Advanced Manufacture by Printing & Functional Applications

3 Day Summer Workshop
on
30th June, 1st & 2nd July 2020
at
College of Engineering Swansea University, Bay Campus

Advanced functional nano and micro materials will be drivers in the 4th industrial revolution as they have the potential to transform the world. Printing is in the midst of a transformational rebirth by delivering benefits across a multitude of industries, helping to increase technical performance and reducing cost. The application by printing and coating of functional materials is a route to the realisation of the efficient manufacture of new products based on new micro and nano materials, such as CNT's, graphene, nano wires and nano diamonds. Attracted by the possibility of higher productivity rates, lower costs, plus differentiating specifications and applications, companies from all industries are congregating around this large-scale additive manufacturing process.

To benefit from this opportunity there is a need to understand the underpinning science and technology of the printing process and to be able to develop inks which incorporate these new materials

This Workshop provides a comprehensive overview of "wet" technologies for printing functional materials, sensors and large area electronics, together with the methodologies for quality control and product evaluation.

iCMP Associates and additional associate delegates	£650 + VAT per person
Non iCMP Associates	£900 + VAT per person
Early Bird Rate (available until 15th of May)	£750 + VAT Per Person
Academic rate	£900 + VAT per person

The registration fee includes, refreshments, lunch and the social events.
Accommodation and travel are the responsibility of the attendee.

To register click here: https://www.eventbrite.co.uk/e/advanced-manufacture-by-printing-functional-applications-3-day-workshop-tickets-92175482349
For further details on WCPC please visit http://wcpcswansea.com/

Timetable

Tuesday 30th June 2020		
08:30	Registration	
09:00	Printed and coated functionality	David Gethin
10:00	Screen printing	Tim Claypole
11:00	Coffee Break	
11:30	Direct write deposition	Ben Clifford
12:30	Rotogravure & Pad printing	Tim Claypole
13:30	Lunch	
14:30	Practicals	
15:30	Networking & coffee break	
16:00	Practicals	
17:00	Close	
18:30	Social event - Tapas "No Sign Wine Bar", Wind Street	

Wednesday 1st July 2020		
09:00	Offset Printing	Tim Claypole
10:00	Flexographic Printing	Davide Deganello
11:00	Coffee break	
11:30	Inks and Coatings	Chris Phillips
12:30	Rheology and Printability	James Claypole
13:30	Lunch	
14:30	Practicals	
15:30	Networking & coffee break	
16:00	Practicals	
17:00	Close	
18:30	Social event - Walk around Mumbles, including Oystermouth Castle, Light House & Pier	

Thursday 2nd July 2020		
09:00	Drying, Curing, Sintering and Calendering	Tim Claypole
10:00	Substrates	Tatyana Korochkina
11:00	Coffee break	
11:30	Surface characterisation	Sarah-Jane Potts
12:30	Electrical characterisation	Ben Clifford
13:30	lunch	
14:30	Analytical Chemistry	Ian Mabbett
15:15	Coffee break	
15:30	Demonstrations	
17:00	Close	

Practicals: Tuesday 30th June 2020				
14:00	Flexo printing (John Lau)	Metrology (Andrew Claypole)	Rheology (Alex Holder)	Screen Printing (James Claypole)
15:00	Comfort break			
15:30	Metrology (Andrew Claypole)	Rheology (Alex Holder)	Screen Printing (James Claypole)	Flexo printing (John Lau)
16:30	Close			

Practicals: Wednesday 1th July 2019				
14:00	Rheology (Alex Holder)	Screen Printing (James Claypole)	Flexo printing (John Lau)	Metrology (Andrew Claypole)
15:00	Comfort break			
15:30	Screen Printing (James Claypole)	Flexo printing (John Lau)	Metrology (Andrew Claypole)	Rheology (Alex Holder)
16:30	Close			

Demonstrations Thursday 2nd July 2019		
15:30	Demo ink Making (Andrew Claypole)	Demo Pulse Forge (John Lau)
16:15	Demo Pulse Forge (John Lau)	Demo ink Making (Andrew Claypole)
17:00	Close	

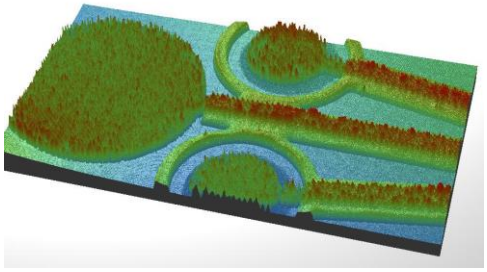
Substitutions may be made at any time

iCMP reserves the right to alter or cancel the programme at short notice.

Summer Workshop
Synopsis of course elements

Printed and Coated Functionality - Prof David T Gethin

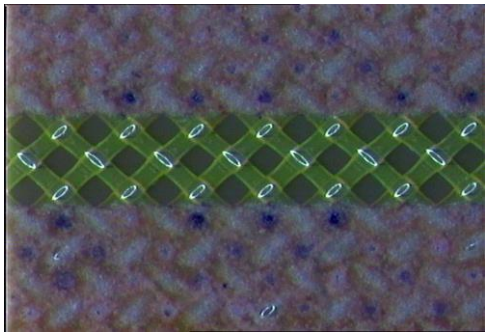
Manufacturing by printing can be used to introduce additional functionality This presentation sets the scene before the course embarks into the details of all aspects of printing of complex functional materials.



The market opportunities are highlighted for applications of printed functional materials such as smart packaging, OLED, Organic PV, flexible displays, electronics, Integrated smart systems (ISS), batteries, super caps antenna, wearables, and health care. The requirements and challenges are discussed with examples of development projects.

Advanced Screen Printing – Prof Tim C Claypole

Screen printing is the most versatile of the printing processes, capable of printing a wide range of materials onto a wide range of substrates. It lays down a thick film and can achieve resolution of 35µm. It is capable of printing large formats to give high production rates. More than 95% of profitable printed electronics production is currently screen printed.



Even though screen printing has been in use in some form for over 2000 years it is “rather complicated” as there are strong interactions between the many process parameters, compounded by the non-Newtonian behaviour of most screen printing inks. Each of the parameters is discussed in turn as it is recent advances in materials and the understanding of the process that is leading to major advances.

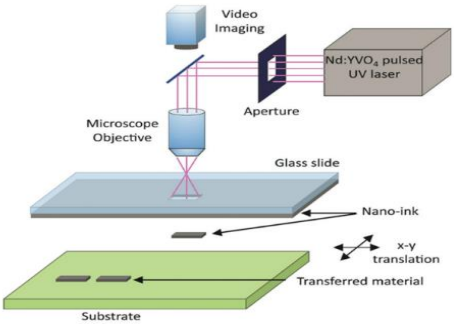
Direct Write Deposition – Dr Ben Clifford

There are many different definitions of the term `direct-write', but generally it refers to any technique or process capable of depositing, dispensing, or processing different types of materials over various surfaces following a pre-set pattern or layout without the need for external masks and/or stencils. The mode of operation and applications of the main direct writing processes are presented.

Aerosol jet deposition, this is one of the most recent techniques in which WCPC has Europe leading expertise. The ink is atomised to form a mist which is collimated with a convergent gas stream and focused through a convergent nozzle. This enables features as small as 10µm to be printed.

Inkjet printing: Most of the development of applications of functional materials have used ink jet because of the relatively low cost of the printer and the small volumes of material required to print. However, it requires a low viscosity low solid content ink.

Laser Induced Forward Transfer (LIFT) uses a pulsed laser beam to selectively transfer material from a solid or liquid donor layer to a target substrate. Printing from solid films allows the printing of multilayers or even entire devices in a single pulse.

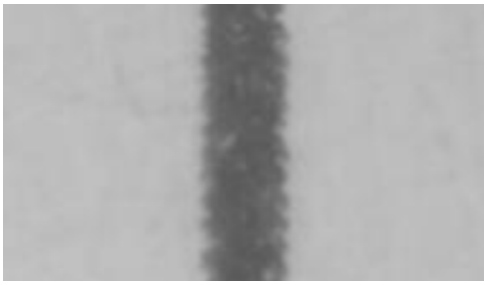


In 3D Printing by Fused Deposition Modelling (FDM), an object is built by selectively depositing melted material in a pre-determined path layer-by-layer. FDM is the most widely used 3D Printing technology with low cost printers.

Stereolithography (SLA), an object is created by selectively curing a liquid photosensitive thermoset polymer resin using a light source. SLA capable of producing high accuracy parts with intricate details with smooth surface finishes which reduces the need for finishing processes.

Rotogravure and Pad Printing – Prof Tim C Claypole

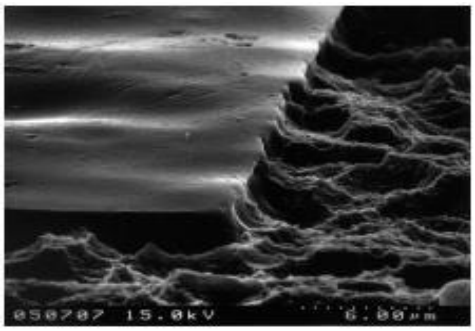
Rotogravure is widely used in high volume applications such as packaging, publication and security printing. The design to be reproduced is engraved as a series of cells into a cylinder. The ink flows during printing to create continuous features. It is capable of handling aggressive solvents and materials.



Pad printing uses an engraved plate as the image carrier. A silicon impregnated pad picks up and transfers the image from the plate. Pad printing is used extensively in the printing of non-conformal surfaces.

Offset Printing – Prof Tim C Claypole

Offset is known in the printing industry as Litho. it is used extensively for the production of graphics and packaging. The image carrier relies on the chemistry of the plate to attract ink to the image. The process is offset in that a polymer covered roll transfers to the image from the carrier to the substrate. This reduces wear on the plate and can accommodate surface roughness of the substrate. It is attractive for functional printing as it can achieve high resolution and registration of continuous features with an easily changed image carrier.



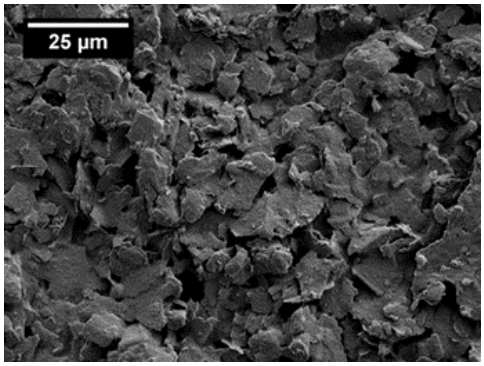
Flexographic Printing – Prof Davide Deganello

Flexography is used extensively for the printed of flexible packaging and cartons. The raised image on the soft flexible high-resolution photopolymer plates, picks up the ink from an engraved cylinder (anilox) and deposits it onto the substrate. Continuous lines can be reproduced, though there is an interaction between the printing pressure and the line quality. The plates which carry the image can be quickly produced. Flexo has potential application for RFID antenna and smart packaging, as well as for high volume electronics and point of care health.

Inks and Coatings – Dr Chris Phillips

Ink comprises of pigment, polymer (to bind pigment to surface), solvents and additives to adjust properties. Inks are formulated to achieve their required function when printed. The choice of process is decided by the feature thickness, resolution and run length. The process determines the viscosity and maximum pigment size (even in functional inks the solid components are often referred to as pigments). Other important considerations are product life and rub resistance.

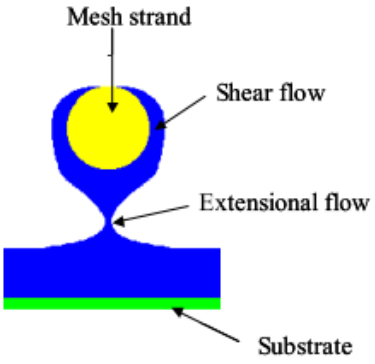
The presentation will cover mixing and milling, the two main processes used in ink manufacture. Materials commonly used in ink formulation are reviewed, before discussing the manufacturing options. An example of formulation and is impact on viscosity, printability and functionality is then given.



Rheology and Printability – Dr James Claypole

Rheology is the characterisation of the key parameters which determine the performance during the printing process and the quality of the finished product. It allows formulations to be optimised more quickly using less materials then through press trials. It is a vital tool for quality control.

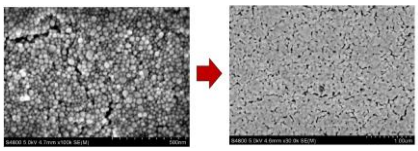
The flow under shear is can measured during ink making and at the press side However, only measured at one condition, which can be misleading as many inks' properties change with shear, Rotational shear rheometers measure the viscosity of a thin film of fluid under different conditions so that a comprehensive picture of its behaviour can be determined. Also creep and recovery once shear is removed (important for flow during curing) can be determined. This presentation will cover Oscillatory rheology is used to determine the viscoelastic properties of the ink.



An example of the relationship between rheology and printability is given from the ARPLAE case study of a model screen printing ink (an exemplar project of the EPSRC Centre for Innovative Manufacture of Large Area Electronics

Drying, Curing, Sintering and Calendering – Prof Tim C Claypole

Drying and curing is an essential stage in the printing process where the liquid ink is turned into a solid. Sintering is also sometimes required to cause pigments to merge and calendering to compact the ink layer. Drying removes the solvent which holds the material in the binder apart causing it to cure. The most common methods used for drying, curing and sintering are discussed, including UV and Electron Beam.



Calendering, where the print is squeezed between rollers, is also used in post processing to compact the ink and further improve performance.

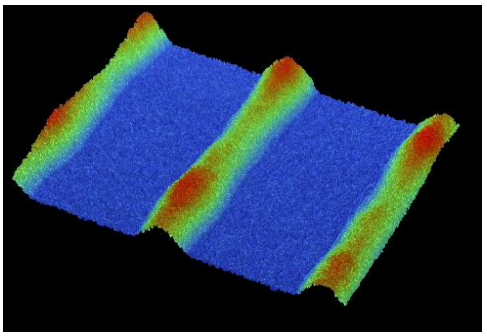
Substrates – Dr Tatyana Korochkina

An increasing number of functional applications print on polymeric (plastic) substrates. Essential polymer science is included which impact on the material strength of the substrate, which in turn impacts on tension and register control, particularly with any heat drying. The critical properties for the substrate include surface finish, tensile strength, friction, wetting, barrier properties and retention. The surface energy needs to be higher than ink but plastics are inherently low, so they can be coated, corona or plasma treated to increase their surface energy. In addition, for some packaging and for moisture/oxygen sensitive materials such as found in OLED, then barrier coatings must be applied.

The most commonly used plastic substrates are described and strategies for choosing the most appropriate substrates for functional applications discussed.

Surface Characterisation – Sarah-Jane Potts

The common terms used to characterise surface topography are first defined before embarking on an overview of the tools which can be used to measure 3D surface topography, starting with stylus profilometry. The optically based techniques for measuring the surface features included are white light interferometry and focus variation microscopy (FVM), which operate with µm resolution. These are both non-contacts, operate in normal atmosphere.



Atomic Force Microscopy (AFM) can operate in several modes. It is significantly higher resolution than the optical methods but scans a smaller area and is much slower.

Scanning Electron Microscopy (SEM) has to be operated in a vacuum but produces a resolution of 100 times the optical microscope. It enables the individual pigment particles to be resolved. At the highest resolution, then individual atoms can be perceived.

Electrical Characterisation – Dr Ben Clifford

The presentation will cover the theory behind the electrical characterisation, including the effect of temperature on resistance, before moving onto the measurement itself. The mode of operation of the handheld multi meter is explained as well as the benefits of the bench multi meter which is capable of the IV sweep. The considerations which have to be taken when performing any electrical measurement to ensure reliable measurements. The 4-point probe used for the measurement of sheet resistance, the Ω/☐ value for ink performance is also discussed.

Analytical Chemistry – Dr Ian Mabbett

This presentation looks at the role of instrumental and analytical chemistry in understanding print processes, exploring the basics of how they work before looking at examples.

Spectroscopy characterises materials based on their response to UV/Vis/NIR. It can be used to analyse colour, colour change in degradation (Aging, weathering or even yellowing through over cure), efficiency of radiative cure, effectiveness of UV blockers.

FTIR characterises materials based on their response to infrared wavelengths. FTIR is used in cure studies, degradation studies, ID of constituents, contaminant location and ID, gas monitoring, anti-counterfeit and CO_2 monitoring for degradation of coatings.

Thermal analysis describes a suite of useful techniques to understand the cure of coatings and inks. Thermo Gravimetric Analysis (TGA) gives data on solvent loss and % solids and can be used to ensure coatings will be fully cured. Differential Scanning Calorimetry (DSC) gives information on energy flow and can give useful data around phase changes. Simultaneous Thermal Analysis (STA) combines functionality of both techniques, limited compared to dedicated systems but a useful hybrid for the majority of measurements.

Gas Chromatography Mass Spectrometry (GCMS) separate gases so that they can be identified and quantified. Evolved gas Analysis enables a thermal event that releases a volatile to be tracked.

Practical Sessions and Demonstrations

The practical sessions utilise the WCPC laboratory facilities which are equipped with all printing processes from bench top through to small scale production with ink development and pilot scale ink making supported by a complete suite of analytical equipment.

Flexo Printing – The principles of flexo printing are demonstrated using the RK Flexi proofer.
Screen Printing – This will be on the DEC research and small-scale production presses
Metrology – Both White light interferometry and focus variation microscopy will be used to measure samples.
Rheology – Dynamic and oscillatory rotational shear measurements will be shown
Ink making – Triple roll milling to create a screen ink will be demonstrated
Photonic Sintering – The Pulse Forge photonic unit will be used to sinter.

Speaker Biographies

Professor David Gethin

Research contribution in the scientific areas that support net shape manufacturing and printing and coating technology.

Net shape manufacturing

This contributed significantly in developing and applying numerical and experimental techniques in casting process variants. Working closely with industry, this has led to documented experimental studies that may be used to benchmark simulation. Recent work has also led for the first time to an integrated system to simulate the direct variant of the squeeze casting process together with an exploration of optimisation techniques that may be used to define process control.

Powder forming

One of the first to develop and apply numerical schemes to simulate the compaction process using a continuum approach and to support this by exploring methods to characterise the mechanical response of powder together with gathering pressing data for validation. Undertaken research to develop and apply the combined discrete and finite element approach to powder forming, with emphasis on tabletting. Uniquely, this uses a discrete scheme to capture gross particle movement and a finite element analysis to compute particle deformation, including the ability to use different material models for each particle.

Work in printing and coating research is undertaken within the Welsh Centre for Printing and Coating

During the last ten years, this Centre has undertaken fundamental scientific work on high speed, high volume graphics printing processes. This has revealed the fundamental understanding that is required to develop these processes scientifically (historically these developments were based on craft knowledge). Drawn on knowledge of thin film hydrodynamics to develop simulation methods and experiments to establish the fundamental process understanding. This work is now being taken forward with current application in the field of polymer electronics and with a future emphasis on biopolymers and biosensing devices.

Professor Tim Claypole

Tim Claypole is a founder and director of the WCPC (Welsh Centre for Printing and Coating, Swansea University). He is a faculty member of the College of Engineering, Swansea University. His areas of research include colour control, manufacturing systems, quality, maintenance, reliability experimental design, fluid mechanics and process thermodynamics. He is a British Expert on ISO TC130 on standards for the graphic arts, printed electronics and nano technology, leading the initial development of process standards for screen and flexo. As well as graphics and packaging, he has internationally leading research on the use of volume printing processes for advanced manufacture of a diverse range of products including electronics, sensors, wearables and point of care health.

Tim led the ERDF funded DIPLE project won the 2009 Regiostars award for "Research, Technology Development and Innovation", reflecting the successful transfer of the research into industry. He continues to work with industry to ensure the translation of the underpinning science into best practice utilising his generic expertise in quality management, process optimisation and maintenance. He led the development projects for the “Web offset Best Practice Toolbox” and the FTA Europe “Flexo Best Practice Toolbox”.

Tim’s contribution to the printing industry has been recognised by the industry with the TAGA Michael Bruno award in 2008 and in 2009 an EFTA special award for outstanding contribution to flexographic printing. He was awarded an MBE for his services to graphic arts and industry in the 2010 Queens New Year's Honours.

The EPSRC, Government and Industry have funded his research that has led to over 170 publications on printing and related topics. He recently finished a prestigious EPSRC Portfolio Grant in "Complex Fluids for Complex flows" and was a founder of the EPSRC Centre for Innovative Manufacture of Large Area Electronics. He is a grant assessor for EU H2020, New Zealand Ministry of Business, Innovation and Employment and Flanders Innovation and Entrepreneurship.

He has also acted as an EU expert for H2020 project monitoring. He is currently Principle Investigator on the ERDF "Avenues of Commercialisation for nano and micro technologies" and the Welsh Government SMART Expertise "Application of Functionalised Micro & Nano Materials – scale up to volume production".

Ben Clifford MEng PhD

Welsh Centre for Printing and Coating, College of Engineering, Swansea University, Fabian Way, Crymlyn Burrows, Swansea, SA1 8EN, Wales, UK

Dr Ben Clifford is a Research Assistant in the Welsh Centre for Printing and Coating (WCPC) within the College of Engineering at Swansea University. Ben is currently working on two funded research projects - Avenues for Commercialisation for Nano and Micro-technologies (ACNM), an ERDF funded operation managed through WEFO aimed to help commercial and industrial organisations access academic research to adopt new processes, increase efficiency and reduce environmental impact. The second part of his research is looking at applications of 3D printing to develop state-of-the-art scintillator holding structures through an ATTRACT funded project.

Ben's research interests lie in the field of digital and direct write manufacturing techniques for applications in printed electronics, semiconductor and biological applications. Prior to becoming a researcher, Ben completed his PhD in the WCPC looking at the Optimisation of Aerosol Jet Deposition for the Development of Printed Electronics. This research looked at the formulation of inks specifically for use in aerosol jet deposition as well as an investigation into the effects of process parameters on print quality and electrical performance.

Ben also holds a Master of Engineering (MEng), first class with honours in Electronics and Computer Science from Swansea University. During his undergraduate studies he completed research that looked at the development and implementation of an intelligent monitoring system for point-of-care monitoring for patients suffering from diabetic neuropathy. His Masters level research project looked at the development of a power logging device for photovoltaic systems to maximise power output.

In addition to Ben's academic studies he has worked in a number of roles in industry including Bluetooth and Electronic Consultant for NextGen Technology and Service Operations Engineer for Vodafone UK.

Professor Davide Deganello

Professor Davide Deganello's research focuses on the development of Printing as an advanced manufacturing process, promoting its transformative potential for novel functional applications, including electronic, biomedical and energy storage applications. His experience encompasses large scale roll-to-roll printing down to micro scale digital additive manufacturing, with applied research supported by the study of fundamental underlying physics and rheology.
Graduating in Mechanical Engineering from Padova University (Italy, 2003), Prof. Deganello completed his PhD at Swansea University (UK, 2008) on the modelling of gravure printing, going on to conduct research for Fast2light, a FP7 project dedicated to the development of roll-to-roll OLEDs technologies.

Appointed as a lecturer in Swansea in 2011, Professor Deganello has since developed a growing collaborative research program, based on a number of Research Council & industrial awards. As Deputy director at the Welsh Centre for Printing and Coating in the College of Engineering, his research has promoted Swansea University as an International leading centre in printing technologies for functional applications.

Recent projects, as Principal Investigator, include an EPSRC award for large-scale energy storage (EP/N013727/1, 2016-19), an EPSRC award on rheology in roll-to-roll printing (EP/M008827/1, 2016), an EPSRC CimLAE Pathfinder project on laser induced forward transfer (SIMLIFT, 2017), an H2020 ATTRACT project on novel solutions for muon detectors through 3D Printing (2019-20). Further, Prof. Deganello has been involved in multiple research & knowledge transfer projects to industry (through ERDF, WG, Innovate UK awards), and interdisciplinary research, such as Co-Investigator in the development of printed diagnostic devices for human cytomegalovirus in new born babies (NIHR, 2018-2021).

Prof. Deganello's research has led to a number of publications in high impact international journals, to patents and industrial investments. Prof. Deganello is a chartered engineer for the Italian Engineering Association and member of the IOP Printing and Graphics Science group.

Dr Chris Phillips

Dr Chris Phillips is a lecturer in College of Engineering, SU and a key member of the WCPC research group. Chris has recently been a co-investigator in a DSTL funded project "Development of a synbio-inspired composite adhesive for transparent defence materials" and has recently completed an Innovate UK project on coatings for water soluble polymers. Chris' research is focussed on the formulation of inks and coatings for functional applications, particularly carbon-based inks, and their deposition in 2 and 3 dimensions. Chris' research has led to a diverse range of journal publications in materials, energy storage, electronics and medical fields.

Chris has a long track record of industrial engagement, having worked directly with over 100 companies in technology transfer and research while he is also supporting "Avenues for Commercialisation for Nano and Micro-technologies (ACNM)", an ERDF funded project managed through WEFO in support of local industry.

Dr James Claypole

James graduated from Cardiff University with a degree in Civil Engineering. He has recently finished his PhD at Swansea University in advanced rheology of printable materials. He worked as an intern at the Welsh Centre for Printing and Coating during his undergraduate study and is now working as a post-doctoral research assistant at Swansea University working on advanced rheology and its impact on the ability to print electronics funded as part of the EPSRC Centre of Innovative of Large Area Electronics based in WCPC.

Dr Tatyana Korochkina

Tatyana Korochkina is a senior researcher at the Welsh Centre for Printing and Coating in the College of Engineering, Swansea University. Her research is primarily focused on functional inks and deposition methods for printed electronics, sensors and energy harvesting. She currently works on the EU funded INTERREG Ireland Wales STREAM project developing printed sensors for remote environmental aquatic monitoring.

Sarah-Jane Potts

Sarah-Jane is currently working as a Scale Up Technology Transfer Fellow at Specific, Swansea University. She is also finishing off her EngD in "Advanced manufacture by screen printing" which she partook at the Welsh Centre of Printing and Coating (WCPC), Swansea University, sponsored by icmPrint Consortium. Her EngD focussed on visualising the effect of ink viscosity and parameter settings on how inks and pastes are deposited during screen printing, using high-speed imaging and a custom-made printer. As well as explored the effect of parameter settings and post processing techniques on print quality and performance. She also has a master's degree (MEng) in Product Design Engineering from Swansea University which she completed in 2015. Her work currently focuses on scaling up printed electronics including perovskite solar cells.

Dr Ian Mabbett

Ian is a senior lecturer in the new chemistry department at Swansea.

Prior to that he was the manager of the Materials and Manufacturing Academy, which incorporates the EPSRC COADTED2 functional coatings centre of doctorate training, of which WCPC is a partner.

Ian has also worked in the SPECIFIC innovation and knowledge centre, with research activities in drying, curing and sintering processes for functional coatings in photovoltaic energy generation and electrochemical energy storage.
Ian has also published papers on rapid sintering of conductive inks for printed electronics with WCPC colleagues.
His background is in the rapid radiative drying and curing of coatings and inks and the study of these processes necessitates expertise in instrumental techniques, particularly spectroscopic techniques, thermal analysis and evolved gas analysis.

Ian holds CChem and CSci status with RSC and CEng status with IOM3, holds FHEA for teaching activities and is a very active STEM ambassador.