists and chemists which I think is rewarding in a way to get new ideas and input to our research.

What attracted you to the applying to the CDT programme versus the 'traditional' PhD route?

What attracted me the most about the CDT programme was the additional training that is offered and in particular that the focus is on sustainability. The CDT programme would give me a set of skills that I wanted that I think would be hard to obtain by going the traditional PhD route.

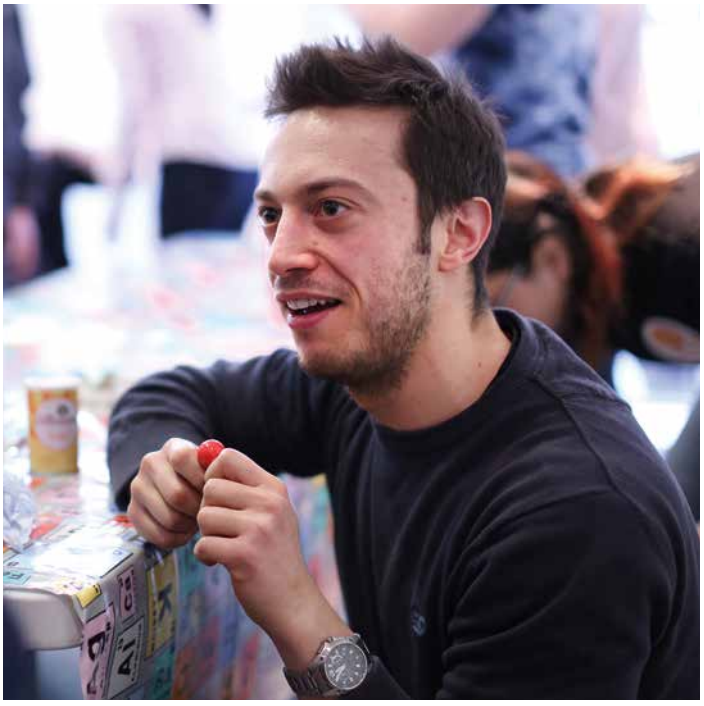
What advice would you give to a prospective postgraduate student interested in applying to the CDT in Sustainable Chemistry?

To do the CDT in Sustainable Chemistry programme you need to be passionate about sustainability, and you need to make sure to show it.

Outreach Highlights

The CDT programme is set to deliver training and development opportunities in a number of areas and these include public engagement.

CDT students have participated in over 30 outreach events aimed at different audiences including attendance of science festivals (Festival of Science and Curiosity, Big Bang Fair, Science in the Park, Gravity Field Festival), talks (PubHd, Chemistry Summer School), online initiatives (I am a scientist get me out of Here) and practical demonstrations (Green Chemistry Masterclass, University Open Day).



Festival of Science and Curiosity 15-18 February 2016

The Centre was represented at the Festival of Science and Curiosity, which took place in Nottingham in February 2016 in various popular city locations. During the event, the students engaged with members of the general public, mainly school age children, through a series of practical chemical demonstrations and discussions.

Green Chemistry Master Class 2 & 9 March 2016

The second year CDT students engaged in the development and delivery of a Green Chemistry master class; a two-day event involving an extensive period of planning and preparation.

This activity was aimed at year 12 students and those taking part were primarily from a 'first in the family to attend university' background. The scope of event was to introduce the 25 participating year 12 students to scientific topics outside the remit of A level course(s) they were studying at the time. In addition to the introduction to 12 Principles of Green Chemistry, the masterclass also covered areas such as awareness of challenges facing modern chemical synthesis, improved practical skills to carry out experiments safely and reliably and appreciation of the diversity of chemical sciences.

The impact of this event has been twofold, the activities represented an encouraging new experience for the participating year 12 students who as result provided outstandingly positive feedback; and the CDT students had an opportunity to further develop a range of transferable skills such as team work, public engagement, time management, experiment demonstration, communication and event planning. In addition the activity has led to the development of a valuable and high quality resource that can be refined further (and delivered yearly) by future cohorts of CDT students.

The comments received by the participating year 12 students included the following:

"I really enjoyed the practical (activity) and the hands-on experiments helped me increase my understanding of chemistry at university", "(the event) provided a good insight and I really enjoyed the independent work", and "it was great!"

I am a Scientist Get Me Out of Here September 2016

Laura Finney (Cohort 1) and Jonathan Hunter (Cohort 2) participated in 'I am a Scientist Get Me Out of Here', a free online event where school students meet and interact with the scientists. The students interact with scientists by challenging them through a fast-paced text-based live conversation and then select their favourite scientists. Both Laura and Jonathan were voted the best scientist in their respective areas, catalysis and antibiotics, and each won a £500 prize to use for future outreach endeavours.

Events Highlights

Green and Sustainable Chemistry Workshop 9-10 February 2016, Breadsall Priory Hotel, Derby

As part of an initiative to increase engagement with other UK based Chemistry themed Centres for Doctoral Training the Centre hosted its first joint workshop that took place in February 2016 at Breadsall Priory Hotel in Derby.

This two-day EPSRC supported workshop brought together a group of 35 CDT students from CDT in Sustainable Chemistry (Nottingham), Centre in Sustainable Technologies (Bath), CDT in Catalysis (Cardiff) and CDT in Chemical Synthesis (Bristol). The event featured talks from a number of University of Nottingham and international speakers including: Prof Paul Anastas (Yale University), Prof Sir Martyn Poliakoff (University of Nottingham), Prof Chris Moody (University of Nottingham), Prof CJ Li (McGill University), Dr Andy Marr (Queen's University Belfast), Prof Jairton Dupont (University of Nottingham) and Prof Walter Leitner (RWTH Aachen University) and provided both the academics and students with plenty of opportunity for discussion and networking.

Industrial Showcase 28 September 2016

EPSRC CDT in Sustainable Chemistry held its first Industrial Showcase in September 2016. The event, which presented an excellent opportunity for CDT students to showcase their research, attracted an audience of 80 industrial partners, academics and students. The delegates had the opportunity to hear 10 talks by second year students and view 14 posters presented by first year students. The event was attended by a number of industry representatives including GSK, Croda, Synthomer, AstraZeneca, Bruker, Endeavour Chemicals, Nuplex Resins and Lubrizol.

CDT publications

Progress in the synthesis of sustainable polymers from terpenes and terpenoids, M. R. Thomsett, T. E. Storr, O.R. Monaghan, R. A. Stockman, S. M. Howdle, *Green Materials*, 2016, 4, 115-134.

(Awarded the Green Materials Prize – Journal Prize for best paper in journal)

Redox-active organic–inorganic hybrid polyoxometalate micelles, K. Kastner, A. J. Kibler, E. Karjalainen, J. A. Fernandes, V. Sans Sangorrin and G. N. Newton, *Journal of Material Chemistry A*, 2017, 5, 11577-11581.

Five of the most explosive non-nuclear chemicals ever made, L. Finney, *The Conversation*, February 2017.

Why that 'clean swimming pool' smell is actually bad for your health, S. Cotton and L. Finney, *The Conversation*, March 2017

Hydrodynamics of the VanA-type VanS histidine kinase: an extended solution conformation and first evidence for interactions with vancomycin, M.K. Phillips-Jones, G. Channell, C. J. Kelsall, C.S. Hughes, A. E. Ashcroft, S.G. Patching, V. Dinu, R. B. Gillis, G.G. Adams and S. E. Harding, *Nature, Scientific Reports 7*, 46180. (DOI: 10.1038/srep46180)

Enantioselective Nickel-Catalyzed Intramolecular Allylic Alkenylations Enabled by Reversible Alkenylnickel E/Z Isomerization, C. Yap, G.M. J. Lenagh-Snow, S.N. Karad, W. Lewis, L. J. Diorazio, and H.W. Lam, *Angewandte Chemie*, May, 2017. (DOI: 10.1002/anie.201703380)

Management Structure

Senior Management Team

CDT Director – Prof Chris Moody, School of Chemistry

CDT Co-Director – Prof Peter Licence, School of Chemistry

CDT Manager – Ms Perislava Williams

Representative from Biosciences – Dr Ian Fisk, School of Biosciences

Representative from Engineering – Dr Victor Sans Sangorrin, Faculty of Engineering

Management Board

Chair - Prof Sir Martyn Poliakoff, CBE, FRS, School of Chemistry

Deputy Chair - Prof Steve Howdle, School of Chemistry

Representative from Engineering - Prof Sam Kingman, Faculty of Engineering

Representative from Chemistry - Prof Chris Hayes, School of Chemistry

Representative from Chemistry - Prof Neil Champness, School of Chemistry

Representative from Chemistry - Dr Nick Bennett, School of Chemistry, Business Partnership Unit

Representative from Food Science - Prof Tim Foster, School of Biosciences

Representative from Business School- Prof Simon Mosey, Business School

Representative from Social Sciences - Dr Sujatha Raman, School of Sociology and Social Policy

Representative from UoN CDTs - Prof Sarah Sharples, Horizon CDT

Representative from Industry - Dr Paul Pudney, Science Leader, Unilever

Representative from Industry - Prof John Leonard, Director, Cadence Pharma Consultants

Representatives of the PhD cohort, elected from Postgraduate Forum - Laura Finney, Daniel O'Connor, Sharad Amin

CDT Director - Prof Chris Moody, School of Chemistry

CDT Co-director - Prof Peter Licence, School of Chemistry

CDT Manager - Ms Peri Williams

Strategic Advisory Board

Representative from an EPSRC funded CDT (Chair) - Prof Kevin Booker Milburn, Director of Chemical Synthesis CDT, University of Bristol

Representative from an EPSRC funded CDT - Prof Matthew Davidson, Director of Sustainable Chemical Technologies CDT, University of Bath

Representative from Industry- Dr Helen F. Sneddon, Head of the Green Chemistry Performance Unit, GlaxoSmithKline

Representative from Industry- Dr Paul Pudney, Science Leader, Unilever

Representative from Industry - Dr Damien Kelly, Head of Global Research and Development, Croda International

Representative from Industry- Dr Simon Hirst, CEO, Sygnature Discovery

Representative from Industry-Prof John Leonard, Director, Cadence Pharma Consultants

Representative from Industry - Dr Jonathan Moseley, Research Director, CatSci

Representative from EPSRC - Dr Eleanor Jaskowska, Physical Sciences Portfolio Manager, EPSRC

Ex officio, Associate Pro-Vice Chancellor for the Graduate School and Research Career Development – Prof Ed Wilding, Faculty of Science

Ex officio, School of Chemistry - Prof Sir Martyn Poliakoff, CBE, FRS, School of Chemistry

Ex officio, School of Chemistry- Prof Steve Howdle, School of Chemistry

Ex officio, CDT Director - Prof Chris Moody, CDT

Ex officio, CDT Co-director - Prof Pete Licence, CDT

Ex officio, CDT Manager - Ms Peri Williams, CDT

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