Centre for Sustainable Chemical Technologies

UNIVERSITY OF BATH

Centre for **Sustainable** Chemical Technologies

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WELCOME

When we opened the doors of the Centre for Sustainable Chemical Technologies in 2008, we immediately got to work assembling a range of people, equipment and research projects to address the major global challenge of sustainable development. Our mission is to advance research in the field of sustainable chemical technologies by bringing together expertise of multidisciplinary scientists and engineers. We do this by developing new molecules, materials and processes for sustainability, structured around four main themes: Energy and Water, Renewable Feedstocks and Biotechnology, Processes and Manufacturing, and Healthcare Technologies.

We bring together academic expertise in collaboration with a network of industrial partners to carry out research, training and outreach in sustainable chemical technologies. We attract the best PhD candidates from across the country and around the world to join our EPSRC Centre for Doctoral Training. Our excellent track record of graduated students demonstrates their continued commitment and application of new technologies in industry and academia.

The Centre has rapidly become an important hub for sustainability in the UK. In the coming years, as we grow, we will continue to advance our knowledge in this field and develop our model in which creative researchers can approach major problems in a nurturing, intellectually challenging and productive environment. I hope this brochure gives you a flavour of some of our activities and culture and I encourage you to take advantage of the many opportunities and resources we have available for joint research projects, collaborations and training.

Professor Matthew Davidson
Director
M.G.Davidson@bath.ac.uk

Centre for **Sustainable**
Chemical Technologies

ABOUT US

Scientists and engineers **working together with industry** for a sustainable future

The Centre for Sustainable Chemical Technologies (CSCT) is a unique, multidisciplinary university research Centre with a strong record of training and graduating PhD students. We develop new molecules, materials, processes and systems from the lab right through to industrial application, with an emphasis on practical sustainability. Our scientists and engineers work together with industry to meet the needs of current and future generations.

We are funded by the British Government (Engineering & Physical Sciences Research Council) as a Centre for Doctoral Training, which has enabled us to develop a full programme of training and development opportunities not usually available to PhD candidates. Our students are graduates of science and engineering disciplines (Biology & Biochemistry, Chemistry, Chemical Engineering, Electrical Engineering, Mathematics, Mechanical Engineering, Pharmacy & Pharmacology and Physics) with a strong interest in sustainable technologies.

Funded by

EPSRC

Established

2008

07
International Partners

23
Industrial Partners

110
Academics Involved

132
PhD students

"The CSCT is an internationally recognised Centre of excellence in both research and training, providing students with a vibrant and supportive interdisciplinary research environment."

Professor Tim Mays, Co-Director

Our Management Team (From left to right):

Co-Director, Professor Tim Mays - T.J.Mays@bath.ac.uk

Training Director, Professor Janet Scott - J.L.Scott@bath.ac.uk

Centre Manager, Francesca Guiso Gallisai - F.Guiso.Gallisai@bath.ac.uk

Centre for **Sustainable**
Chemical Technologies

OUR RESEARCH

With leading academic research groups in many relevant areas, and state-of-the-art facilities, we carry out research that crosses traditional boundaries between chemical science and engineering. All our research projects are multidisciplinary in nature, to deliver new and sustainable chemical technologies for the future.

Energy and water
Solar cells, Fuel cells & batteries, Sustainable water supply, Water cycle & human health

Renewable Feedstocks & Biotechnology
Biofuels, Biopolymers, CO_2 utilisation, Platform chemicals

Processes & Manufacturing
Reaction engineering, Sustainable integrated processes, Process intensification, Flow chemistry

Healthcare Technologies
Synthetic methodology for pharmaceuticals, Rapid sensing in hospital environments, Infection detection, Diagnostic nanomedicines

CASE STUDY

Biodegradable materials from renewable resources

We are combining a knowledge of materials processing using ionic liquids, production of nanoparticles and derivatization of particle surfaces with the use of renewable non-food biopolymers, such as plant cellulose (the most readily renewed biopolymer), to produce more sustainable rheology modifiers, emulsion stabilisers, microbeads and other formulation ingredients. Exploration of the fundamental mechanisms of dissolution, the development of structure and particle interactions allows us to understand the materials and so refine these for specific applications.

This has led to development of materials with various industrial partners on topics as diverse as recovery of precious metals from industrial waste streams to production of "natural" and biodegradable ingredients for fast moving consumer goods – collaborative research projects funded by Innovate UK and the EPSRC in the Manufacturing the Future and IB Catalyst programmes.

Partners

PhosphonicS · Micropore · Unilever · CRODA · VEOLIA

CSCT students involved

- James Courtenay, cohort 2014
- James Coombs OBrien, cohort 2013
- Remigius Wirawan, cohort 2012
- Duygu Celebi, cohort 2010

Key research papers

Soft Matter, **2018**, 14, 255
Phys. Chem. Chem. Phys., **2017**, 19, 17805
ACS Sustainable Chem. & Eng., **2017**, 5, 5931
ACS Sustainable Chem. & Eng., **2016**, 4, 6200
Int. J. Pharm., **2016**, 514, 238
Green Chem., **2014**, 16, 3322
Green Chem., **2012**, 14, 300
Chem. Commun., **2011**, 47, 2970

"Public concern about plastic microbead pollution has led to bans, but many other materials used in 'washaway', or single use, products are not sustainable either. Developing manufacturing processes and products together and underpinning this with a deep understanding of the science leads to new ingredients that our industrial partners are keen to exploit commercially."

Professor Janet Scott

New biodegradable microbeads made from materials naturally found in plants, algae, and shellfish will replace polluting plastic particles found in cosmetics.

"Research into perovskite solar cells is at a very exciting stage, the technology was unheard of six years ago and is now showing solar conversion efficiencies that rival silicon photovoltaics."

Dr Petra Cameron

The projects span a wide area from the synthesis of new materials, advanced materials characterisation, to the preparation and testing of complete solar cells.

Partners

specific® | CATALYSIS CONSULTING

CSCT students involved

- Robert Baker, cohort 2016
- Bethan Charles, cohort 2015
- Isabella Poli, cohort 2015
- Dominic Ferdani, cohort 2014
- Oliver Weber, cohort 2013
- Adam Pockett, cohort 2013

Key research papers

J. Mat. Chem. A, **2017**, 5, 42
J. Mat. Chem. A, **2017**, 5, 43
J. Mat. Chem. C, **2017**, 5, 452
J. Phys. Chem. C, **2015**, 119, 3456
J. Power Sources, **2015**, 297, 504
Ceram. Int., **2016**, 42 (10), 11989

CASE STUDY

Halide perovskite solar cells as next-generation photovoltaics

Organic-inorganic lead halide perovskite solar cells are the newest type of third generation photovoltaics. Recent years have seen remarkable developments in halide perovskite materials which are easy to prepare and have some remarkable optoelectronic properties. These properties, combined with simple and low-cost fabrication routes, have led to a very rapid growth in power conversion efficiencies. However, to use perovskite solar cells in the real world several problems still need to be overcome. The solar cells need to be moisture, oxygen and heat stable – which can be challenging due to the 'soft' nature of many perovskite materials. Ideally the cells need to be lead free, to be prepared using green solvents and easily deposited on cheap and flexible substrates.

Experimental groups within the CSCT are working on understanding the degradation of thin film perovskites in atmospheric conditions and finding promising strategies to improve the moisture and water resistivity of the device. Through the collaboration of chemists, physicists and engineers, we combine experiment with modelling to design new materials and device architectures to make this technology commercially viable.

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CASE STUDY

Sustainable materials for regenerative medicine

Our interdisciplinary research has developed new, sustainable materials for regenerative medicine, which allow mammalian cells to grow and thrive, as opposed to synthetic materials. For example, researchers from Chemistry and Chemical Engineering found multiple ways to modify cellulose, the most abundant and sustainable biopolymer, to promote cell attachment and spreading, without the use of animal derived proteins.

Research in our labs has also identified formulations and forms of materials, which allows us to investigate different applications, pathological states, and phenomena. We recently made a blend with chitosan that requires no further modification for cell culture. Using inkjet printing, we can introduce precise modifications to define regions for cells to attach, spread, and function.

Partners

LNNano · USP · University at Buffalo

CSCT students involved

- James Courtenay, cohort 2014
- Marcus Johns, cohort 2012

Key research papers

ACS Omega, **2018**, 3 (1), 937
Cellulose, **2018**, 25, 925
J. Mater. Chem. B, **2017**, 5, 3879
Cellulose, **2017**, 24, 253

"These materials have the potential to be developed for both clinical applications as well as biomedical engineering technologies."
Dr Ram Sharma

We are developing the next generation of biomaterials that are sustainable and do not require the use of animal derived proteins to support cells. An interdisciplinary approach has been used to develop these materials that will streamline the manufacturing process.

Centre for **Sustainable** Chemical Technologies

ABOUT THE CDT

The Centre for Doctoral Training (CDT) in Sustainable Chemical Technologies brings together a thriving community of over 60 PhD students who conduct high quality, challenging, truly interdisciplinary research directed jointly by academic staff from across the University of Bath in collaboration with our international and industrial partners.

Why study with us?

- Practical & relevant research
- Interdisciplinary research
- Industrial and international collaboration
- Flexible project choice
- Supportive peer group
- Broad technical and transferable skills training
- Intellectually challenging and positive environment
- Full and part studentship funding available
- Additional internship and travel funding available
- Support for international students

How to Apply

Online application system:
www.csct.ac.uk/study-with-us

Interviews start from November each year. Applications are always open but competitive.

"What attracted me to join the CDT was the opportunity to work on an interdisciplinary PhD project with a clear focus on industrial impact and the chance to undertake a three month placement to further develop my skills."

Dominic Ferdani, cohort 2014

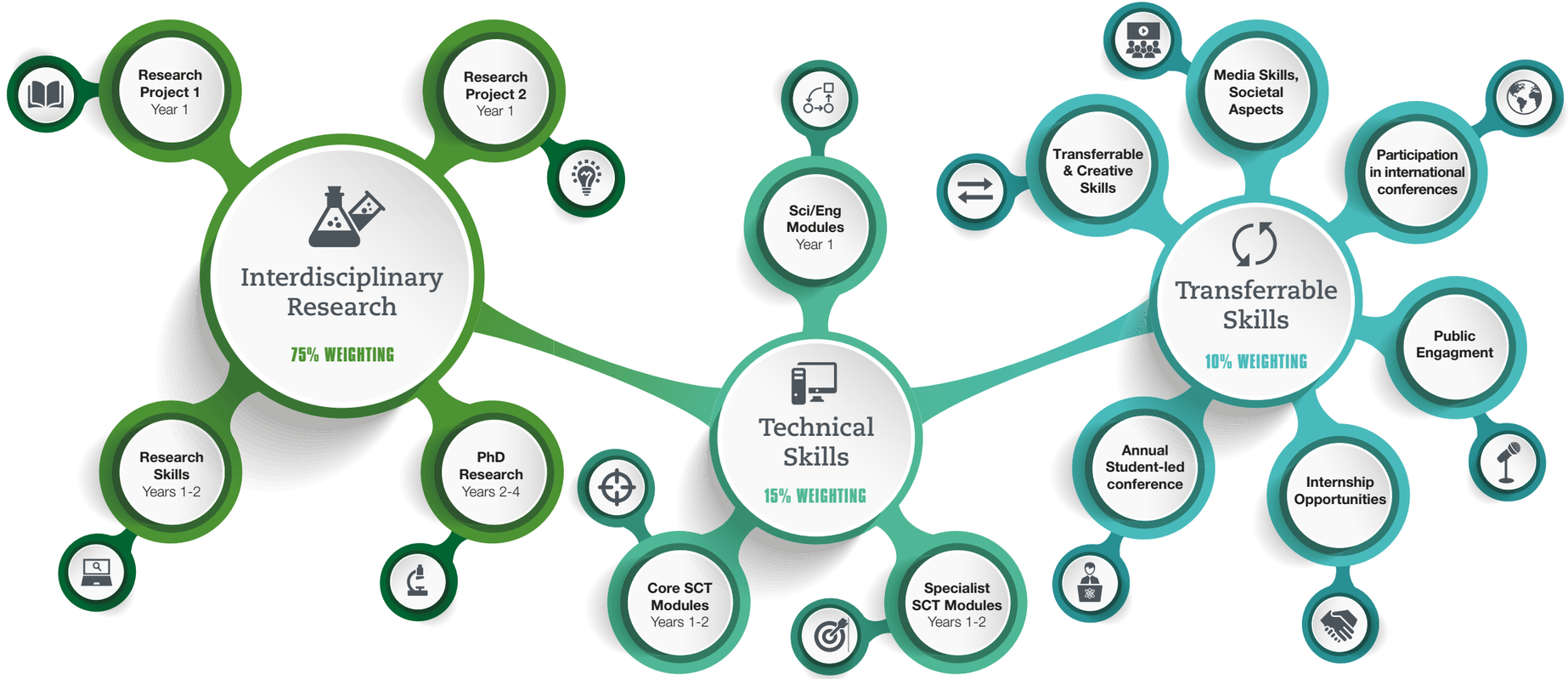
Centre for **Sustainable** Chemical Technologies

THE STRUCTURE OF OUR PROGRAMME

The four-year Integrated PhD in Sustainable Chemical Technologies comprises two small research projects, technical training and transferable skills training in year one, followed by a main PhD project and advanced training courses in years two to four.

All students in the Centre receive foundation training to supplement their undergraduate knowledge, as well as training in sustainable chemical technologies and transferable skills.

"It's more than just a PhD."
Emma Sackville, cohort 2013



Centre for **Sustainable** Chemical Technologies

OUR PROGRAMME IN NUMBERS

Applications to join CSCT

141 / 163
Offers accepted

163 / 788
Offers made/Applications

Gender balance

45.3 / 54.7%

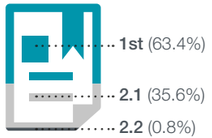
Applications from all over the world

53.8%
Home

32.2%
Rest of World

13.9%
EU

Degree classification



Applications by subject studied for degree

51.5%
Chemistry

21.4%
Chem Eng

13.1%
Other

9.3%
Medicine/Bio

2.7%
Physics/Maths

2%
Natural Science

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Citations & Publications

214
Publications

8,220
Scopus views

2,532
Citations

39%
Publications in Top 10 most cited worldwide

70%
Publications in Top 10 Journals in their subject area (CiteScore)

34%
Publications are international collaborations

Grants

£42.7M
funding awarded

Awards

36
Poster prizes at conferences

15
National Public Engagement Awards

Graduates leaving to pursue careers in

52%
Industry

31%
Academia

15%
Research Management

2%
Teaching

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WHORROD FELLOWS

Our Whorrod Research Fellowships were made possible by a £1m donation from entrepreneur and University of Bath graduate Roger Whorrod and his wife Sue Whorrod.

Roger Whorrod

"Sue and I were delighted to invest in early career researchers to develop their research ideas into strong programmes, particularly with the emphasis on sustainable development. We are very pleased that the fellowships have been and continue to be a complete success producing work of the highest standard."

Professor Aron Walsh

"The Whorrod fellowship helped to launch my independent research career. During my time at the CSCT, my group expanded to 15 researchers and we tackled some of the most challenging issues in the development of new materials for energy generation and storage."

Dr Marta Coma

"My research falls in the area of environmental biotechnology, specifically in the treatment and valorisation of waste streams to produce renewable (sustainable) chemicals. The multidisciplinary nature of the CSCT provided an integrated approach for my work."

Dr Antoine Buchard

"Having worked both in academia and in industry, the CSCT was the natural place for me to start my independent research career. Our research group investigates the synthesis of novel degradable plastics from renewable resources such as carbon dioxide and sugars from biomass or foodwaste."

Dr Chris Chuck

"Working for the CSCT has given me the opportunity, industrial links and resources to develop truly sustainable technologies to reduce our impact on the environment. For example we have developed a yeast substitute for palm oil, that we are now taking to the industrial pilot scale."

Dr Ulrich Hintermair

"The CSCT provides the perfect environment for our work which deals with applied homogeneous catalysis for sustainable manufacturing and renewable energy conversion. The Centre produces highly skilled students performing world-class research, and the strong industrial links provide pathways for immediate real-world impact of our work."

Centre for **Sustainable** Chemical Technologies

CASE STUDY

Plastic from waste, sugars and CO_2

We are developing new, sustainable catalysts, processes and renewable building blocks for polymers such as polyesters (including PET, polylactide, poly (ethylene) furanoate, PEF), polyurethanes (PU) and polycarbonates (PC) which are used as commodity plastics and for high value biomedical applications.

We have, for example, developed a synthesis of cyclic carbonate monomers that replaces the use of toxic phosgene derivatives by carbon dioxide at low pressures and ambient temperature, and makes the process a lot safer. The conversion of CO_2 to valuable products also works towards reducing atmospheric greenhouse gas emissions.

We have used this methodology to produce a series of new monomers made from natural sugars (but which do not come from edible crops), for the synthesis of BPA-free polycarbonates. These renewable plastics are transparent and particularly resistant to heat, and they can be degraded back into carbon dioxide and sugars when needed by the action of enzymes, which makes them promising sustainable alternatives to petrochemical materials.

In collaboration with industrial partners, we are currently investigating their use for biodegradable packaging. Between Chemistry and Chemical Engineering teams, we are also exploring their potential for regenerative medicine applications.

Partner

Corbion purac

CSCT students involved

- Bethan Charles, cohort 2015
- Strachan McCormick, cohort 2015
- Georgina Gregory, cohort 2012

Key research papers

Polym. Chem., **2018**, 8, 2093
Polym. Chem., **2018**, 9, 1577
Chem. Commun., **2017**,53, 2198
Polym. Chem., **2017**, 8, 1714
Polym. Chem., **2017**, 8, 2093
Macromolecules, **2016**, 49, 7165
RSC Advances, **2015**, 5, 39404

"With an ever-growing population, there is an increasing demand for plastics. Sugars are the main building blocks of nature: their abundance, diversity and biocompatibility are ideal for the development of a new generation of sustainable, renewable plastics, that would be price and performance competitive with traditional petrochemical materials. And because they are biodegradable, they will not contribute to growing ocean and landfill waste."

Dr Antoine Buchard

In this project, we use the latest development in catalysis and synthetic chemistry to transform sugars, nature's building block, into renewable and degradable alternatives to petrochemical materials.

"The collaborative project brings together chemists, engineers and biologists, the combination of disciplines leading to real breakthroughs in the area."

Dr Matthew Jones

We are exploiting the use of bacteria for the production of terpenes, present in citrus, turpentine and pine oils to replace crude oil in plastics.

Centre for **Sustainable** Chemical Technologies

Partners

Isobionics

artis

CSCT students involved

- Martyn Bennett, cohort 2016
- Stefanie Federle, cohort 2016
- Josh Tibbetts, cohort 2015
- Richard Maltby, cohort 2014
- Kasia Smug, cohort 2014
- William Cunningham, cohort 2013
- Helena Quilter, cohort 2013

Key research papers

Polym. Chem., **2017**, 8, 833
Faraday Discuss., **2017**, 202, 483
FEBS J., **2017**, 284, 1700

CASE STUDY

How peel could replace crude oil in plastics

The movement away from fossil-based raw materials is a key 21st century challenge. Terpenes, present in citrus, turpentine and pine oils, are an abundant and underutilised class of hydrocarbon based natural products.

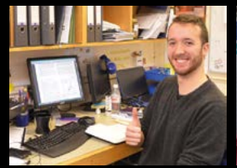
There are several key areas we are working on. We are exploiting the use of bacteria for the production of terpenes, ultimately from waste sugars at elevated temperatures. With terpenes in hand from either fermentation or natural resources we are then upgrading them using various catalytic methods into useful building blocks and additives for the chemical and polymer industry. The challenge lies in translating the novel processes developed into flow in terms of kinetics and separation. Moreover we are establishing integrated technologies to scale up the processes we have developed, to achieve a detailed appreciation of the technical, and environmental factors.

By working across Chemistry, Biology and Chemical Engineering our work is able to look at the process holistically with work from each area informing and improving the direction of research in the other areas, rapidly progressing beyond first principles and leading to numerous publications and industrial collaborations.

The CSCT has an almost unbroken record of winning the Vice-Chancellor's Postgraduate Prize for Public Engagement with Research – Lisa Sargeant (winner) in 2014, Jon Chouler (winner) in 2015, Jemma Rowlandson (winner) in 2016, Emma Sackville (runner up) in 2017 and Bethan Charles (winner) in 2018.








PUBLIC ENGAGEMENT

"Learning about how our work and research relates to industry and society was eye opening. The Public Engagement activities really help to put the work done at the Centre into perspective and develop communication skills which are crucial for success."

Michael Joyes, cohort 2014

For more information:

csct-public-engagement@bath.ac.uk

blogs.bath.ac.uk/csct/category/public-engagement

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PUBLIC ENGAGEMENT

Students describe their research in a limerick

Doctoral researchers have been challenged to use their rhyming skills to describe their PhD research on social media in the form of a limerick. The challenge was taken up by several institutions such as Royal Society of Chemistry, Physics World, The Chemical Engineer, Wellcome Genome Campus, Sanger Institute, University of Oxford, Imperial College and University of Texas at Dallas

At the CSCT we provide our doctoral students with a variety of opportunities to think broadly about improving their communication and public engagement skills, from condensing their research into three minutes with the Three Minute Thesis competition, to working with policy makers and doing hands-on science demonstrations to the public at the Cheltenham Science Festival.

> "We thought that challenging our doctoral students to write limericks would be fun but both the level of interest and the rhyming skills displayed have been amazing. I hope students from other institutions will continue to get involved and use the hashtag to show us what they can do."
>
> Professor Matthew Davidson

INDUSTRIAL & INTERNATIONAL PARTNERS

A wide range of multinational industries, innovative SMEs, and international institutions are closely involved in the Centre, demonstrating the broad societal importance of sustainable chemical technologies.

Our partners greatly value the enhanced postgraduate training offered by our doctoral programme. Participation in the Centre includes partnership in PhD research projects, strategic advice, hosting of internships, participation in training and involvement in our industrial forum.

"I've been a fan of the CSCT right from its beginning. I've loved the work that the Centre has done. The whole idea of sustainable technologies and bringing together different capabilities are absolutely essential if we're going to build something that has impact."

Dr Steve Martin, Founder, Inspire Biotech
(CSCT Industrial Partner)

Some of the many partners we have worked with:

AIRBUS GROUP
artis
BRUKER
CatSci Innovation in Catalysis
Cellesce
Corbion purac
cfh docmail ltd
cpi
gsk
ISIS
Isobionics
Johnson Matthey
KERRY
MONASH University
NANYANG TECHNOLOGICAL UNIVERSITY
NNFCC
NOVARTIS
THE OHIO STATE UNIVERSITY
PhosphonicS
Pragmatic
RWTH AACHEN UNIVERSITY
sasol
SHARP
specific
UNIVERSITEIT STELLENBOSCH UNIVERSITY
Tetra Pak
Unilever
USP
Yeast Extract a YTL company
YONSEI UNIVERSITY

40
Internships

Key:
Location of Internship placement

INTERNSHIPS

All students have the opportunity to undertake up to three months of internship during their research to enhance their PhD.

As part of our Global Innovation Initiative (GII) collaboration, Jamie spent 2 months at University of Campinas (UNICAMP) in São Paulo, Brazil, where he got the opportunity to use cutting-edge instruments to characterise cellulose-based materials and dip his hands into computational modelling for the first time.

Jamie's PhD project investigates opportunities for novel, sustainable ingredients for formulated products and tissue engineering scaffolds. The goal is for his research to be used for biomedical applications.

> *"One day I want to be able to use tissue engineering to find ways to treat serious injuries that athletes come across and put them back up on their own feet. Without this collaboration, I would have never had this unique life-changing opportunity to learn from the best and gain numerous life skills."*
>
> Jamie Courtenay, cohort 2014

> *"It's very important for our students to build international networks as early in their careers as possible. The more experience they have outside the UK, the better equipped they are to deal with the global science economy."*
>
> Professor Janet Scott, Training Director

OUR GRADUATES

Our Alumni programme has seen our graduates move on to industrial employment or further research across the globe. The graduates are invited back to reconnect with the current members of the Centre and share valuable insights into their career choices.

Graduates leaving to pursue careers in

52%
Industry

31%
Academia

15%
Research Management

2%
Teaching

Employment

100%
of graduates are in employment

Returning Alumni

15 Alumni returned to deliver talks

What they say

"The extra training given in the CSCT on science communication, public engagement and sustainability has been fundamental in my career so far. I definitely wouldn't be where I am today without that knowledge."

Dr Simon Bishopp, Researcher at **Shell**, Amsterdam

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"I had a great time at the CSCT and made some lifelong friends. We were constantly provided with the support to take us to a higher level and help us to stay in the competition. This could be by means of attending conferences and workshops related to your research, doing an internship in your preferred company and obtaining resources necessary for your knowledge growth."

Dr Duygu Celebi, Senior Formulation Scientist at Unilever, Connecticut, USA

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