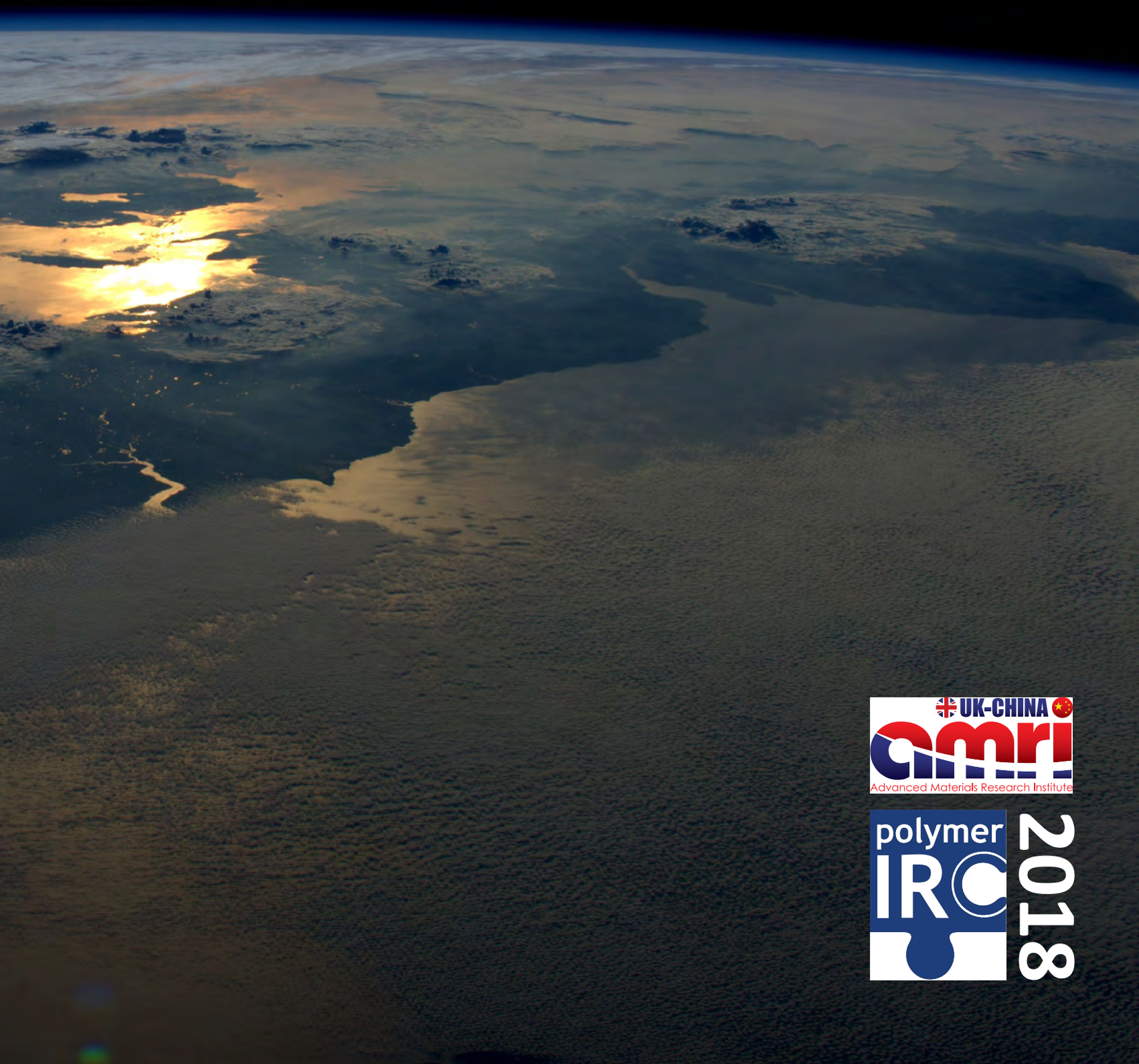
P70

Polymer Engineering International/ 10th UK-China AMRI Research Workshop

18-20 September 2018



UK-CHINA amri Advanced Materials Research Institute

polymer IRC 2018

UNIVERSITY of BRADFORD

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cover picture: Summer sun over UK, taken by UK astronaut Tim Peake from the International Space Station, 5 June, 2016

Polymer IRC

2018

P70 Polymer Engineering International

P70 - Polymer Engineering International/ UK-China AMRI

An international conference celebrating the 70th birthday of Phil Coates
Bradford 18-20 September 2018
in conjunction with the
10th UK-China Advanced Materials for Healthcare Research Workshop

www.polyeng.com/phil7

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A Division of the Institute of Materials, Minerals and Mining

P70 Polymer Engineering International is an international conference celebrating the 70th birthday of Phil Coates, in conjunction with the 10th UK-China Advanced Materials for Healthcare Research Workshop.

The event will not only mark Phil's special birthday but also and the award-winning innovative science and many international collaborations, friendships and the associated international research community he has helped to promote over the past 40 years. It will be a chance for our Laboratory and friends to celebrate together the three recent International Awards, which reflect the standing of the Polymer IRC laboratories at Bradford and the excellent team here, notably the Chinese National Science & Technology Award for International Cooperation (2017), the SPE International Award (2018) and the PPS J L White Innovation Award (2017) - please see the back pages of this book.

WELCOME

Professor P D Coates

BSc ARCS MSc PhD FREng FIMechE FIMMM CEng

Professor Phil Coates is a Physics graduate (Imperial College), London. His PhD research was on solid phase deformation processing of polymers (Leeds University). Prof Coates was elected a Fellow of the Royal Academy of Engineering in 1995. He was Pro Vice Chancellor for Research & Knowledge Transfer at Bradford for 7 years (2004-11), and is Professor of Polymer Engineering, at the University of Bradford. He is Director of the internationally recognised Polymer Interdisciplinary Research Centre (IRC) (across the Universities of Leeds, Bradford, Durham and Sheffield), with some 50 researchers at Bradford involved at the leading edge of in-process measurements for process monitoring, analysis and control, and computer modelling in a 4500 m2 laboratory. The research targets high value polymer products for a range of sectors – healthcare technology (including bioresorbable polymers for orthopaedic applications), pharmaceuticals processing, optical, automotive and advanced materials developments, including nanocomposites and reactive grafting, all with pioneering in-process measurement and modelling. He is a director of MeDe Innovation, the £5.7m EPSRC Centre of Innovative Manufacturing in Medical Devices, founded in 2013 across Leeds, Bradford, Newcastle, Nottingham and Sheffield Universities. His research has substantial support (over £55 million total grants and contracts) from UK Government sources and industry, with over 150 companies

Prof Phil Coates FREng
Director, Polymer IRC
Director, Science Bridges China

International Science & Technology Co-operation Award of PR China (2017)
中国国际科学技术合作奖获得者
Famous Overseas Scholar, MoE China
中国教育部海外名师
Sichuan Province Foreign Expert
四川省外国专家局外国专家
Leading International Professor, Sichuan University
四川大学高端外籍教师
Honorary Professor, Sichuan University
四川大学名誉教授
Honorary Professor, Beijing University of Chemical Technology

collaborating in the research programmes from the USA, Europe, the Middle East, China, Australia and Japan. Similarly, the research involves strong international cooperation in the UK, Europe, N America, India, Japan and particularly China.

He directs the RCUK Bradford Science Bridges China/ ESPRC Global Engagements programme – a government sponsored collaboration (which has achieved over £15m total UK and China support to date) with over 20 Chinese Universities focussed on advanced materials for healthcare technologies, based around a research and open innovation platform. He leads the UK-China Advanced Materials Research Institute (UK-China AMRI). He is an Honorary Professor of Sichuan University and Beijing University of Chemical Technology, and a Molecular Sciences Forum Professor at the Institute of Chemistry, Chinese Academy of Sciences, Beijing and CIACAS Changchun, and has high quality joint publications with these groups. He has three joint laboratories with leading Chinese groups: (1) The first formed in 2010 with Sichuan University State Key Laboratory of Polymer Materials Engineering, on Polymer Microprocessing – this is a nationally approved (by MOST) 'national international' laboratory, and we have a range of joint international grants from MOST, NSFC and MoE in China; (2) The second formed in 2015 with Changchun Institute of Applied Chemistry Chinese Academy of Sciences, in Polymer Process Physics. We have joint

grants (Royal Academy of Engineering Fellowship (2014-5) and a Royal Society Newton Advanced Fellowship (Prof Y Men, 2015-18), plus joint high level publications and research exchanges; (3) the third in Dec 2016 with Beijing University of Chemical Technology on Soft Matter Technologies. He is also a Famous Overseas Scholar and member of the National Bureau of Foreign Experts of China. He was the first recipient of the Tianfu Friendship Award in 2015, and received the first International Science Cooperation award from Sichuan in 2016. He co-founded (with Prof Li Guangxian, senior Vice President of Sichuan University) the UK-China Advanced Materials Research Institute (www.ukchina-amri.com) in 2012, which maps onto our continuing Science Bridges China platform, which continues to thrive with researcher exchanges. He has just been honoured with the Chinese National Science & Technology Award for International Cooperation (2017), presented by President Xi Jinping and other Chinese leaders in January 2018.

He runs research workshops (11 to date, at 1 or 2 per annum in the UK and China) with Chinese and UK academic partners (Leeds, Sheffield, Durham, Nottingham and Newcastle in particular), linking also with the EPSRC CIM in Medical Devices (MeDe). In addition, Prof Coates is involved with research in India, particularly in the leading Institute for Chemical Technology, Mumbai and the CSIR National Chemical Laboratory, Pune.

Prof Coates was a director of Medilink (Y&H) Ltd (2004-18). He was a founder member of the Leeds City Region Local Enterprise Partnership Business, Innovation and Growth Panel (for 8 years, part as chairman), and has continued to promote the international potential for links.

He was honoured by the award of the Institute of Materials (IOM3) Netlon Gold Medal for Innovation in Polymer Processing (1999); the Plastics Industry Award for personal contribution to the industry (2006); the IOM3 Swinburne Award (2008); the Tianfu Friendship Award of Sichuan Province (2015); the Sichuan International Cooperation Award (2106); the JL White International Innovation Award of the international Polymer Processing Society (2017); the National Science & Technology Award for International Cooperation of the People's Republic of China (2017) – China's highest honour for foreign scientists; and the International Award 2018 of the Society of Plastics Engineers, their top award. He is a long-standing member of the International Polymer Processing Society committee, and has organised a wide range of international conferences, and regularly gives invited, keynote and plenary lectures. He has published extensively – over 300 papers in scientific journals and has co-authored 9 books, and edited 7 books. He holds 15 patents. He is Chief Editor of the IoM3 international journal, Plastics, Rubber and Composites: Macromolecular Engineering. He is married to Jane (for over 46 years), with four children and four grandchildren; in addition to family, his chief interests are in music, his church and computers.

Web sites: www.polyeng.com = the gateway web site to Prof Coates' laboratories at Bradford, and www.polymerirc.org is the central Polymer IRC website; www.ukchina-amri.com and www.sciencebridgeschina.com show the UK-China programmes; www.polyeng.com/ukieri reflects the UK-India programmes; www.ceforplastics.uk reflects our increasing involvement in the circular economy for polymers.

P70 - Polymer Engineering International/ UK-China AMRI Research Workshop

Tuesday 18 September

Norcroft Conference Centre, University of Bradford

	8.55	**Welcome**
		Processing Science & Technology 1
T1	9.00	Cell morphology on injection-molded PMMA microstructures as function of surface energy *Clemens Holzer, University of Leoben, Austria*
T2	9.20	Slip of polypropylene melts over different laser-induced periodic nano-structures in thin-wall injection molding *Giovanni Lucchetta, University of Padua, Italy*
T3	9.35	Development of highly conductive hybrid composite *Aminul Islam, Technical University of Denmark, Denmark*
T4	9.50	Extrusion melt flow characterized in real time using in-line rheo-optical techniques *Sebastião Canerovolo, UFSCar, Brasil*
T5	10.05	In-process materials characterization during small-scale extrusion under constant operating conditions *Jose Covas, University of Minho, Portugal*
	10.25	**Coffee & Posters/ Exhibition/ Photo 1**
		Processing Science & Technology 2
T6	11.05	Melt Processing of Polymers for Pharmaceutical Applications *Adrian Kelly, Polymer IRC, University of Bradford, UK*
T7	11.20	Preparation of flexible polymer sensors by Spatial Confining Forced Network assembly *Xiaolong Gao, Beijing University of Chemical Technology, China*
T8	11.35	Selective Laser Sintering of Polyamide11/ Barium Titanate Piezoelectric Composite Powder *Ning Chen, Sichuan University, China*
T9	11.50	Continuous Manufacturing of Cocrystals Using Solid State Shear Milling Technology *Sachin Korde, PharmaceuticaL Engineering Science, University of Bradford, UK*
T10	12.00	Injection moulding and micro-injection molding with local cavity temperature control *Roberto Pantani, University of Salerno, Italy*
T11	12.15	3D Printing: recent advances in material developments *Ludwig Cardon, University of Gent, Belgium*
	12.35	**Lunch & Exhibition, Posters**
		Processing Science & Technology 3
T12	13.30	Advances in Injection Moulding Simulation *Russ Speight, Autodesk Moldflow, Australia*
T13	13.50	Fibre Dispersion and Fibre Length Distribution in Long Glass Fibre Reinforced PP Injection Mouldings *Millan Gilson, Polymer IRC, University of Bradford, UK*
T14	14.00	Wittmann Battenfeld 10th Anniversary Showcase *Barry Hill, Wittmann Battenfeld Ltd, UK*
T15	14.10	The use of micron scale surface features in the fight against counterfeit goods *Phil Harrison, Sofmat Ltd, UK*
T16	14.20	Roll-to-roll processing for flexible devices *Hazel Assender, Oxford University, UK*
T17	14.30	UK government strategy aligned to polymer activities; and how the Knowledge Transfer Network can support you *Sally Beken, Materials KTN, UK*
	14.45	**Coffee & Posters/ Exhibition**
		Processing Science & Technology 4
T18	15.15	Properties depend on structures; what is the origin of these structures? *Gerrit Peters, Technical University, Eindhoven, Netherlands*
T19	15.35	Reactive Jet Impingement: A New 3D Printing Process for Cell filled Gels *Kenny Dalgarno, Newcastle University, UK*
T20	15.50	Comparison of biophysical properties characterized for microtissues cultured using microencapsulation and liquid crystal based 3D cell culture techniques *Mansour Youseffi, Polymer IRC, University of Bradford, UK*

T21	16.00	Smart hydrogels for controlled drug delivery *Bana Shriky, Polymer IRC, University of Bradford, UK*
T22	16.10	Molecular Design of Highly-Stretchable Ionomers *Quan Chen, Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, China*
T23	16.20	Development of improved bio-based polymeric compounds for durable applications *Nikolaos Kassos, Polymer IRC, University of Bradford /Floreon Ltd UK*
T24	16.30	Design, Prepartion and Application of Biobased Itaconic Acid Ester typed Elastomer Materials *Xinxin Zhou, Beijing University of Chemical Technology*
T25	16.40	Flow induced crystallisation in polymers: from molecules to processing *Richard Graham, University of Nottingham, UK*
	16.50	**Polymer IRC Laboratory demonstrations**
	18.15	**Tour and Reception, City Hall Bradford**
	19.00	**Conference Banquet – City Hall Bradford, with the Lord Mayor & Deputy Ambassador to the UK, PR China**

Wednesday 19 September

Norcroft Conference Centre, University of Bradford

	9.00	**STRATEGY** *Guangxian Li, Sichuan University/ Director AMRI;* *Qin Zhu, Minister of the Chinese Embassy in the UK;* *Matthew Rous, CEO, China Britain Business Council* *Jiansheng Du, UK Department of International Trade* *Kersten England, Chief Executive Bradford City Council* *Phil Coates, Director Polymer IRC & Science Bridges China/ AMRI*
		Med Tech 1
W1	9.50	Leeds City Region Medtech *John Fisher, Director MeDe Innovation, University of Leeds, UK*
W2	10.10	The Development of Next Generation Bioresorbable Coronary Scaffold (ArterioSorb™) *Kadem Al-Lamee, Arterius Ltd, UK*
W3	10.20	Electrospinning of Polymer Solutions for Biomedical Applications *Pete Twigg, Polymer IRC University of Bradford, UK*
W4	10.30	Regenerated Silk Fibroin Fibres and Textiles for Medical Applications *David Farrar, Xiros Ltd, UK*
	10.40	**Coffee & Posters/ Exhibition - Conference Photograph**
		Processing Science & Technology 5
W5	11.10	Network structure determines failure property of semicrystalline polymers *Yongfeng Men, Changchun Insitute of Applied Chemistry Chinese Academy of Sciences, China*
W6	11.30	Nanoindentation analysis of oriented polypropylene *John Sweeney, Polymer IRC University of Bradford, UK*
W7	11.40	Developments in PEEK medical applications *Lin Ye, Sichuan University, China*
W8	11.50	Tailored Fixation Devices Via Oriented Polymers with Shape Memory *Fin Caton-Rose, Polymer IRC, University of Bradford, UK*
W9	12.00	Finite element modelling of solid-phase tube die-drawing *Paul Spencer, Polymer IRC, University of Bradford, UK*
W10	12.10	Multicomponent Fiber Processing for Novel Applications *Takeshi Kikutani, Tokyo Institute of Technology, Japan*
	12.30	**Lunch & Exhibition & Posters**
		Med Tech 2
W11	13.30	Determination of material distributions in drug delivery systems *Jiwen Zhang, Shanghai Institute Materia Medica Chinese Academy of Sciences, China*
W12	13.50	Exploiting shape memory properties of polymers in the development of drug eluting soft tissue fixation devices *Karthik Nair, Polymer IRC, University of Bradford, UK*
W13	14.00	Destabilization of polyacrylic acid gel by counter ion replacement *Anant Paradkar, Pharmaceutical Engineering Science, University of Bradford, UK*
W14	14.10	Enhanced bioavailability of Curcumin loaded nano-hydroxyapatite injectable paste *Niten Jadav, Pharmaceutical Engineering Science, University of Bradford, UK*
W15	14.20	Multi-functional Materials for the Manufacture of Antimicrobial Medical Devices *Paul Hatton, University of Sheffield, UK*

W16	14.30	Orthopaedic compression screws formed from body-temperature reverting, shape-memory polymers *Brian Thomson, Polymer IRC, University of Bradford, UK*
W17	14.40	Mechanical Assessment and Preclinical Development of Shape Memory Sutures: A MeDe Innovation Collaboration *Tony Herbert, Leeds University, UK*
W18	14.50	Material Characterisation of Tubular Electrospun PCL and PLGA for Vascular Tissue Engineering *Farshid Sefat, Polymer IRC, University of Bradford, UK*
W19	15.00	EfferShield technology Innovative approach for manufacturing of effervescent product *Sudhir Pagire, Pharmaceutical Engineering Science, University of Bradford, UK*
	15.10	**Coffee & Posters/ Exhibition**
		Med Tech 3
W20	15.40	Highly branched poly(N-isopropyl acrylamide) responsive to fungi *Steve Rimmer, Materials Chemistry, University of Bradford, UK*
W21	16.00	Hemosome formed by protein–polymer conjugate assembly as oxygen carrier for cancer therapy *Yubin Huang, Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, China*
W22	16.15	Using smart scaffolds to promote stem cell homing and tissue for in situ repair of cartilage lesions caused by trauma and early osteoarthritis *Aileen Crawford, University of Sheffield, UK*
W23	16.25	Sustainable development of polymer materials: stability and degradability as well as utilization of solar energy and renewable resources *Yi Dan, Sichuan University, China*
W24	16.35	Harnessing nano-patterning and incorporation of antimicrobials to manufacture orthopaedic trauma implants that resist microbial colonisation *Maria Katsikogianni Polymer IRC, University of Bradford, UK*
W25	16.45	Bio-inspired Anti-oxidant Defence System Constructed By Electrospun F127-based Fibers *Qiang Shi, Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, China*
W26	16.55	Chain Structure design, synthesis and applications of polyvinyl alcohol *JIang Long, Sichuan University, China*
W27	17.05	Development of Universal (Viscometric) Size Exclusion Chromatography Calibrated by DOSY NMR *Tom Swift, Materials Chemistry, University of Bradford, UK*
W28	17.15	Cyclic Trimeric Phosphaze Base as Catalyst for ROP of Cyclic Esters *Zhibo Li, Qingdao University of Science & Technology, China*
W29	17.25	Distinctive Cooperative Effects of Diastereomeric Bimetallic Titanium Catalysts in Olefin (Co)Polymerization *Liu Shaofeng, Qingdao University of Science & Technology, China*
	17.35	**Brief Laboratory visit**
	18.30	**Banquet - Midland Hotel**

Thursday 20 September

Norcroft Conference Centre, University of Bradford

		Processing Science & Technology 6
Th1	9.00	Molecularly Engineered Non-particulate and Continuous Ultra-Low Density Hybrid Silica Aerogels: Superstrong and Superinsulative *Chul Park, University of Toronto, Canada*
Th2	9.20	Microcellular Foam extrusion and reducing Carbon footprint, improving Sustainability *Simon Dominey, MuCell Extrusion, USA*
Th3	9.30	Preparation of PVDF film with high performance by Solid State Shear Milling (S3M) and Biaxial Stretching *Li Li, Sichuan University, China*
Th4	9.40	Polymers for the rolling bearing applications in the variety of industries *Karolis Vilcinskas, University of Bradford/ BNL Ltd, UK*
Th5	9.50	Exchange Researches in University of Bradford ---study on polymer blends in micro-injection molding and die-drawing *Qi Yang, Sichuan University, China*
Th6	10.00	In-situ Shrinking Microfibers Enhance Strain Hardening and Foamability of Linear Polymer *Patrick Lee, University of Toronto, Canada*
	10.15	**Coffee & Posters/ Exhibition**
		Processing Science & Technology 7
Th7	10.45	Self-Healing Polyurethane Elastomer Materials *Hesheng Xia, Sichuan University, China*
Th8	11.05	A method for predicting geometric characteristics of polymer deposition during fused-filament-fabrication

		Michael Hebda, Polymer IRC, University of Bradford, UK
Th9	11.15	Film characterisation for the development of prototype automated stretch wrapping system *Cristina Tuinea-Bobe, Polymer IRC, University of Bradford, UK*
Th10	11.25	Stereocomplex formation crystalline structure of long chain branched poly (L-lactic acid)/poly (D-lactic acid) blends: Effect of melting temperature *Zhongguo Zhao, Sichuan University, China/ Polymer IRC, University of Bradford, UK*
Th11	11.35	Process fingerprinting for optimised production of thermoplastic microneedle arrays using ultrasonic microinjection moulding *Mert Gulcur, Polymer IRC, University of Bradford, UK*
Th12	11.45	Three-Dimensional Porous Carbon Materials with Tunable Super-Wettability toward Oil Spill Remediation and Electrochemical Capacitive Energy Storage *Wei Zhang, Sichuan University, China*
Th13	11.55	Moulding of micro and nano scale features for surface functionalities *Ben Whiteside, Polymer IRC, University of Bradford, UK*
Th14	12.15	Thanks *Phil Coates, Polymer IRC, University of Bradford, UK*
	12.20	**Lunch/ Exhibition & Posters**
		Social Event
	13.30	Coach departs travel through Yorkshire Dales countryside Arrive at Harewood House House tour Reception & Meal
	20.30	Coach returns

sponsored by:

Processing Science & Technology 1

T1 Cell morphology on injection-molded PMMA microstructures as function of surface energy

Clemens Holzer[1], Matthias Katschnig[1], Boris Maroh[2], Silke Patz[3], Natascha Andraschek[2], Sandra Schlögl[2], Ulrike Zefferer[3], Elisabeth Bock[4], Gerd Leitinger[4], Christa Trattnig[3], Maria Kaufmann[5], Werner Balika[5], Ute Schäfer[3]
1 Montanuniversitaet Leoben, Austria
2 Polymer Competence Center Leoben GmbH, Austria
3 Medical University of Graz, Department of Neurosurgery, Austria
4 Medical University of Graz, Gottfried Schatz Research Center, Austria
5 STRATEC Consumables GmbH, Austria

Various studies have demonstrated that the topography of cell environment leads to significant cell modulations. Hence, the aim of this work was a systematic approach to investigate the ability of several synthetic microstructures on a cell-friendly base polymer to control neuronal cell development regarding morphology and differentiation. This approach should provide basic knowledge for cell culture substrates that deliver healthy cells in high numbers, easy culturing and defined cell development to neuronal target tissue.
Neural and bone cells were grown on PMMA microscopy slides with several surface structures, including cubes or walls at the low micrometer scale. The mold inserts comprising the microstructure negative were produced by LIGA lithographic process. Final PMMA slide fabrication was established by variotherm injection molding. For efficient and effective handling in the cell laboratory, a special assembly was designed. Microstructure analysis was carried out by SEM, AFM and contact angle measurements. Cell behaviour was determined using LSM for morphology and RT-PCR for gene expression analysis.
SEM and AFM proved that the demolding quality was appropriate. Gene expression analysis of the cells on microstructures indicated no influence on cell differentiation compared to non-structured control. However, a profound impact on cell morphology, especially an elongation alongside walls, and on cell adhesion, especially on cubes, was shown with LSM. Further, contact angle measurements with water and diiodomethane on microstructures denoted enhanced hydrophobic traits on cubes that counteracted the focal adhesion of cells and pronounced surface energy anisotropy on walls that caused a lengthwise spreading of the test liquid droplet, similar to cell elongation. The latter could be caused in both cases by asymmetrical energy barrier heights. Hence, we propose a water-drop-model that might deliver a common physicochemical cause regarding the similar cell and droplet geometries on microstructures and non-structured control. Furthermore, the water-drop-model might shed light on the lack of cell adhesion on cubes.

T2 Slip of polypropylene melts over different laser-induced periodic nano-structures in thin-wall injection molding

D. Masato[a], M. Sorgato[a], A. Batal[b], S. Dimov[b], G. Lucchetta[a]

[a] Department of Industrial Engineering, University of Padova, via Venezia 1, Padova, Italy
[b] Department of Mechanical Engineering, University of Birmingham, Birmingham, UK

In injection molding, high pressure is required to completely replicate the mold geometry, due to the viscosity of thermoplastic polymers, the reduced thickness of the cavity and the low mold temperature. The reduction of the drag required to fill a thin-wall injection molding cavity can be promoted by inducing the strong slip of the polymer melt over the mold surface, which occurs within the first monolayer of

macromolecules adsorbed at the wall. In this work, the effect of LIPSS on the filling flow resistance in thin-wall injection molding of polypropylene was investigated. The use of ultrafast laser processing of the mold surface allowed the generation of different surface topographies, which are characterized by nano-scale ripples of different orientation and morphology.

The results of the injection molding experiments showed that the different LIPSS topographies affect the filling resistance by modifying the critical shear stress in regards to the onset of the wall slip effect. In particular, nano- structuring was observed to reduce the density of adsorbed macromolecules at the polymer/mold interface. The highest reduction of the injection pressure (i.e. 13%) was obtained when molding PP over the intersecting ripples. In fact, considering the reduced dimensions of the LIPSS troughs, the polymer is not able to replicate the nano-scale topographies and adsorption is limited near ripples intersections. Moreover, it was observed that the ripples parallel to the flow favors the bending of the adsorbed chain loops, and thus promoting the disentanglement from those adsorbed in the bulk in comparison with those normal to the flow.

The effect of laser treatment on wall slip was further investigated using a numerical model that was calibrated by determining the slip velocity value that minimizes the difference between the simulated and experimental values. In fact, the higher the drag reduction the higher the slip velocity, due to the smaller interaction at the polymer/mold interface. The good linear correlation between the calibrated slip velocity values and the shear stress at wall, obtained from the simulations, shows that the flow conditions are characterized by a strong slip regime.

The effect of increasing the mold surface temperature was investigated both experimentally and numerically. The results show that the LIPSS treatment affects the filling flow by shifting the onset of the strong slip phenomenon to higher shear stress values. Indeed, the higher adsorption density at a higher temperature results in lower deformability of the macromolecules attached to cavity walls and thus in a higher resistance to their bending when under strong flow conditions.

T3 Development of Highly Conductive Hybrid Composites

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Centre for Acoustic-Mechanical Micro Systems, Department of Mechanical Engineering,
Technical University of Denmark, Lyngby, Denmark

Electrically conductive plastic composites are developed to overcome the major short comings of naturally conductive polymers. Conductive plastic composites combine the properties of metals with the polymers. But the state of-the-art conductive plastics available in the market are also characterized by the short comings for example, the low electrical conductivity compared with the standard metallic conductors. This low conductivity of the materials is the bottleneck for many fascinating applications of the composites where they can provide lot of process and design related advantages. The work presented here attempts to overcome this short coming of the conductive composites by developing hybrid composites to enhance the conductivity network inside the polymer matrix. It discusses the on-going work on the development of the composite based on metal-graphene hybrid system. The production and properties of novel composites based on Polyamide 6, Graphene nano-platelets (GNPs) and Cu fibers are discussed. The mechanical, electrical, and thermal properties of the produced hybrid composites are studied. The influences of the factors like filler contents, filler characteristics, annealing etc. on the electrical, thermal, and mechanical properties of the composites are presented. The presentation discusses the underlying mechanisms responsible for the modulation in the properties of the hybrid composites. Experimental work shows that the combination of GNPs and metallic micro fillers leads to significant improvements in thermal and electrical conductivities. To some extent GNPs acts as conductive bridges in minuscule gaps of the Cu fibers to increase the number of contacts in the constructed network. The combination of the two different fillers increased the mechanical properties up to 133 % compared to the metal reinforced composites indicating stronger interfaces between the fillers and polymer matrix. Rheological investigations also confirm the effectiveness of

hybridization. Furthermore, the influences of annealing on the conductivities of the specimens are studied. Adding an annealing step following the nanofiller inclusion within the metal filled composite resulted in 250 and 151 % enhancement in the thermal and electrical conductivities respectively.

Key words: *Injection moulding, Polymeric composites, Nanofillers, Electrical conductivity*

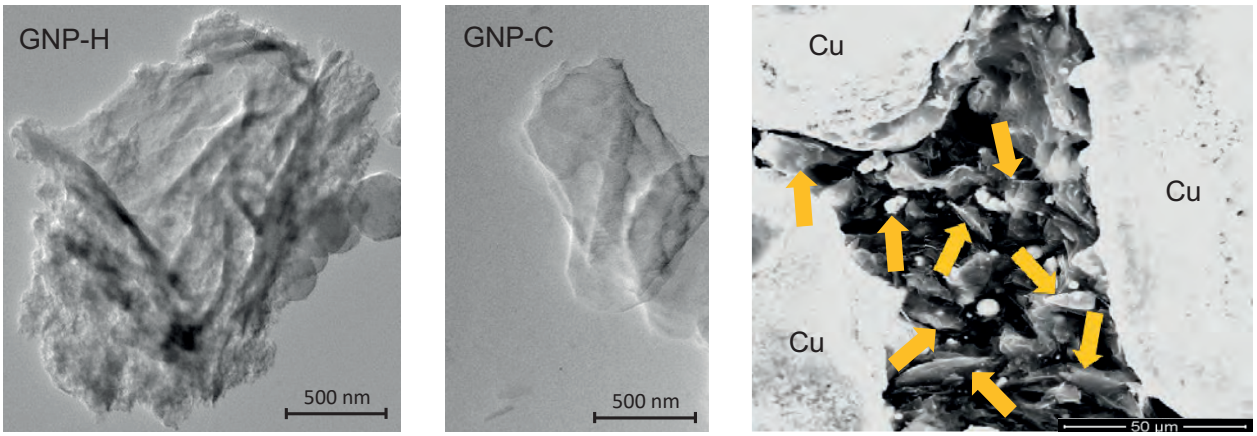

Fig: Left: Picture of graphene platelet (CNP-H), middle: picture of graphene platelet (GNP-C), right: presence of graphene in the space among the copper fibers.

T4 Extrusion melt flow characterized in real time using in-line rheo-optical techniques

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The polymer melt flow can be studied in-line using simultaneous rheo-optical techniques. The rheological behavior is obtained recording the pressure drop along the slit-die. Optical effects like light scattering and structure anisotropy are measured as turbidity, birefringence and low angle laser light scattering (LALLS). For this purpose we have designed and constructed an instrumented slit-die with three ports to measure pressure drop along the slit and two transparent windows for the optical measurements. It includes measuring turbidity and birefringence in the first window and LALLS at the second. The morphology of flowing polymer blends and composites are evaluated in the molten flowing field using, i) a known flowing field produced by a Cambridge Shearing System and ii) during extrusion in a Werner & Pfleiderer ZSK 30. Using different polymer blends and processing conditions the rheo-optical variables can be obtained and the morphological characteristic of the polymer flow be studied. The results can be compared with any conventional off-line measurement like, thermal (DSC), spectroscopic (FTIR) and morphology (POM, SEM, TEM), taken from samples collected during extrusion. Examples of various set of data will be presented during the conference, including diluted polymer blends and composites.

Keywords: process monitoring; extrusion; low angle laser light scattering; turbidity; flow birefringence.

T5 In-process materials characterization during small-scale extrusion under constant operating conditions

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Extrusion is not only a major plastics manufacturing technique, yielding products such as pipes, profiles, films, and sheeting, but is also an efficient method for generating new advanced materials such as polymers blends, functional polymers, composites, and nanocomposites. Consequently, the availability of experimental set-ups using small volumes of sample, creating a thermomechanical environment similar to that developing in practical processing, and providing real-time process-related material characterization data is particularly useful for swifter material development, process set-up, scale-up, and optimization. Furthermore, in-process measurements offer much quicker access to the material attributes than conventional off-line procedures. The selection of suitable in-process techniques and experimental procedures for a given extrusion process depends on the purpose of the data, on the required rate of sensing, on the coupling possibilities accepted by the processing equipment, and on its user friendliness, among others.

Coupling instrumented slit dies to extruders for in-line measurements seems particularly promising. Shear viscosity and normal-stress differences become accessible at shear rates in the region of practical processing. Optical methods, such as light scattering, may characterize the morphology of suspensions. When performing an experiment at a certain operating condition and measuring both the resulting throughput and pressure drop, a single point of the viscosity vs. shear rate curve is obtained. To generate a range of shear rates, either the screw speed (single screw extruder) or the feed rate (twin screw extruder) must be changed. This action will modify the thermomechanical environment (residence time, temperature, hydrodynamic stresses) and could induce changes in the homogeneity, thermal stability and/or morphology of the material. Thus, at each shear rate, a distinct material could be characterized. To circumvent this problem, a double-slit die is adopted in this work. It consists of measurement and extrusion channels, with different design. The former enables the determination of both viscoelastic and morphological characteristics. The die is used to perform rheological measurements of complex polymer systems.

Processing Science & Technology 2

T6 Melt Processing of Polymers for Pharmaceutical Applications

A L Kelly, T Gough, E C Brown, S Korde, S Pagire, C Wood, A Paradkar
Centre for Pharmaceutical Engineering Science/Polymer IRC,
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Polymers are widely used in pharmaceutical applications as excipients (non active ingredients) in oral dosage forms, for example to protect the drug from dissolving in stomach acid or to masking bitter taste. More recently, polymers have been used to increase the solubility and bioavailability of drugs by locking them in a more soluble amorphous form. More than 40% of newly discovered drug compounds are either poorly soluble or water insoluble and so delivery of poorly soluble drugs is one of the major challenges confronting formulation scientists in the pharmaceutical industries. Active ingredients can be mixed into polymeric matrices by processes such as spray drying, which involves dissolving the polymer and drug in a solvent, or by melt mixing. The most common method of melt mixing is twin screw extrusion whereby the drug, polymer and any other excipients are melted and mixed together to form particulate dispersion or more preferably a molecular solution. Suitable polymers must be classified as safe to ingest, and are generally amorphous and water soluble in nature with processing temperatures between 100 and 160°C. Many pharmaceutically accepted polymers were not developed for melt processing and so are not well suited to processes such as extrusion although recently several new copolymers have appeared on the market. Research performed at the Centre for Pharmaceutical Engineering Science and Polymer IRC at the University of Bradford has sought to combine expertise in pharmaceutical science and polymer engineering to provide improved understanding and control of pharmaceutical polymer processing. Here, the hot melt extrusion process is demonstrated through a number of case studies, and the importance of polymer selection and process conditions highlighted. Novel melt processing applications of polymer/drug compounds are shown, such as extrusion of sheet for trans-mucosal patches, extrusion of hollow micro pellets and injection moulding of oral tablets. Real-time process monitoring has also been applied to the pharmaceutical extrusion process in order to control or better understand the material behaviour. Examples include monitoring spectroscopy, ultrasound and melt rheology in the extruder die.

T7 Preparation of flexible polymer sensors by Spatial Confining Forced Network Assembly

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With the popularity of smart terminals, wearable electronic devices, smart robots, drones, smart cars, smart homes, etc. present a huge market prospect. As one of the core components, flexible sensor will affect the functional design and future development of the terminal products. The flexible polymer sensor has the characteristics of being portable, excellent electrical performance and high integration, making it one of the most concerned electrical sensors. The talk is about how to prepare a highly flexible and sensitive sensor based on conductive polymeric composites. Firstly, a novel method of Spatial Confining Forced Network Assembly (SCFNA) was uesd to ensure the high flexibility of piezoresistive materials by building a more compacted conductive network in polymer composites with less conductive fillers. Secondly, forming with micro-nano structure array on the surface of the material can improve the sensitivity and stability of the sensors.

T8 Selective Laser Sintering of Polyamide11/ Barium Titanate Piezoelectric Composite Powder

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Selective Laser Sintering (SLS), as an important 3D printing technology, enables to fabricate parts with any complicated shapes that can't be achieved by traditional polymer processing technology, and is widely used in aerospace, defense equipment, medical apparatus, automobiles and other high-tech fields. At present, the SLS processing faces the bottlenecks in the limited range of polymer materials, lacking function and the high cost in the production of powder.

In this work, spherical PA11/$BaTiO_3$ piezoelectric composite powder suitable for SLS processing was prepared at a large-scale by innovatively combining the solid state shear milling (S^3M) and spheroidization techniques. The results indicated that the S^3M technique could efficiently realize better dispersion of $BaTiO_3$ particles in the PA11 matrix and improve their interfacial compatibilities. The tetragonal structure of the $BaTiO_3$ particles was not destroyed by S^3M treatment. Moreover, the sintering window and viscosity of the S^3M treated PA11/$BaTiO_3$ composite were increased and decreased, respectively, endowing the composites with better processability. The spherical PA11/$BaTiO_3$ piezoelectric composite powders with uniform structure were obtained by our patented technique for spheroidization of polymer-based micro/nano functional composite powder. The spheroidized powder exhibited higher initial flow property and improved stability, consolidation, permeability and fluidization properties as compared with the raw powder. Finally, the porous PA11/$BaTiO_3$ piezoelectric parts with complex shape and excellent mechanical-to-electrical conversion property that can't be achieved by traditional polymer processing, were fabricated for the first time by macro/micro structure design and SLS processing. The generated output was sufficient to light up twelve commercial light-emitting diodes (LED) bulbs instantaneously.

This work was supported by the National Natural Science Foundation of China (51433006).

T9 Continuous Manufacturing of Cocrystals Using Solid State Shear Milling Technology

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Solid state shear milling (S3M) is reported as a scalable, continuous, polymer assisted cocrystallization technique. A specially designed milling pan was employed to provide high levels of applied shear, and the addition of a polymeric processing aid enabled generation of high stress fields. Carbamazepine−salicylic acid cocrystals were produced with 5−25 wt % of poly(ethylene oxide) (PEO). A systematic study was carried out to understand the effect of process variables on properties and performance of the cocrystals. S3M offers an important new route for continuous manufacturing of pharmaceutical cocrystals.

T10 Injection moulding and micro-injection molding with local cavity temperature control

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The control of mold surface temperature allows to obtain injection molded parts with low filling pressure, better surface finishing, more accurate surface replication and reduced frozen-in orientation.
At the University of Salerno, two systems for obtaining a fast temperature evolution were developed and applied to a conventional injection molding machine and to a micro injection molding machine, respectively. Both of them are based on thin heating devices located just below the mold surface, in order to obtain high temperature during filling and a fast cooling at heated deactivation.
This work aims at presenting the results obtained by applying this method in terms of control of cavity pressure evolution and of filled volume, control of the morphology distribution inside the moldings, change of surface hydrophobicity for the obtained parts, replicability of micro- and nano- features.

T11 Recent Advances in Extrusion based Additive Manufacturing Material Developments

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Extrusion-based Additive Manufacturing (AM) such as fused filament fabrication (FFF), also known as fused deposition modeling (FDM), is a widely used 3D Printing technique. AM with polymers has been exploited in a number of innovative ways to produce materials and functional devises in many fields. A major challenge of extrusion-based AM is the lack of commercially available materials compared to those in well-established processes like injection moulding or extrusion.

As example, Poly(3-hydroxybutyrate) (PHB) is a biodegradable thermoplastic with biocompatibility and ecological safety and can be extruded, moulded and spun using conventional plastic processing equipment. Bio-sourced PHB are used in 3D printing to broaden the material pallet for FFF. PLA, also a biodegradable polymer, is used to improve the printing and mechanical properties of PHB. Many people investigated the PLA/PHB blend for food package or other applications, but PHB and PHB/PLA blend used in 3D printing have not yet been well investigated.

Within the presented research, filaments of PHB/PLA blends were produced and processed via extrusion based AM. Afterwards, mechanical and thermal properties were characterized.
It was found, when adding more PHB into the PLA/PHB blend, samples can be 3D printed under lower temperature, thus saving energy. PHB has a bad adhesion on the printing bed due to warpage and shrinkage. Blending with PLA can solve this adhesion problem. Besides adhesion, modulus and stress at break increased when adding PLA. Elongation at break reached maximum with a PHB content of 40wt% as pure filament, while it showed highest value with 20wt% PHB for printed tensile bars. The impact strength increased slightly when adding PLA and reached maximum with 20wt% PHB. VST of PLA/PHB blend was always above 150°C due to the good crystallization effect of PHB. To improve the mechanical and thermal behavior, post heat treatments after 3D Printing have also been investigated.
The developed research methodology and derived results will be used for future investigation of new candidate thermoplastic materials for extrusion based AM technologies.

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T12 Advances in Injection Moulding Simulation

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Injection moulding simulation by finite-element methods began commercially in the late 1970's and has continually developed in sophistication to the present day. The evolution has been driven by market forces in the global plastics industry, new manufacturing processes, new materials and exponential growth in compute power. Expectations from simulations have changed. Historically, an analysis would be run over several hours/days for a single set of process conditions on a local high-power computer, by a 'power-user' with in-depth knowledge of every function and widget of the software. Today simulation is focused on providing 'user work-flows', where multiple analyses are run in shorter times, where the user is focused on the part design, and where in-depth knowledge of simulation is not a prerequisite. Despite this, user expectations regarding simulation accuracy of flow front position, injection pressure, shrinkage and warpage are continually increasing, for an ever-growing number of engineering materials.
New advanced technologies are changing the way parts are designed and made, shaping the future of manufacturing. Our strategies to advance industry knowledge include active support of Autodesk-funded Ph.D. students at leading universities around the world. Additionally, material testing technology has evolved to meet the increased demands of simulation. Testing methods for the viscous, thermal, visco-mechanical, thermo-mechanical and mechanical properties have progressed. Investment in 'state-of-the-art' equipment and continued involvement in research ensures advancement and expansion of the Moldflow materials database, with continually improving accuracy.
As computing technology moved from mainframes, to mini-computers, to personal computers, and now to the almost infinite computer power of the cloud, the simulation compute model has also evolved. Advances in machine learning will be discussed, specific to the injection molding process, from simulation through to the factory. Machine learning will enhance and complement human capability, not replace it, and machines will continue to change the way humans work, liberating workers from repetitive and dangerous tasks.

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T13 Fibre Dispersion and Fibre Length Distribution in Long Glass Fibre Reinforced PP Injection Mouldings

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Franco Costa, Autodesk Moldflow, Australia

Fibre reinforcement of commodity polymers, such as polypropylene, is an established method for the manufacture of components with significantly increased mechanical properties compared to their unfilled counterparts. Glass fibre polymer composites incorporate short glass fibres, 250 µm, or long fibres, up to 17 mm in length, within a polymer matrix. The mechanical performance of any moulded component is highly dependent on the final fibre orientation, in the case of short fibres, alongside fibre length distribution and overall fibre dispersion, long fibres. In this presentation, a 20 & 40 wt% long glass fibre filled PP has been used to investigate the effects of processing parameters on fibre degradation and dispersion during the injection moulding process. Results show that over 50% of 17 mm long fibres have reduced in length to between 0.25 and 1.25 mm by the time they enter the mould. Additionally, micro-CT images show a complex flow field within the screw and nozzle sections prior to the mould, which in some cases continues down the sprue.

T14 Wittmann Battenfeld 10th Anniversary Showcase

Barry Hill
Wittmann Battenfeld UK

On the 1st April 2008 Battenfeld moulding machine manufacture was acquired by The Wittmann Group, a leading supplier of ancillary equipment used on moulding machines.
At the 10th Anniversary celebrations in Vienna over 1200 guests toured the company's four Viennese manufacturing sites. There they witnessed our €45 million financial investment in factory expansion and in capital spend on machine tools for efficient machining of parts.
In 2008 Battenfeld was producing machines from 5 to 650 ton locking force. Since the successful Wittmann take over a complete new range of machines entitled power have been introduced and the range has been extended from 5 to 2,000ton.
Expansion has not only been carried out at the main moulding machine factory but also at the company's three other principal locations: The material handling\drying equipment is now produced in a new purpose built facility and this has enabled the previous site to be fully taken over by the production of mould temperature control equipment. Meanwhile the robot factory has doubled in size and now produces well over 2,000 linear robots per year.
The Sept 2018 Bradford paper will outline the full scope of these developments – illustrating the full integration of two plastics equipment giants – Wittmann and Battenfeld.
The result today is an equipment supplier that designs and provides all that is needed for the modern plastics manufacturing cell – moulding machinery, materials drying and handling, automation, recycling, and temperature control - a 'one stop shop' for discerning and demanding injection moulding companies.
In addition, the advent of Industry 4.0 has meant the development of Wittmann 4.0 – a system that allows full integration of all the equipment for maximum efficiencies, security and health and safety.
Wittmann Battenfeld is also pioneering manufacturing solutions in important markets such as medical and healthcare; integrating cleanroom technology and precision moulding techniques.
The Sept 18th material will also be illustrated with a short video from Wittmann Battenfeld UK's successful shortlisting for Supplier of Year, 2018 Plastics Industry Awards.

T15 The use of micron scale surface features in the fight against counterfeit goods

Phil Harrison
Sofmat Ltd

SofMat Ltd have developed novel technology for use in the Anti-Counterfeit and Brand Protection arenas. The product is based around the ability to produce specific micron scale surface features on the surface of goods either during the production process or post-production. This is backed up by the ability to identify these features using an in house developed portable reader. The company has had a six year relationship with the Bradford University Polymer IRC that has proven essential in the development of the product and the hope is to continue this relationship for future iterations of the technology.

T16 Roll-to-roll processing for flexible devices

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The breakthrough of flexible electronics depends upon suitable large-scale manufacturing routes, likely requiring very low cost, high-throughput processing techniques. Our approach considers high-speed roll-to-roll processing routes already employed industrially, to consider their applicability in creating functional devices e.g. circuits, sensors and thermoelectric generators. In some cases polymer materials form part of the functional layers and in all cases the interaction of the process and device with the polymer substrate needs to be considered.

T17 UK government strategy aligned to polymer activities; and how the Knowledge Transfer Network can support you

Dr Sally Beken
IOM3 Fellow | Knowledge Transfer Manager - Polymers; Plastics & Elastomers

The UK government has set out its Industrial Strategy to boost the productivity and earning power of people throughout the UK. It describes how we are building a Britain fit for the future – how we will help businesses create better, higher-paying jobs in every part of the UK with investment in the skills, industries and infrastructure of the future.

High level strategy challenges have already been articulated and funded and have led to funding competitions open to polymer research and innovation. In addition the Plastics Research Innovation Fund announced in March by the Chancellor Philip Hammond is already in progress and has led to both industrial led and academic funded programmes specific to polymer research.

The presentation will give an insight to the strategy underlying UK polymer focussed funding streams and how you can benefit from them and future ISCF programmes

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T18 Properties depend on structures; what is the origin of these structures?

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Properties of isotactic polypropylene (iPP) result from a complex interplay between molecular architecture, additives and the morphological structure, the latter depending strongly on the thermo-mechanical history experienced during the solidification procedure. These "tools" create flexibility in tuning all kinds of properties, which is the main reason that iPP shows such a broad application range.

Focusing at a fixed molecular architecture, in this case that of high tacticity iPP, one can still obtain huge differences in terms of crystal lattices and morphologies and, therewith, variation in physical and mechanical properties [1]. Optimization of the properties by tuning the morphology with the applied conditions during the production process is a novel route towards improved performance, but, first, this requires knowledge about the structure–property relations and, moreover, on how this structure is created. Here we will focus on the latter. Depending on the crystallization conditions, multiple crystallographic structures can be formed in iPP such as monoclinic a-crystals for sufficiently high isotacticity and relatively low pressure, orthorhombic g-crystals for low isotacticity or very high pressures and, by addition of b-specific nucleation agent or application of high shear rates pseudo-hexagonal b-structure. Moreover, quenching iPP at high cooling rates leads to meso-phase formation.

All this can be clearly observed in injection moulding samples. Using X-ray scattering methods, a distribution of the four different phases (α, β, γ, meso) over the thickness of the sample is found [2], [3]. From several experimental methods, including extended dilatometry (PVT combined with shear deformation) the multi-phase, multi morphology (shish-kebab, cross-hedging also known as parent and daughter structures) crystallisation kinetics were determined [4] and validated [5]. Next, we used a prototype industrial flow device (piston driven slit flow) combined with in situ wide angle X-ray diffraction and small angle X-ray scattering to measure the evolution of the (oriented) crystalline structures and phases (α, β, γ) for different flow conditions [3.

We developed an accurate numerical model able to describe flow-induced crystallization of isotactic polypropylene at high pressures and high shear rates. The finite element model includes a full coupling of nonlinear viscoelasticity, compressibility, non-isothermal flow and flow induced crystallization equations. The slit flow is used as a test case that is simulated at a wide range of imposed pressures and piston speeds. The build-up and relaxation of the pressure difference and the development of the different structures and phases during and after flow are accounted for. Quantitative agreement with experiments is obtained. To our knowledge, this is the first time that such an extended modelling is presented. This work should be a major building block in predicting final iPP product properties, even for complex products as obtained by injection moulding.

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T19 Reactive Jet Impingement: A New 3D Printing Process for Cell filled Gels

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Bioprinting is a growing research area which aims to produce tissue-like constructs for tissue repair or disease modelling. The most common bioinks are cell-laden hydrogels, and both processing and formulation must allow printing of living cells. An optimal process will allow for successful printing of cells at a high density, to enable biological processes to progress quickly, and the ideal bioink should combine certain biological and materials specifications, including processability, mechanics, degradability and bio-functionality. This presention will describe a new bioprinting process, Reactive Jet Impingement (ReJI), processing a novel collagen-alginate-fibrin (CAF) hydrogel, and will demonstrate that the ability of the ReJI process to print high cell densities has a clear effect on gene and protein expression of MSCs, supporting accelerated bone tissue formation.

T20 Comparison of biophysical properties characterized for microtissues cultured using microencapsulation and liquid crystal based 3D cell culture techniques

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Growing three dimensional (3D) cells is an emerging research in tissue engineering. Biophysical properties of the 3D cells regulate the cells growth, drug diffusion dynamics and gene expressions. A novel microencapsulation technique based on flicking and liquid crystal substrate to grow microtissues has been developed. Microencapsulation is a technology of packaging cells within alginate spheres (microcapsules) in single core or polycores. Flicking can be performed by tapping the extrusion of alginate solution from a syringe and breaking the alginate droplets into smaller size microcapsules. This work involved comparisons of two different 3D cell culture systems in influencing the growth phases, viability, surface morphology, biochemistry, nuclei organization and membrane structure for the same cell type.

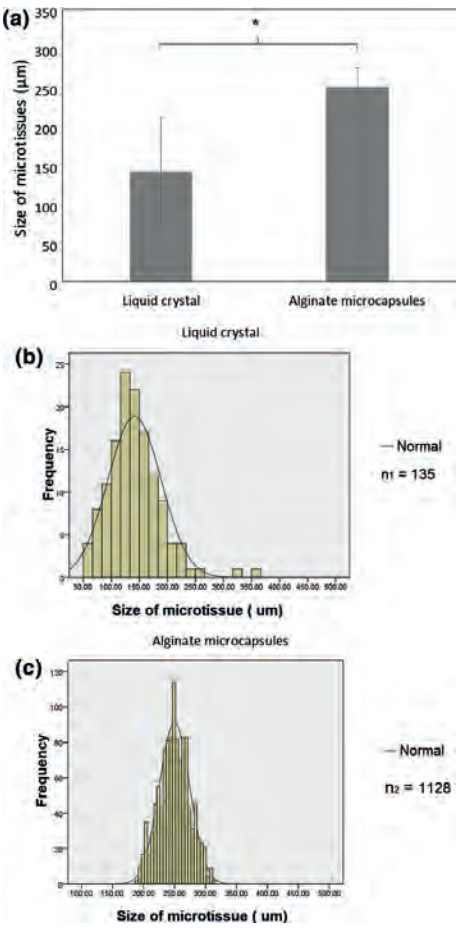

*Figure 1. (a) Size in mean ± SD (p = 0, N = 3) and (b), (c) size distribution of microtissues produced using liquid crystal substrates and alginate microcapsules 3D cell culture techniques. *Indicates statistical significant difference for p<0.05 as computed using Student's t test. Both data sets are normally distributed for liquid crystal and alginate microencapsulation based 3D cell cultures at p = 0.2 and p = 0.07, respectively (normal for p>0.05, Kolmogorov-Smirnov test). The parameters, n_1 and n_2 are the total quantity of microtissues obtained from liquid crystal and alginate microencapsulation cultures for three repeats of experiments.*

T21 Injectable hydrogels for controlled release drug delivery

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This study seeks to develop smart hydrogel formulations for injectable controlled drug delivery from Pluronics to enhance patient compliance, decrease side effects and reduce dose and frequency. Pharmaceutically, these systems are attractive due to their unique sol-gel phase transition in the body, biocompatibility and safety and are injected as solutions before transforming to gel matrices at body temperature. Pluronic F-127 is a triblock copolymer (PEO-PPO-PEO) that gels at low concentrations and can be tuned using other excipients.

We have quantified the structural changes of neat F-127 systems mixed with a control drug and additives under controlled temperature after steady shear and combined with extensional flow as experienced during real bodily injection. The induced structural transitions were measured in situ by Small angle x-ray and neutron scattering (SAXS, SANS) in two orthogonal planes. The newly revealed oriented structures offered a better understanding of the systems interactions with the environmental conditions and correlating these changes to the drug delivery design will allow us to optimise novel injectable pharmaceutical formulations with enhanced temporal release.

T22 Molecular Design of Highly-Stretchable Ionomers

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Application of ionomers is often disturbed by their brittleness originating from limited stretchability of the network strands physically crosslinked by the ionic sites therein. Thus, an effective method of improving the ductility is to increase the length of network strands (and/or entanglements). Considering this point, this study examined linear viscoelasticity (LVE) and nonlinear elongational rheology of unentangled copolymers of hexyl methacrylate (HMA) and the ionic monomer, Sodium 4-vinylbenzenesulfonate hydrate (SSNa). The ionized SSNa monomer, being randomly distributed along the chain backbone at a concentration ranging from less than one to ~four monomers per chain, served as the physical crosslink (or physical branching point). The LVE data showed a sol-to-gel transition, and the ductility of the sample turns out to be strongly related to the degree of gelation.

Analysis of those data gave an average length of the network strands, and the ductility of the ionomer samples detected in the nonlinear elongational test was well correlated with this strand length in most cases. An exception was found for the sample slightly above the gel point: the ductility of this sample was much larger than expected from the strand length, possibly due to the “pseudo-yielding” behavior that reflected exchange of the ionic, physical crosslinks and the resulting motion/displacement of the ionomer chains.

T23 Development of improved bio-based polymeric compounds for durable applications

Nikos Kassos, Adrian Kelly, Tim Gough, Polymer IRC University of Bradford,
Andy Gill Floreon Ltd

Biodegradable polymers have been under the microscope for the last years as an alternative to oil based polymers in various applications, especially in packaging and disposable plastics. Improving PLLA's properties and overcoming its limitations such as impact strength without significantly decreasing its key advantages, such as high strength and stiffness, is one step in replacing oil based polymers. Introducing PLA in more durable applications though, will require improvements in heat resistance and cycle time. The focus of this research is to investigate ways to overcome PLLA's limitations without compromising its strong points.

Results indicated that incorporation of a small loading of PBS (polybutylene succinate) had a synergistic effect on the PLLA-PCL (polycaprolactone) blend properties. Miscibility was improved and enhanced mechanical properties were observed for a ternary blend containing 5wt% of both PBS and PCL compared to blends containing 10% of each polymer alone. An additional study showed that, the use of small amounts of PLLA's enantiomer, PDLA, had an accelerating effect in crystal formation and increase in melt strength.

T24 Design, Preparation and Application of Biobased Itaconic Acid Ester typed Elastomer Materials

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With extensive interest in sustainable development, the chemical industry is making great attempts to replace petrochemical-based monomers with natural ones [1]. It is strategically important to construct new polymers or replace present polymers by renewable resources. Compared with bio-based plastics, few bio-based elastomers, especially those targeted for engineering applications, were produced. We intended to synthesize a series of novel elastomers, which should possess high molecular weight, low glass transition temperature (Tg), and comprehensive mechanical properties based on renewable monomers that are produced on a large scale [2]. Novel poly(lactate/butanediol/sebacate/itaconate) (PLBSI) copolyesters with sustainability and biocompatibility were synthesized by using direct melting polycondensation [3]. The PLBSI elastomers were highly reinforced with nanosilica which can meet the tensile strength requirements for the majority of rubber products. More importantly, the PLBSI elastomers can be used as PLA toughenerers owing to the similar lactate structures of PLA and PLBSI.

By combining a molecular structural design with a nanosilica-silane technology to tune the viscoelastic properties of the elastomer composites, we have successfully manufactured silica/poly(di-n-butyl itaconate-co-butadiene) nanocomposite-based green tires that have very low roll resistance and excellent wear-resistance that promote fuel efficiency and our dependence on petrochemical resources. Bio-based poly(dibutyl itaconate-ter-isoprene-ter-4-vinylpyridine) (PDBIIVP) elastomers with different 4-vinylpyridine (4-VP) contents were synthesized by redox emulsion polymerization for the purpose of designing and preparing green graphene oxide (GO)/PDBIIVP nanocomposites with strong interfacial interaction [4].

For the GO/PDBIIVP with 7.0 wt% of 4-VP and 4 phr of GO, the tensile strength increased by 700%, the volume loss of abrasion decreased by 53%, and the gas permeability decreased by 63% compared with those of the neat PDBIIVP. This method may become an important strategy for developing GO-based polymer nanocomposites with high performance.

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Keywords: Biobased elastomer, Itaconic acid, Itaconate.

T25 Flow induced crystallisation in polymers: from molecules to processing

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Flow profoundly influences the crystallisation kinetics and morphology of polymeric materials. By distorting the configuration of polymer chains, flow breaks down the kinetic barriers to crystallisation and directs the resulting crystallisation. This flow-induced crystallisation (FIC) in polymers is a fascinating, externally driven, non-equilibrium phase transition, which is controlled by kinetics. Furthermore, the effect is of central importance to the polymer industry as crystallisation determines virtually all of the useful properties of semi-crystalline polymer products.

However, simulating and modelling flow-induced crystallisation in polymers is notoriously difficult, due to the very wide spread of length and timescales. I will present results from an ongoing multi-scale modelling project. Our project combines molecular dynamics simulations of nucleation, highly coarse-grained simulations of nucleation, continuum-level nucleation models, a polydisperse tube model for non-linear flow and finite element modelling of polymer processing. I will summarise current results and connections between the modelling techniques. I will also present some experimental data from the same project.

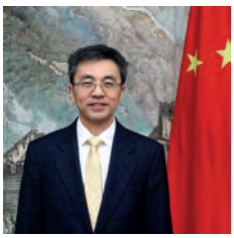
Strategy Session

A Successful Science Bridge, The Fruitful Cooperation Achievements
– A Review of Our Over Ten-year Journey of Great Collaboration

Professor Guangxian Li
State Key Lab of Polymer Materials Engineering, Sichuan University, China, and Co-Director of AMRI

This presentation reviews the wonderful development process and fruitful achievements of the great collaboration between UK and China Scholars in in the field of polymer science and engineering. Professor Philip David Coates and his team have been making unique efforts in last many years to promoting a closer cooperation with our Chinese partners (SCU, BUCT, IC-ACS, CCIAS-CAS,C,SHIMM-SAS). The milestones and good memories during the twelve-year journey of great collaboration between us were presented, from the maiden visiting of Prof Coates to Sichuan University in July 2006 to his award of the International Science and Technology Cooperation Award of the People's Republic of China in the early 2018. The inspiring achievements obtained, including the joint projects, scientific research, cultivation of young talents and the establishment of several international research bases, all attest the success of collaboration between us. These achievements are attributable to the hard work of both sides and especially to the greatly active contribution made from Prof Coates. We sincerely hope that greater and more fruitful achievements will be produced through our friendly cooperation.

Professor Guangxian Li,
DirectorSKLPME Sichuan University/
Co-Director UK-China AMRI



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Med Tech 1

W1 Leeds City Region Medtech

Professor John Fisher
University of Leeds

The Medical Technologies Science and Innovation Audit for the Leeds City Region was published by the UK Department of Business Energy and Industry Strategy in 2017. It described the Future Opportunities and Growth for Medical Technologies in the City Region, serving a population of over 3 million people. Subsequently ambitious investment and development plans were defined as part of as part of the UK Office of Life Sciences Industry Strategy and Sector Deal. The progress in the development of these plans will be described, which include the development of an integrated Regional Health Technology Innovation System, involving Universities, Industry, Local Government and Health and Care providers in the region. This has the potential to deliver over £250m of additional new investment and £1bn/year economic growth and £1bn/year health and care benefits by 2025.

W2 The Development of Next Generation Bioresorbable Coronary Scaffold (ArterioSorb™)

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Coronary artery disease (CAD) is the leading cause of death both in the UK and worldwide. It is a chronic condition affecting people's quality of life, and can lead to acute myocardial infarction, heart failure and death. The primary treatment is percutaneous coronary intervention (PCI). PCI has undergone major evolutions in stent technology, from bare metal stents (BMS), to drug-eluting counterparts (DES), to the development of bioresorbable scaffolds (BRS). Stent treatment uses a small tubular cage expanded within the narrowed artery to open the vessel and restore normal blood flow. The limitations of rigid metallic stents have led to the development of BRS, which facilitate vascular healing, restore normal endothelial function following resorption, while providing equivalent mechanical properties to metallic DES in the earlier stages. BRS provide attractive advancements over DES and have shown promising results in clinical studies. However, the failure of the first generation of BRS (Absorb - 157μm wall thickness, by Abbott Vascular) is due to; not as easy to implant as metallic BMS and DES, strut thickness much greater than DES, Radial strength inferior to DES, comprehensive range of sizes and lengths not yet available particularly in the smaller diameters, re-absorption longer than the promised two years, cost not comparable to DES, and inferior clinical results as compared to DES. Due to these problems, Abbott pulled Absorb-BVS from the market in May 2017 while it focuses on the development of their next generation thin-strut Falcon-BRS.

Development of next generation of BRS with improved mechanical performance is believed to be the next evolutionary leap in interventional cardiology. Leading cardiologists believe that metallic stents "cage the vessel", restricting vasomotion, leading to neoatherosclerosis. Uncaging the vessels to allow restoration of physiology has become a significant unmet need, especially when dealing with complex multi-vessel or diffuse disease that requires long vessel segments to be stented (Cardiology News, Conference Coverage from CRT 2018).

Our product ArterioSorb™ (lower wall thickness 95μm) is produced from the FDA approved polymer, poly-L-lactic acid (PLLA). The polymer is processed using a unique solid-phase orientation technology that enables the cost-effective manufacture of BRS with high strength and stiffness and greater flexibility than the metallic stent. Over four years of collaboration between the Polymer IRC group at Bradford

University, headed by Professor Phil Coates, and Arterius Limited team, the bioresorbable material processing technology has been developed.
In this presentation the promising bench testing and pre-clinical evaluation results of ArterioSorb™ will be discussed.

W3 Electrospinning of Polymer Solutions for Biomedical Applications

Pete Twigg, University of Bradford, UK

Electrospinning is a technique that draws fine polymer fibres (typically submicron in diameter) from solution using the application of a high voltage between the die (a needle) and a collector. The technique produces non-woven porous structures with huge surface area to weight ratios. This makes them attractive for controlled release or absorption applications, or as filters. These structures also make excellent scaffolds for tissue engineering and have biomedical applications as implants and dressings.

This paper describes recent work to control the structure and properties of electrospun polymers through their process parameters. This includes the use of rotating collectors to control orientation and geometry. Coaxial spinning is also used to differentiate between fibre core and surface materials, which has a profound effect on the release of active pharmaceutical ingredients and the attachment of cells to the spun structure. Combining electrospun and conventional fibres has further potential for creating materials and structures with tailored mechanical, chemical and biological properties.

W4 Regenerated Silk Fibroin Fibres and Textiles for Medical Applications

David Farrar, Xiros Ltd, Leeds, UK

Silk fibres have been used for many years in medicine as a suture material and they have also been the subject of much research as a biomaterial for a range of other applications including artificial ligaments/tendons and scaffolds to support cell and tissue growth. However, in order to overcome some of the limitations of natural silk, many groups have investigated regenerated silk in which native silk is dissolved in a solvent and re-spun. Despite a large body of published work, commercial development has been hampered by lack of a good solvent system.
In this paper the development and characterisation of regenerated silk fibres using a novel proprietary solvent system is described. This solvent allows the facile spinning of fibres at commercial scale. Fibres have been produced by both wet-spinning and dry-jet-wet-spinning processes. Yarns can have a variety of properties including multifilament and monofilament, variable linear density and differing filament count.
The regenerated silk fibres have been further processed into a range of formats including woven, knitted and non-woven textiles. The fibres have been shown to have good mechanical properties although strength is somewhat less than the native silk fibre. Biocompatibility is excellent both in-vitro and in-vivo with very low levels of sericin and residual solvent. Preliminary studies have investigated the use of the regenerated silk fibres as a scaffold for both tendon and dermal wound repair with promising results.

W5 Network structure determines failure property of semicrystalline polymers

Ying Lu[1], Zhiyong Jiang[1], Phil Coates[2], Yongfeng Men[1]

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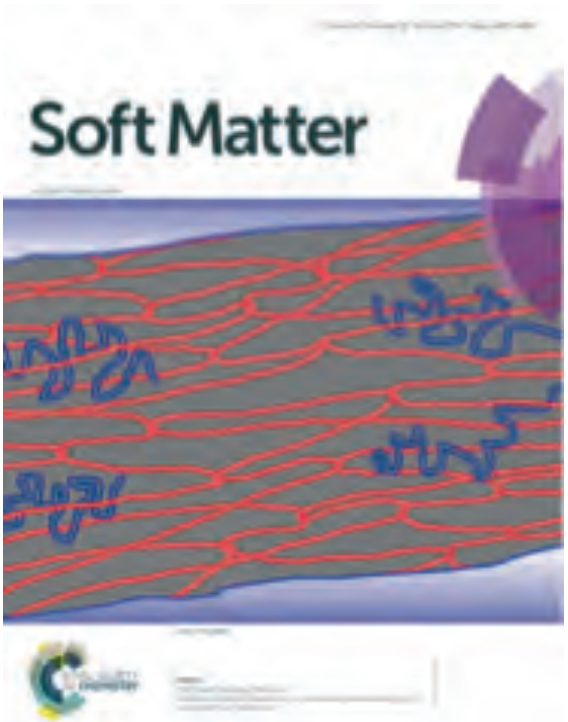
Semicrystalline polymers, such as polyethylene, polypropylene, polybutene-1 and so on, are normally used as structural materials making their mechanical properties extremely important. Upon tensile stretching, several characteristic events can occur including plastic flow or/and cavitation. Cavitation presents at small and large strain regimes independently. It turns out that all observed structural developments could be understood as a consequence of stretching two interpenetrated networks of hard crystalline skeleton and soft amorphous entangled network. At small strain, hard crystalline skeleton determines the mechanical behavior. When crystalline block slips can be activated, plastic flow takes place. Otherwise, breakage of crystalline skeleton induces cavitation of the system. The cavitation at small strain regime normally does not introduce catastrophic failure of the sample. Further deformation causes a fibrillation transition which transforms isotropic spherulitic structure into highly oriented fibrillar one via a stress-induced melting and recrystallization mechanism. The resultant oriented structure is built up by highly stretched inter-fibril/inter-microfibril tie chain network embedded by fibrils/microfibrils. Therefore, ultimately, breakage of such tie chain network sets in at large strain regime introducing another type of cavitation before macroscopic failure.

Acknowledgement:
This work is supported by NSFC (21134006, 51525305) and Royal Society (Newton Advanced Fellowship NA150222).



latest joint publication between Changchun and Bradford featured on the cover of Soft Matter

W6 Nanoindentation analysis of oriented polypropylene

D. Vgenopoulos[b], J. Sweeney*[a], C. A. Grant[c], G. P. Thompson[a], P. E. Spencer[a],
P. Caton-Rose[a], P. D. Coates[a]
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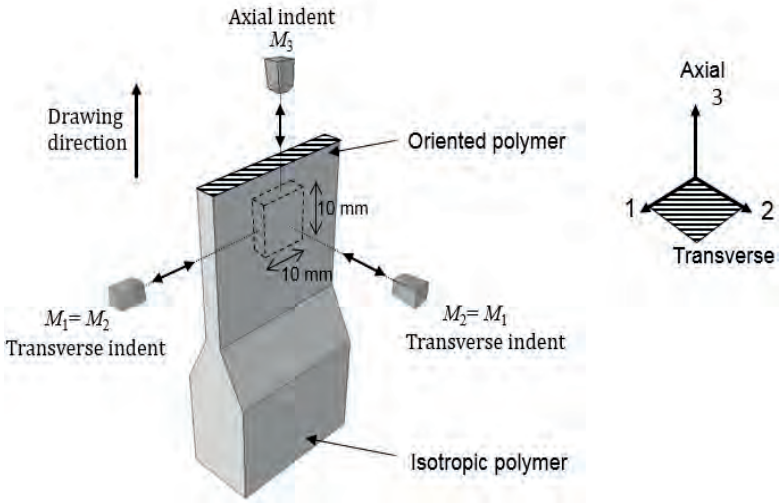
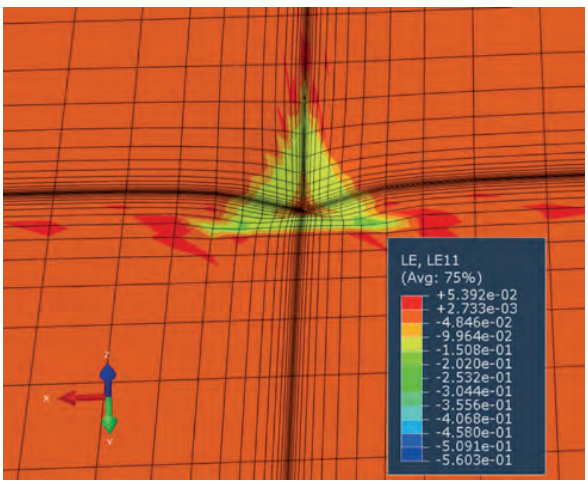
Polypropylene has been oriented by solid-phase deformation processing to draw ratios up to ~16, increasing tensile stiffness along the draw direction by factors up to 12. Nanoindentation of these materials showed that moduli obtained for indenter tip motion along the drawing direction (3) into to 1-2 plane (axial indentation) were up to 60% higher than for indenter tip motion along the 2 direction into the 1-3 plane (transverse indentation). In static tests, tensile and compressive determinations of elastic modulus gave results differing by factors up to ~5 for strain along the draw direction. A material model incorporating both orthotropic elasticity and tension/compression asymmetry was developed for use with Finite Element simulations. Elastic constants for the oriented polypropylene were obtained by combining static testing and published ultrasonic data, and used as input for nanoindentation simulations that were quantitatively successful. The significance of the tension/compression asymmetry was demonstrated by comparing these predictions with those obtained using tensile data only, which gave predictions of indentation modulus higher by up to 70%.



Indentation measurements on die-drawn strip



Finite element simulation of nanoindentation

W7 Progress on Highly Oriented Poly (lactic acid) Produced by Solid-phase Die Drawing: Structure, Mechanical and Biological Properties

[1]Xiaowen Zhao, [1]Zhengqiu Li, [1]Jiafeng Li, [2]Fin Caton-Rose, [2]Phil Coates, [1]Lin Ye*

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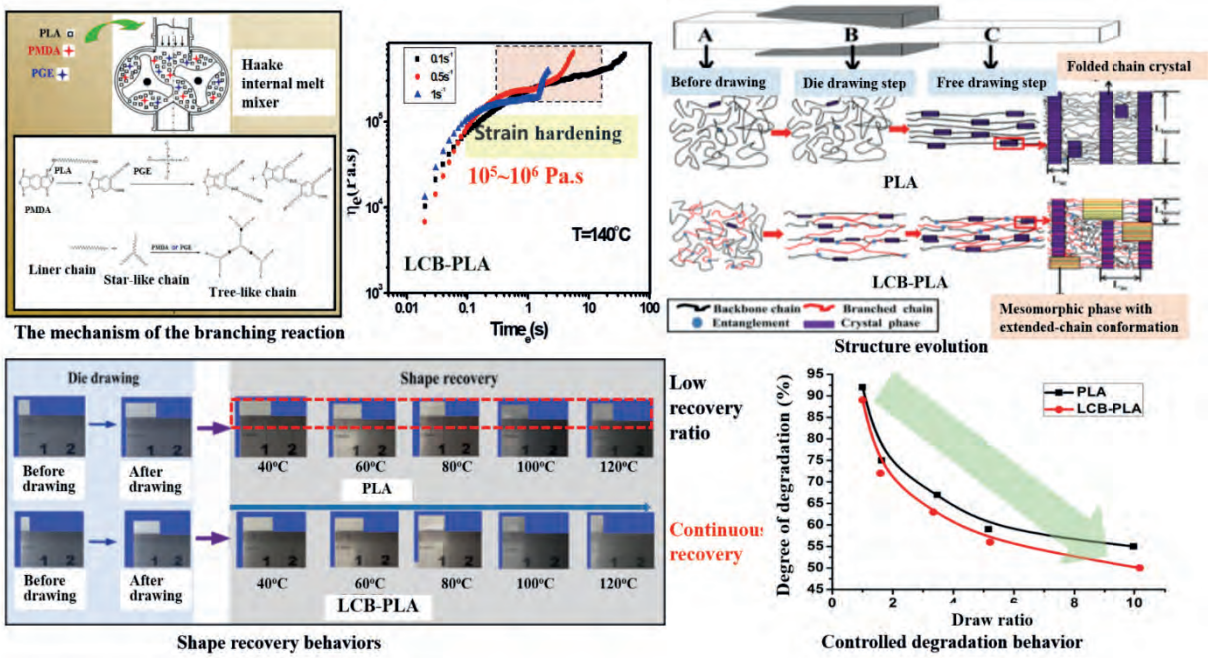
Aiming at the development of self-reinforced poly (lactic acid) (PLA) as biomedical materials for bone fixation, through reactive processing, PLA materials with strain-hardening rheological properties were first prepared by the method of chain extension, branching and long-chain branching to increase entanglement degree of PLA molecules. On this basis, the shear/tensile rheological behavior of PLA was studied, and the solid-phase die drawing technology was established to realize highly oriented microfibrillation and self-reinforcement of PLA, while the tensile strength and modulus reached as high as 228 MPa and 7.2 GPa, respectively, which met the requirements of mechanical properties for bone fixation materials. The effect of drawing speed and die thickness on the formation of oriented crystalline structure of PLA during die/free drawing process was further studied, and the structure/morphology evolution and orientation mechanism of PLA were explored. The shape memory effect of highly oriented PLA was investigated, and the shape recovery mechanism was explored, in order to control the shape recovery ratio as well as mechanical strength effectively by regulating the recovery temperature. The effect of the oriented microfibrillation degree on the biocompatibility, surface-interface properties and degradation behavior of PLA was studied, and the mechanism of improving biocompatibility, delaying hydrolysis degradation and regulating degradation rate of PLA were revealed. As a result, PLA can be endowed with excellent biological properties, like self-reinforcement, self-fastening and controllable biodegradation as bone fixation materials.



W8 Tailored Fixation Devices Via Oriented Polymers with Shape Memory

P. Caton-Rose, D. Vgenopoulos, K. Nair, P.D. Coates, J. Sweeney, G. Thompson
Polymer IRC, University of Bradford

In this paper we demonstrate the capability of amorphous and semi-crystalline polymers, oriented through solid phase processing, to achieve viable shape memory behaviour for fixation devices within the healthcare sector. Prototype products for soft tissue fixation are compared to commercially available products in terms of pullout force in sawbone and bone, showing equatable and improved performance. Figure 1 shows the pullout force in bone of an example ACL screw before and after recovery.

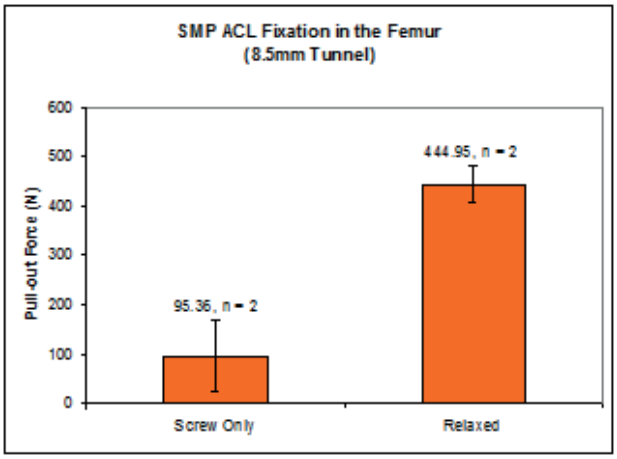


Figure 1: ACL pullout force in bone before and after recovery

Future development of fixation devices as part of our ongoing EPSRC funded research is described. These activities include the use of multiple processing stages (solid phase orientation and overmoulding) and controlled cross-sectional shape design during die drawing (via billet and die design), Figure 2.

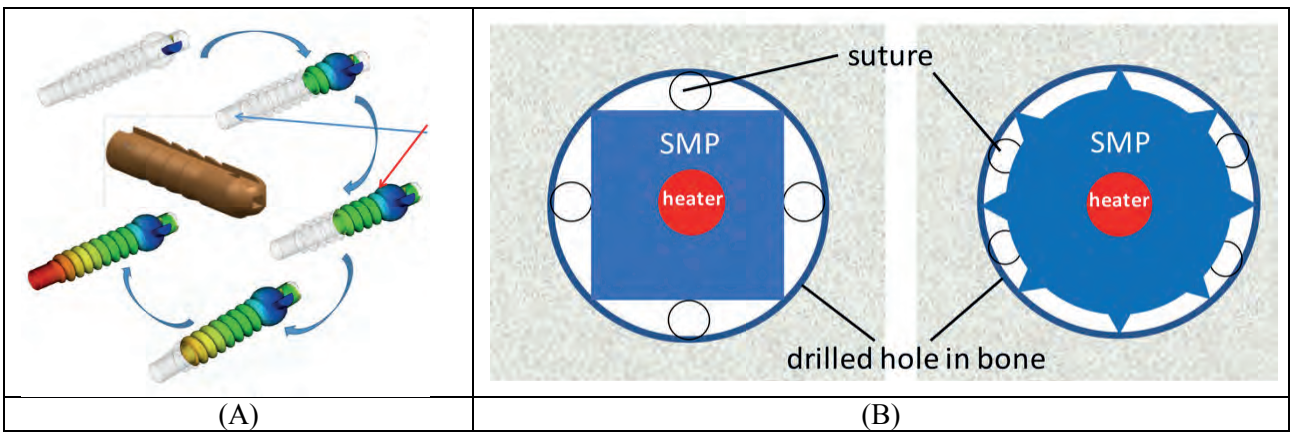


Figure 2: Development fixation devices production methods (A) oriented polymer overmoulded and (B) cross-sectional design or oriented devices

W9 Finite element modelling of solid-phase tube die-drawing

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Solid-phase polymer processing, such as tube die-drawing, is now an established technique to manufacture highly oriented polymer products in large section. The tube drawing process involves pulling a cylindrical polymer billet over a fixed mandrel at elevated temperature (Figure 1[a]), producing a stretch in both the axial and hoop directions. As the polymer cools, the induced orientation of the polymer chains is "locked in" to give a stable final product with enhanced mechanical properties. While simple in principle, the details of the operation vary depending on the polymer and the drawing conditions, making the precise dimensions and degree of orientation of the product difficult to predict. For this reason, a detailed numerical investigation is a necessary means of fully understanding the process. Here we model the tube-drawing process using 3D state-of-the-art techniques within the commercial Finite Element software Abaqus. It is essential to capture the strain-hardening and strain-rate effects of the polymer material within the model. Accordingly, a rate-dependent elastic-plastic material law parameterised by material data from a large set of free-drawing experiments was used. The Finite Element predations agree well with tube-drawing experiments in terms of the deformed geometry over the mandrel (Figure 1[b]) and the axial strain measured on the outside surface of the tube. The model is also able to predict the axial and hoop stresses and strains within the deforming polymer billet (Figure 1[c]) for a given set of process parameters (drawing temperature and speed). Combining experimental and numerical investigation in this way leads to a more detailed understanding of the conditions required to produce orientation.

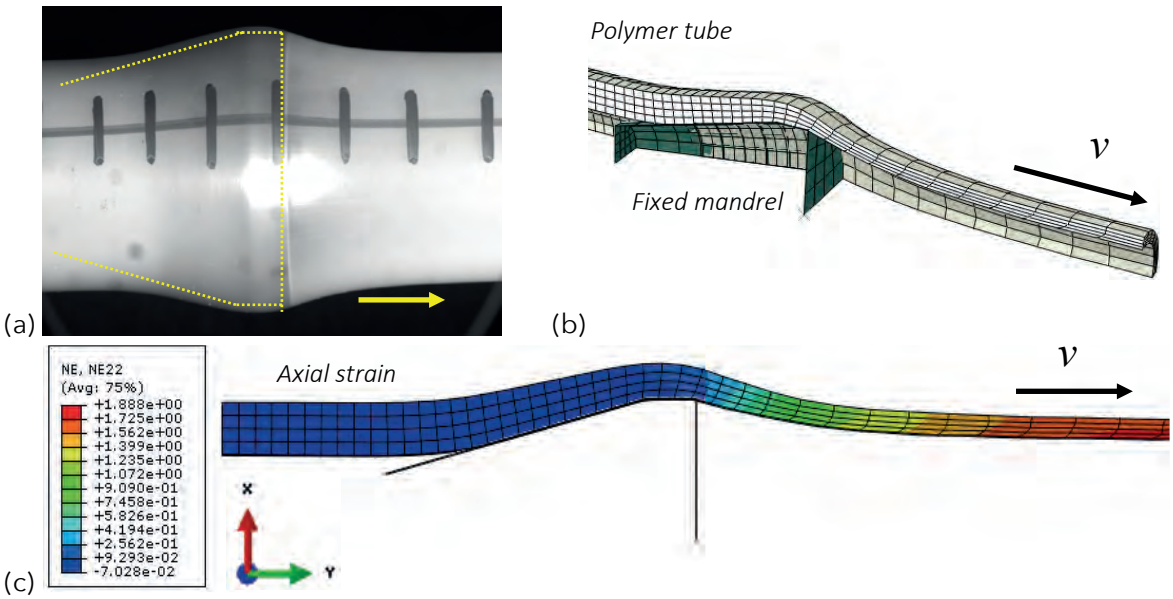

Figure 1: (a) Solid-phase tube-drawing of PP over a fixed mandrel to produce oriented product with enhanced properties, and the associated Finite Element prediction of (c) deformed geometry and (c) axial draw ratio within the material.

W10 Multicomponent Fiber Processing for Novel Applications

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In the polymer processing, control of the shape of products as well as control of the high order structure in the products is crucial. In this presentation, utilization of multi-component fiber spinning for the better controllability of shape and high order structure will be discussed. Optical functionality can be introduced to the polymer products through the control of refractive index and its anisotropy. Interference colored fiber was developed by incorporating the alternating multi-layered structure of two polymers into fiber cross-section. We have tried to produce the RPF (reflective polarizing film) by embedding the aligned bicomponent fibers with controlled refractive index anisotropy in the UV cure resin. In this case, good controllability of molecular orientation of sheath and core components in the high-speed melt spinning process was utilized. Control of molecular orientation also leads to the development of fibers with unique thermal-mechanical characteristics. Highly crimped fibers were produced through the melt spinning of side-by-side bicomponent fibers consisting of virgin and recycled-modified poly(ethylene terephthalate). Mutual interaction of two components for the structure development behavior in the melt spinning process was utilized to fabricate sheath-core bicomponent fibers consisting of polyethylene and polypropylene. The fiber, which have a unique characteristics of spontaneous elongation upon annealing, is now widely applied for the production of non-woven fabrics of soft touch. All thermoplastic fiber-reinforced composites can be prepared through the compression molding of sheath-core bicomponent fibers consisting of high melting temperature core and low melting temperature sheath components. Since the compression molding of bicomponent fiber is possible if the sheath part is consisting of a crystalline polymer in an amorphous state, fiber-reinforced single-polymer composite was prepared through the compression molding of sheath-core bicomponent fibers consisting of low and high molecular weight PET.

Keywords: bicomponent spinning, optical functionality, thermoplastic composites.

W11 Determination of material distributions in drug delivery systems

Jiwen Zhang[1], Peter York[2], Xianzhen Yin[1,2], Qun Shao[2], and Tiqiao Xiao[3]
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The determination of material distributions in a drug delivery system (DDS) is a challenge to pharmaceutical analysis since conventional analyses are not space/structure relevant. For any internal architecture of DDS, material distributions are highly complex at varied scales. Three-dimension (3D) characterization of material distribution in DDS, especially in situ detection is very much of interest to material science and drug delivery applications.

Synchrotron is a powerful tool for characterization of internal structure of pharmaceutical particles as well as sub-unit distribution in DDS. Synchrotron radiation micro-computed tomography (SR-μCT) has been tried in many dosage forms and uncovered insights structural features that are unavailable by conventional imaging methods.

As it is well demonstrated that the SR-μCT enables to characterize the structure layers and subunit distribution within DDS, an innovative combination of SR-μCT with chemically quantitative determination methods like High Performance Liquid Chromatography (HPLC) or High Performance Liquid Chromatography-Tandem Mass Spectrometry (HPLC-MS/MS), the material composition of each structure layer were determined via structure guided micro-sampling to obtain the material distribution within the single tablet. The dynamic structural changes and the cumulative release of the drug in the dissolution process were structurally correlated.

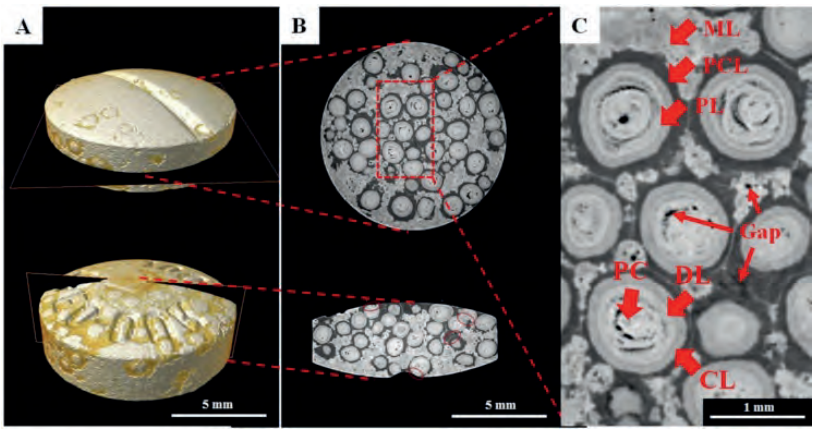

Fig 1 Structure layers in a tablet

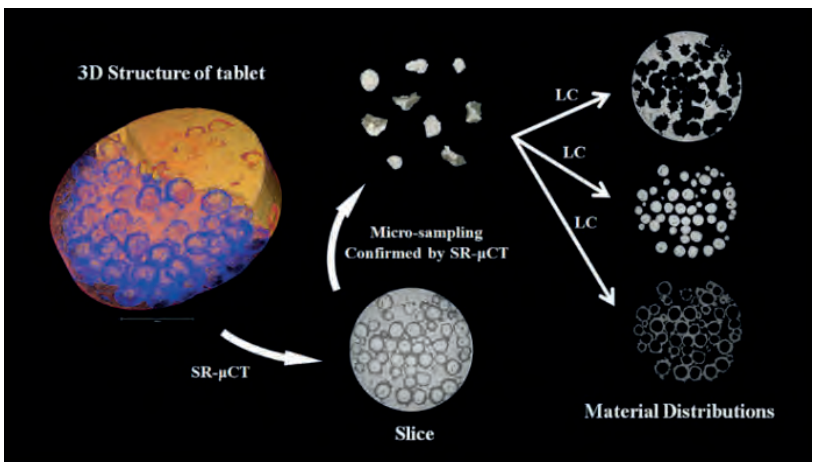

Fig 2 Determination of material distributions in tablet

Reference:
Zhang L, Wu L, Wang C, Zhang G, Yu L, Li H, Maharjan A, Tang Y, He D, York P, Sun H, Yin X, Zhang J, Sun L. Synchrotron radiation micro-computed tomography-guided chromatographic analysis displays the material distribution in tablets [J]. Analytical Chemistry, 2018, 90 (5): 3238-3244.

W12 Exploiting shape memory properties of polymers in the development of drug eluting soft tissue fixation devices.

Karthik Nair[1], Tony Herbert[2], Ben Whiteside[1], Maria Katsikogianni[1], Dimitrios Vgenopoulos[1], Ken Howell[1], Glen Thompson[1], Farshid Sefat, Tom Swift & Phil Coates[1]

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INTRODUCTION

New drug delivery systems form one of the fastest growing health care sectors and these technologies also help the life cycle of a drug when its patent expires. In this study we develop new manufacturing techniques for drug eluting thermosensitive shape memory sutures using the micro- die drawing process. We discuss the ability to impart shape memory properties to a range of medical grade polymers, particularly bio resorbable copolymers of polylactide and polyglycolide. The key to the shape memory technology lies in the orientation of the polymer molecules using solid phase deformation processes such as die drawing (Li *et al*, 2016). These multifunctional oriented sutures possess excellent mechanical properties and self-tighten at the incision site at body temperature whilst releasing drug to enhance wound healing. However, control of shape memory activation temperatures within a range acceptable in the body is critical and this can be achieved by lowering the T*g* of the polymers using additives and control of the polymer composition. We have explored a range of additives such as curcumin, silver, lidocaine, triclosan and ibuprofen to the PLA based co polymer to get additional benefits of antibacterial effects and pain relief. Furthermore these shape memory devices are then characterised for its mechanical properties, drug delivery, *in-vitro* degradation, biocompatibility and shape memory properties.

MATERIALS AND METHODS

PDLGA (85% D,L-lactide-co-15% glycide; Tg~47C) was extruded with different ratios of additives and was then die drawn into 0.5mm sutures. Size, morphology were evaluated using SEM, mechanical strength and constrained recovery force (self-tightening) measurements were carried out using a customised tensile testing rig machine. DSC/XRD was performed to understand how the drug loading has affected the polymer crystallinity and to measure the drop in T*g* to get body temperature reversion. GPC and DOSY NMR was utilized to evaluate the polymer MW and to measure extent of degradation during the extrusion and die drawing process. *In vitro* biomechanical and drug release from sutures were also carried out and measured using HPLC.

RESULTS AND DISCUSSION

Die drawn PDLGA sutures showed high degree of molecular orientation and were able to revert at body temperature. The addition of actives, especially curcumin and triclosan, increased the recovery forces without negatively affecting the tensile strength. The antimicrobial efficacy testing showed that 1% triclosan was enough to inhibit the bacterial growth, through release in the case of *S.aureus* and by contact in the case of *E.coli*.

CONCLUSIONS

This study demonstrates great promise towards the manufacturability of multi-functional sutures that can promote wound healing, reduce pain locally and minimise the risks of infection.

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ACKNOWLEDGEMENT

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W13 Destabilization of polyacrylic acid gel by counter ion replacement

Mukesh Bansiwal, Sudhir Pagire, Sachin Korde, Yulia Ryabenkova,ǁNazira Karodia, Elaine Brown, Maha Nasr and Anant Paradkar

We demonstrate destabilisation of drug-excipient ionic liquid (IL) (ibuprofen-diisopropanolamine) by another excipient Carbopol, an acrylic acid based gelling agent via counter-ion replacement. ATR-FTIR was used for in-situ tracking of this replacement. Skin deposition and permeation data of ibuprofen from the IL drug formulated as gel explains significance of tailoring the task based drug-excipient IL for achieving desired drug penetration. This understanding has significant therapeutic and regulatory impact as these excipients are widely used in pharmaceutical, nutraceutical and personal care products

W14 Enhanced bioavailability of Curcumin loaded nano-hydroxyapatite injectable paste

Niten Jadav, Yulia Ryabenkova, Marco Conte, Gentile Piergiogio*, Phil Coates, Pete Twig and Anant Paradkar
Pharmaceutical Engineering Sciences/ Polymer IRC, University of Braford, UK
*Newcastle University, UK

Abstract: In the present study we synthesise a set of stable injectable ternary pastes of hydroxyapatite (HA), curcumin (CUR) and solutol (Sol). The scope is to use curcumin, a natural polyphenolic compound with wide window of therapeutic activity like antioxidant, anti-inflammatory, anticancer and antimicrobial, to enhance the clinical performance of bone treatments. We prepared 10%, 15% and 20%wt of CUR/HA paste by adding solutol as a solubiliser. Particle morphology, stability of paste and interactions of their components were evaluated using TEM, P-XRD, TGA and FTIR. DFT calculations were performed to evaluate the possible interaction between HA, CUR and Sol in the paste and determine its implications on the release profile of curcumin. Dissolution properties of curcumin in HA/Sol/CUR pastes were evaluated and they display a decrease in drug release of about 40-50% in first 60 minutes, which we ascribe to the formation of a stable CUR/HA complex. The rheological properties of the final paste revealed non-Newtonian shear-thinning behaviour. Biocompatibility for all the paste samples were studied against the raw materials and it was suggested that antitumor activity of curcumin-based pastes displayed reduction in the cell proliferation based on the concentration of curcumin in the paste. In fact, higher concentrations of curcumin at 15% and 20%wt in HA/Sol/CUR pastes displayed significant inhibitory effect on cell proliferation. Thus, this injectable paste complex of nano-HA and curcumin gained significant potential in the treatment of osteosarcoma, malignant bone cancer associated with locally aggressive growth and metastatic potential.

W15 Multi-functional Materials for the Manufacture of Antimicrobial Medical Devices

Paul Hatton (MeDe Innovation and the School of Clinical Dentistry, University of Sheffield, UK)

Deep bone and related device-associated infections are a serious and growing challenge in orthopaedic, craniofacial, and dental surgery. In general, biomaterials used in bone tissue regeneration do not provide antimicrobial properties – indeed they frequently provide a favourable surface for biofilm formation – and antibiotics remain the primary means of treating deep bone infection. Researchers at Sheffield, sometimes working in collaboration with external groups including in China, have developed and/or evaluated a range of manufacturing methods to introduce antimicrobial properties to medical devices. These include modifications to the design of bioactive glasses, fabrication of inorganically-modified nanoscale calcium phosphates, and incorporation of functional antibiotics into the surfaces of a range of common biomaterials. The aim of this paper is to review the progress made in each area, and determine

which of these approaches offers the best opportunities to suppress the growth of pathogenic bacteria, and therefore find application in the manufacture of a new generation of antimicrobial devices.
The EPSRC are acknowledged for funding through MeDe Innovation. Numerous colleagues have been involved in this research including Dr Cheryl Miller, Dr Aileen Crawford, Dr Graham Stafford, Dr Ilida Ortega, Dr Piergiorgio Gentile, and Dr Tom Paterson.

W16 Orthopaedic compression screws formed from body-temperature reverting, shape-memory polymers

Thomson Brian*, Nair Karthik, Thomas Lee, Howell Ken, Thompson Glen, Barker Dave and Coates Phil
Bradford University, UK

Orthopaedic compression screws promote fracture-repair by drawing-together and stabilising adjacent bone fragments. Shape memory polymers (SMP) are smart materials that switch from one macroscopic shape to another following the application of an external 'triggering' stimulus (e.g. by heating above Tg). SMP orthopaedic compression screws that shorten in length following surgical implantation (i.e. SMP devices that display body temperature reversion) could potentially pull bone fragments together and thereby facilitate fracture healing. Unfortunately, whilst standard biocompatible, bioresorbable polymers (e.g. polylactides) can show shape memory properties, their triggering temperatures are too high for routine clinical use.

We have made a body-temperature reverting SMP by blending the biocompatible, bioresorbable polymer polylactic acid (Purasorb 7038; PLDLA) with the plasticiser tributyl O-acetylcitrate (3.5% v/w; TAC). Shape memory devices made from this plasticised material are dimensionally stable when stored dry at room temperature (22°C) but show shape memory reversion when incubated under physiological conditions (saline at 37°C).

Prototype SMP orthopaedic compression screws were designed, based upon existing metal implants and knowledge of the orthopaedic market. To produce SMP orthopaedic compression screws from PLDLA-TAC, isotropic rods (5mm OD) were prepared from PLDLA and TAC using an Xplore Pharma Melt Extruder, a pelletizer and a Dr Collins single screw extruder with a 6 mm die. These isotropic rods were die-drawn through a 2.5 mm die using a custom made drawing rig (speed 50 mm/s; temperature 60˚C) to produce 2.5 mm PLDLA-TAC rods with shape memory properties.
The die drawn cylindrical PLDLA-TAC SMP rods were then moulded into screws with zonal shape memory properties using a two component mould. The first portion of the mould produced the cylindrical, shape memory shaft of the screw. This mould component was 3D printed from aluminium (Shapeways) and consisted of a refrigerated cylinder (2.5 mm internal diameter) that maintained an internal temperature of 6 - 10˚C, thereby holding the PLDLA-TAC SMP rod below its Tg and preventing it from reverting. The second portion of the mould produced highly localised and controlled heating which melted a portion of the PLDLA-TAC SMP rod, (removing its shape memory properties), but forming the thread. The heated portion of the mould was 3D printed from brass in order to obtain a more precise profile (Shapeway). Its temperature cycle (between 22˚C and 165˚C) was controlled on a 50 millisecond feedback loop using 8 x 100W cartridge heaters (Omega), a computer controlled cooling water valve (West Group), 4 x thermocouples and a Velleman 8055 input / output board.

The resulting experimental PLDLA-TAC SMP components consisted of a single 53 mm long piece of plastic with a 12 mm non-shape memory threaded region and a 41 mm shape memory, cylindrical 'shaft' region. When stored dry at room temperature these components remained dimensionally stable for 5 weeks. However, when incubated in saline at 37°C for 3 days, the shafts reverted (showing a 71% reduction in length) whilst the threaded region showed only an 11% reduction in length.
Future work will further investigate the biomechanical properties of these components.

W17 Mechanical Assessment and Preclinical Development of Shape Memory Sutures: A MeDe Innovation Collaboration

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Shape memory sutures (produced by die-drawing) offer a novel approach to wound treatment, delivering bioresorbable materials capable of "self-tightening" and wound closure when activated with heat such as body temperature. A successful ongoing collaboration in this area has been formed between the Universities of Leeds and Bradford, facilitated through the EPSRC Centre for Innovative Manufacturing in Medical Devices (MeDe Innovation). This talk discusses some of that work, in particular the mechanical assessment and preclinical development of a number of suture variants. These include plain PDLGA and PDLGA with the following quantities of additives; 1% Ag (known to have anti-microbial properties), 10% curcumin (known to have antioxidant properties), 10% Lidocaine (an anaesthetic), 5% PEO, 1% triclosan (known to have anti-bacterial properties).

Drawn (0.5mm diameter) and undrawn (1mm diameter) sutures were subjected to tensile testing to determine the effects of the die-drawing process on their material properties. In all but one case, tensile strength, Young's modulus and extensibility were found to have significantly improved following die-drawing. The recovery forces and stresses (a measure of self-tightening) of die-drawn sutures were measured in a water bath at three different temperatures; 60, 47 and 37 degrees Celsius (figure 1). Recovery response was found to be additive and temperature dependent with curcumin generating the most forces/stresses. In-vitro preclinical assessment is currently underway, however preliminary proof of concept studies have been very successful. Following loose suturing of porcine skin flaps with 10% curcumin and 1% Ag materials and submersion in PBS at 37 degrees Celsius for 24 hours, sutures were found to have self-tightened and completely closed the wound sites (figure 2).

The mechanical response of shape memory sutures has been found to be temperature and additive dependent, allowing for tuning to different requirements. In-vitro preclinical studies are currently underway but have been highly encouraging to date, demonstrating proof of concept.

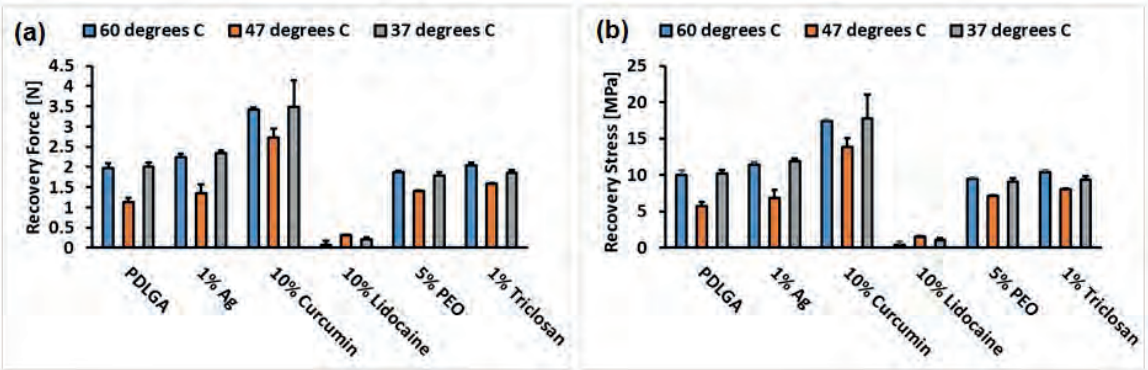

Figure 1. (a) Recovery force and (b) recovery stress measured for shape memory sutures at 60, 47 and 37C

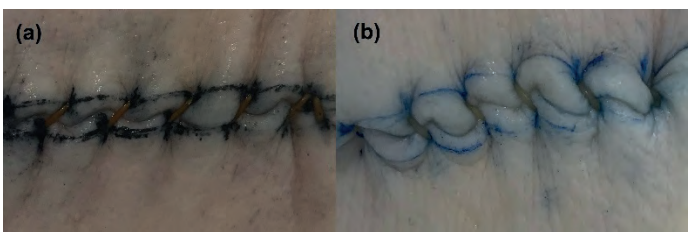

Figure 2. (a) PDLGA+10% curcumin and (b) PDLGA+1%Ag sutures in porcine skin following 24 hours submersion in PBS at 37C.

W18 Material Characterisation of Tubular Electrospun PCL and PLGA for Vascular Tissue Engineering

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Introduction

Electrospinning has recently emerged as a leading technique for generating biometric scaffolds fabricated of synthetic and natural polymers for tissue engineering applications. Electrospinning allows the integration of various biomaterials to be effectively tailored to create constructs that provide the essential characteristics. Fabricating vascular grafts aims to regenerate and mimic the extracellular matrix structure abundant in the walls of the inherent vessels. Prior to implantation, the investigation of scaffold characteristics such as degradation and solid surface tension are vital in ensuring appropriate and effective function.

Materials and Methods

Polycaprolactone (PCL) and Poly (lactic co-glycolic acid) (PLGA) 85:15 are biopolymers that were selected for this investigation due to their outstanding properties such as biocompatibility, degradability and cost effectiveness. For this project, a total of six scaffolds were fabricated of which three were of PCL 15% (W/V) and three PLGA 10% (W/V). Spin time varied with periods of 30, 60 and 90 minutes. Once fabricated, the scaffolds were cut and weighted prior to the initiation of the 12-week experiment. The degradability was assessed via scaffold weight-loss and the change in fibre diameter. Scaffold topography was evaluated using scanning electron microscopy (SEM) which, highlighted the morphology, structure and physical characteristics including fibre diameter occurring over the 12-week period. Furthermore, the wettability of the scaffold was determined using various solutions alongside scaffold handling were examined. Additionally, this experiment also looked at scaffold behaviour under controlled conditions thus, the fabricated constructs were exposed to a controlled temperature of 37°C for a duration of four weeks. Again, six scaffolds were removed weekly to be assessed under the SEM to assess the degradation.

Results & Discussion

Overall both PCL and PLGA scaffolds displayed exceptional fibre structure and excellent degradability over the course of the experiment. The fibre diameter gradually increased thus, exemplifying gradual degradation. The percentage weight-loss of the scaffold increased and so, indicated the degradability of the scaffold. Although, both PCL and PLGA degraded, the results represented significant degradation in PLGA compared to PCL. As expected, this was also significant in the scaffolds observed under controlled conditions.

Conclusion

The conclusions drawn from this project are that both PCL and PLGA coupled with the correct testing provide great promise for future endeavours within vascular tissue engineering. However, for future work we are aiming to fabricate more complex architecture including coaxial electrospinning to provide a better scaffold for vascular tissue engineering.

W19 EfferShield technology Innovative approach for manufacturing of effervescent product

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Recently, co-crystals have been emerged as a new form of modification to tailor the physicochemical properties of the crystalline active pharmaceutical ingredients (Jones et al., 2006). Co-crystal is a multicomponent crystalline entity, which contains at least two molecular or ionic components, whichare held together in the same crystalline lattice either by hydrogen bonds, halogen bands or π-π interactions.

Co-crystals have already been proven its potential applications in improving drug dissolution rate and bioavailability, tailor mechanical properties, tune colour and taste of molecules well as improvement of photo-stability. Here, we have demonstrated for the first time co-crystal as a means of improving the stability of the pharmaceutical/nutraceutical effervescent formulations during their manufacturing and storage period. In particular, we have generated a non-hygroscopic co-crystal of acidic agent of the effervescent formulation to address the hygro-thermal control challenges during manufacturing and storage of effervescent formulations. In addition, we have studied the crystallographic features responsible for the improved stability of effervescent formulations. Also this is the first attempt where co-crystallisation of the formulation excipient was focused rather than the drug co-crystal to achieve/improve the formulation stability.

Med Tech 3

W20 Highly branched poly(N-*iso*propyl acrylamide) responsive to fungi

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Fungal diseases are a growing problem in the tropics and can be fatal for patients with supressed immune systems. Treatment often requires the use of relatively toxic drugs such as amphotericin B. Therefore, increasing the efficacy of this and similar drugs addresses a significant need. On the otherhand detection of fungal infections and differentiation from bacteria is a key goal in the fight against antimicrobial resistance. Here we describe a branched polymer with amphotericin end groups. We show how the polymer binds to its usual target, ergosterol, and retains antifungal activity. The polymer responds to the binding of the target by desolvation of polymer chain segments and we report early indications of increased activity against some strains of fungi. The MIC against two strains of *Candid albicans* were 1.23 (SC5314) and 1.0 (ATCC90028) μmol of amphotericin mL^{-1} compared to MICs against the same strains of 0.48 amd 4.76 μmol of amphotericin mL^{-1} for amphotericin B not attached to the polymer. The action of the polymer against fungi is in contrast to our previously reported work on similar polymers, which respond to bacteria (by desolvation) but did not kill the organisms. We tentatively propose that the maintenance of the efficacy is associated with increasing local concentration of the amphotercin ligands and the potential for the desolvated globule to disrupt the cell membrane. Importantly the polymer showed no toxic effects to corneal epithelial cells even at concentrations as high as 5 mg ml^{-1}. In contrast amphotericin B was toxic at and above 10 μg ml^{-1}.

Improved and faster diagnosis can inform treatment and negate strategies such as polypharmacy.

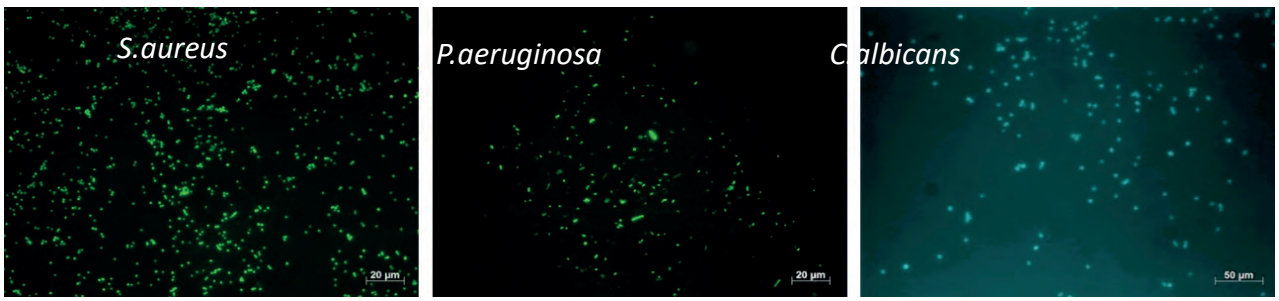

Figure 1 Bacteria and fungi attached to hydrogel functionalzed with H-PNIPAM carrying ligands each class of organism

We have, therefore, developed a diagnostic device that carries three HB-PNIPAM polymers functionalized with ligands for Gram-negative, Gram-positive or fungal infections. Each of these polymers is attached to a methacrylic hydrogel membrane. These three classes of organism can then be attached the membrane as shown in Figure 1. Importantly in this immobilized format the amphotericin HB-PNIPAM does not kill fungi. The device has been sown to be effective for sampling infections in *in vivo*.

W21 Hemosome formed by protein−polymer conjugate assembly as oxygen carrier for cancer therapy

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Nanocarriers based on nature's biomaterials such as peptides and proteins have shown great advantages in the field of nanomedicine such as inherent biocompatibility, biodegradability and immunogenicity. However, the complicated preparation and additional denaturation of protein may limit their further uses. Herein, a novel protein - nanoparticle drug delivery system was prepared based on the self-aggregated property of proteins in the state of isoelectric point with mild reaction conditions, simple preparation method and good biocompatibility. In this study, albumin and hemoglobin was chosen as model protein for the preparation of empty and drug-loaded nanoparticles, and did not denaturation or inactivation in the process of preparation. The protein particles are stable in physiological buffers and could release their therapeutic payload quickly into cancer cells after a time dependent cellular uptake owing to the PH sensitive of Schiff base crosslinked bond. Furthermore, as a function of protein, the ability of transport oxygen of hemoglobin can enhanced antitumor activity of photosensitizer compared with that of free photosensitizer in vitro. This new approach for protein particle preparation are applicable to variety proteins with not denaturation or inactivation had great potential as a drug delivery for cancer therapy.

W22 Using smart scaffolds to promote stem cell homing and tissue for *in situ* repair of cartilage lesions caused by trauma and early osteoarthritis

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Introduction: Osteoarthritis (OA) is a major concern for aging populations throughout the world. It is a major cause of functional disability in older adults and has an appreciable economic impact on health and social care systems (1-2% of GDP in industrialized countries. OA is a complex global disease characterized by progressive articular cartilage degeneration. It causes painful stiff joints, joint deformity and loss of joint mobility which can have a substantial impact on quality of life. Typically, the knee and hip joints, spine and fingers are affected. Due to its progressive nature and disabling impact, OA has a high economic burden on health and social care systems of 1-2% GDP.

Currently, there is no cure for OA and ultimately, replacement of the affected joint by a prosthetic one may be required to eliminate pain and restore joint mobility, particularly in weight bearing joints such as the knee and hip joints. While very successful, joint prostheses have a finite working life and do not have the full range of natural movement. More importantly, device failure, due to loosening, is a longer-term problem requiring further invasive surgery. We are developing a biomimetic, scaffolds for regeneration of articular cartilage and the technology can be customised for ligament/tendon and bone regeneration. The scaffolds are designed to induced homing of stem cells into the scaffold and promote cell retention and subsequent tissue regeneration. Our scaffold is bio-functionalised in a similar conformational and biochemical context to native articular cartilage.

Methods: Poly-L-lactic acid (PLLA) was used as an example scaffold. The PLLA was electrospun into random-fibre scaffolds (median fibre diameter 4.2 μm) and surface -modified using cold plasma polymerisation. The surface-modified scaffolds were treated with glycosaminoglycans and ng amounts of chondrogenic and stem-cell homing factors. The bio-functionalized PLLA was assessed *in vitro* for ability to support long-term

cell viability (5 weeks) and chondrogenesis by bone-marrow and synovial fluid mesenchymal stem cells (MSCs) and primary chondrocytes in absence of other added growth factors or FCS. The bio-functionalised scaffolds were also assessed for i*n vivo* activity by implantation into surgically-created chondral lesions in the medial condyles of sheep. Microfracture was used to release MSCs on implantation of the scaffold.

Results: In vitro, scaffolds bio-functionalised with a combination of of stem-cell migratory and chondrogenic factors promoted MSC attachment and ingress throughout the implant, and chondrogenic differentiation. Cell viability and differentiation was maintained in the absence of added chondrogenic factors or serum for at least 5-6 weeks. *In vivo* implantation, the functionalised scaffolds showed biological efficacy with regeneration of neo-cartilage with hyaline features occurring at 4 weeks with the bio-functionalised scaffold but not in the empty defects or control non-functionalised scaffolds which showed fibrous tissue formation only.

W23 Sustainable development of polymer materials: stability and degradability as well as utilization of solar energy and renewable resources

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To develop polymer materials sustainably, resources saving and environment friendly as well as the utilization of solar energy and renewable resources have been addressed much attentions and they are becoming important issues. Resource saving includes recycling/reusing materials and extending service life of materials, which is closely related to stability and degradability of materials. Accordingly, recent years, we have focused on the study of aging and anti-aging of polymer materials[e.g., Aging life prediction system of polymer outdoors constructed by ANN. 1. Lifetime prediction for polycarbonate, Polymer Degradation and Stability, 2014, 105, 218-236], the study of new environment friendly polymer materials[e.g., Macromolecular chain structure design, synthesis and analysis of poly(*L*-lactide) linking ultraviolet absorbing groups, RSC Advances, 2014, 4, 63118-63127], and the study of polymer materials with function of visible light-induced catalysis[e.g., Dramatic enhancement of visible light photocatalysis due to strong interaction between TiO_2 and end-group functionalized P3HT, Applied Catalysis B, Environmental, 2015, 174-175, 193-202]. As examples, herein, we report some research results in these three aspects. Figure1 shows that, after exposing outdoor for certain time, the polycarbonate behaves as a variation in appearance, a reduction in transmittance and degradation in macromolecular chains, partly revealing the law of change of the polymer and giving the basis for extending service life of the polymer materials. Figure2 shows the improved uv stability of designed new poly(*L*-latic acid)(PLA). Introducing uv-absorb group onto the polymer chains can slow uv degradation of PLA. This research provides a new idea for developing environment friendly polymer materials with new function and high performance. Figure3 demonstrates that the polymers with conjugated structure can play a role of using solar energy, not only making energy saving but also treating harmful pollutants.

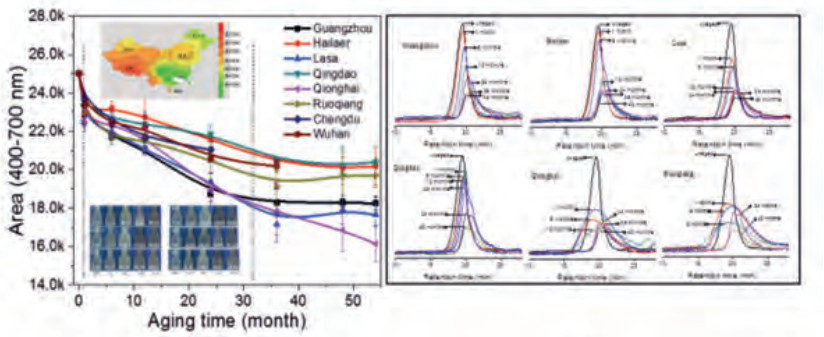

Figure1 Variation of (a) transmittance as well as appearance and (b)molecular weight distribution of polycarbonate materials vs. exposing time at different areas with different climate

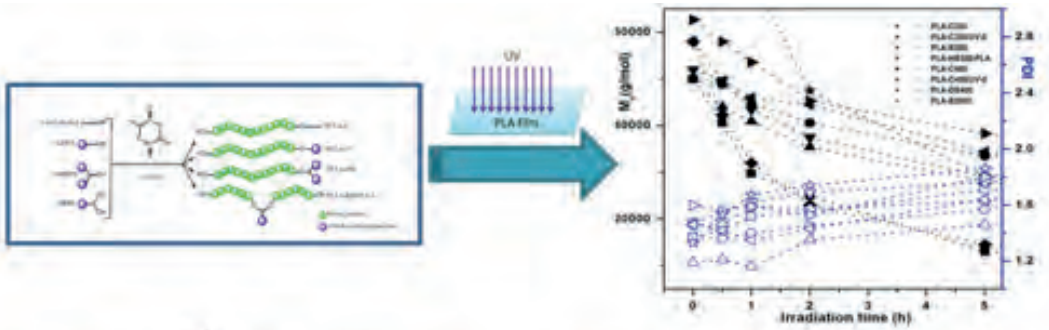

Figure2 (a)Structure of designed new poly(*L*-latic acid) (PLA) and (b) molecular weight and its PDI of the PLA after irradiated under UV light for different hours

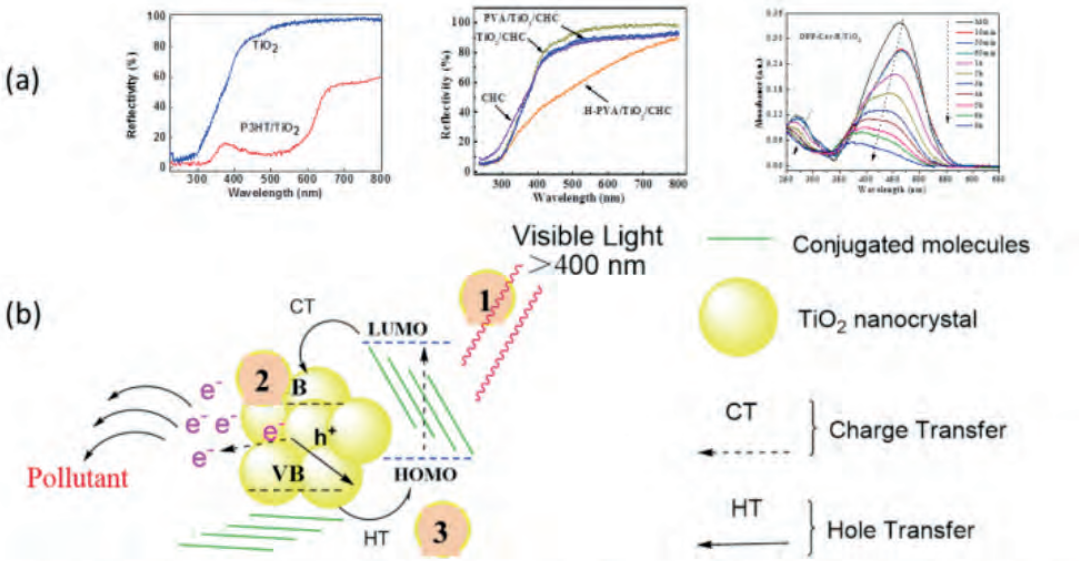

Figure3 (a)Reflective/absorb characteristics of polymer materials with conjugated structure and (b)schematic process for treating pollutant under visible light irradiation

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W24 Harnessing nano-patterning and incorporation of antimicrobials to manufacture orthopaedic trauma implants that resist microbial colonisation

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Introduction: More than 2 million people/year in the UK suffer a bone fracture that is addressed primarily using metal implants. Such implants facilitate microbial colonisation which can lead to medical device associated infections. Antimicrobial strategies supplemental to systemically administered antibiotics can involve modification of the medical device biomaterial surface rendering it less amenable to colonisation. In this respect, the aim of this study was to evaluate the engineering of biomaterial surfaces at the nanoscale, with or without the addition of antimicrobials, for the preparation of orthopaedic trauma implants that prevent microbial colonisation.

Materials and Methods: VICTREX® PEEK 150G, without reinforcement, and 30% glass fibre reinforced; and PEEK 150GL30, were micro-injection moulded using a Wittman Battenfeld Micropower 15 moulding system and flat or nanostructured mould inserts. In parallel 1% and 10% (w/w) triclosan impregnated polydimethysiloxane (PDMS) was compression moulded on a flat or nanostructured mould. The moulded structures were assessed in terms of geometric uniformity using surface measurement techniques including Confocal Laser Scanning Microscopy (CLSM) and an Asylum Atomic Force Microscopy (AFM). The mechanical properties of the moulded components were measured using a Hysitron nanoindentation system. Contact Angle Measurements (CAM) determined the materials' surface energy. The non-fouling and antimicrobial performance of the moulded components was assessed (microscopically and by culture) against bacterial adhesion and subsequent biofilm formation of Gram-positive and Gram-negative bacteria.
Results and Discussion: Geometric characterisation of the moulded PEEK surfaces showed excellent replication of the mould inserts at the nanoscale. The mechanical properties of glass reinforced PEEK matched those of cortical bone and this was not affected by the presence of nano-structuring. CAM showed higher wettability of the structured surfaces in comparison to the flat ones. In terms of antimicrobial performance, flat surfaces retained more bacteria, while structured surfaces were inhibitory to bacterial adhesion and biofilm formation. In the case of PDMS, mechanical characterisation showed that increasing amounts of triclosan significantly reduced the Young's modulus of the samples and the quality of pattern replication. Of note was that 1% triclosan killed all tested bacteria on both flat and patterned surfaces within 1 h. In the case of PDMS without triclosan, patterned surfaces reduced bacterial adhesion and viability. Reproducible pattern replication was important for ensuring enhancement of the antimicrobial activity of triclosan-impregnated PMDS. This combined physical and chemical strategy provides a novel approach to generating non-fouling properties to medical device biomaterials.

Acknowledgments: Professor Peter Giannoudis is acknowledged for valuable discussions in the area of orthopaedic implant associated infections. This work was funded by MeDe Innovation, the EPSRC Centre for Innovative Manufacturing in Medical Devices, under a "Fresh Ideas" Feasibility Study Funding Award.

W25 Bio-inspired Anti-oxidant Defence System Constructed By Electrospun F127-based Fibers

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Cells were continuously exposed to oxidative damage by overproduction of reactive oxygen species (ROS) when they contacted implanted biomaterials. The strategy to prevent cells from oxidative injures remains challenge.[1] Inspired by the antioxidant defence system of cells, we constructed a biocompatible and ROS-responsive architecture on the substrate of elastomer. We demonstrated that the stable and hydrophilic architecture was constructed by phase separation of polymer components and crosslinking between polymer chains during electrospinning; the ROS-responsive fibers controlled the release of antioxidants to reduce the oxidative damage to cells. The bio-inspired architecture not only reduced mechanical and oxidative damage to cells but maintained normal ROS level for physiological hemostasis.[2]

Keywords: anti-oxidant defence system, reactive oxygen species, electrospinning

Acknowledgements
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W26 Chain Structure design, synthesis and applications of polyvinyl alcohol

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Polyvinyl alcohol (PVA), one of the most important water-soluble polymers, is widely used in a wide range of industrial areas including water-based paints, paper making, adhesives and surfactants. Since these applications are highly related to its melt or solution properties, design and well-control of PVA backbone architectures by introducing block, crosslink and especially branch architecture may hold promise as an efficient strategy for tuning its physico-chemical properties and developing new material with expanding applications. Thus, a series of synthetic methodologies for PVA with well-defined chain architectures have been developed in our group recently. Consequently, chain structure, molecular aggregation structure and physico-chemical property relationships in PVA were revealed, and novel functional materials based on PVA were developed. [1-3]

Combining self-condensing vinyl polymerization (SCVP) with "living"/controlled radical polymerization (CRP), PVA with well-defined branch architectures were achieved by selective alcoholysis of PVAc with the corresponding branch structures. To avoid the cleavage of the branches in the PVAc precursor during converting PVAc to PVA by alcoholysis, either inimer with strong linker (N-allyl-(2-ethyl xanthate) propionic amide, NAPA) or vinyl ester with an easy-to-remove chloroacetyl pending group (vinyl chloroacetate, VClAc) were employed as comonomers for preparing the PVAc precursor with designed branch architecture. Meanwhile, by the introduction of a monofunctional chain transfer agent (l-CTA) as a co-CTA to tune the copolymerization of vinyl ester and inimer, simultaneous control of molecular weight and branched architectures during SCVP-CRP was achieved.

Although controlled radical polymerization will offer good chain architectural control, it suffers from the drawback that an inimer containing the desired CTA moiety often needs to be synthesized by complex multistep process, thus it is of great exploring value to develop robust synthetic methods that can produce branched PVA using commercially available inimers. Thus, a facile and robust approach based on a commercially available inimer to synthesize branched PVA via redox-initiated self-condensing vinyl copolymerization (redox-SCVP) were developed, and the development and evolution of branch structures during the polymerization were revealed. This novel methodology involves only commercially available monomers and conventional radical polymerization and so offers promising future for preparing branched PVA at large scale and low cost.

Influence of chain structures, including branch architecture, comonomer content, and VAc unit sequence distribution in PVA chain on its molecular aggregate states, as well as melt and solution properties was systematically investigated. Furthermore, functional materials such PVA-based surfactants and porous PVA-monolith were developed.

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W27 Development of Universal (Viscometric) Size Exclusion Chromatography Calibrated by DOSY NMR

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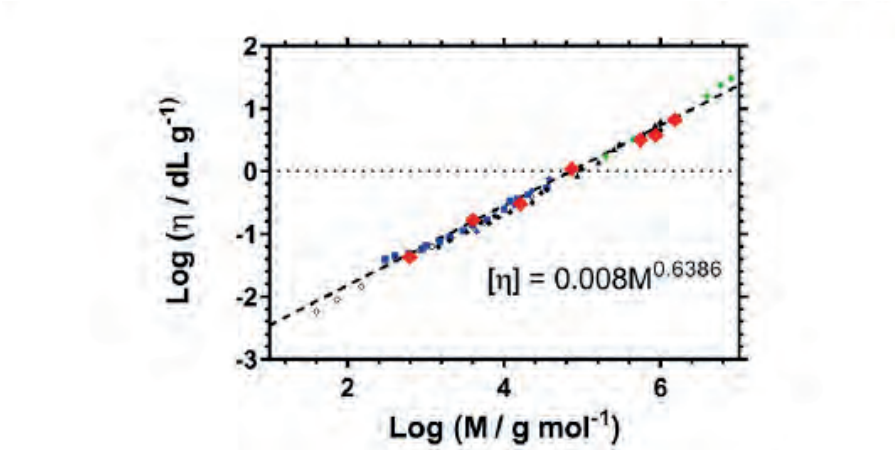
Polymers physical properties are dominated by size. Smaller polymers are often called 'oligomers'. Most solutions are subject to 'dispersity' where there are a distribution of chains of different sizes.
Synthetic polymer chemists have been working on new, improved, polymerisation synthesis methods to reduce Đ for decades.
Viscometric size Exclusion Chromatography (SEC) is one of the most efficient ways to measure the molar mass distribution, however the technique is limited for columns / solvents that cause adsorption onto / from the stationary phase.
We have developed a means of using DOSY NMR to predict the intrinsic viscosity of polymers in solution, widening the available solvent / columns choices for universal SEC and improving polymer characterisation options.

DOSY determined intrinsic viscosities (red) compared to literature values from light scattering and viscometric direct measurements.



	K	Alpha	R^2
DOSY	0.0008	0.64	0.995
Armstrong	0.0004	0.68	0.995
Kawaguchi	0.0006	0.66	0.989
Woodley	0.0001	0.80	0.996
Amu	0.0001	0.90	0.996
Kirincic	0.0012	0.59	0.985
Fabula	0.0001	0.78	0.999

W28 Cyclic Trimeric Phosphaze Base as Catalyst for ROP of Cyclic Esters

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Synthesis of biodegradable aliphatic polyesters via metal-free catalyzed ring-opening polymerization of cyclic esters is of great importance to their applications in biomedical and microelectronic fields, and is therefore becoming the most appealing research topic in polyester synthesis. As a category of organic

superbases, phosphazene exhibits good biocompatibility and considerably high catalytic activity in ring-opening polymerization of cyclic esters. The catalytic performances of phosphazene catalysts highly depend on their structure and basicity. However, the application of phosphazene catalysts is limited due to the lack of structural diversity and successive basicity. Therefore, it is of great urgency and necessity to design and develop novel phosphazene catalysts.

From the point of view of catalyst design, we proposed a series of novel phosphazene catalysts. Herein, a new superbase, cyclic trimeric phosphazene base (CTPB), was prepared with high yield and purity. In the presence of alcohol, the CTPB can serve as highly efficient organocatalyst for ring-opening polymerization (ROP) of "non-polymerizable" γ-butyrolactone to offer well-defined poly(γ-butyrolactone) with high conversions (up to 98%) at -60 °C. The produced polymers have high molecular weights (up to 22.9 kg•mol-1) and low polydensity distributions (1.27-1.50). NMR analysis of initiation process and the structural analysis of resulted polymers by MALDI-TOF suggest an activating initiator mechanism.

The preparation of block copolymers containing poly(γ-butyrolactone) block remains as a synthetic challenge owing to the unfavorable thermodynamics towards the ring-opening polymerization (ROP) of "non-strain" five-membered ring, which makes it prone to copolymerizing with other cyclic lactones or lactides rather than formation of homopolymer. By choosing an suitable organophosphazene superbase as catalyst, we realized the successful one-pot preparation of poly(γ-butyrolactone)-b-poly(L-lactide) by sequential ROP of γBL and L-LA for the first time. The thermal stabilities, crystallization and melting behaviors of the obtained diblock copolyesters were also investigated.

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W29 Distinctive Cooperative Effects of Diastereomeric Bimetallic Titanium Catalysts in Olefin (Co)Polymerization

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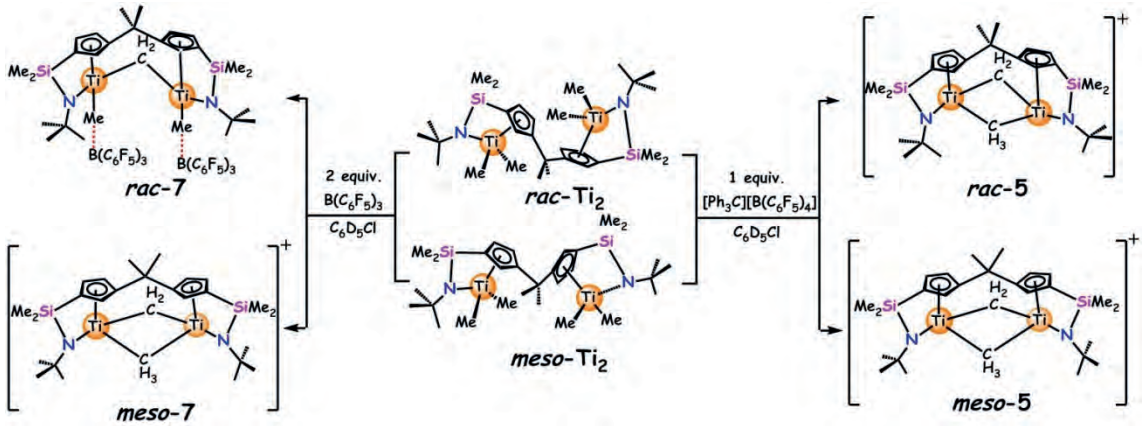
In Nature, multimetallic metalloenzyme active sites play key roles in organizing reactive functional groups to achieve enhanced turnover frequencies and product selectivities. Inspired by such biocatalysts, research on abiotic multimetallic catalysis has focused on mimicking the function of enzymes to discover more efficient catalytic processes.[1] Moreover, bimetallic complexes have emerged as powerful polymerization catalysts, and metal···metal cooperative effects dramatically and instructively impact polymer microstructure.[2] Although the magnitude of bimetallic cooperative effects on product M_n and comonomer enchainment selectivity has been documented with respective to metal identity, supporting ligation, and metal···metal proximity, the effects of catalyst stereochemistry are virtually unexplored.[3-5] The goal of this research is to design bimetallic catalysts which show diastereo selectivity effects on catalytic olefin polymerization. We report a new series of bimetallic constrained geometry catalysts in which the two diastereomers are separable and characterized by spectroscopic, analytical, and diffraction techniques. Furthermore, the nature of the active species in coordinative polymerization catalysis is a topic of general interest.[6] Although intense studies are devoted to this subject and many cationic complexes and ion pairs for monometallic catalysts are reported recently, the active species or intermediates for bimetallic catalysts

are barely understood, in particular by the informative structures. We will present observations on the activation of these bimetallic complexes by both of $[Ph_3C][B(C_6F_5)_4]$ and $B(C_6F_5)_3$ cocatalyst/activator (Scheme 1), the structural characterization of the resulting binuclear cations and ion pairs by NMR and X-ray analysis, and their olefin polymerization characteristics.[7]



Scheme 1. Activation of bimetallic diastereomers ***rac*-Ti$_2$** and ***meso*-Ti$_2$**.

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Th1 Molecularly Engineered Non-particulate and Continuous Ultra-Low Density Hybrid Silica Aerogels: Superstrong and Superinsulative

Sasan Rezaei, Amirjalal Jalali, Ali M. Zolali, Solmaz Karamikamkar, Chul B. Park*
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This paper presents a new method by which to generate a vinyl trimethoxy silane (VTMS)-based hybrid silica aerogel, which possesses an innovative non-particulate, reticulated structure and superior properties. Aerogels derived from pre-polymerized silica-based precursors are known to exhibit outstanding mechanical and insulation properties. But these require a long aging time, and their density reduction has been limited by their poor connectivity.

Our new aerogel technology has dramatically decreased the processing time by removing the aging step, and has significantly increased the void fraction. These improvements are due to the non-particulate structure's increased connectivity that was produced by the spinodal decomposition. Let alone the outstanding material properties of the VTMS-based aerogels, the non-particulate structure, rapidly generated by spinodal decomposition (SD), gives significant advantages over other aerogels.

Th2 Microcellular Foam extrusion and reducing Carbon footprint, improving Sustainability

Simon Dominey, Vice President, Mucell Extrusion, USA

Normally I talk about the Microcellular Technology developed at MIT to reduce the cost of Plastic extrusions. However as some of you may know one of the reasons for the original project at MIT was to reduce the impact of plastic on the environment. At the time there was very little interest in that element of the development, so for years the emphasis has been on cost reduction.

In the last 3 or 4 years there has been a significant increase in attention paid to the environmental benefits with in some applications Carbon foot print reduction etc. being the primary motivating force. So today I want to talk about environmental issues of Microcellular foam Extrusion

Short introduction to the technology:
The benefits to the environment fall under several headings, the significance of the individual benefits depend on the product produced, manufacturing methods, the transportation operations, handling of product, physical performance requirements. Etc.
Each application needs to be correctly assessed to balance the objectives in the most beneficial way.

Primary Factors:

1. Reduced quantity of plastic in a given extruded article.
This is the most obvious impact, every Kg of plastic used significant energy to be produced so reducing the amount of plastic in the product has a direct result, typically measured as reduction in energy consumption. (Reduced Carbon footprint). Reduction of polymer is typically 10-30%

2. Light weighting.
Transportation requires less fuel, Diesel for trucks, Jet fuel for air, Power for lifting loads etc.

In addition some product applications are used in weight sensitive applications such as Automotive components and aircraft parts. For these products we see a reduction in Fossil fuel use in the application itself.
3. Recycling:
This technology uses the same polymers as the solid product so the polymer identification number will be the same.
The process is direct injection of gas not chemicals, so there are no residuals elements to affect recycling.
We define the process as High Density Foaming Technology, when chopped up bulk density is similar to the solid product, in a reclaim system it is very close to processing solid articles, the very small cells are crushed, in most cases the cells by now only contain air in small quantity.

4. Environment:
The most popular gases are Nitrogen and Carbon Dioxide
Both are benign gases with no explosion risk, N2 is of course in the air around us
Whichever gas is used the quantity of gas compared to the volume of polymer is extremely low.

Illustrations of business/organizations interested in environmental benefits of this technology (see slide)

Th3 Preparation of PVDF film with high performance by Solid State Shear Milling (S^3M) and Biaxial Stretching

Huili Zhang, Yan Zhu, Li Li*
State Key Laboratory of Polymer Materials Engineering, Polymer Research Institute of Sichuan University, Chengdu 610065, China

Poly (vinylidene fluoride) (PVDF) with special electric properties has been widely used in the fields of electronic component of cars, boats and aerospace, etc. The excellent electric properties of PVDF are closely related to its β phase with all trans (TTTT) planar zigzag conformation and maximum polarity. But β phase is unstable at high temperature, so cannot be obtained by melt crystallization. How to improve the content of β phase of PVDF is attracting increasing attentions. The widely used way is uniaxially stretching PVDF films at low temperature during 80-100°C, but leading to the inhomogeneity of structure and properties in transverse direction (TD) and machine direction (MD).

In this paper, by combining the solid state shear milling (S^3M) technique and biaxial stretching technique, PVDF films with high content of β phase and homogeneous structure and properties in both TD and MD were prepared. The results showed that induced by the strong shear force of pan milling, the TGTG' conformation of PVDF for α phase translated into the TTTT conformation for β phase, and PVDF micro-particles with the content of β phase above 90% were obtained. Such a high β phase content endowed PVDF biaxially stretched film with higher β phase content and dielectric constant compared with the biaxially stretched film prepared from normal particles, although some β phase recovered to α phase at the high melt casting temperature in the process of preparing PVDF sheets used for biaxial stretching. However, some chain breakage might be occurred during the pan-milling process, making the tensile strength of the biaxially stretched film prepared from PVDF micro-particles slightly lower than that prepared from normal particles, but still higher than 120 MPa with 3.5×3.5 ratio.

This work was supported by the Program of Innovative Research Team for Young Scientists of Sichuan Province (2016TD0010) and National Natural Science Foundation of China (51721091).

Th4 Polymers for rolling bearing applications in a variety of industries

A Knowledge Transfer Partnership (KTP) project

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[2] School of Engineering and Informatics, University of Bradford, Richmond Road, Bradford

BNL Bearings is the world leader in integrated polymer bearing solutions for variety of industries, most notably the automotive sector, in which a heavy emphasis has been placed on reducing CO_2 emissions [1,2] and improving fuel economy [3,4]. Replacing metals with lighter and versatile polymeric materials brings about a reduction in the overall vehicle weight, and hence decreased CO_2 emissions by about 20 kilograms of CO_2 with every kilogram of the overall vehicle weight reduction [5].

Bespoke BNL bearings have already been successfully utilized in the commercial vehicle steering columns, where they are positioned in the lower and middle sections of the steering column assembly to ensure a smooth and robust rotation. The company now aims to strengthen its position in the automotive market by expanding its product portfolio to the upper and firewall bearing positions in the steering column assemblies. However, the harsh environment, in which these bearings operate, calls for the polymeric materials that are impervious to heat and possess outstanding mechanical properties. Furthermore, the distinct nature of polymers and the complex tribological behaviour of polymer bearings render the polymer bearing performance and lifetime prediction difficult. Thus, if BNL Bearings is to achieve its strategic goal, it is vital that the company gains in-depth knowledge and qualified support from an academic partner.

Since October 2016, BNL Bearings have been closely working with The Centre for Polymer Micro and Nano Technology at the University of Bradford. This alliance, formed through the Knowledge Transfer Partnership programme, has provided the company with access to the world class research facilities and academic staff. As a result, the company has been able to implement the research and development programme into polymeric materials that are suitable as bearings in the extreme environment described earlier.

During this time, the extensive trials of the new polymer materials have been carried out at the company's R&D facility, and the pre- and post-life properties of the currently available plastic bearings as well as the R&D bearings produced from new polymer materials have been thoroughly investigated at the university. In my presentation, I will share the key findings and summarise the results obtained through this partnership.

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Th5 Exchange Researches in University of Bradford -study on polymer blends in micro-injection molding and die-drawing

Qi Yang[1,2], Yinghong Chen[1,2], B Whiteside[2], Fin Caton Rose[2], P D Coates[2]
1.College of Polymer Science and Engineering；The State Key Laboratory for Polymer Materials Engineering, Sichuan University, Chengdu 610065, China
2. IRC in Polymer Science & Technology, Dept of Mechanical & Medical Engineering University of Bradford, Bradford BD7 1DP, UK

I began to do the exchange researches in the University of Bradford 10 years ago. During the period of time, professor Coates invited me more than once to the University of Bradford to do the experiments. And I have presented related academic conferences and research workshops many times, in Bradford, Chengdu, and Beijing, etc. Especially, during the period of 2011.4 to 2012.2, based on the support of China Scholarship Council, I worked in the University of Bradford for about 1 year as a visiting scholar.

The main fields of these researches focused on micro-injection moulding and die drawing. I applied polymer blends in the special polymer processing methods in the University of Bradford. Many research achievements have been made in these exchange researches.

I would like to do some future cooperation with the colleagues in the University of Bradford through many channels. In the next researches, I would like to: (1) to find more high properties and functional polymer blends used in micro-injection molding technique; (2) to put chemical changes (reaction) into the processing of die drawing; (3) to design and get special or micro-structures formed from polymer blends used for drug delivery

Th6 In-situ Shrinking Microfibers Enhance Strain Hardening and Foamability of Linear Polymer

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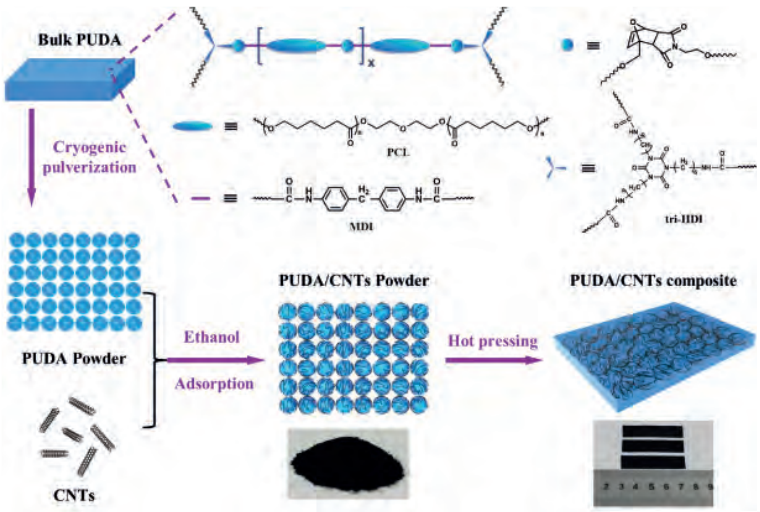
Strain hardening has important roles in understanding material structures and polymer processing methods, such as foaming, film forming, and fiber extruding. A common method to improve strain hardening behavior is to chemically branch polymer structures, which is costly, thus preventing the users from controlling the degree of behavior. A smart microfiber blending technology, however, would allow cost-efficient tuning of the degree of strain hardening. In our previous study, we hypothesized and proved that compounding polymers with heat-shrinking fibers enhances the strain hardening of a polymer. In this study, we more systematically investigated the effects of compounding polymers with microfibers for both shear and extensional rheological behaviors and characteristics, and thus, for final foam morphologies formed by batch physical foaming with carbon dioxide. Extensional rheometry showed that compounding of in situ shrinking microfibers significantly enhanced strain hardening compared to compounding of non-shrinking microfibers. Shear rheometry with linear viscoelastic data showed a greater increase in both the loss and storage modulus in composites with shrinking microfibers than in those with non-shrinking microfibers at low frequencies. The foaming results demonstrated a greater increase in the cell density and expansion ratio with in situ shrinking microfibers than with non-shrinking microfibers. The total enhancement due to the shrinkage of compounded microfibers decreased with temperature implying that we can tailor the strain hardening by changing conditions such as temperature.

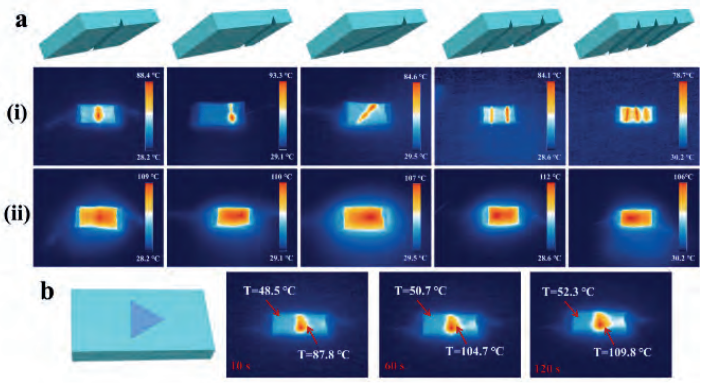
Th7 Self-Healing Polyurethane Elastomer Materials

Xili Lu, Wuli Pu, Li Yang, Daihua Fu, Xinpeng Gan, Zhanhua Wang, Hesheng Xia*
State Key Laboratory of Polymer Materials Engineering, Polymer Research Institute, Sichuan University, Chengdu 610065 xiahs@scu.edu.cn

Self-healing materials have attracted great attention because of their potential applications in many fields. The novel healable PCL-based polyurethane networks with Diels−Alder (DA) bonds (PUDA), i.e. furan-maleimide adducts, alternately located in the backbone of polymer chains between adjacent crosslinking points was designed and prepared. DA motifs in the chain backbone can undergo reversible bond breaking and reformation under heating or ultrasound treatment to provide healing property. Based on the self-made healable PUDA, a flexible conductive composite composed of PUDA and carbon nanotubes (CNTs), which possesses both crack diagnosing and self-healing functions. The introduced dynamic Diels-Alder bonds endow the materials self-healing function and the powder-based preparation route based on the specially designed CNTs-coated PUDA micro powders leads to the formation of segregated CNTs network, which makes the composite possess excellent mechanical properties and high conductivity. Using the same electrical circuit, the crack in the PUDA/CNTs composite can be non-invasively detected firstly and then be autonomously healed. Also by introducing polydopamine particles (PDAPs) into PUDA, a new kind of ultrafast near-infrared light responsive shape memory assisted self-healing polyurethane composites were prepared. Owing to the outstanding photothermal effect of PDAPs and excellent dynamic property of Diels-Alder bonds, the composites possess rapid light responsive shape memory and self-healing properties.



Design strategy of PUDA/CNTs composite



Autonomous crack diagnosing and self-healing induced by electricity:

Acknowledgements:
This work is supported by NSFC (51433006) and EU Horizon 2020（H2020-MSCA-RISE-2016-734164 (Graphene 3D)

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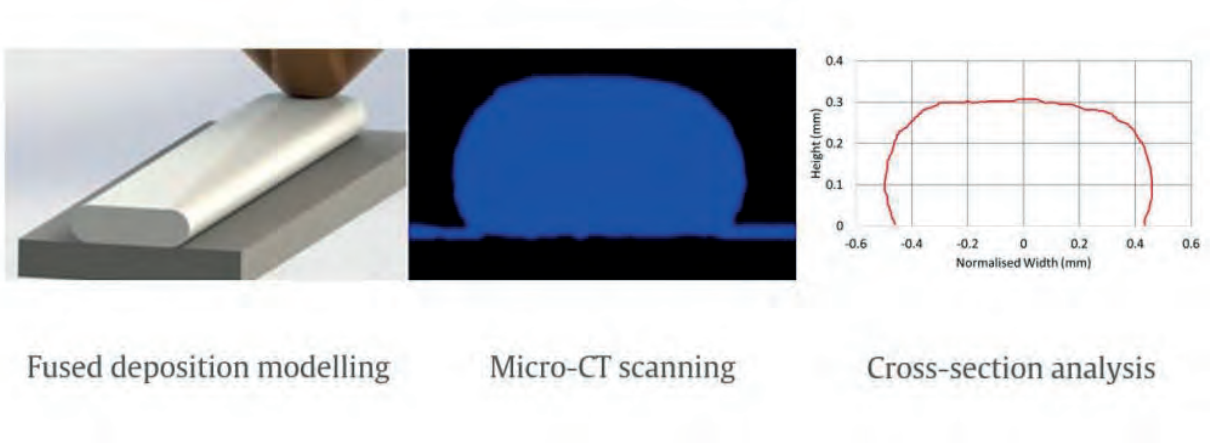
Th8 A method for predicting geometric characteristics of polymer deposition during fused-filament-fabrication

Michael Hebda, Ben Whiteside, Fin Caton-Rose, Phil Coates
Polymer IRC, University of Bradford, UK

In recent years 3D printing has gained popularity amongst industry professionals and hobbyists alike, with many new types of Fused Filament Fabrication (FFF) apparatus types becoming available on the market. A massively overlooked component of FFF is the requirement for a simple method to calculate the geometries of polymer depositions extruded during the FFF process. Manufacturers have so far achieved adequate methods to calculate tool-paths through so called slicer software packages which calculate the required velocities of extrusion from prior knowledge and data. Presented will be a method for obtaining height, width and cross-sectional area values for given parameters within the FFF process for initial laydown on to a glass surface.



Th9 Film characterisation for the development of prototype automated stretch wrapping system

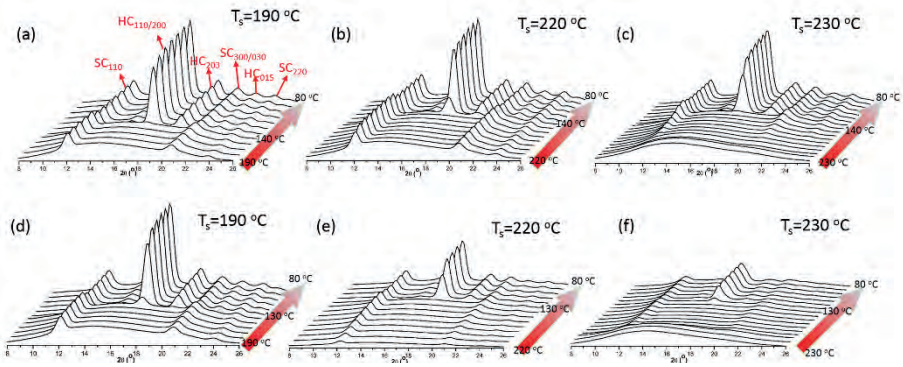
C L Tuinea-Bobe[1], M Leeming[2], D Robinson[2], P Chapman[2], R Thaker[2], D Colhoun[3], A Norwood[3], G Michailidis[3], M Villa[3], B R Whiteside[1], J Sweeney[1]
[1]Polymer IRC, School of Engineering, Design and Technology, University of Bradford, UK
[2]TrakRap Ltd, UK
[3]MTC, UK

This paper presents a comparative method to analyse and predict the forces developed in a stretch wrapping process. We are developing an automated packaging system that uses stretch wrapping aiming to replace shrink wrapping, a method for secondary packaging to assemble individual items, such as cans or other consumer products, into single packages. The shrink wrapping method involves conveying the packages into heated tunnels and so has the disadvantages that it is energy-intensive, and, in the case of aerosol products, potentially hazardous. The proposed packaging method aims to address both problems, by using a mechanical rather than a thermal process. In this study we present mechanical analysis data for the stretch wrapping materials. The stretch wrap materials are oriented LLDPE polymer and therefore elastically anisotropic. The materials are tested for three directions to obtain a full mechanical behaviour assessment. The tests were performed at strain rates similar those applied by the stretch wrap device. A high speed image capture system was used to measure the film strain during the wrapping process. Furthermore, we mapped the films' crystallinities with their mechanical properties. The mechanical data was used to develop material constitutive models that include both anisotropy and nonlinearity. These material models are to be incorporated into computer simulations of the automated stretch wrapping system.

Th10 Stereocomplex formation, crystalline structure of long chain branched poly (L-lactic acid)/poly (D-lactic acid) blends: Effect of melting temperature

Zhongguo Zhao[a,b], Qi Yang[a], Phil Coates[b], Ben Whiteside[b], Adrian Kelly[b], Yajiang Huang[a],
[a] College of Polymer Science and Engineering, the State Key Laboratory for Polymer Materials Engineering, Sichuan University, Chengdu, PR China
[b]Polymer IRC, Faculty of Engineering and Informatics, School of Engineering, University of Bradford, Bradford, UK

A feasible approach is proposed to enhance the ability of stereocomplex (SC) crystallization and depress the homocrystallization in long chain branched poly(L-lactic acid)/poly(D-lactic acid) (LCBPLA/PDLA) blends with hydrogen bond interactions. Increasing the PDLA content and molecular weight of PLA can significantly promote the formation of SC. Promoted stereocomplexation in long chain branched racemic blends is proposed to be due to the more branched sites and improved intermolecular crystal nucleation/growth. The formation of SC makes it possible to stay at diverse states by changing the melt temperature from 190 °C to 230 °C, acting as a nucleation agent for PLA. The speculated mechanisms of the stereocomplex formation and the effectiveness as a nucleating agent are schematically described. Nonisothermal and isothermal crystallization show that the reserved SC crystallites can remarkably accelerate the crystallization rate of PLA due to heterogeneous nucleation effect. Besides, increasing the melting temperature (less than 220 °C) can significantly improve the perfect of SC and raise the melting point.



WAXD patterns collected upon cooling of PLA/PDLA blends at different temperatures: (a), (b) and (c): LCBPLA+10%PDLA, (d), (e) and (f): PLA+10% PDLA

Th12 Process fingerprinting for optimised production of thermoplastic microneedle arrays using ultrasonic microinjection moulding

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Ultrasonic microinjection moulding is a promising replication and manufacturing process for producing microparts. This new technology could be an interesting option for medical applications and capability of this process has been assessed for fabrication of microneedle arrays. The technique have the advantage of heating and melting the polymer instantly without exposing the material to elevated temperature for long periods. This aspect of the technology could be beneficial for producing pharma grade materials with active ingredients such as drugs.
From the micromanufacturing perspective, fast and robost quality assurance procedures should be implemented to lower the quality inspection efforts made for microparts. For this purpose, process fingerprint concept is introduced where process sensitive variables from the process were taken and related to the final part quality. Fingerprints chosen include process related variables such as thermal

imaging data and injection piston information and geometric measurements taken from the microneedle patches that were micromoulded. Final quality of the micromoulded thermoplastic microneedle arrays are evaluated in terms of microneedle height and correlated to the process parameters. Since the ultrasonic moulding technology is quite recently developed and commercialised, process issues are defined, and solutions are implemented in order to have a moulding process with accuracy and precision.

Th13 Three-Dimensional Porous Carbon Materials with Tunable Super-Wettability toward Oil Spill Remediation and Electrochemical Capacitive Energy Storage

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Three-dimensional porous carbon materials (3D-PCMs) with an interconnected network architecture have shown promising potentials for energy and environmental applications. However, their complicated preparation conditions, high costs and poor surface-wettability create big obstacles for large scale commercial production. Herein, we report a novel and scalable strategy for the fabrication of multifunctional 3D-PCMs with tunable super-wettability via a simple dip-coating step in cellulose solutions prior to the pyrolysis process of commercial melamine foam (MF). The resultant 3D-PCMs demonstrate many unique features, such as ultra-light weight, great mechanical properties, high electrical conductivity and excellent surface properties. In particular, we discover for the first time that the as-prepared carbon-layer-coated carbon foam (CCF) with superhydrophobicity is capable to cleanup and collect oil spill very rapidly and continuously without any external force or auxiliary equipment. To our knowledge, this is the simplest and most effective method reported so far for oil spill remediation. On the other hand, by adding a certain amount of NiCl 2 in the cellulose solution, the pyrolyzed carbon foam (NiO@CCF) is found to have numerous "enokitake-like" NiO nanorods uniformly distributed along its skeleton. The NiO@CCF exhibits superhydrophilicity, which makes it an ideal electrode material for supercapacitors with extraordinary electrochemical capacitive performance even at bending and compression conditions. This simple, efficient and green method combined with the low-cost and widely available attributes of the raw materials may pave a road for industrial manufacturing of multifunctional 3D-PCMs for various applications.

Th14 Moulding of micro and nano scale features for surface functionalities.

Ben Whiteside,
Polymer IRC, University of Bradford

The ability to produce micron and submicron surface structures and patterns on polymer components can provide interesting physical functionalities that add value and potentially reduce the number of steps in manufacturing processes. The field of surface biomimetics has emerged to artificially synthesise such surfaces found in nature and current application areas of interest include the ability to improve the tribological behaviour of surfaces in contact, superhydrophobic and anti-fouling behaviour, anti-microbial responses, and aesthetic/optical effects. Injection moulding processes have been successfully applied for replication of simple sub-micro surface features for decades (with CD manufacturing being a prime example), but the range of pattern geometries and component complexities which are of current interest pose significant challenges to developing a successful manufacturing route for realising these new functional behaviours. This talk will review the state of the art for replication processes, discuss existing technological challenges, demonstrate successfully replicated functional surfaces and show potential routes forward for large scale manufacturing of such devices.

Awards in the Polymer IRC

The internationally leading nature of the Polymer IRC is reflected in a range of prestigious international and national awards.

International Awards (Prof Coates)

2015 Tian Fu Friendship Award, of the People's Government of Sichuan Province (first ever awarded)

2016 Sichuan Science and Technology Progress Award: International Scientific Co-operation (2016) –first time awarded.

2017 James L White Innovation Award of the International Polymer Processing Society, the top award of the PPS for leading achievement in polymer innovation

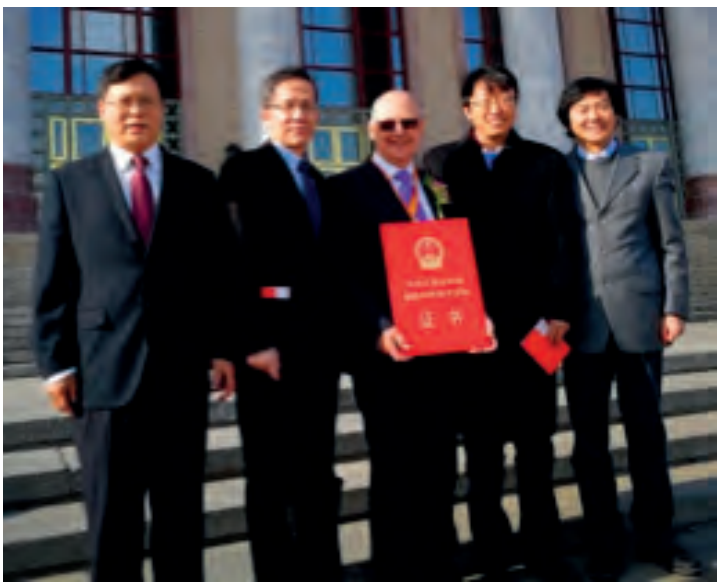
2018 Society of Plastics Engineers International Award, the top award of the Society, for lifetime achievement in polymer engineering

2018 International Science & Technology Cooperation Award of the People's Republic of China, presented by President Xi Jinping

The award; pre-meeting of awardees with President Xi Jinping and the full leadership team of the PR China

Award Ceremony in the Great Hall of the People

Medal presentation by Vice President, Madam Liu



Outside the Great Hall - with great support from Chinese colleagues, Prof Hesheng Xia, Prof Guangxian Li, Prof Liqun Zhang and Prof Yongfeng Men

Personal Awards

Prof Phil Coates:

- 1986 Elected Fellow of the PRI (later Institute of Materials)
- 1990 Elected Fellow of the Institution of Mechanical Engineers
- 1995 Elected Fellow of the Royal Academy of Engineering
- 1999 Netlon Award (Gold Medal) for Innovation in Processing, Institute of Materials
- 2006 Plastics Industry - Award for Personal Contribution to the Sector
- 2008 IoM3 Swinburne Award & Gold Medal – personal
- 2008 Honorary Professor (2008) Sichuan University
- 2008 Molecular Sciences Forum Professor, Chinese Academy of Sciences, Institute of Chemistry, Beijing
- 2009 Honorary Professor (2009) Beijing University of Chemical Technology
- 2010 Famous Overseas Scholar, Ministry of Education, China / Sichuan University
- 2010 High End Foreign Professor, Sichuan University
- 2011 Top Foreign Expert of the State Foreign Experts Bureau
- 2012 Changchun Institute of Applied Chemistry, Chinese Academy of Sciences honorary lecturer

Science Bridges China team awards

- 2008 RCUK Bradford Science Bridgs China top ranked bid
- 2008 UKTI/Y&H China Business Award – Best Education
- 2011 Interdisciplinary Working Award, Bradford University
- 2014 Vice Chancellor's Award for Outstanding Achievement, University of Bradford

Industry-related Awards

2007 Yorkshire Forward Innovation Award
2007 Best Knowledge Transfer Partnership Award, NE England
2008 EU Regio-Stars Award - Centres of Industrial Collaboration
2011 Medical Design Excellence Gold Award - Supplier
2014 Horners Award (Propoint)

Funding awards

We have over £10m current portfolio of research funding (over £30m in the past decade) from UK research councils, companies and international programmes.

Some key awards include:

- 1988-90 Wolfson Foundation: Wolfson personal Research Awards Scheme (£0.2m)
- 1989-2000 IRC in Polymer Science & Technology original award (£23m)
- 1998-2000 Enhamced Polymer Processing EPSRC award (Bradford, Queens Belfast, Brunel) (£2m)
- 1998 - 2003 MUPP EPSRC awards (Leeds, Bradford, Cambridge, Durham, Oxford, Sheffield) (£2.2m)
- 2007-9 EPSRC Virtual Institute - Polymer Process Structuring, with China (£0.23m)
- 2008 -12 RCUK Science Bridges China - top ranked award (£1.25m)
- 2012 EPSRC Global Engagments: China (£0.5m)
- RCUK-MOST 2013-15 (Bradford, Sheffield, Durham, Sichuan, ICCAS) (£0.2m)
- 2013-2017 111 programme (Sichuan/ Bradford, + international team (USA, Europe, led by Bradford; (9m RMB)
- 2013-18 EPSRC Soft tissue fixations (£0.9m)
- 2013- 2018 EPSRC MeDe: UK Centre of Innovative Manufacturing in Medical Devices (Leeds, Bradford, Newcastle, Nottingham, Sheffield Universities; (£5.7m)
- 2013 - 2021 Sinopec BRICI polymer orientation (£0.68m)
- 2014-2024 EPSRC Capital Grant: Advanced Materials for Healthcare (£5.42m including £2m UoB)
- 2015-18 Royal Society Newton Advanced Fellowship with Prof Men, Changchun; (£0.11m)
- 2015-2019 EU H2020 Marie Curie Microman network (£3.57m)
- 2017- 2020 EU H2020 HIMALAIA injection mouding platform (£3.9m)
- 2018-21 EPSRC Healthcare Innovation Partnership (£1.1m)

The UK Polymer Interdisciplinary Research Centre

A simple philosophy:

Aim to be the best at what we do

Build bridges – science, technology and people

Cross the bridges!

don't give up - collaboration is worth it!

Delivering 21st century polymer-related research and knowledge transfer aligned with UKRI strategic aims, we provide researchers with an environment in which ideas and innovations can flourish. We build locally, nationally and globally (with 3 Joint laboratories in China), to help develop fundamental understanding, meet societal needs and benefit our industry sector. We work with over 100 companies, and have an excellent track record of delivery.

Early career 'rising star' researchers are particularly important to us – we have in the past few years run over 60 Researcher Exchanges with overseas partners, including our collaborators in other UK universities, to help develop longer term research strengths and international relationships.

Our 'process structuring' research addresses a wide range of sectors, including advanced healthcare, precision engineering devices, electronics, transport, construction products and consumer goods. We are at the leading edge of advanced manufacturing technologies, including process instrumentation, process modelling and control. We uniquely reach across polymer synthesis, polymer physics and engineering and pharmaceuticals processing.

Polymers are vital materials - too good to waste – they are chemically rich, made from the amazingly rich oil (only a small fraction of which is turned into polymers, which contain the same calorific value as the oil they are derived from); it makes no sense to scrap polymers having invested in making these important and highly useful materials. We are consequently much involved in 'green processing' and in promoting the Circular Economy approach which aims to promote recycling, re-use, and to move away and from the traditional make-use-dispose economic model.

We strongly welcome interdisciplinary collaborations in the UK and worldwide.

Professor Phil Coates FREng
Director, Polymer IRC

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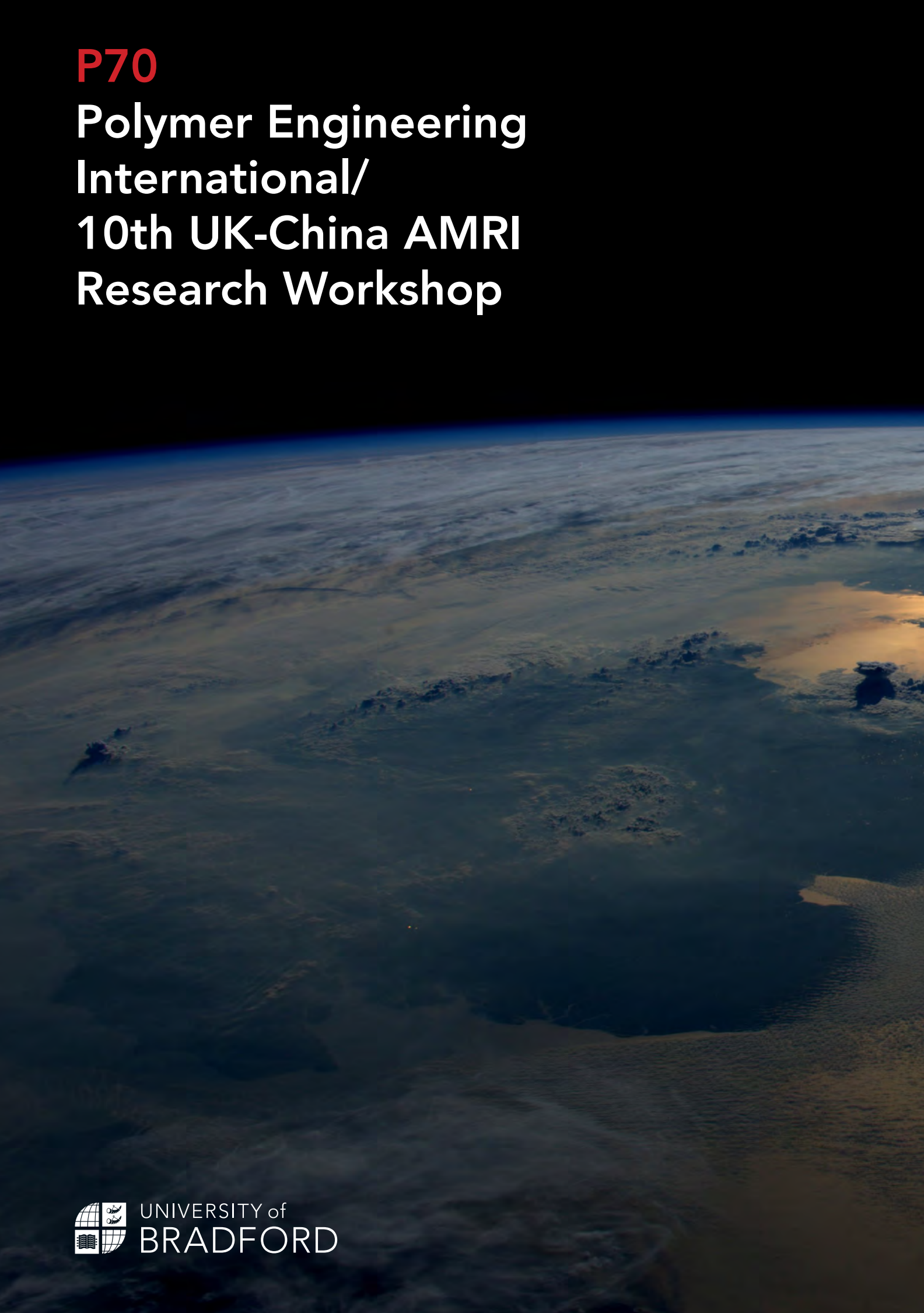
Polymer Engineering International/ 10th UK-China AMRI Research Workshop



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