

**ABSTRACTS
OF
LECTURES**



**UK Polymer Showcase 2007
London College of Fashion
5/6/7 September 2007**

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Director, Polymer IRC**

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University of Leeds**

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Durham University**

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Future Factories UK**

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**Lynne Walker
Carnegie Mellon University
Pittsburgh, USA**

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**Alma Hodzic
University of Sheffield**

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**Karl Coleman,
Durham University**

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The DyeCat™ Process

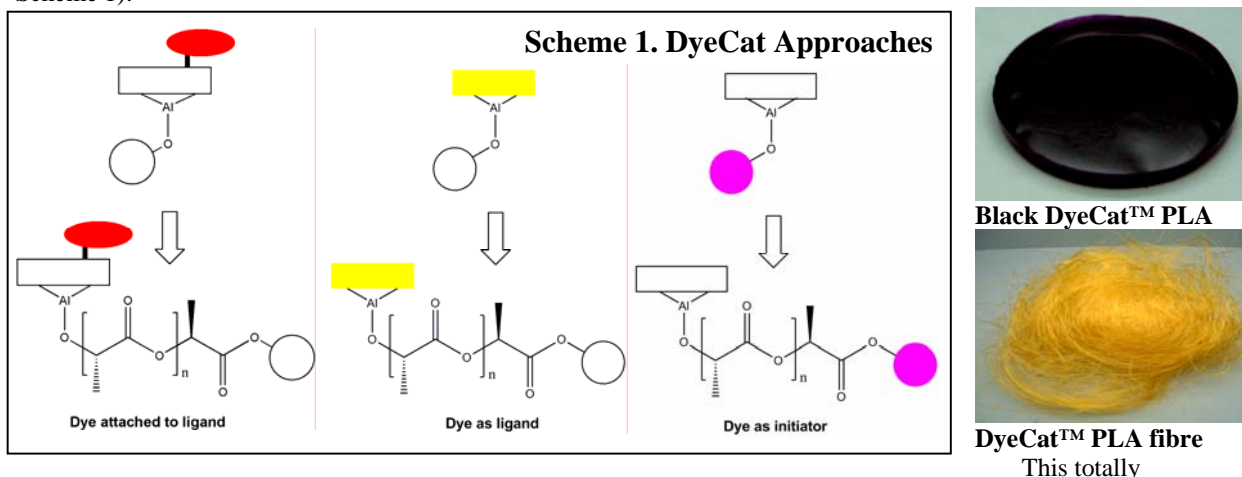
Sustainable Production of Coloured Polymers
Richard Blackburn, Patrick McGowan,
Chris Pask and Chris Rayner



With the depletion of petrochemical feedstocks, it is necessary to produce new, useful and environmentally friendly polymers for a sustainable future. Poly(lactic acid) (PLA) is a linear aliphatic thermoplastic polyester derived from 100% renewable sources such as corn and sugar beet, and the polymer is biodegradable. NatureWorks LLC (USA) has developed large-scale operations for the economic production of PLA polymer used for packaging and fibre applications. It is important that such fibres are used in fabric for apparel applications. This is for several reasons: polyesters currently used for apparel applications, mainly poly(ethyleneterephthalate) (PET), account for over 40% of world textile consumption (second only to cotton) and their use is constantly increasing; production of such polyesters consumes fossil fuel resources and disposal of the polymer adds to landfill sites as they are non-biodegradable and are not easily recycled. PLA fibre, in contrast, is derived from annually renewable crops, it is 100% biodegradable and its life cycle potentially reduces the earth's carbon dioxide level.

PLA is formed by ring opening polymerisation of the cyclic dimer of lactic acid (lactide). As the range of potential applications continues to grow, coloration becomes a significant problem as it is required for most large-scale (tonnage) applications. The dyeing of PLA is an obvious approach to this, however there are very significant problems with this, not least hydrolysis of the PLA under the aqueous conditions typically required for dyeing, and sustainability issues associated with the dyeing process.

The focus of the lecture will be novel polymerisation technology we have developed in Leeds, referred to as the DyeCat™ Process, which allows coloration of PLA to be carried out at the polymerisation stage by incorporating appropriate chromophores into the catalyst structure, which remain in the polymer at the end of the process (see Scheme 1).



This totally eliminates any subsequent dyeing step which also avoids potential hydrolytic degradation; produces a superior polymer with homogeneous coloration throughout; and because the dye is covalently bound to the polymer, gives unrivalled colour fastness compared with polymers coloured using conventional dyeing techniques. Importantly it also allows us to access colours which are otherwise difficult to achieve on PLA (e.g. black, see above) due to the high dye loadings usually required.

In order to exploit this technology, we have established DyeCat Ltd. as a spin out from the University of Leeds, with funding from Yorkshire Forward and Techtran (Dr Rob Rule). The DyeCat approach is patented, and can be applied to a range of different polymers in addition to PLA. The focus of the company is on giving superior polymer properties while reducing the environmental impact of textiles and plastics, as well as giving significant cost reduction compared to conventional technology.



Adsorption Dynamics in Polymer-Surfactant Mixtures

*Colin D. Bain
Department of Chemistry
Durham University*

Water soluble polymers are ubiquitous in aqueous formulations for cleaning and personal care products, agricultural formulations, inks and paints, food emulsions and oil-field applications, to name but a few. These polymers serve many functions including dispersants, rheology modifiers, wetting agents and lubricants. Polymers are generally mixed with surfactants either for their synergistic effects or because surfactants are present in the formulation for other reasons. There has been a great deal of research on the bulk properties of polymer-surfactant mixtures, but much less on the interfacial properties and very little at all on the dynamic interfacial properties. This gap in our knowledge is important: first, because formulations are very frequently used under dynamic conditions and second, because dynamic interfacial properties are not easily extrapolated from equilibrium measurements alone.

This talk will describe experiments on adsorption in the strongly interacting polymer-surfactant mixture: poly(dmdaac) + sodium dodecyl sulphate. This system shows bizarre equilibrium properties, with cliff edges in the surface tension isotherm. In our work, we use an overflowing cylinder to study the dynamic adsorption processes at the air-water interface on the one-second timescale. A combination of laser Doppler scattering, ellipsometry and external reflection FTIR are employed to characterise adsorption and fluid dynamics. Interactions and aggregation in the bulk phase are found to play a dominant role in determining the interfacial properties under dynamic conditions.

[Campbell, R. A.; Ash, P. A.; Bain, C. D. *Langmuir* **2007**, 23, 3242]



The hierarchical modelling of the effect of polymer molecular structure on fibre composite strength

*Shabnam Behzadi, Joel Foreman, Frank R Jones
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In a unidirectional (UD) fibre composite, the statistical strength distribution along the fibres results in a large discrepancy between the failure strength of a real composite and the one predicted from a simple rule of mixtures. A fibre-break is a critical micro-event in a UD composite. The stress released by a fibre-break should be redistributed among the intact adjacent fibres to re-establish a local load equilibrium. Therefore, the stress is intensified in the neighbouring fibres to a fibre-break. The strain (or stress) concentration factor (SCF) increases the probability of fracture of neighbouring fibres and hence controls the ultimate failure of the composite material. The SCF value is a key parameter used in the predictive computer models for the failure strength of a UD composite. The matrix surrounding the fibres plays a significant role in transferring stress to the fibres adjacent to a broken fibre. It is believed that interfacial shear yielding of an elasto-plastic matrix governs the redistribution of the overload among the intact fibres. Therefore, the behaviour of an elasto-plastic matrix under load can alter the micromechanics of the fracture in a fibre composite.

Along with the experimental methods, Group Interaction Modelling (GIM) has also predicted the properties of epoxy resin matrix for input into modelling codes. This technique is a relatively new theoretical method of estimating the thermomechanical and engineering properties of a polymer from its fundamental functional group parameters. While the use of this method on linear polymers is relatively straightforward, the modelling of crosslinking is complicated by the 3D network structure of such systems. The modelling side of this project aims to create a set of self-consistent, realistic stress-strain curves for some commonly-used amine cured epoxy resins. The data produced can then be used to model real systems using finite element codes. Hence, the GIM-predicted stress-strain curves to yield for TGDDM and TGAP cured with DDS are presented. The importance of correctly describing the events that occur during the beta and glass transitions is emphasised. The variation of strain rate is incorporated directly into the model and the effects seen are shown compared to experimental data.

In this work a link has been established between the matrix yielding properties of two most commercially used epoxy resins (i.e. TGDDM and TGAP) and the ultimate failure strength of UD carbon fibre composites by statistical methods using the strain concentration factors in neighbouring fibres at the vicinity of a fibre-break. In this way a hierarchical model is being developed which can predict the strength of an artefact from the chemical structure of the polymer resins.



Developments in Reactive Extrusion for Precision Grafting Control

Emma-Louise Burton, T D Gough, M Woodhead and P D Coates

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A B S T R A C T

The investigation of methods of reactant addition is an important part of optimising reactive extrusion processes. The introduction of liquid reactants into extruder barrels at one position can be problematic as mixing reactants together may incur a reaction leading to blockages in the tubing and losses of reactants prior to extrusion. This work has explored multiple injection point addition of reactants for the peroxide induced grafting of glycidyl methacrylate (GMA) onto polypropylene on a closely-intermeshing co-rotating twin-screw extruder (16mm screws, 40:1 L/D). Both position and order of reactant addition was investigated as a route to improving graft yields and reducing side reactions (degradation).



Mechanism of Block Copolymer Vesicle Formation

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ABSTRACT

Amphiphilic block copolymers are known to adopt a number of interesting morphologies in aqueous solution including micelles, worm-like micelles and vesicles. The exact structure formed is known to be sensitive to many parameters including temperature and co-solvent but the exact mechanism of formation of these different morphologies is currently not known.

We have been tackling the issue of structure formation in block copolymer systems as part of a collaborative project and here we present our results and strategy towards understanding the mechanism of the structure formation in these systems.



Solid phase orientation processing & modelling of polymer composites

*Fin Caton-Rose
Polymer IRC,
University of Bradford*

Abstract

Short glass fibre reinforcement is well established as a means of significantly improving mechanical performance without compromising processability, and many glass filled polymer grades and products are commercially available. Apart from the fibre and matrix properties, the mechanical properties of a fibre reinforced component are crucially dependent on the fibre orientation distribution (FOD) developed during the process, as well as other aspects such as the resulting fibre aspect ratio and the fibre/matrix interface. Whilst this statement is true for melt processing, it is possible to further improve composite mechanical properties by orientation of the polymer chains within the matrix material.

Such orientation can be produced during solid phase processes such as roller or die drawing. Within these posters we describe an initial investigation of the combining effects of short glass fibre reinforcement of polypropylene and solid phase polymer matrix alignment through die drawing on final fibre orientation, fibre degradation, mechanical properties and finite element analysis of the process.



From contact lenses to proteomics: Can surfaces be used to influence performance?

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A B S T R A C T

The ability to control interactions between biomolecules and surfaces can influence a widely divergent number of bioengineering applications. *In vivo* we desire materials that can control cellular adhesion, selectively adsorb specific proteins or mimic the structure of a cell surface. *In vitro*, high sensitivity proteomic and diagnostic applications require the immobilization of specific biomolecules without any loss of native function and with spatial control. This range of applications presents challenge in terms of both surface modification methods and the sensitivity of techniques we use to characterize these systems. This talk will explore how a range of polymeric surface modification techniques may be used to influence protein and cellular interactions with materials in applications ranging from tissue engineering through to proteomics.



AN UPDATE ON THE MICROSCALE POLYMER PROCESSING PROJECT

**P.J.Hine, Polymers and Complex Fluids Group,
Physics Department, University of Leeds, Leeds, LS2 9JT, UK.**

The Microscale Polymer Processing project brings together a multidisciplinary team of academics and industrialists with the aim of understanding how molecular variables affect processing and ultimately properties. The vision of the programme is to develop a software-embedded, validated set of molecular-based tools for the design of advanced polymers and processes, with the ultimate goal of being able to design the perfect polymer resin and process, tailored exquisitely for the needs of the final product. In this ideal scenario, every aspect of manufacture would be optimised; each molecule arriving at its final destination in the product with the ideal orientation, and all this done without trial and error: the whole concept designed computationally from the polymerisation reaction up.

The initial EPSRC funded “Microscale Polymer Processing” project, or “ μ PP” for short, ran from 1999-2003. Polymers with tailored molecular architectures were designed and specially manufactured, allowing polymer-physics-based molecular models to be tuned to predict the behaviour of these ‘monodisperse’ polymers. The rheology and processing behaviour of these specially synthesised polymers was found to be very rich and the interplay between experimental studies and theoretical modelling proved very valuable. A good summary of this first stage of the μ PP project, and the underlying philosophy which matches specially synthesised polymers, new experimental techniques and development of theoretical models, can be found in the paper of Collis *et al.* [1].

With these initial accomplishments, a second round of funding was successfully obtained, with an enlarged consortium consisting of 8 Universities and 7 industrial sponsors entitled “Microscale Polymer Processing 2” (μ PP²). This second project is driven by industrial companies, who wanted to see the μ PP project methodology applied to broader applications in polymer processing such as 2Phase materials and crystalline polymers.

In order to address all these issues, the work in the current μ PP² project is divided into three streams: TOOLBOX, CRYSTAL and 2PHASE. The TOOLBOX stream, continues the work of the first μ PP project but expanding the scope to investigate blends of different molecular architectures, theories and experiments for polydispersed ‘industrial’ polymers and more exotic architectures such as dendrimers and Cayley trees. In CRYSTAL and 2PHASE the strategy is very much to continue the μ PP philosophy (linking experiment and theory via molecularly aware physics based models) for crystalline polymers and 2Phase materials. This paper will highlight the recent exciting developments in these three streams.

- 1 Collis, M. W., A. K. Lele, et al., "Constriction flows of monodisperse linear entangled polymers: Multiscale modeling and flow visualization." *Journal Of Rheology* 49 (2005) 501-522.



The Emotional Wardrobe

EPSRC/AHRC Designing for the 21st Century Cluster

Sharon Baurley, Central Saint Martins College of Art and Design, University of the Arts London

According to the Venture Development Corporation's market report on smart textiles, development in products is slow, despite the hype that has grown up around over the last ten years. VDC cites a number of reasons for this: that the killer applications for smart textiles are unknown, and consumer education. It is very difficult to forecast what will be the take-up of new products, or how people will respond to them and integrate them into their lives. Such foresight is especially difficult to obtain when it comes to putting technology on the body. I, therefore, believe that using design to gain new understandings about people's behaviour and what they are capable of doing is very valuable in generating new design concepts for consumer fashion wearable technology – this process is the focus of *The Emotional Wardrobe*.

We all know that fashion and clothing is used to define ourselves, and group ourselves into social groups and communities. What is happening now is that digital communications technologies have common attributes with fashion/clothing in terms of how they enable people to construct an identity, to be expressive, to differentiate themselves, and declare their uniqueness, which enables communication between people allowing them to form communities. The revolutionary growth of digital media is allowing smaller groups and individuals to collaborate, create and share their own material. Sites such as YouTube allow people to express themselves, and MySpace allows people to congregate online and form communities. Mobile communications is now a part of fashion, with brands such as Prada collaborating with consumer electronics corporation LG, to develop mobile phones. And the use of marketing language in Nokia's new *L'Amour Collection* of phones is one of fashion, using sensory descriptors to entice consumers. This new fashion range of Nokia phones enables its customers to ask 'which side of me shall I be'?

When fashion converges with ICT and materials technology, what will happen? We can't anticipate all of the end-use applications in advance because what actually happens in practice is the emergent outcome of user dynamics, e.g., texting caught service providers by surprise. If we extrapolate from what is happening in mobile and web-based communications and apply that thinking to new genres of products such as clothing that are networked and dynamically changeable, will we see similar patterns of behaviour emerging? How can we gain prior knowledge of emergent behaviour? These new genres of products have the potential to empower people, but how can we understand what they are capable of doing? These are new kinds of 'value-added' that are related to emotional needs, sensory, and self-actualisation, that go beyond mere functionality of a heart rate monitoring vest or integrated MP3 switching panel.

The central idea of the Cluster is *The Emotional Wardrobe* (EW), in which the conventions and cultures of fashion, as an expressive, emotional and communicative medium, are extended by integrating computer intelligence and digital communications. It was concerned with the process of eliciting consumer desire in order to gain insight into the catalysts and drivers and potential emergent consumer behaviour for this new genre of fashion/clothing. During this presentation I will present the activities and the findings of the 12-month EPSRC/AHRC Designing for the 21st Century Cluster, *The Emotional Wardrobe*. Our aim was to establish an interdisciplinary community centred on these themes, willing and able to advance design research by combining conceptual work with practical design examples and working prototypes. We used of design as a tool to scope this unknown territory, and to identify new design spaces, and as a tool to facilitate multi-disciplinary working, in order to manage knowledge flows between people, to facilitate knowledge creation and sharing, and shared understanding. (www.emotionalwardrobe.com)



POLYMER SCIENCE AND THE FASHION PARADOX.

***PHILIP SAMS
WHITESPACE
UNILEVER R&D
PORT SUNLIGHT***

The Fashion Paradox, so named by Prof. Sandy Black of London College of Fashion, can be summarised as: how to square Fashion's must-have, disposable culture with the emerging imperatives of sustainable, ethical action? This short talk will use some eco-fashion concepts that invite the Polymer community to focus their technology on Paradox issues.

Fashion is a great metaphor for branded products of all sorts, so this approach also suggests possibilities for addressing a more general “Growth Paradox” in many market categories.



THE APPLICATION OF SMART POLYMERIC TEXTILES IN A CLOTHING 'LAYERING SYSTEM'.

*Jane McCann
University of Wales
Newport*

ABSTRACT

This paper looks at the application of smart technical textiles, in a clothing 'layering system' that has the potential to address the functional demands of the modern global 24 hour society, mixing work, relaxation and everyday activities. Relevant market sectors include performance sport, corporate wear, travel wear and inclusive design. It highlights a particular relevance to promoting health and wellness and the demands of an ageing community. In particular, this paper looks at innovations in polymeric textiles that may enhance comfort and performance in a clothing 'layering system' for the rapidly growing 'active ageing' community.

The design development of functional clothing is approached from a product design, user-needs driven, perspective. Requirements capture of the technical, aesthetic and cultural demands of the identified end-user, informs the selection and positioning of textile assemblies within an ergonomically designed 'system'. It looks at the sports type 'layering system', traditionally tried and tested in military combat wear, as an inter-dependent system of base-layer, mid insulation layer and outer protective layer. This demands the selection of a complementary mix of technical textiles, and the specification of appropriate construction methods, to address the design requirements of the chosen wearer. Novel garment construction methods may be adopted to position technical textiles, that include light-weight, protective, thermally regulating, moisture wicking, compact and stretch attributes, in relation to the particular requirements of different areas of the body.

Smart clothing and related textile products, with embedded technologies, provide an important interface between wearers and their environment. To bring emerging wearable technologies to near market products must function and look good. Consideration should be given to both the aesthetics and comfort of functional clothing. For wearable electronic technology to be truly useable the user interface must be simple and intuitive for an inclusive audience. To date, many examples of well-designed apparel products, with wearable technologies, are within the sportswear sector. This paper proposes that some of these generic technologies may be adapted to a suitable format to be useable by the active ageing community. The paper makes reference to her leadership of a "New Dynamics of Ageing Preparatory Network" that promotes collaborative research under the topic "Design Enabling Autonomy and Independence through Smart Clothes and Wearable Technology.



Insects did it first: Biomimetic mushroom-shaped fibrillar adhesive microstructure

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A B S T R A C T

To improve the adhesive properties of artificial fibrillar contact structures, the attachment systems of beetles from the family Chrysomelidae were chosen to serve as a model. Biomimetic mushroom-shaped fibrillar adhesive microstructure inspired by these systems was characterized using a variety of measurement techniques and compared with a control flat surface made of the same material. Results revealed that pull-off force and peel strength of the structured specimens are more than twice those of the flat specimens. In contrast to the control system, the structured one is found to be very tolerant to contamination and able to recover its adhesive properties after being washed in a soap solution. Based on the combination of several geometrical principles found in biological attachment devices, the presented microstructure exhibits a considerable step towards the development of an industrial dry adhesive.



Biofunctional Polymers Inducing Tissue-Specific and Immune-Specific Reactions

Professor Jeffrey A. Hubbell

Institute of Bioengineering, Ecole Polytechnique Fédérale de Lausanne

Polymeric nanoparticles hold tremendous potential in medicine, especially if modes of biofunctionality can be incorporated into them. Such biofunctionality could include sensitivity to particular biological environmental signals (here, oxidative environments, reductive environments), targeting capacities (here, targeting of the lymph nodes and dendritic cells therein), and binding capacity (here, binding to cartilage, binding to hyaluronic acid within tissues). We present novel chemical schemes by which to achieve such biofunctionality in polymer systems with watery cores for delivery of bioactive macromolecules and with hydrophobic cores for delivery of low molecular weight hydrophobic drugs.

Our laboratory has recently described a novel family of AB and ABA block copolymeric amphiphiles that are capable of forming micelles and vesicles. As a hydrophilic block, we employ polyethylene glycol (PEG), because of its well known toxicological profile and its well defined and low polydispersity. As a hydrophobic block, we have selected polypropylene sulfide (PPS), a low T_g polymer that can be synthesized by a ring opening polymerization also with low polydispersity. In previous work, we have demonstrated that these polymers form mesoscopic aggregates that are sensitive to oxidative environments. In current work, we are seeking to render these same structures sensitive to reduction, to allow destabilization of vesicles within the early endosome after endocytosis by linking the two blocks with a reduction-sensitive disulfide.

Our laboratory has also recently described an emulsion polymerization process by which to form very small (20 - 200 nm) crosslinked PPS nanoparticles, and we have demonstrated that these rubbery-core nanoparticles are useful in carrying hydrophobic drug. We are seeking to employ these nanoparticles to target the lymph nodes for delivery of antigen to intranodal dendritic cells.

Finally, we are developing schemes by which to provide specific biofunctionality for tissue binding. We are employing peptide-on-phage ligand discovery approaches to seek novel peptide ligands that bind to the surface of cartilage; such ligands would be useful for biofunctionalization of polymeric micelles and nanoparticles for injection within the joint capsule for treatment of osteoarthritis, for example.



BIORESORBABLE POLYMERS IN ORTHOPAEDICS

*David Farrar
Smith & Nephew Research Centre, York, UK*

ABSTRACT

In many medical implant applications material degradation is an undesirable feature that we strive to minimise or avoid through appropriate choice of materials and design. However, bioresorbable implants turn this otherwise unwanted phenomenon into a virtue; and bioresorbable polymers are increasingly being used to replace metals in orthopaedic devices where only temporary fixation of tissue is required. In this talk the use of bioresorbable polymers in orthopaedic surgery will be reviewed, looking at how and why they are used, available materials and their properties, some of the challenges that remain in developing new materials, and recent developments in the field.

Bioresorbables can be defined as materials or devices that, when implanted in the body, break down into harmless by-products that can be eliminated from the body by natural processes. Such materials are currently being used in orthopaedic devices such as suture anchors/tacks, interference screws for ligament repair and fracture fixation screws, pins and plates. The most obvious advantage over their metal counterparts is the avoidance of long-term pain or complications that can occur with metal implants and/or the elimination of the need for a second surgical procedure to remove the implant.

To date only a relatively small number of monomers have been accepted for use in approved devices but these have been combined in many ways to produce a wide variety of copolymers and blends. The most widely used materials are those based on lactide and/or glycolide polymers.

Despite the success of these bioresorbable polymers, and the growth in their use, a number of key challenges remain to be addressed by a new generation of materials. These include optimisation of degradation rates to better match healing rates of tissues; development of materials with improved mechanical properties for greater load-bearing applications; and improved biocompatibility of breakdown products and long-term in-vivo performance.

Given the significant regulatory barriers to introducing new chemistries there is a large premium in extending the properties of existing polymers either through the development of advanced processing techniques or the combination of approved materials in novel composites. Examples of these developments will be presented.



Polyetheretherketone Polymer for Medical Implant Applications

**Dr Stuart Green
Invibio Ltd.
Thornton-Cleveleys**

Abstract

A medical grade of polyetheretherketone (PEEK) polymer has been engineered by Invibio to meet demanding clinical needs across a broad range of medical applications. This polymer is biocompatible and has physical properties similar to bone. It is lightweight and is easily processed into medical artefacts by moulding or machining. This remarkable biomaterial is also highly chemically resistant, biostable and is compatible with all common methods of sterilisation. These factors, together with other excellent mechanical and physical properties, including low creep, high fatigue resistance, and compatibility with modern imaging technologies, including Magnetic Resonance Imaging (MRI) and Computer Tomography (CT) have contributed to the global success and widespread clinical acceptance of this high quality cGMP manufactured product from Invibio.

This presentation will describe the manufacturing process, quality testing and safety approval of PEEK-OPTIMA[®] polymer and compare this and related materials based on PEEK with other polymeric resorbable and non-resorbable biomaterials, metallic medical alloys and ceramic biomaterials.



NESTA - SUPPORTING INTERDISCIPLINARY RESEARCH AND INNOVATION

*Rachel Brazil
Project Manager,
NESTA Connect*

A B S T R A C T

What sparks innovation? A clash of ideas, a fresh perspective, a fusion of expertise? Innovation occurs at the point where disciplines, organisations or cultures collide. NESTA aims to investigate the intersection of these areas and encourage the collisions between different worlds that stimulate innovation.

NESTA is the National Endowment for Science, Technology and the Arts. It is the largest single endowment devoted exclusively to supporting talent, innovation and creativity in the UK. NESTA's mission is to transform the UK's capacity for innovation. NESTA invests in early stage companies, informs innovation policy and encourage a culture that helps innovation to flourish.

As part of this mission, NESTA runs a series of experimental projects which include NESTA Connect. One of this programmes focuses is academic or industrial research activity that creates innovation through the interaction of two or more disciplines or sectors.

This talk will explain NESTA's mission and describe some of the programmes and mechanisms that NESTA is using to encourage innovative interdisciplinary research.



GOVERNMENT'S ROLE IN TECHNOLOGY

SIMON EDMONDS
DIRECTOR, BUSINESS RELATIONS 1
Department of Business, Enterprise and Regulatory Reform

The UK Government has developed many schemes designed to help UK businesses. Many have been successful but is the range confusing and off-putting. A programme to rationalise and co-ordinate means that the future looks less cluttered and more effective. The roles of the different parts of the DTI need to be understood to get the most out of them. The presentation will aim to make this landscape clearer.



Knowledge Transfer Networking in the Polymer Industry

Dr. Robert Quarshie, Director, Materials KTN

ABSTRACT

Knowledge Transfer Networks (KTNs) are a UK Government Business Support Solution delivered through the Technology Programme. They are designed to stimulate innovation in the UK's key technology sectors by promoting collaboration, best practice and knowledge sharing between industry and academia. KTNs aim to deliver improved business performance through accelerated innovation.

All KTNs are required to contribute to the development of the Government's Technology Strategy by helping to identify the challenges and opportunities which face industry in their chosen field of technology or business application. They are instrumental in brokering business-to-business and business-to-academia collaborations in response to National or EU calls for project proposals and in providing a medium for the dissemination of project results.

Plastics and rubber continue to be an integral part of the UK economy. With a combined turnover of £19.9 billion, the industry employs over 216,000 people, a 6.4% share of total manufacturing employment. Demand for plastics materials is expected to grow globally by 4% to a volume of around 116 million tonnes by 2010.

Due to the significant contribution of the plastics and rubber industry to the UK economy, the Government has provided funding for Knowledge Transfer activities within the industry. The Polymer Innovation Network is one of the largest networks operating as part of the Materials KTN. It is built on the previous Faraday Plastics to include the rubber community and to widen its national coverage.

As well as encouraging front-end industrial involvement in defining and shaping research priorities, the Materials KTN has polymer technology translators and business innovators have been working closely with companies to address immediate technological and innovation problems to enable companies to build a future based on sound foundations.



WONDERLAND

Prof. Tony Ryan⁽¹⁾ and Prof. Helen Storey⁽²⁾
⁽¹⁾University of Sheffield
⁽²⁾London College of Fashion

Professor Tony Ryan OBE

Professor Ryan is ICI Professor of Physical Chemistry and EPSRC Senior Media Fellow at the University of Sheffield. His media work includes many appearances on Radio 4's Start the Week and the Material World programmes, as well as presenting the four part series of 2002 Royal Institute Christmas Lectures for Channel 4, and writing articles for The Independent and the Daily Telegraph. His research field covers the structure development in polymer processing, including applications to soft nanotechnology. He was recently awarded an OBE in the New Years Honours List.

Professor Helen Storey

Professor Helen Storey began her career in the early 80's as a fashion designer. Dressing celebrities such as Madonna, Cher, Michael Jackson and Prince, she was twice nominated for Designer of the year and won awards for best exporter and Best of British Innovation.

In 1995 she was commissioned to write her autobiography " Fighting Fashion" by Faber and Faber, which became something of a testament to business tenacity and personal endeavor.

An award from The Wellcome Trust under the Sci/Art Initiative in 1995 changed her career for good, starting with the creation of Primitive Streak - a collection elucidating the first 1,000 hours of human life in textiles and fashion. Having collaborated with her sister Dr Kate Storey on this work, she has since, been working in collaboration with a number of scientists from around the world and currently sits at the cutting edge between the world's of art, science and technology. Her current interest is exploring how this combination of disciplines can together solve some of the global challenges we currently face.

Today, Tony and Helen will be talking to you about their collaboration Wonderland, how it came about and what together they have discovered.



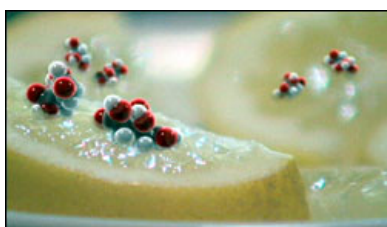
Lighting-up the invisible: advertising molecules

Dr Cristina De Matteis
School of Pharmacy, University of Nottingham



Beautiful, eye catching and visually stylish images are combined with molecular graphics to show the role of molecules in everyday life. By marrying photography and video with computer graphics representations of molecules, a clear visual link between an event or material and its constituent molecules is created. The role and relevance of the molecule is immediately understood, and there is no need to use scientific language, which may intimidate or alienate the audience.

The target audience is primarily young adults between the ages of 16 to 35, who are not normally exposed to or interested in science. To achieve this, the content and visual language used in the photographs and films draws on the life style, fashion and enjoyment of young people. The visuals appear advert-like, rather than scientific, with visual imagery reflecting the culture of young people in Britain and Europe. By providing a strong link between recreation, style and enjoyment, and the scientific content, the aim is to counteract many of the common misconceptions about molecular science, including perceived lack of relevance and negative image.



New material challenges for a post-industrial era

Lionel Dean
Future Factories UK

The mass production paradigm is being challenged by digital manufacturing and an associated demand for different modes of consuming.

Digital manufacturing is already taking off in a number of niche markets. It would seem certain that this will spread to low volume production in the near future and perhaps ultimately to medium volume manufacturing. The rise of this technology will affect the entire manufacturing landscape.

Digital technologies can build almost any form imaginable; revolutionary materials are now required to make dreams a reality. Materials are needed that not merely mimic those associated with more conventional manufacturing but that go far beyond. Product forms no-longer need to reflect particular materials or modes of manufacture. Once a file is created it can be built in any material available, from a process point of view therefore, materials become interchangeable. Added to this, there is the opportunity and indeed a financial imperative (to compensate for process expense) to replace assemblies (often of multiple materials) with a single digitally manufactured piece.

Now in its fifth year, FutureFactories continues to explore the possibilities for direct manufacturing through a range of products ranging from gallery pieces to retail products. These products and the interest they have generated highlight some exciting possibilities. In this presentation FutureFactories projects will be used as examples in an examination of the opportunities and challenges for new materials presented by digital technologies in a post industrial age.



Control and Behavior of Nanocomposite Block Copolymer Co-Crystals

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ABSTRACT

Self-assembled block copolymer templates can be used to control the nanoscale structure of materials that would not otherwise order in solution. In this work, we have developed a technique to use close-packed cubic and cylindrical mesophases of a thermoreversible block copolymer (PEO-PPO-PEO) to impart spatial order on dispersed nanoparticles. The thermoreversible nature of the template allows for the dispersion of particles synthesized outside the template. This feature extends the applicability of this templating method to many particle-polymer systems and also permits a systematic evaluation of the impact of design parameters on the structure and mechanical properties of the nanocomposites. The criteria for forming co-crystals has been fully characterized using contrast-matching small-angle neutron scattering (SANS) and the mechanical properties of these soft crystals determined. SANS experiments also demonstrate that shear can be used to align the nanocomposites into single-crystal macro-domains; the first demonstration of the formation of single-crystal nanoparticle superlattices. Numerous crystal structures have been reported for the block copolymer system and we have taken advantage of several to generate soft co-crystals. We are currently utilizing SANS to understand the flow mechanisms of several types of these co-crystals.



Instabilities in Polymers: Computational Modelling

Helen J. Wilson

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It is a difficult challenge to predict when polymer processing flows will fail – and a key goal to prevent these failures. Recently, computational modelling has progressed to the point where we can distinguish between numerical and physical instabilities. Numerical instabilities are failures of the computational simulation to adequately capture reality: unsteady flows and large stresses may be predicted in what ought to be a smooth flow. Physical instabilities, on the other hand, are real, and a simulation which is modelling true flow well must show unsteady behaviour where the real flow behaves badly.

We have been using *linear stability theory* to assess the stability of quasi-two-dimensional flows. We can look at any flow scenario where the ideal flow is steady and close to two-dimensional. The basic assumption is that when we have instability problems in processing, the reason is that the ideal flow would be destroyed by even the smallest amount of noise. This isn't necessarily true; but while the assumption might cause us to miss some instabilities, it will never cause a false positive: if linear stability predicts problems, then there will be problems.

The computational method is straightforward but quite powerful. We first solve for the ideal flow (steady and two-dimensional) and then look at the response to every possible manner of small noise perturbation. This leaves us solving an eigenvalue problem, whose leading eigenvalue gives the most unstable mode.

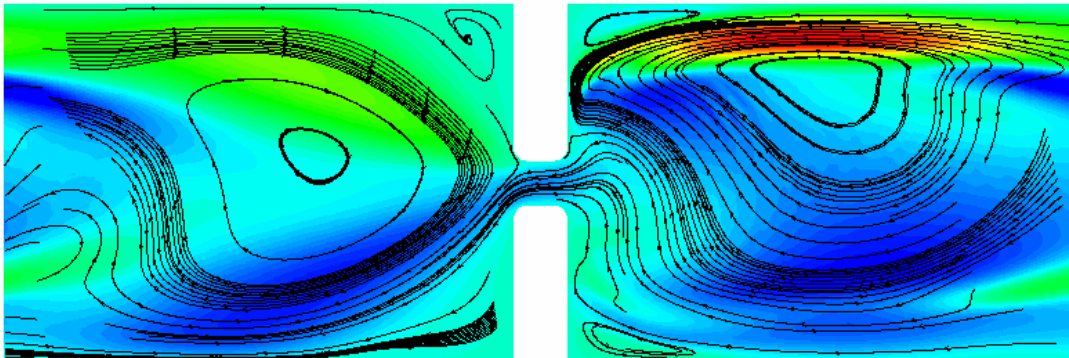


Figure: The most unstable mode for a 2D contraction–expansion flow (the lines are streamtraces and the colours represent the magnitude of the velocity from left to right).

These unstable modes can then be probed for information about the instability mechanism, and compared directly with experiments. I will present results using this style of computation for several geometries, and compare with experiments.



Simulation and Process Control – A Synergistic Pairing?

*Peter K. Kennedy
Chief Technology Officer
Moldflow Corporation*

A B S T R A C T

Injection molding simulation began in the 1970's and continues to be an important part of the molding industry. Today there are many simulation capabilities available. Independently, there have been many advances in process control. We contend that there are valuable connections between these fields that could lead to improved design and manufacture of products.

In this talk we will outline what can be done today with simulation and indicate the benefits of linking this to process control. We highlight advantages to be gained from sharing information from product design, and the simulation environment, and manufacturing, where process control is familiar, that would be of mutual benefit and so lead to improved productivity.

While this possibility exists today, there are potential developments that could lead to better results. While these are speculative, we propose some approaches that could be useful.



Multifunctional nanocomposites fibres ... or how to get the most out of carbon nanotubes

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Up to now, most research in the area of nanocomposites has focused on the synthesis and characterisation of so-called 2-dimensional structured nanocomposites (e.g. clay platelets), however, with the discovery of carbon nanotubes (CNTs) more and more interest is addressed to the so-called 1-dimensional nanocomposites. Not only have CNTs attracted interest as reinforcing fillers because of their superb mechanical properties (Young's modulus 1 TPa and tensile strength 150 GPa), but they are also regarded as the ultimate fillers for creating electrically conductive polymer composites (CPCs). Nanotubes are expected to transform an insulating polymer into a conducting composite at very low loading because of their high aspect ratio.

Despite their amazing properties, the success of carbon nanotubes in polymer composites has been limited. So far they have not yet lead to a wide range of commercial products, especially not those requiring mechanical reinforcement, one reason being the difficulty in dispersing them in the hosting matrix. This is not a trivial task, since the extremely large surface area that characterizes nanotube is responsible for their strong tendency to form agglomerates. In addition, good interfacial interaction and stress transfer between carbon nanotubes and polymer matrices is essential for good mechanical properties of the composites. Finally, similar to macromolecules the excellent intrinsic mechanical properties of CNTs can only be completely exploited if uniaxial orientation is achieved.

The introduction of nanofibres in oriented polymer systems like fibres and films would lead to materials that are truly inspired by nature. Natural materials such as bone and tooth are composites of proteins, which exhibit many levels of hierarchical structures and use nano-scale fibres as building blocks for micron-sized fibres. The creation of such 'man-made' nano-structured fibres could be used for the creation of newly 'designed' composite materials with additional levels of hierarchy.

In the presentation, the real potential of carbon nanotubes (CNTs) as reinforcing nanofibres in polymer composites will be explored through their use in oriented systems like films and fibres. In addition, the use of carbon nanotubes as conducting fillers will be addressed. The effect of incorporating CNT in an elastomeric matrix will be presented with particular emphasis on their application as sensor fibres for smart textiles.



The Science of Composite Interfaces

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The science of composite interfaces has entered a new era. The challenge of the past was to design adhesives, surface coatings and coupling agents that will environmentally protect fibres and allow effective stress transfer between fibres and matrices [1]. The present challenges lay in design of complex mechanisms within a nanomodified composite structure where pure and functionalized nanoparticles interact with matrices and fibre-matrix interfaces.

Many years of research have been invested in the investigation of chemical structure and physical properties of various composite interfaces. Interface is a bond between fibre and polymer matrix formed by the interdiffusion of atoms or molecules across the boundary between two different molecular structures. From a physical point of view, interface represents a weak point in a composite material, as the weak atomic bonds join different molecules at their ends. The interface region of a composite represents a sum of all individual fibre-matrix contact surfaces, and is also the region which is directly responsible for the stress redistribution between the matrix and the fibres. The performance of the composite material directly depends on the length, strength and adhesion of the fibres with the polymer matrix.

The morphological features, chemical compositions and thermo-mechanical properties of the interphase are distinct from the bulk materials. It is not yet clearly understood how the matrix properties are affected in the interphase region, where the adhesives and surface coatings physically and chemically interact with the matrix polymer. In order to understand better the interfacial mechanisms in composite materials and the role of coupling agents, several experimental techniques have been designed and employed to test local regions in the composite materials. Single fibre tests have been developed to reduce the influence of complicated stress transfer mechanisms in composites and to observe a test specimen containing a single bond. Important measurements have been carried out by means of Raman spectroscopy where it was observed that the stress distribution at the interface was far from linear and dependent on a surface treatment of the fibres [2]. Other experimental techniques such as Fourier transform infrared spectroscopy and NMR spectroscopy have been focused on the chemical aspects of the interphase region. Nano indentation and nano scratch tests have been successfully employed in the investigation of composite interphases, indicating that each composite interface and interphase has a different width and hardness value [3]. Some nano-indentation results indicated that the interphase region was harder than the matrix and this was confirmed by the strong change in the coefficient of friction along the interphase region in the nano-scratch test.

Recently, addition of nanoclays, carbon nanotubes and nanospheres into polymer matrices resulted in a variety of materials properties. Although the mechanical properties of polymer matrices were improved, the presence of nanoparticles in the interface region reduced the mechanical properties of thermosetting composites. There is a need to design a more systematic manufacturing protocol, and this presentation will address those issues.

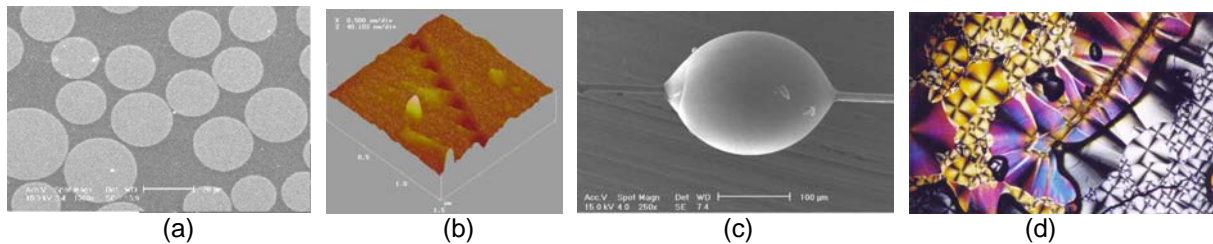


Figure 1. Investigations of fibre-composite interfaces: (a) Scanning electron microscopy of polyester-glass interface, (b) atomic force microscopy of nanoindentations in glass-phenolic interface, (c) single fibre test of polyester-glass interface and (d) hot-stage optical microscopy of natural fibre – biopolymer interface [4].

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Chemically modified carbon nanotubes and their application in polymer composites

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Single walled carbon nanotubes (SWNTs) have been shown to have impressive electrical, thermal and mechanical properties and have attracted interest and excitement across a broad spectrum of sciences and technologies including engineering, materials, chemistry and the biosciences. SWNTs can be metallic or semiconducting depending on their structure and have a strength comparable to that of steel. They have an equally impressive thermal conductivity which is better than diamond. Owing to these exceptional properties many potential applications for carbon nanotubes have been envisaged ranging from energy storage, sensors and field emission devices to nanoscale electronic components such as transistors, diodes, logic gates and bits of memory. But perhaps the most interesting potential application is the use of such material in polymer composites.^[1] Such composites have been found to have exceptional thermal transport properties and behave as excellent conductive plastics. Uniform dispersion within the polymer matrix and nanotube / matrix wetting and adhesion are all said to be important issues in the development of nanotube composites. To date nanotube based polymer composites have focussed primarily on pristine unmodified nanotubes, but due to their relatively inert nature the successful incorporation into a polymer matrix to produce a high performance composite has been difficult. The interaction of the nanotube with the polymer matrix is critical. However, it should be possible to engineer such interactions by careful control of the surface groups (and therefore properties) of the SWNTs.^[2-5] It is also envisaged that modifying the surface of SWNTs will allow us to control the dispersion of the nanotubes and avoid aggregation, a major problem in the processing of nanocomposites. Here we present some of our recent results in the chemical modification of SWNTs and describe some of their electrical and mechanical properties when assembled as thin films and when incorporated into a polymer matrix.

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