The University of Sheffield
Department of Engineering Materials

Research in Progress 2010

INCORPORATING
RESEARCH PUBLICATIONS AND GRANTS AWARDED IN 2009

April 2010
Cover Photography:
Background Image (left)
Peter and Andrew of the Advanced Metallic Systems Centre for Doctoral Training try their hand at sand casting.

Background Image (middle)
E-Futures: Doctoral Training Centre in Interdisciplinary Energy Research students visit the Advanced Manufacturing Park.

Background Image (right)
Typical appearance of plasma discharge during EPP treatment.

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1. Preface

The Department of Engineering Materials continues to play a key role as a driving force for innovation in research and postgraduate training. Over the past two years our involvement in four pioneering Centres for Doctoral Training (CDTs) has raised the bar for the delivery of PhD programmes both within the University and nationally. Also, our involvement in transformative research (especially with industrial interactions) has received many plaudits. The recent government report “The Current and Future Role of Technology and Innovation Centres (TICs) in the UK” by Dr Hermann Hauser\(^1\) cites the University’s Advanced Manufacturing Research Centre (AMRC) as an example of good practice in co-location with “the leading research expertise into materials and metals in Sheffield University” – thereby confirming the beneficial inputs of the Department’s research leaders in the AMRC’s development.

Our nationally-leading position in Knowledge Transfer Partnerships (KTPs) was endorsed with the award of a prize in 2009 for “The best KTP building on EPSRC-funded research”. The project was based on the fabrication of dielectrically-loaded antenna cores from glass-ceramics and the industrial partner was Sarantel Ltd. The academic lead was Professor Ian Reaney.

During 2009 our research awards again exceeded £8 million (not including CDT grants) and came from various sources, as shown in the pie chart. We are particularly proud of the increase in the level of research funding obtained directly from industry, which illustrates the highly relevant nature of our work to the nation’s real economy.

Also during the year, we are delighted to report that three of our staff members were promoted to Readerships: Russell Hand, Eric Palmiere and Neil Hyatt; and two were promoted to Senior Lectureships: Karl Travis and Adrian Leyland. Also we congratulate Gino Hrkac for obtaining a Royal Society Research Fellowship and this further strengthens our thriving Modelling group.

The huge success of our CDT programmes mentioned above builds on several key factors. First they all address key technology areas of vital importance to the UK economy: Nuclear Fission, Energy, Advanced Metallic Systems and Tissue Engineering with Regenerative Medicine. Secondly, at the University we have world-leading expertise and facilities in these fields. Thirdly, we have in place a well-designed PhD programme structure which aims to provide CDT students with excellent taught course provision and exposure to industry coupled with scientifically challenging and industrially-relevant research projects.

The award of a CDT is regarded by many (including the Research Councils themselves) as a key benchmark by which university research excellence is best assessed. For this Department to lead two and be partners in two more is a remarkable accolade.

Centres for Doctoral Training provide a new approach to postgraduate training. They aim to enrich the student experience, giving them the range of skills needed to become research leaders of the future. Our CDT programmes build on the Department’s established reputation for research training excellence through a range of activities designed to broaden the student’s research exposure and enhance their transferable skills. The cohort-based approach which we adopt means students are able to learn from and support each other as they progress, whilst working in partnership with other departments, both within the University and with other institutions. This provides new opportunities for exciting multidisciplinary research and enables students and staff to benefit from the complementary expertise of our academic and industrial partners.

The CDT programmes have a number of features in common. Students enter each 4-year course with a range of first degrees and the first year provides them with the core knowledge and understanding they need to underpin their research, delivered through taught masters-level courses and mini research projects. The breadth of topics covered means students explore a range of research areas before committing to a pre-defined PhD project or proposing their own topic of research. Years two to four focus on PhD research with additional skills training including outreach projects and industrial or international placements.

\(^1\)Dr Hermann Hauser “The Current and Future Role of Technology and Innovation Centres in the UK”, Crown Copyright March 2010 BIS/Pub/Xk/03/10.NP:URN 10/843.
The **Nuclear First** CDT is a partnership with The University of Manchester focussing on nuclear fission science and technology to supply highly trained specialists for the expanding UK nuclear industry. The DTC builds on long-standing successful collaboration between two BNFL University Research Alliances: the Immobilisation Science Laboratory and Centre for Radiochemistry Research. Understanding the social and ethical context of nuclear research is an important part of the programme and students undertake a range of innovative public engagement activities. As an example of this, EPSRC and its partner organisations organised an “IMPACT” exhibition in London to showcase the impact of scientific developments, and our CDT students collaborated with an artist based at the Royal College of Art (Zoe Papadopoulou) to produce a display illustrating how nuclear science can provide benefits such as boosting economic growth and reducing carbon emissions. To communicate aspects of nuclear power and radioactivity the students and the artist baked yellow cakes using ingredients high in potassium – 40, a radioactive isotope (such as bananas, Lo-salt (TM) and Brazil nuts). They later met with members of the public and Professor Robert Winston to explore public perceptions of nuclear energy over tea and cake!

The **Advanced Metallic Systems** CDT, also a partnership with The University of Manchester, addresses the growing shortage of high quality metallic materials specialists facing UK industry. The 2009 cohort of 12 students includes chemists, physicists, mechanical and civil engineers as well as some students returning to university after working in industry. They have gelled as a team and impressed us with their hard work and enthusiasm. In the first year, Advanced Metallics attracted 23 industrially-sponsored PhD project proposals highlighting the continued importance of this research area for UK industry across a range of sectors.

The **E-Futures** Doctoral Training Centre in Interdisciplinary Energy Research draws together 16 academic departments across the Faculties of Engineering, Science and Social Science within the University of Sheffield. It brings together diverse areas of expertise to train engineers and scientists with the skills, knowledge and confidence to tackle today’s evolving issues regarding energy generation, management and supply. In its first year, E-Futures has been very successful in attracting 21 skilled and highly motivated graduates with science, engineering and social science backgrounds. As part of efforts to interact with industry, an open day in October 2009 attracted over 50 industry delegates resulting in over 40 mini project proposals. Fourteen students are undertaking industrial projects and it is expected that many of these will lead to sponsored PhDs.

The **Tissue Engineering and Regenerative Medicine** (TERM) CDT is a White Rose University partnership with Leeds and York providing a multidisciplinary research and training environment at the life sciences interface. A highlight of the year is the residential induction week bringing together all the members of the CDT. This year it included team building and problem solving activities as well as visits to all the CDT research centres and to industrial companies.

We are naturally proud of the many research successes outlined in this report, and we hope that you enjoy reading about them. Above, the CDTs have been given special mention as they underline not only the firm scientific foundations on which the Department and Faculty are built, but also our commitment to providing highly-skilled personnel for industry and enhancing the career prospects of bright engineers and scientists.

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**Allan Matthews**

**April 2010**
2. Staff in the Department of Engineering Materials

Head of Department:
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Prof J H Harding  j.harding@ 0114 2225957  Functional Materials
Prof S MacNeil  s.macneil@ 0114 2225995  Cell and Tissue Engineering
Prof W M Rainforth  w.m.rainforth@ 0114 2225469  Materials Science and Engineering
Prof I M Reaney  i.m.reaney@ 0114 2225471  Ceramics
Prof T Schrefl  t.schrefl@ 0114 2225965  Functional Materials
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Prof P Tsakiropoulos  p.tsakiropoulos@ 0114 2225960  Metallurgy
Prof G Ungar  g.ungar@ 0114 2225457  Polymers and Organic Materials
Prof A R West  a.r.west@ 0114 2225501  Electroceramics and Solid State Chemistry

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Dr N C Hyatt  n.c.hyatt@ 0114 2225470  Nuclear Materials Chemistry
Dr B J Inkson Beverley.inkson@ 0114 2225925  Nanomaterials
Dr G Mób us  g.moebus@ 0114 2225512  Microscopy and Materials Science
Dr M I Ojovan  m.i.ojovan@ 0114 2226033  Waste Immobilisation and Materials Science
Dr E J Palmiere  e.j.palmiere@ 0114 2225978  Ferrous Metallurgy
Dr I Todd  i.todd@ 0114 2226011  Metallurgy
Dr S Zhang  s.zhang@ 0114 2225958  Structural Ceramics and Refractories

Senior Lecturers:
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Dr C K Chong  c.k.chong@ 0114 2225984  Biomedical Engineering
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Dr S J Matcher  s.j.matcher@ 0114 2225994  Biomedical Engineering
Dr K P Travis  k.travis@ 0114 2225483  Modelling
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Emeritus Professors:
Prof B B Argent
Prof M Cable
Prof H A Davies
Prof F G F Gibb
Prof G W Greenwood

Associate Professors:
Prof P V Hatton

Associate Senior Lecturers:
Dr D H Kirkwood

Associate Lecturers:
Dr J Devlin
Visiting Staff:

- Prof N A Chapman, ITC, Switzerland
- Prof P Curtis, DSTL
- Prof S Franklin, Philips, The Netherlands
- Prof A A Howe, Corus
- Prof P T McGrail, Composites and Polymers Consultant
- Dr S Owens, Nexia Solutions Limited
- Dr D Porter, Department of Zoology, University of Oxford
- Dr W Smith, CCLRC Daresbury Laboratory
- Prof J L Thomason, University of Strathclyde
- Prof S Van der Zwaag, Delft University of Technology

Senior Experimental Officer: Dr P Korgul 0114 2226005

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- Dr D A W Taylor 0114 2225497

Short Courses Director: Dr P A Kapranos 0114 2225509

Departmental Superintendent: Mr J W Smedley 0114 2225500

Financial Administrator: Mr D M Binns 0114 2225979

E-Futures DTC Programme Manager: Dr N J Lowrie 0114 2225506

Engineering Manager (IMPC): Dr M Ruffo

CCL Manager: Mr G Brown 0114 2225971

Project Engineer: Mr F Derguti

Learning Technologist (DTC): Mrs K Thomson 0114 2225475

Project Manager (DTC): Dr C Hinchliffe 0114 2225478

Research Fellows and Research Assistants:

- Mr A Ahmed
- Dr A J Beck
- Dr P A Bingham
- Mr M L Blackmore
- Dr M Bryan
- Dr A J Bullock
- Mr K Butler
- Dr A Connelly
- Dr D Cumming
- Dr J Dean
- Dr D Deivasagayam
- Mr F Derguti
- Ms P Deshpande
- Dr R Dost
- Dr J W Eichler
- Visiting Scientists:
- Mr M Kawakami
- Dr E Krajewska
- Mr M Lahirigoyen
- Ms Y Lei
- KTP Associates:
- Mr T Burnett
- Miss J Corfield
- Dr M Darby
- Ms M Ricca
- Mr N Schreven
- Dr C Stone
- Prof J-B Sun
- Mr W S Flores Roman
- Mr Y Kadaveru
- Mr P Svara
- Dr Y N Kok
- Dr Y N Zhang
- Dr Z Mirza
- Dr X Xu
- Dr A Sidambe
- Dr L E Smith
- Dr M C Stennett
- Miss I Sterianou
- Mr T Swait
- Mr H Uppal
- Dr C Utton
- Dr A L Yerokhin
- Dr P Zeng
- Mrs W Zhang
- Dr Z Zhou

- Dr Z Mirza
- Dr X Xu

- Dr X Yuan
- Ms C Zhang
- Dr N Zhu
- Miss B Zalinska
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Mrs V M Dalton          PA to Head of Department, WMR/PT, Secretary to Advanced Metallic Systems DTC
Mrs K A Burton          PGR/PGT Admissions, Monitoring and Progress, ISL
Ms W Dutton             Exam Preparation and Monitoring/Prizes, FRJ/GU, Out of Hours, Research in Progress, Short Courses, Dept List
Miss R Fearon           Purchasing and Accounts, General Enquiries
Miss K L Heard          Secretary to SMN, Kroto Institute
Miss F E Kirk           Research Secretary to E-Futures DTC Director
Mrs L C Mason           Undergraduate Secretary/Support/DTQC Secretary/Enquiries/Exam Results
Mrs A Newbould          PG Monitoring and Progress, Secretary to HAD/JHH/DCS/MRJG
Miss E Noble            Support Secretary, Kroto Institute
Mrs T V Sampson         Teaching Databases, Taught Courses, UG Admissions (with UG Tutors)
Mrs A E Sargent         Purchasing and Accounts, JWS

Technical Staff:
Miss M Baran            Tissue Engineering
Mr S Bater              Materials Processing
Miss D Bussey           Nanoindentor, STM, Undergraduate Laboratory
Mr M Carter             Teaching Laboratories
Mr M G Cooper           Graphics, DTP, Web Pages, Audio Visual
Mr F G Fletcher         Electronics, Computing
Mr P J J Hawksworth     Surface Engineering, Magnetic Materials
Mr D Haylock            Mechanical Testing, Materials Processing
Miss C Johnson          Tissue Engineering
Mr R I Kangley          Electrical, PAT and IT
Ms B C Lane             Materials Characterisation
Mr A G Mould            Electroceramics and Waste Immobilisation
Mr V C Rhodes           Stores
Dr C Shields            EPMA
Mr P Staton             Mechanical Testing, Metallography
Mr M J Wagner           Cleanroom Manager, Tissue Engineering
Mr I P Watts            Materials Processing
Dr P Zeng               Electron Microscopy

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3. Industrial Liaison Committee

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4. Academic Staff Profiles

Dr Dan A Allwood  
BSc PhD MnstP CPhys  
Senior Lecturer in Materials Physics  
Current research focuses on investigating the behaviour of magnetic domain walls in lithographically-defined magnetic nanowires. These nanowires are increasingly assuming worldwide importance as part of novel sensor, memory and logic technologies. Here, a magneto-optical instrument is being developed that is sensitive to magnetisation changes in a single nanostructure on a nanosecond timescale. This is being used to investigate the dynamics of domain wall propagation in individual nanowires and of domain wall interactions at wire junctions. Although predominantly experimental in emphasis, this research also seeks to understand these processes on a theoretical level.

Dr Chuh K Chong  
BSc PhD  
Senior Lecturer in Biomedical Engineering  
Main research interest centres on cardiovascular fluid mechanics, focusing on understanding the role of haemodynamics in the pathogenesis of arterial diseases, the pharmacokinetics of drug-eluting stents, and the design and performance of vascular implants. Another interest is in tissue engineering, focusing on the biomechanics of soft tissues, developing functional cell-seeding device, bioreactors, scaffolds and matrices with desired architecture and material properties, understanding the effects of materials, mass transport, biochemical cues and mechanical stresses on cell activities in purpose-designed bioreactors.

Prof Michael Cable  
BScTech PhD DScTech TkDhc HonFSGT  
Emeritus Professor  
Current projects concern the history of glass technology as revealed by authorities of earlier times. Five books, three translated from French or German, covering the period from 1662 to 1868 have been published. The translation of the sixth, a long book by Eberhard Zschimmer, one of Schott’s early scientific collaborators, (which Schott suppressed on its publication in 1912) is nearing completion. The seventh, a reprint of Rosenhain’s “Glass Manufacture” of 1918, is also completed.

Prof Neil A Chapman  
BSc PhD FGS CGeol  
Visiting Professor of Radioactive Waste Management  
Principal interests are in all aspects of deep geological disposal of solid radioactive wastes, including geological characteristics of repository sites (geochemistry and hydrogeology), system evolution over tens of thousands of years, performance and safety assessment, long-term waste-form and engineered barrier behaviour, natural and archaeological analogues of repository materials, repository design and construction. Chairman of the ITC International School of Underground Waste Storage and Disposal, Switzerland. Member of the International Technical Advisory Committee (ITAC) of the Japanese National Radioactive Waste Management Organisation, NUMO. Member, IAEA review mission to NECSA, South Africa (borehole disposal of disused radiation sources).

Prof Hywel A Davies  
BSc PhD ARSM DIC CEng CPhys MnstP FIMMM FREng  
Emeritus Professor of Physical Metallurgy and Magnetic Materials  
Research has concentrated mainly on the science and technology of solidification at ultra high cooling rates. The areas covered include: (i) the mechanisms of formation of metastable microstructures, with particular emphasis on amorphous and nanostructured alloys; (ii) the structures, properties and development of several classes of materials, including metallic glasses, novel nanophase hard and soft magnetic alloys and microcrystalline ferrous and non-ferrous alloys; (iii) the principles and applications of rapid solidification processing of advanced alloys, including the direct casting of thin strip and wire and powder atomisation followed by consolidation.

Dr Frederik Claeyssens  
Licentiate PhD Member RSC MRS  
Lecturer in Biomaterials  
Current research is focussed on biomaterials manufacture with laser based techniques. This research broadly falls into three sub-projects: Coatings for biology: Biocompatible surface coatings of semiconductors to be integrated into cell-silicon interfaces for biosensors. Bioprinting: Laser based techniques for printing biomolecules/cells for producing biomolecule arrays and biosensors. Biomaterials manufacture via microstereolithography: Production of microstructured biomaterials for usage as tissue engineering scaffolds, via a laser based photocuring technique. Via scanning the laser through a photocurable resin, user-defined microstructures can be produced from a biocompatible polymer. This technique can be combined with self-assembly approaches to achieve hybrid biomaterials as 3D scaffolds for implants, tissue engineering and pharmaceutical testing.
Prof Fergus G F Gibb
BSc PhD FGS
Emeritus Professor of Petrology and Geochemistry
Areas of expertise are in geological materials (minerals and rocks) and the geological disposal of radioactive waste, especially the concept of very deep borehole disposal on which he is an international research leader. Specific interests and activities in the context of this research currently focus on high pressure and temperature experimental mineralogy (especially nucleation, crystal growth and reaction kinetics) and modelling of heat flow in and around deep borehole disposals of heat-generating nuclear wastes. Career-long interest in (i) the electron probe microanalysis of minerals, glasses and other materials and (ii) the mineralogy and petrology of igneous rocks, particularly geochemical processes relating to the origins of basic/ultrabasic intrusions led to recognition as an international authority on the petrogenesis of basic sills.

Dr Russell Goodall
MEng PhD
Lecturer in Metallurgy
Principal research interests are in the processing, mechanical / thermal properties and applications of open-celled porous metals, with particular reference to aluminium foams or sponges. These materials are being examined for applications in a range of heat transfer situations and are processed using the NaCl-based replication method (where liquid aluminium is infiltrated into the spaces between grains or agglomerates of salt, which are dissolved in water after solidification of the metal). He is also looking at innovative processing techniques for porous materials fabricated from higher melting point metals, such as titanium.

Prof Geoffrey W Greenwood
BSc PhD DMet CPhys CEng FIMMM FInstP FREng FRS
Emeritus Professor
Interests are centred on atomic movements, especially in relation to microstructure and to the flux paths under mechanical, chemical and thermal driving forces. The applications relate to microstructural evolution, properties of interfaces and transitions between different modes of deformation and fracture.

Prof Michael R J Gibbs
BSc PhD CPhys FInstP MIEEE
Professor of Materials Physics and Director of the Centre for Advanced Magnetic Materials and Devices
Current research includes: the study of magnetoelastic materials, bulk and thin film; the study of permanent magnet thin films; the study of magnetic microelectromechanical systems (MagMEMS); the application of magnetic materials in sensors and actuators; the study of materials for applications in spintronics; the study of the principles and application of magnetic force microscopy

Prof John Harding
MA PhD CPhys FRSC FInstP
Professor of Functional Materials Visiting Professor of Physics, University College London
Current research includes the development of methods to simulate atomistic processes with long timescales and their application to problems in bulk ceramics and at interfaces; simulation of the structures of interfaces of ceramics; simulation of organic/inorganic interfaces, nucleation and self-assembly (particularly in the context of biomineralisation and biomimetics); simulation of nanomaterials; mesoscale simulation of plasma-sprayed coatings. He is the organiser of an annual Summer School in Molecular Simulation.
Dr John W Haycock  
BSc PhD  
Reader in Cell and Tissue Engineering  
Research interests are in the biochemistry, cellular and molecular biology of living cells following interactions with synthetic and native peptide structures and matrix proteins. Current research includes: investigations into the anti-inflammatory action of peptide molecules; the biological performance of cell/biomaterial interactions; the free radical mechanisms of gene control.

Dr Simon A Hayes  
BEng PhD  
Lecturer in Aerospace Engineering  
Research interests encompass smart materials, nanocomposites and nanomechanical property determination. He is involved in the development of sensors for damage detection, cure monitoring and through life environmental condition monitoring in polymer-matrix composites. He has also developed a patented technology for the healing of damage within composite structures. He has projects examining the mechanical properties of clay and nanotube-based nanocomposites. He is also involved in the development of nanoindentation for the analysis of soft viscoelastic materials.

Prof Andy Howe  
MA PhD FIMMM CEng  
Visiting Professor, Corus Group plc  
Research interests cover microstructural evolution in steels including solidification and microsegregation, solid state phase transformation and recrystallisation. Current research includes the streamlined modelling of solidification at the micro-scale for coupling with macro-models, and the development of ultra-high strength steels.

Dr Gino Hrkac  
Dr techn Dipl INg  
Royal Society University Research Fellow  
Main research area is computational and theoretical magnetism, and especially the development of a numerical model to investigate and predict the behaviour of magnetic spin valve systems and the effect of eddy currents in nano-scale materials. He is working on the theoretical and numerical description of spin electronic devices on a length scale ranging from the computation of the local spin current density and magnetization dynamics with a sub-nm resolution in micron size devices (magnetic nano pillars and Magnetic Tunnel Junctions). A prominent example for his work is the theoretical explanation of the angular dependency of phase locking phenomena in point contacted spin valves and his work on the simulation of spin current induced magnetization dynamics that explained the low frequency oscillations found in point contact devices that were explained by vortex oscillations. His latest research includes ab initio simulations of atomic structures, solid state molecular dynamics for the simulation of the transition of amorphous to crystalline grain boundaries in NdFeB magnets within the framework of an industrial funded project on permanent magnets (European-Japanese consortium).

Dr Neil Hyatt  
BSc PhD MInstP  
Reader in Nuclear Materials Chemistry  
Research is focussed on the understanding of structure – property relationships in the solid state and the application of diffraction techniques under extreme (high pressure/temperature) conditions. Current areas of research interest include the synthesis and characterisation of dielectric and ferroelectric materials; the immobilisation of high level nuclear waste in glass and ceramic matrices; structural studies of the vitreous state; pressure induced spin state transitions in perovskite related oxides; and the synthesis of new materials under extreme conditions.

Dr Beverley J Inkson  
MA PhD  
Reader in Nanomaterials  
Research interests focus on the mechanical and electrical properties of metals and ceramics at the nanoscale, with an emphasis on how nanostructures and surface films behave differently from conventional bulk materials. Current projects include tribology and surface wear of structural nanocomposites, mechanical stability of nanowires, reliability of MEMS devices, nanoprocessing of surface structures using focused ion beams (FIB), nanocharacterisation (3D TEM/SEM/FIB, tomography, in-situ TEM), and nanoindentation.
Research in Progress 2010

Dr Martin Jackson
MEng PhD DIC
Royal Academy of Engineering/ EPSRC Research Fellow and Lecturer Elect

Research interests centre on solid state processing, microstructural/textural evolution and phase transformations in light alloys. Major research focus is development of low cost non-melt consolidation routes for particulate titanium-based feedstock from emerging reduction processes. Current research in titanium also includes; (i) microstructural evolution during isothermal forging of high strength alloys used in airframe forgings; (ii) alpha case formation/crack initiation in alloys used in aeroengine gas turbine compressors. Other research interests include the superplastic behaviour of aluminium and magnesium alloys during processing for automotive applications.

Dr Hajime Kinoshita
BEng MEng DEng
Lecturer in Materials Chemistry and Geochemistry

Main interest of research is in thermodynamic aspects of environmental materials for waste treatment. Research interests include: electrochemical aging of durable materials for prediction of long-term stability in geological environments; CO2 immobilisation in recycled cementitious materials; decontamination of alloys with molten salts; influence of thermodynamic parameters on O2 ion conductivity in stabilised zirconia; molten state processing of ceramic materials for waste immobilisation; thermodynamic modelling and phase diagram calculation.

Prof Frank R Jones
PhD FIMMM CEng FRSC CChem CSci
Emeritus Professor of Polymers and Fibre Composites

Research centres around correlations between molecular aspects and macroproperties of polymer matrix composites using micro-mechanical and surface analytical techniques. He has extensive research programmes on interfacial molecular engineering using plasma polymerisation; development of phase-stepping photelastic techniques for quantifying adhesion; environmental effects specifically mechanisms of moisture absorption and thermal and hygrothermal degradation of advanced high temperature matrix systems. Group Interaction modelling of resin properties for understanding the durability of a composite from a full knowledge of the matrix performance.

Prof Howard Jones
BSc PhD CEng FIMMM
Emeritus Professor of Metallurgy and Materials

Research interests include mechanisms and modelling of solidification in general and especially, the mechanism of dendritic and eutectic growth in alloys. He has a longstanding interest in the high temperature behaviour of materials, in particular the stability of microstructure and mechanical properties. Other areas of interest include: consolidation of particulate rapidly solidified materials, together with the development of intermetallics as engineering materials, the fundamentals of ceramic/metal bonding, metallic matrix composites and wettability studies.

Prof Dr Adrian Leyland
BSc PhD MInstP
Senior Lecturer in Surface Technology

Research interests are focused on Surface Engineering and Tribology, specialising in plasma-assisted Physical Vapour Deposition (PVD) of nanostructured ceramic coatings (for wear resistance and/or adaptive behaviour in extreme environments), metallic nanocomposite/glassy-metal coatings (for combined wear and corrosion protection), duplex plasma-diffusion/PVD-coating treatments (to improve the load-bearing capacity of light alloys and stainless steels in sliding wear applications) and the development of tribological testing/property evaluation techniques for coatings.

Prof Sheila MacNeil
BSc PhD
Professor of Cell and Tissue Engineering

Research is focussed on cell biology, specifically the actions of extracellular matrix (ECM) proteins which influences wound healing, neo-plastic invasion of melanoma and also pigmentation. Particular areas of on-going work include investigations into the regulation of melanocytes of skin, hair and eye and the development of tissue engineered human skin for clinical use. In the latter case a University spin-out company (CellTran) has been formed and is progressing this work in “proof of concept” clinical studies.
Dr Stephen J Matcher
BSc, PhD, Member SPIE, OSA, BMS, ESM
Senior Lecturer in Biomedical Engineering
Current research interests: development of optical imaging and spectroscopy to characterize bioengineered tissues in vitro and in situ. Main techniques are optical coherence tomography and microscopy, elastic scattering spectroscopy, second-harmonic and two-photon microscopy. I am particularly interested in the collagen structure of connective tissue and how this is altered in disease, in techniques to assess tissue perfusion and cellular bioenergetics in vivo and in Doppler techniques to study the microcirculation.

Dr Nicola Morley
MPhys PhD MemInstP
Lecturer in Material Physics
Current research includes: the anisotropy and magnetostriction of epitaxial Fe and Co on GaAs substrates; the anisotropy and magnetostriction of thin Fe-based magnetic films; novel spintronic devices, which include organic polymer spacer layers; organic intrinsic magnetoresistance of conjugated polymers and small-molecules.

Prof Allan Matthews
BSc PhD FIMMM FIMechE FIEE FIMF
Head of Department; Professor of Surface Engineering
Main research interests involve plasma-based surface coating and treatment processes, and techniques for surface characterisation and evaluation. Current projects include the deposition of nanocomposite tribological coatings by sputter-deposition, the surface modification of lightweight metals by plasma electrolytic oxidation, low-temperature deposition of phase-stabilised oxide ceramic coatings, and plasma diagnostics and control studies. He is also involved in the development of computer-based coating selection systems.

Dr Günter Möbus
DiplPhys Dr rer nat (PhD)
Reader in Microscopy and Materials Science
Research is focused on the characterisation of materials on the atomic and nano-scale, including development of quantitative electron microscopy techniques for 3D-mapping of microstructure, composition, strain, and retrieval of crystal defect structures. Within the context of immobilisation science, modern characterisation techniques, such as tomography, 3D reconstruction, and fine structure spectroscopy are used to detect the local composition and microstructure in glasses and ceramics, and to determine local coordination and oxidation states of cations.

Dr Eric J Palmiere
BSc MSc PhD CEng
Reader in Metallurgy
Research involves the microstructural evolution, and the subsequent development of mechanical properties, during the thermomechanical processing of both ferrous and non-ferrous alloys with a primary focus on ferrous alloys such as stainless, microalloyed steels and associated model alloy steels. He is particularly interested in developing a basic understanding between those softening (i.e. recovery, recrystallisation) and strengthening (i.e. solid solution formation, precipitation) mechanisms which occur either in austenite or in ferrite.

Dr Michael I Ojovan
MSc PhD DSc FRANS FMRS MSGT
Reader in Materials Science and Waste Immobilisation
Research interests focus on physics of metastable states, structure and properties of disordered systems and Rydberg matter, radiation-induced effects in solids. Recent work has included analysis of durability and long term performance of nuclear waste immobilising glasses and glass-composite materials, development of nuclear waste processing techniques including thermochemical decontamination and self-sustaining immobilisation.
Prof John M Parker
MA PhD FIMMM CEng FSCT
Emeritus Professor of Glass Science and Engineering

Research has included a number of themes based around structure, crystallisation and optical properties. Current major topics are glass colour and how specific ions can act as probes for local structure associated with segregation such as complex formation or fictive temperature behaviour. A particular interest is the modelling of absorption spectra as an aid to composition design for glass makers particularly when using high fractions of recycled glass. An ongoing interest is how the formation of nanocrystals within a matrix can influence the environment of dopant ions and produce specific optical effects.

Prof W Mark Rainforth
BMet PhD MIMMM CEng FInstP CPhys
Professor of Materials Science and Engineering

Research focuses on developing a mechanistic understanding of microstructural evolution as a basic pre-requisite to the development of physically based modelling of both metals and ceramics. Huge gains have been made in the quantification of microstructure across the length scales, including field emission gun TEM techniques for determining chemical and physical structure at the atomic scale, focus ion beam (FIB) microscopy for the determination of surface structure (e.g. oxides) and high resolution back-scatter electron diffraction (EBSD) for texture and phase distribution analysis. Such techniques are applied to the structure of nanoscale coatings, the evolution of deformation and precipitation substructures during hot working, and surface structures developed through friction and high temperature exposure.

Prof Ian M Reaney
BSc MSc PhD MInstP CPhys CEng FRMS
Professor of Ceramics

Main research theme is the use of transmission electron microscopy to study the structure and microstructure of electroceramics as well as the development of new or improved materials for commercial applications. His research activities are mainly concerned with dielectric resonators for microwave communications as well as materials for sensor and actuator applications. He has an interest in crystallisable glasses for biomedical and photonic applications, studying their phase evolution as a function of temperature and composition.

Dr Gwendolen Reilly
BSc DPhil
Lecturer in Tissue Engineering

Background: bone biomechanics; transduction of mechanically induced signals in bone cells; bioactive glasses as a scaffold for bone tissue engineering; skeletal cell differentiation. Research aims: investigating the use of mechanical stimuli to enhance strength of tissue engineered bone and cartilage; examining the effect of biomaterial scaffolds on skeletal cell mechanical responses; mechanical manipulation of tissue engineered matrix structures. Our laboratory is particularly interested in using tissue engineering to create 3D bone models for use as an alternative to animal experiments in the testing of orthopaedic pharmaceuticals and devices.

Prof Thomas Schrefl
DI Dr Techn
Professor of Functional Materials

His expertise is in materials and device modelling using finite element and fast boundary element methods. The primary goal of his modelling is to obtain a better understanding of the influence of the microstructure on the properties of the materials and the application of this knowledge to simulate the functional behaviour of devices over multiple length scales. Current research includes: the simulation of hard disk recording, finite element micromagnetics, nanostructured magnetic materials, spin electronic devices, magnetic memories (MRAM), and magnetoelastic sensors.

Prof C Michael Sellars
BMet PhD DMet HonCMechD FREng FNAE (India) FIMMM
Emeritus Professor of Metallurgy

Current research interests centre on thermomechanical processing of metals and alloys, with emphasis on the microstructural changes produced and their effects on properties. The work is based on basic laboratory studies using plane strain compression testing, laboratory scale rolling, extrusion and forging, which have been used to provide data required to develop computer models of microstructural evolution and to validate the predictions of the models. Experimental studies have been carried out on a wide range of alloys including high strength low alloy (HSLA) steels, stainless steels, aluminium alloys, nickel-based superalloys, IF steels and iron aluminides.
**Prof John H Sharp**  
*BSc PhD CEng FIMMM*  
Emeritus Professor of Ceramic Science  
Major on-going interest is in the chemistry of cements. Current topics include the hydration reactions and durability of Portland cement and composite cements (involving the partial replacement of Portland cement by waste materials or mineral products) used for nuclear waste management, and durability studies into the formation of delayed ettringite and thaumasite in Portland cement systems. In particular, the effects of pH, temperature and carbon dioxide on the thaumasite form of sulfate attack.

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**Prof Derek C Sinclair**  
*BSc PhD CChem MRSC*  
Professor of Materials Chemistry  
Research interests are primarily involved with the synthesis and characterisation of oxide-based electroceramics. Current work includes investigating composition-structure-property relationships in important electroceramics, explorative phase diagram studies and speculative synthetic work on ‘new’ materials with superior electrical properties. The latter approach is being used to discover new mixed ionic/electronic conductors, proton conductors, microwave dielectrics, ferroelectrics, piezoelectrics and low-temperature cofired ceramics.

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**Dr Richard Thackray**  
*BEng PhD DIC*  
Corus Lecturer in Steelmaking  
Research interests are in continuous casting of steel, in particular the role of mould powders in the processing route, where models have been developed which relate the viscosity, break temperature, and crystallinity of the powder to the successful performance of the casting operation. New research into evaluating the suitability of F-free fluxes to replace existing fluxes will also be carried out in the near future. In addition, work to understand the complex flow of metal during the casting process, and the associated heat transfer effects and product quality implications, using process modelling techniques is also ongoing.

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**Dr Iain Todd**  
*BEng PhD*  
Reader in Metallurgy and Research Director of the Innovative Metals Processing Centre  
The development of novel processing technologies and metallic materials forms the core of my present research activity. Current work includes: the development of novel processes for the production of titanium components by powder metallurgical routes; modelling microstructure evolution during additive manufacturing processes; the manufacture of Ti components for biomedical applications and the kinetics of Bulk Metallic Glass formation and their physical properties. Work is conducted through the Innovative Metals Processing Centre and in collaboration with Industry and the Advanced Manufacturing Research Centre with Boeing at the University of Sheffield.

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**Dr Karl P Travis**  
*BSc PhD CChem MRSC*  
Senior Lecturer in Modelling Materials  
Research interests cover Theoretical and Mathematical Physics, particularly of condensed phases; structure-property relationships of materials; and the thermo-dynamic behaviour of nana-confined fluids. Research is currently focussed on applying atomistic, mesoscale and continuum modelling techniques to problems connected with the storage of nuclear waste. Some current topics under investigation include: modelling radiation damage in ceramic wasteforms, modelling the conductive flow of heat in very deep geological disposal scenarios and developing Dissipative Particle Dynamics for predicting phase behaviour and rheology in complex mixtures.

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**Prof Panos Tsakiropoulos**  
*D Eng Mining Eng - Metallurgy*  
MMet PhD  
Professor of Metallurgy and POSCO Chair of Iron and Steel Technology  
Research interests are in the design and development of ferrous and non-ferrous alloys and composites for the energy, transport and aerospace industries via process-microstructure-property studies. Materials processing under equilibrium and non-equilibrium conditions is also researched as part of the alloy development. The emphasis of the research is on establishing (i) the effects of processing on the microstructure and properties of structural engineering materials and (ii) how processing can be tailored to particular engineering requirements for desirable microstructures and properties. Currently, alloys of Fe, Mo, Nb, Ti and Zr are under investigation.
Prof Goran Ungar  
BSc PhD CPhys  
Professor of Polymers and Organic Materials  
Research interests include the study of structure and phase behaviour of liquid crystalline (l.c.) and supramolecular polymeric, oligomeric and low molecular mass systems. A second area of research is the structure and morphology of semicrystalline polymers. In particular, monodisperse model polymers in the form of very long chain n-alkanes are studied: new crystallization mechanisms have been proposed (“self-poisoning” effect) and new layer superlattices discovered.

Prof Anthony R West  
BSc PhD DSc CChem CPhys FRSC  
FinstP FIMMM FRSE  
Professor of Electroceramics and Solid State Chemistry  
Current research includes: the development of new spinel cathode materials such as LiCoMnO₄ for lithium batteries; synthesis and characterisation of new ferroelectrics and relaxor ferroelectrics with tetragonal tungsten bronze structure; new Li⁺ ion and O²⁻ ion conducting solid electrolytes; structures of Mn-based complex perovskites and Bi pyrochlores; probing the structure-property correlations that control the performance of zinc oxide varistors, barium titanate PTCR devices and CaCu titanate barrier layer capacitors. He is also well-known for his books on Solid State Chemistry.

Prof Peter V Wright  
BSc MSc PhD  
Emeritus Professor of Polymers  
Best known as the inventor in the mid-1970s of polymer electrolytes. His main research activities are now involved with electroactive polymeric materials, particularly low dimensional crystalline and liquid-crystalline systems with enhanced conductivities. Another major area of research is the development of novel ‘large-area’ polymer films with switchable impedances, in particular for the control of microwave transmission (“microwave smart windows”). Other areas of interest include: the interaction of ions with water soluble polymers in aqueous solutions and ring-chain equilibria, particularly in polysiloxane systems.

Dr Bradley P Wynne  
BEng PhD  
Senior Lecturer in Metallurgy  
Research interests focus on the thermomechanical processing of metals and alloys, particularly the interrelationship between the constraints imposed by the deformation conditions and the constraints on flow behaviour generated by crystal structure and crystallographic texture, which in turn determines deformation microstructure evolution. Currently his major focus is on the effects of non-linear strain paths on microstructure evolution. The overall aim of this research is to develop true internal state models for microstructure evolution to replace our current empirically based models which are often inadequate when deformation conditions are complex.

Dr Shaowei Zhang  
BSc MEng PhD  
Reader in Structural Ceramics and Refractories  
His main research interests are in the processing, microstructures and properties of structural ceramics and refractories. Current research topics include development of next generation carbon-containing refractory composites, improvement of hydration resistance of lime-based refractories, molten salt synthesis of ceramic powders, and preparation of oxide nanoparticles. Other work includes fabrication of carbon nanotube-based composites, development of ultrahigh-temperature ceramics and in-situ generation of carbide/oxide nanotubes/nanorods.

Dr Xiangbing Zeng  
BSc MSc PhD  
Lecturer in Polymers  
Current research concerns 1-d, 2-d, 3-d ordered nano-structures (1-100 nm) in macromolecular and supramolecular systems, with potential applications for molecular electronics, photonics etc. The main methods used are small angle x-ray and neutron scattering (SAXS and SANS). These experiments are often carried out in real-time in order to catch transient structures and rapid transformations such as occur in real-life, industrial processing of polymers.
5. Materials-Based University Research Centres

5.1 Sheffield Centre for Advanced Magnetic Materials and Devices

This Research Centre provides a focus for research innovation for the study and exploitation of magnetic materials and devices. Activities range from basic research to applications, bringing together materials processing and fabrication, state-of-the-art characterization techniques, and multiscale simulation of materials and devices. The long term objectives are to provide the collaborative framework for the investigation and exploitation of novel magnetic phenomena and the development of new and improved materials, structures and devices, and where appropriate to apply these to the needs of industry and commerce.

The academic staff associated with the Centre comprises Profs M R J Gibbs, T Schrefl and Drs D A Allwood and N A Morley, with Prof H A Davies now an Emeritus Professor. Dr G Hrkac is a Royal Society Advanced Research Fellow in the Centre.

Highlights for 2010 include a very strong presence at the joint MMM/INTERMAG conference in Washington. More than ten papers were presented involving staff from the Centre. Several EPSRC grants have been secured, together with Yorkshire Forward proof-of-concept funding for device development. Applications in bioscience, healthcare and security are attracting commercial interest.

Spintronics, the recognition and exploitation of the spin as well as the charge on the electron, is a very hot topic in world-wide magnetics research. Dr Morley and Prof Gibbs are leading the Centre activity in this area, looking at combining organic materials that show magnetoresistance with more conventional ferromagnetic materials. Progress has been rapid with new results coming from collaborations with the Paul Scherrer Institute in Switzerland and Queen Mary College in London.

Modelling on a number of length scales is an increasingly important tool in magnetics research. The award of the fellowship to Dr Hrkac will very strongly underpin this effort over the coming years.

The programme on magnetic nanowires continues to develop, led by Dr Allwood with strong support from Prof Gibbs and Prof Schrefl. Whilst there is much fundamental science to be explored in terms of dynamic response of such structures, there are also many potential application areas. Novel applications in atom trapping for potential use in quantum information processing are being actively pursued.

Industrial linkage for our projects is an important part of our activities, and there are active collaborations with Hitachi Global Storage Technologies, Seagate Technology, Toyota and Ultra Electronics. Consultancy is also provided, together with research quantities of material where appropriate.
5.2 Research Centre in Surface Engineering

The Research Centre in Surface Engineering (RCSE) laboratory houses equipment for plasma-assisted deposition by both magnetron and remote-plasma sputtering and by electron beam evaporation – as well as facilities for plasma immersion ion implantation surface treatment and other novel ion-assisted coating methods, including High-Power Impulse Magnetron Sputtering (HiPIMS). A purpose-built laboratory area has also been created for the study of plasma electrolysis treatment techniques, such as Plasma Electrolytic Oxidation (PEO).

The group’s main coatings research involves vacuum-plasma based methods, with particular emphasis on present on new sputter-deposited nanocomposite and multi-functional coatings, with controlled mechanical properties. There is increasing activity in electrolytic-plasma processes for surface hardening - and other functional treatments - of (primarily) lightweight alloys of aluminium, magnesium and titanium, funded by both the EPSRC and industrial sponsors. The RCSE has also been investigating low-temperature growth of metal-oxide films by PVD techniques - with additional underpinning support for the group provided by an EPSRC Platform Grant. In late 2009 we obtained a major EPSRC capital equipment grant (together with Leeds and Sheffield Hallam Universities) and with this funding we will acquire in 2010 a new high temperature multi-source, multifunctional PVD coating and plasma treatment facility from Tecvac Ltd. The multifunctional capability incorporates both electron beam and sputter deposition with low-pressure plasma diffusion treatment, under enhanced plasma conditions – and at higher temperatures than were previously possible for such processes.

The RCSE team recently completed a 3-year DTI/TSB Technology Programme project (“LIBTEC”), under the “Materials for Extreme Environments” funding round. The project objective was to develop new, advanced plasma surface engineering treatments & coatings for titanium alloys – allowing them to be used in high-load bearing applications as a weight-saving, low maintenance alternative to traditional materials. The project partners, Tecvac Ltd, NMB-Minebea and Airbus UK, jointly developed new surface engineering techniques to permit a 2-to-3 fold increase in load-bearing capability for Ti6Al4V alloy – with the RCSE team providing key plasma processing and mechanical property evaluation expertise to the industrial consortium. This has opened up numerous opportunities for Airbus to implement significant weight-saving measures on passenger aircraft, such as in landing-gear bearings on the forthcoming A350 range of aircraft. A second TSB Technology Programme project (“SMARTHIP”) awarded under the 2009 “Smarter, Bioactive and Nanostructured Materials for Health” funding round is currently in progress, with Tecvac Ltd and Corin (a prosthetic device manufacturer), and with two other UK Universities (QMUL and Imperial College), to develop multifunctional ‘smart’ coatings for hip & knee joint prosthetic devices – and a third Technology Programme project (“SUSCOAT”) was recently awarded under the “Sustainable Materials” funding round, commencing Autumn 2009. The latter aims to develop corrosion- and wear-resistant metallic coatings to substitute toxic coatings & processes such as cadmium, hard-chrome and chromate conversion treatments (used widely in aerospace and power-generation) with environmentally benign plasma-based alternative technologies.

The group has recently hosted two visiting researchers sponsored via the EPSRC-funded ‘Bridging the Gaps’ scheme. Dr Evgeny Parfenov from Ufa State Aviation Technical University (Russia) participated in a project dedicated to the development of new process diagnostic & control tools for plasma assisted electrochemical processes, while Professor Lyubov Snizhko from the Ukrainian University for Chemical Engineering, Dnepropetrovsk, worked on modelling growth processes of PEO films on Al and Mg alloys under high anodic potentials. We were recently awarded funding by the Cyprus Research Promotion Foundation (RPF), to continue our interactions with Prof. Rebholz’s group at the University of Nicosia, Cyprus. The project involves reciprocal visits between Nicosia and Sheffield, to test and evaluate new diamond-like carbon (DLC) coatings for biomedical applications.

During 2009 the RCSE benefited - together with the Tribology Group in the Department of Mechanical Engineering - from a generous benefaction of supporting funds to establish “The Leonardo Centre for Tribology and Surface Technology”. We hope this initiative will act to improve co-operation across the University in the fields of surface engineering and tribology. The benefaction provides direct support for two full time Academic posts (one in Engineering Materials and the other in Mechanical Engineering) - and for a part time Visiting Professor from Philips in Holland, Professor Steven Franklin. This link has proved enormously beneficial, not only for collaborative research within the Faculty but also in facilitating undergraduate student placements in the “High Tech Campus” at Philips in Eindhoven.

Our Yorkshire Forward “Capacity Building” Programme in surface engineering (“Surface Engineering Group”, SEG), run jointly since 2006 with the National Metals Technology Centre (NAMTEC), Corus, The Welding Institute (TWI) and Sheffield Hallam University has continued to be successful in assisting local industry to benefit from optimal use of advanced surface engineering technology - with around 70 Yorkshire companies already helped to safeguard and increase regional jobs. We currently have three Knowledge Transfer Partnerships (KTPs) running. One is to develop novel hard-facing treatments for oil drilling equipment with Cutting and Wear UK Ltd, Rotherham; another, with E Wood Ltd (3M), Northallerton, is to improve the performance of polymeric coatings for pipelines and a third, with Silverline, Leven, Scotland is to improve the anti-corrosion performance of metallic paint pigments. A fourth project awarded in 2009 is with Technicut Ltd, a Sheffield-based manufacturer of high-performance cutting tools. Starting early 2010, this project aims to develop improved materials and coatings for optimised machining of advanced composites in future aircraft structural components.
Bioengineering Peripheral Nerve

Injuries to the peripheral nervous system (PNS) are extremely common and although nerve regeneration is possible, this typically occurs over very short distances of 1-2mm. However, individuals who receive this type of injury will have life-long disability. When damage to the nerve is too significant for regeneration to take place, surgical intervention is required, such as end-to-end suturing or autografting. However, reconstructive surgery does not result in complete or effective functional recovery and a major disadvantage of autografting includes a secondary surgical procedure and donor site morbidity. Previous studies have demonstrated that a high number of nerve cells do not survive, with 35% to 40% dying following injury. Strategies to bioengineer peripheral nerves are therefore being developed in John Haycock’s group. The use of entubulation devices such as nerve guidance conduits (NGC) provides a favourable microenvironment and a degree of basic physical guidance for improving the rate of nerve growth. Many types of NGC materials have been studied in the past, including natural materials such as autologous veins and arteries. However, disadvantages exist with natural materials such as a limited supply and unnecessary surgical procedures. Therefore, the use of synthetic NGC materials is increasingly being studied. The advantages of synthetic materials include control over properties such as physical flexibility, porosity, biocompatibility and biodegradability, while also having control over material purity and quality.

The delivery of Schwann cells to an injured PNS can improve nerve growth and alignment. However, gap injuries have no spatial information between the proximal and distal nerves, and so we are designing scaffolds for the growth of Schwann cells in the form of aligned biodegradable fibres for improved nerve fibre alignment. In the present work, we have fabricated aligned microfibre scaffolds made from the hydrolysable polymer, poly-L-lactide, by high-speed electrospinning. Fibres have then been surface coated using acrylic acid plasma polymerisation which has been found to improve the ability to support Schwann cell adhesion and growth. Schwann cells can be grown on fibre sheets to rapidly evaluate an ability to support cell growth and alignment. Thereafter, once the scaffold conditions have been established for the optimal support of Schwann cell growth, they can be constructed to form experimental nerve guidance conduits for the 3D culture of Schwann cells using a closed loop perfusion bioreactor. Figure 5.3.1 shows the design of the perfused bioreactor for culturing Schwann cells under controlled flow conditions and figure 5.3.2 shows confocal micrographs of alive (green) and dead (red) Schwann cells growing on aligned PLLA microfibres. Figure 5.3.2 also illustrates the importance of an acrylic acid deposition, where a) top panel is PLLA fibres alone and b) bottom panel is PLLA fibres coated with acrylic acid.

Bone Tissue Engineering

The Reilly group is interested in how mechanical forces can be used to improve tissue engineered matrix production just as in the body our tissues respond to the stresses and strains they receive throughout life. A particular interest is in mechanical influences on bone tissue production. In collaboration with the University of Kansas (Missouri, USA), a newly developed bone cell line has been used which rapidly synthesizes matrix to develop a system for studying the mechanical modulation of bone matrix formation in 3D using a cyclic compressive loading stimulus. Polyurethane (PU) open cell foam scaffolds were seeded with bone cells under static conditions and loaded in compression at 1Hz, 5% strain in a sterile fluid-filled chamber, designed by Bose ElectroForce systems group. Loading was applied for only 2 hours per day at day 5, 10 and 15 of culture and cell-seeded scaffolds were assayed on days 10, 15 and 20 of culture. Collagen content was significantly (2 fold) higher at days 15 and 20 in loaded samples compared with static controls. Calcium content was significantly (4 fold) higher by day 20. The number of viable cells was higher in loaded samples at day 10 but there was no difference by days 15 and 20. Loaded samples also had higher stiffness in compression by the end of the experiment. The gene expression of the bone matrix proteins type I collagen, osteopontin and osteocalcin was higher, after a single bout of loading, in loaded than in non-loaded samples as assayed by RT-PCR. In conclusion, mineralisation by fully differentiated bone cells was shown to be highly sensitive to mechanical loading.
with short bouts of mechanical loading having a strong effect on mineralised matrix production. The 3D system developed will be useful for systematic investigation of the modulators of in vitro matrix mineralisation by osteoblasts in mechanobiology and tissue engineering studies.

Figure 5.3.3

**Skin Tissue Engineering**

2009 has led to major developments in our research in the area of detection and treatment for infected skin wounds. To support this work the MacNeil group developed a 3-dimensional bacterially infected human skin wound (Shepherd et al., 2009). This has proved invaluable for testing the antimicrobial activity of novel biocompatible wound dressings based on triblock copolymer hydrogels through a collaboration with Professor Steve Armes in the Department of Chemistry (Bertal et al., 2009). These latter hydrogels are capable of entering both mammalian and bacterial cells and certain combinations of the triblocks have intrinsic antimicrobial activity. The hydrogels are also capable of releasing drugs and we have been exploring their potential both as topical drug delivery vehicles and as inherent antimicrobial dressings.

Also in 2009 we developed a surface modified contact lens for the transfer of limbal epithelial cells to the cornea for ocular surface diseases (Deshpande et al., 2009) and in another project with Chemistry we developed a biodegradable electrospun scaffold for tissue engineering which is also capable of releasing ibuprofen as it degrades. This is also covered by a patent application as it represents a useful material in treating inflamed skin wounds. Essentially it is being designed to provide an anti-inflammatory to both reduce inflammation and pain for the patient and, as the dressing is biodegradable, it doesn't need to be removed - yet fibres are in place for providing skin cell guidance and migration.

**2D and 3D Patterning of Cells and Biomolecules**

In 2009, the Claeyssens group investigated diamond-like-carbon (DLC) coatings for bioelectronics coatings. DLC is an amorphous form of carbon and can be deposited at room temperature via pulsed laser deposition. This research has been carried out with colleagues at the School of Medicine at Bristol University and has been published in Biomaterials (Biomaterials 31 (2010) 207-215).

Diamond-like carbon (DLC) is an attractive biomaterial for coating human implantable devices. Our particular research interest is in developing DLC as a coating material for implants and electrical devices for the nervous system. We previously reported that DLC is not toxic to N2a neuroblastoma cells or primary cortical neurons and showed that phosphorus-doped DLC (P:DLC) could be used to produce patterned neuron networks. In the present study we complement and extend these findings by exploring patterning of dorsal root ganglion (DRG) explants, human neural progenitor cells (hNPC) and U-87 astrogliaoma cells on P:DLC. Further P:DLC data is provided to highlight that P:DLC can be used as an effective coating material for in vitro multi-electrode arrays (MEAs) with potential for patterning groups of neurons on selected electrodes. We also introduce ultraviolet (UV) irradiation as a simple treatment to render DLC neurocompatible. We show that UV:DLC can be used to support patterned and unpatterned cortical
neuron growth. These findings strongly support the use of DLC as a tailorable and tuneable substrate to study neural cell biology in vitro and in vivo. We conclude that DLC is a well-suited candidate material for coating implantable devices in the human nervous system.

In 2009 we have also been developing a 3D microstructuring technique based on UV microstereolithography. Additionally we have been developing a laser based printing technique for producing biomolecule arrays and biosensors. This technique is able to print viscous fluids containing DNA, proteins and even living cells.

Anastomotic Engineering

Biomechanical forces have been suggested to play important roles in arteriosclerosis, intimal thickening (IT), and restenosis related to stented arteries or surgical anastomosis. Research in CK Chong’s group show that certain haemodynamic features e.g. low mean wall shear stress (WSS), oscillating WSS, abnormal temporal and spatial shear stress gradients, and high particle residence times, are found in the locations where IT preferentially develops. This suggests a possible link between these features and cellular responses and failure of the endovascular device or surgical bypasses. It is evident from our works (Figure 5.3.6 lower panels, variation of WSS on the arterial floor over space and time due to increasing graft-to-artery diameter ratio) and others, that geometrical features play an influential role in controlling the flow features and therefore there is clinical relevance and benefits for anastomotic engineering, a process of modifying the geometry of the graft or anastomosis to improve their haemodynamic performance. Thus far, we have developed a computational model, validated by particle imaging velocimetry (Figure 5.3.6 left upper panel, comparing the variation of wall shear stress at different locations on the hood of graft and floor of artery), to quantify haemodynamic parameters in distal coronary anastomoses and it was confirmed that geometric factors like diameter ratio and angle between the graft and host artery (Figure 5.3.6 right upper panel, variation of spatial WSS gradient on the floor), and smooth graft-artery transition play similar roles in distal coronary anastomoses as in the peripheral region. The impact of geometric alteration on haemodynamics was further demonstrated in infragenicular supplementary vein cuffs which configuration, specifically the length-to-height ratio, is critical in controlling local haemodynamics. However, it is still not entirely clear which and to what extent, these flow parameters actually trigger the undesired cellular response and the true mechanisms involved. We are currently developing a flow system capable of exposing viable cells cultured/co-cultured in well-defined geometries to precisely-controlled flow parameters to systematically understand and establish the quantitative correlations (employing both experimental and computational approaches) and, hopefully obtain more insights on the true mechanisms (e.g. biochemical cascade) involved. The information is expected to be useful in developing anastomotically-engineered vascular tissue graft, acknowledging that anastomosis is inevitable.

Biophotonic Imaging of Tissues

The optical imaging group, led by Steve Matcher, is developing non-destructive imaging modalities to study the development of tissue-engineered constructs in bioreactors. 2009 saw a series of experiments in which a new technique, swept-source optical coherence tomography, was used to image the development of tissue-engineered skin constructs fabricated in the MacNeil lab. Optical coherence tomography (OCT) is an optical analogue of ultrasound imaging but offering axial resolution of 1-10 microns over depths up to 2 mm in biological tissues. Our swept-source system is based on a 1300 nm frequency-swept laser, fibre-optic interferometer and telecentric beam scanning optics (see Figure 5.3.7).
Skin constructs were fabricated by seeding de-epithelialized acellular dermis (DED) with keratinocytes and fibroblasts. The constructs were then grown in cell culture medium at an air-liquid interface for up to 21 days. OCT imaging was performed at a series of time-points from day 1 to day 21. At day 21 OCT (Figure 5.3.8, top) demonstrated the formation of neo-epidermis that correlated with invasive histological assessment (Figure 5.3.8, bottom). This data was reported at BioS 2010 (Smith et al., 2010).

2009 also saw the group complete the construction of a swept-source polarization-sensitive OCT system. This is an enhanced version of an earlier design that produces "phase-retardance" images in addition to the structural images illustrated above-left. Such images provide information on the presence of directionally organised collagen, via its linear birefringence.

Figure 5.3.9 (Ugryumova et al., 2009) shows retardance images of the same site on equine articular cartilage taken with two different illumination directions. The strong banding pattern visible on the left is not a structural feature but instead reveals the presence of strong linear birefringence. The absence of the banding on the right image, despite the measurement site being the same, provides information on how the collagen fibres are oriented in 3-D (the fibres must be nearly parallel to the beam direction to produce low birefringence). We are working to develop this idea into a tool that can characterise the ECM geometry of articular cartilage samples and thus guide the design of scaffolds to produce tissue engineered cartilage replacements.
5.4 The Sorby Centre for Electron Microscopy and Electron Microscopy Research

Director: Prof W M Rainforth
Senior Experimental Officer: Dr P Korgul
Experimental officers: Dr Peng Zeng, Dr Cathy Shields

The Sorby Centre is one of the largest electron optical characterisation and analysis facilities in the UK, housing 11 electron microscopes for scanning and transmission electron microscopy, a broad range of specimen preparation equipment together with experience and expertise in a variety of materials applications.

In particular, the facilities comprise:

- TEM: JEOL 3010 300kV high resolution electron microscopy.
- TEM: FEI Tecnai 200kV imaging and analytical TEM (EDX).
- TEM: Philips 430 300kV imaging and InSitu heating experiments.
- TEM: Philips 420 120kV imaging, EDX, and user training applications.
- SEM: FEI Sirion FEGSEM. High resolution imaging, EDX, EBSD, STEM.
- SEM: FEI Inspect F, FEGSEM. High resolution imaging, EDX, EBSD.
- SEM: JEOL 6400, for SEM imaging, EDX, EBSD.
- SEM: Further basic instruments for routine SEM imaging and user training.
- FIB: FEI Quanta 3D. Surface sectioning and TEM sample preparation, ESEM.
- A CAMECA SX51 Electron Microprobe with WDX spectroscopy in the process of being setup.

Further facilities through joint access to the Engineering Faculty FEGTEM & FIB facility (operated by Dept of Electronic and Electrical Engineering) are:

- JEOL 005 FEGTEM with aberration corrected probe and imaging, EFTEM, EELS.
- JEOL 2010F FEGTEM with EDX, STEM, EFTEM, EELS, and cooling stage.
- JEOL Fabrika dual beam FIB-FEGSEM. Focused Ion Beam nanofabrication and imaging with ion and electron beams.

News during 2009:

i. The Sorby Centre successfully moved to the Kroto Research Institute in 2009, with the new laboratory costing £1.3m to develop. This has provided us with a substantial increase in space (size and quality) and a substantial reduction in environmental pollution. The current working environment is excellent and sets a UK leading standard.

ii. Our European Regional Development Fund (ERDF) grant for the initiation and running of the ‘Sorby Nano Investigation Centre (SNIC)’ has fulfilled its ERDF objectives and substantially enhanced input into South Yorkshire industry, as well as providing a new environmental dual beam focused ion beam microscope (ESEM-FIB), a FEG-SEM, a Raman Laser Tweezers and a Laser Confocal, all of which will add to the already substantial equipment base.

iii. The joint venture with the Department of Electrical and Electronic Engineering has reached its summit with the installation of the world beating aberration corrected TEM. The 300kV JEOL instrument has a cold field emission gun and delivers sub Å resolution in both coherent and incoherent imaging and high energy resolution spectroscopy.

Sorby Centre Webpage: www.shef.ac.uk/materials/research/centres/sorby.

Information for Academic Users: The Centre currently supports research projects from 7 University Departments. See our webpage for contact information and registration of new users.

Information for Industry: We operate a full service for industry through the Sorby Nano Investigation Centre (SNIC). See www.sorbynano.org.

Historical Background: The name of the Centre reflects the early and pioneering work of Sheffield scientist Henry Clifton Sorby on light microscopy of geological and metallurgical cross sections back in the mid-nineteenth century.

His research is internationally recognised as the birth of scientific metallography, and is remembered today e.g. by the annual Sorby Award of the International Metallographic Society. The Centre maintains the ambition to provide state-of-the-art characterisation facilities for the benefits of the traditionally-strong Sheffield-based Materials Research Centres.

The Sorby Centre in Pictures:

Figure 5.4.1: FEGSEM image of porous self-ordered anodic alumina oxide nanochannel array with general close-packing order (courtesy Yong Peng, NanoLAB group).
Figure 5.4.2: Bright field image of a focused ion beam prepared cross-section of a g-TiAl alloy following high temperature oxidation, along with X-ray maps of the chemical distribution from the same area (Courtesy J Walker, I Ross).

Figure 5.4.3: Award winning micrograph showing the growth of oxide on steel, taken by Nelson Garza.
5.5 IMMPETUS

IMMPETUS, the Institute for Microstructural and Mechanical Process Engineering: The University of Sheffield (http://immpetus.shef.ac.uk/imm/) is a multidisciplinary research centre established in 1996 to study the thermomechanical processing of metals, to model the events taking place, and to develop improved planning and control of industrial processes. IMMPETUS is based within three host Departments: Engineering Materials, Mechanical Engineering and Automatic Control and Systems Engineering. Across the three Departments it involves over fifty people: academic and research staff, research students, an administrator, a computer programmer and three technicians. Since 1996 IMMPETUS has been funded by three substantial EPSRC grants, the last one of £5.5m started in 2007. IMMPETUS seeks to integrate a range of modelling methodologies and experimental skills to provide true multidisciplinary research to develop physically-based models that predict the microstructure of metals as a function of process route. The work of IMMPETUS covers all major metals, including steels (carbon, high strength, tool and stainless), wrought aluminium alloys, nickel based superalloys, near-a titanium alloys, magnesium alloys, copper alloys and many more. Our work focuses on the hot deformation of metals (by rolling, forging etc) but also on other aspects of metals processing, including solidification and powder processing technologies.

Research in IMMPETUS is supported by a world leading deformation simulation laboratory and world class materials characterisation facilities. The Thermomechanical Compression Machine (TMC) provides high strain rate deformation, coupled with complex heating and cooling cycles that simulate hot rolling or forging. The new arbitrary strain path test machine (ASP) has been used to investigate the effect of a complex series of changes in strain direction/strain rate commonly known as strain path effects. This machine is unique in the world. IMMPETUS has access to state-of-the-art microstructural characterisation that allows quantification of microstructure across the length-scales. Our field emission gun EBSD facility system allows quantification of microstructure, texture and deformation substructure with high spatial resolution (50-100nm), but with the ability to acquire data from large specimen areas (cm² possible). The field emission gun TEM (a facility based in the Department of Electrical and Electronic Engineering) can undertake atomic resolution imaging, and also identify the chemical distribution and state of bonding at the nm level. The dual beam FIB allows site-specific surface sections to be removed for either SEM or TEM investigation, to examine, for example, the structure of surface oxides.

IMMPETUS provides a platform for defining and solving the next generation of problems for advancing further the state of the art in metals processing, serve as a resource for those seeking assistance with current problems, and train researchers to offer solutions to industrial problems. We are proud for the wide and fast dissemination of the Institute’s discoveries and innovations to academia and industry, the exposure of our researchers to industrial research and technologies and opportunities for developing new industrially relevant research. IMMPETUS research is disseminated through member publications in peer reviewed journals and conference proceedings, our annual Colloquium, national and international conferences, and through University publications such as PhD and MPhil theses and other publications from each of the three academic departments, including the Institute’s and Departments’ regularly updated websites and IMMPETUS newsletters. Members of IMMPETUS serve in national committees of their professional institutes such as IoM3, IFAC, IMechE, and contribute to the organisation and running of national meetings and symposia on key engineering topics. The Faculty of Engineering supports an entrepreneurial research culture and assists with university-industry research partnerships.

Figure 5.5.1: IMMPETUS Colloquium 2009 Group Photo.

Figure 5.5.2: IMMPETUS Annual Report 1 August 2008 – 31 July 2009. For a copy please contact: Prof P Tsakiropoulos (p.tsakiropoulos@sheffield.ac.uk).
The Ceramics and Composites Laboratory (CCL) was launched in September 2003 with a 5 year Portfolio Partnership award of £6M from the EPSRC. The group brought together researchers from the areas of ceramics, composites and polymers. The group comprised of Profs F R Jones, W E Lee (now at Imperial College, London), W M Rainforth, I M Reaney, A R West and P V Wright and Drs R J Hand and D C Sinclair.

The CCL has continued since 2008 with funding from an EPSRC Large Grant award and is now based on researchers focussing on new and improved electroceramics. It comprises Profs I M Reaney, A R West, D C Sinclair, A J Bell (Institute for Materials Research, University of Leeds) and Profs J H Harding and W M Rainforth. The award in 2008 of £4.5M gives the academic investigators guaranteed underpinning research funding for 4 years. In addition to the EPSRC Large Grant the group has also continued with significant funding from other EPSRC Grants, European Grants and a significant link with Knowledge Transfer Programmes (KTP).

The range of research interests covered by the CCL is very broad. It includes, for instance:-

- Fundamental materials development and characterisation on several fronts in the field of electroceramics.
- Functionality in novel perovskite, layered rock salt, tetragonal tungsten bronze and sillenite-based materials via structure-composition-property relationships.
- Fabricating a range of known and new electroceramic materials in thin- and thick-film format as feasibility studies for potential device development.
- Using advanced materials characterisation techniques, such as aberration corrected electron microscopy and local probe impedance spectroscopy, helping to create a step change in the understanding of structure and microstructure of electroceramics.
- Experimental materials development software programmes with advanced modelling strategies to simulate the electrical properties of heterogeneous electroceramics and underpin investigations into structure-property relations.
- Establishing a long term strategic alliance between the electroceramic groups at Sheffield and Leeds and to facilitate the development of electroceramics, in collaboration with industry, that have potential device applications.
- Continuing existing and developing new international academic collaborations.

The success of the CCL in producing high quality research is demonstrated by the fact that it has published over 450 papers since it was launched in 2003. In addition over 30 postgraduate students have completed their research degrees and graduated with either a PhD or MPhil. The CCL holds an annual meeting for the discussion and development of research that involves over 60 academics, researchers and PhD students.

The CCL has also achieved significant success in developing collaborations with industry. The development of KTPs was an early development in 2004 with the appointment of Dr Fred Dobson by the CCL to establish Knowledge Transfer Partnerships for the group. The CCL views such industrial partnerships as a vital outreach activity and this has been also been very successful in extending the University of Sheffield’s wider involvement in KTPs.

For further information about the group please contact the manager Gordon Brown (gordon.brown@sheffield.ac.uk) visit the group’s website (http://www.shef.ac.uk/ccl).
The NanoLAB Research Centre was set up in 2004, funded in large part through a RCUK Basic Technology Award. We conduct research into advanced nanomaterials and nanotechnology, including the fields of nanomaterials processing, 3D characterisation, nano-electromechanical testing, and development of nanomanipulation devices.

The scientists associated with NanoLAB include academic staff Drs Beverley Inkson, Günter Möbus and Cornelia Rodenburg in Engineering Materials, interdisciplinary collaborators in Dentistry and Electronic and Electrical Engineering, and 14 PDRAs/ PhD/PG students.

NanoLAB activities have significantly expanded in 2009. Real-time manipulation and testing of nanostructures inside electron microscopes is now rapidly moving from instrumental development to a variety of high-profile applications in nanotribology and surface modifications. New methods have been developed for the construction of nanowire circuitry, nanowelding and accurate nanoscale electrical testing. Developments in tomography and 3D reconstruction are continuing with applications in nanocomposites and nanoparticles, and now also include a new area of “tomographic nanofabrication” in which 3D-fabrication and 3D-characterisation are combined. SEM nanomanipulation, energy filtered SEM, and the new technique of He-ion beam microscopy are also further major research topics.

The NanoLAB Centre webpage, with up-to-date information on activities and publications can be found at www.nanolab.org.uk, while the Basic Technology Programme has its homepage at www.nanomanipulation.org.

NanoLAB initiated and contributes to a taught Masters course, successfully running since 2006/07, on Nanomaterials for Nanoengineering.

NanoLAB activities are underpinned by a number of significant Research Funding awards. New Programmes for 2009 include a £0.8m Basic Technology Translation award for expansion of the successful NanoLAB technology to new academic and industrial applications, and an EPSRC award to study nanoparticle architectures in collaboration with Cranfield and Bath Universities.

NanoLAB has been active organising a number of conferences during 2009, including the organisation of an Advanced School on Nanomanipulation and Nanofabrication, and the bi-annual international Institute of Physics EMAG2009 conference on electron microscopy in Sheffield during September. We also organised the Mechanical Characterisation using in-situ Methods Symposium at EUROMAT 2009 in Glasgow, and NanoFIB 2009: Advances in Focused Ion Beam microscopy, in Cambridge, March 2009.

Figure 5.7.1: Carbon onion generated by the rubbing of amorphous carbon thin films.

Figure 5.7.1: Atomic resolution tomography, simulated for a CeO2 nano-octahedron.
5.8 The Immobilisation Science Laboratory (ISL)

The Immobilisation Science Laboratory, ISL, established in August 2001, is one of four University Research Alliances (URAs) set up by BNFL to address the decline in the UK nuclear science knowledge base. ISL Research is focussed on radioactive waste processing, immobilisation and disposal, and materials for the nuclear renaissance. ISL academic staff include Director Neil Hyatt (nuclear materials chemistry), John Harding (materials simulation), Russell Hand (vitrification and glass research), Michael Ojovan (waste immobilisation), Karl Travis (materials modelling), Günter Möbus (electron microscopy), and Hajime Kinoshita (materials chemistry). ISL activity is supported by several visiting and associate academics, including Neil Chapman from Nagra in Switzerland (Chair of the ITC School of Underground Waste Storage and Disposal); Fergus Gibb (deep geological disposal); and Ewan Maddrell from the National Nuclear Laboratory.

The ISL research training platform enjoyed strong growth in 2009-10, most notably as a key player in winning two flagship Centres for Doctoral Training. Dr Neil Hyatt led the ISL in securing £7.1M from EPSRC to establish the Nuclear FIRST Doctoral Training Centre, as a national platform for nuclear skills training, in collaboration with Prof. Francis Livens at the University of Manchester. Furthermore, a partnership of six research groups, including the ISL, secured successful renewal of the Nuclear Engineering Industrial Doctorate Centre, led by The University of Manchester, supported by the award of £5.1M from EPSRC.

In recognition of the national importance of ISL capability and expertise, a new Research Chair in Radioactive Waste Management was established in 2010 with investment of >£1M from the Nuclear Decommissioning Authority, Royal Academy of Engineering, and The University of Sheffield. This prestigious appointment is the first of its kind to be supported by the NDA and consolidates ISL’s position as a world leader in radioactive waste management.

Significant EPSRC research awards in 2009-10, included: £333k to John Harding and Karl Travis, as part of a £750k programme of research aimed at understanding the chemistry of ceramic materials under irradiation; £567k to Neil Hyatt as part of the £4.3M DIAMOND University research consortium, to investigate glass and ceramic wasteform performance; £80k to Michael Ojovan, Günter Möbus and Karl Travis for detection of radiation-induced nanoscale stress wave emission in crystalline wasteforms using acoustic emission; and £269k to support three CASE awards led by Neil Hyatt and Karl Travis.

Other selected highlights from 2009-10 include:

- A new collaboration with CEA (France), ITU (Germany), KTH (Sweden), CNRS (France), to develop a thermodynamic database for advanced nuclear fuels, led by Hajime Kinoshita.
- A new collaboration with Bruce Ravel at the National Synchrotron Light Source, to develop XAS methods applied to radiation damaged materials, led by Neil Hyatt.
- Award of an RWMD travel grant to PhD student Daniel Reid, to speak on “Synthesis, Structure and HREM of Model Ceramics for Plutonium Disposition” at MS&T 09 in Pittsburgh, PA.
- Award of The University of Sheffield’s Foster Research Prize in Glass Technology to Andrew Connelly for his thesis project on nuclear waste glasses.
- Election of Neil Hyatt to Chair of the International Scientific Advisory Committee for the MRS Symposium on the Scientific Basis for Nuclear Waste Management.

Hinkley Point ‘A’ Power Station (HPA) in Somerset was a twin reactor Magnox nuclear power station commissioned in 1965. The power plant was permanently shut down in 2000 and the nuclear fuel was removed by the end of 2004. The site is now in the process of being decommissioned. Wet Intermediate Level Waste (Wet ILW) was generated during operation of HPA and essentially occurs in three forms: ion exchange resins, sludges and sand. Following a review of process options, immobilisation of this wet ILW by vitrification has been identified as a potential process. Drs Paul Bingham, Neil Hyatt and Russell Hand of the ISL are working with Magnox South Ltd, the site license company tasked with the cleanup of HPA Site, to develop a range of glass formulations that are suitable for vitrification of the Wet ILW envelope arising from decommissioning of the HPA Site. This high-profile project is amongst the first serious efforts in the UK to vitrify ILW. It has therefore generated considerable interest from the wider nuclear industry. Project Engineering Lead, Dr Steve Kenney from Magnox South commented “Innovation by the Magnox South – ISL partnership is leading the way for safe immobilisation of legacy wastes at Hinkley Point.”

Further information regarding the ISL is available from Mrs. Karen Burton k.a.burton@sheffield.ac.uk or by visiting the ISL website http://www.immobilisation.net.
5.9 The Polymer Centre

The Polymer Centre of the University of Sheffield brings together over 40 academic staff, 50 postdoctoral research fellows and approximately 100 postgraduate research students across the Faculties of Engineering, Science and Medicine, Dentistry and Health. Established in 2001, it provides an interdisciplinary opportunity for collaboration in the field of polymeric materials. The Centre has its origins in the long and distinguished research and teaching in the Department of Engineering Materials (dating from 1963), the appointments of Prof Tony Ryan (Chemistry), Prof Richard Jones (Physics) and the transfer of the Polymer Group led by Prof John Ebdon from the University of Lancaster.

The Centre's business development team tailor technology and training opportunities for industry: short-term consultancy; short- to medium-term contract R&D (through spin-out FaraPack Polymers); longer term research projects carried out as PhD or postdoctoral projects; and IOM3-accredited CPD courses. The team have maintained their “Customer First” accreditation since 2006, a quality assurance standard for Business Support.

The current Director of the Sheffield Polymer Centre is Prof Steve Armes (Chemistry). The Steering Group consists of Profs Richard Jones (Physics and Astronomy), Peter Styring (Chemical and Process Engineering) and Paul Hatton (School of Dentistry) and Drs Alma Hodzic (Mechanical Engineering), Xiangbing Zeng (Engineering Materials) Simon Jones (Chemistry) and Mark Geoghegan.

The former Polymer centre manager, Dr Malcolm Butler has recently taken the roll of Director of Faculty Operations in Engineering and was succeeded by Dr Liam Sutton. Liam now combines this role with the Management of the nascent “Sheffield Science Gateway”, a Knowledge Transfer initiative based on the “Sheffield Engineering Gateway” model.

Collaboration with colleagues in Leeds, Bradford and Durham has continued in the form of the Polymer IRC and continues to be a focus for polymer research across the 4 universities. The IRC in Polymers/Polymor Centre held its most recent showcase meeting at the English institute of Sport in Sheffield in September 2009. The sports theme resulted in presentations ranging from Composites in Formula One Motorsports to Tissue Engineering for Cartilage Repair.

The Polymer IRC series of annual short courses in polymers continued this year. Prof F R Jones with Prof C Soutis made their usual excellent contributions to the 1-day course on Composites and Multiphase Materials and a new module in Organic Electronics was introduced, presented by Polymer Centre colleagues from Physics and Chemistry.

For further details, please visit the website www.polymercentre.org.uk where a number of animations illustrating the interdisciplinary work of the centre are given.
5.10 E-Futures: Doctoral Training Centre in Interdisciplinary Energy Research

Background

In December 2008, the University of Sheffield, led by Prof. Tony West, was successful in a bid to attract £7.3M funding from EPSRC for E-Futures, a Doctoral Training Centre (DTC) in Interdisciplinary Energy Research. The collaborative grant draws together world-class research within 16 academic departments, across the three faculties of Engineering, Pure Science and Social Science.

Aims

E-Future brings together diverse areas of expertise to train engineers and scientists with the skills, knowledge and confidence to tackle today’s evolving issues regarding energy generation, management and supply. E-Futures also represents a new working culture, fostering relationships between teams in universities and forging lasting links with industry and other external organisations.

Over the 8 years of funding, 100 students will receive a formal programme of taught coursework to develop and enhance their technical interdisciplinary knowledge, and broaden their set of skills. Alongside this they will undertake a challenging and original research project at PhD level.

Departmental Contribution

The Department of Engineering Materials has contributed a refurbished laboratory (M7) where students are co-located in their first year. A number of materials-related lectures have been delivered by staff and a new module on ‘Materials for Energy Applications’ has been developed for E-Futures and for the wider student body.

Progress to Date

In its first year, E-Futures has been highly successful in attracting skilled and highly motivated graduates. The first cohort of 21 students contains scientists, engineers and social scientists, all of whom have either a First Class or Upper Second Class honours degree.

As part of efforts to interact with industry, an open day in October 2009 attracted over 50 industry delegates and a call for two-month mini-projects shortly afterwards resulted in over 40 industrial projects. Fourteen students will undertake mini-projects for ten organisations. It is expected that some of these mini-projects will lead to sponsored PhDs.

Figure 5.10.1: Student visit to Advanced Manufacturing Park.
5.11 Advanced Metallic Systems Centre for Doctoral Training

The Advanced Metallic Systems Centre for Doctoral Training was established in 2009 with a £6.3M grant from the EPSRC as one of 45 new centres providing research training across science and engineering. The CDT is jointly hosted by the Department of Engineering Materials at Sheffield and the School of Materials at Manchester building on our complementary expertise in metallic materials and state of the art facilities.

The Metallics CDT aims:

- To provide a stimulating multidisciplinary training experience.
- To teach topical courses that balance cutting edge technologies with fundamental principles and core concepts.
- To develop professional transferable skills in leadership, business and research management.
- To foster innovative, internationally leading research.
- To work in partnership with industry to provide industrial experience and maintain relevance.

A PhD with a Difference

Our students come from a range of science and engineering backgrounds. The 2009 cohort includes chemists, physicists and mechanical and civil engineers, as well as some students returning to university after time spent in industry.

In the first year students develop a core understanding of materials topics through MSc-level courses, case studies, projects and industrial visits. After nine months students are able to make an informed choice of PhD topic and develop a PhD project proposal with CDT staff members. This then forms the basis of their doctoral thesis project over the next 3 years. The majority of projects are carried out in collaboration with industry to ensure relevance and enhanced training.

In parallel to the technical programme, students undertake a range of other activities including transferable skills training, public engagement projects, international summer schools and conferences and the CDT seminar series. This leads to a Diploma in Professional Skills over the course of the four year programme.
The DTC for Nuclear Fission Research, Science and Technology (Nuclear FiRST) was established in January 2009, with a £7.1M investment from the Engineering and Physical Sciences Research Council (EPSRC). The DTC is led by Dr Neil Hyatt in the Department of Engineering Materials at The University of Sheffield and Prof. Francis Livens at the School of Chemistry at The University of Manchester. The DTC is supported by over 20 industrial and international research organisations.

Nuclear FiRST aims to underpin UK Energy and Defence strategy by addressing a growing doctoral skills gap in nuclear science and engineering. We offer an exciting and interdisciplinary approach to postgraduate research training combining a three year Doctoral level thesis project with a foundation year to develop research skills and a broad knowledge of nuclear science and engineering. This is supplemented by training in professional skills and project placements in industry, research institutes and public bodies in the UK and overseas.

Our 2009 cohort is drawn from a range of physical science and engineering backgrounds, including: earth and environmental science, physics, chemistry, and mechanical, chemical and civil engineering. Competition for entry to the DTC was extremely strong with over 50 applications for the 10 places available.

Our first event was a team building activity, during orientation week in September 2009, in which both staff and students successfully navigated the tree top adventure course at Go Ape in Buxton (below). Following 12 weeks of intensive problem based learning activities, students were examined by viva voce examination in December. Our first DTC Winter School, held in the Barcelo Palace Hotel in Buxton, was a great success, with special guest lectures given by Prof. Nik Kaltsoyannis (UCL, UK), Prof. Melissa Denecke (INE Karlsruhe) and Prof. Gerry Lander (ILL, France). The DTC cohort and staff also worked with designer Zoe Papadopoulou, to create an interactive exhibit for the EPSRC sponsored IMPACT! exhibition at the Royal College of Art between 16 and 21 March 2010. Using knowledge drawn from the DTC programme, the exhibit aims to stimulate thinking of how nuclear technology could boost economic growth, reduce CO$_2$ emissions, and enhance the environment of host communities. The table display features a Vaseline glass cake stand, upon which is served a selection of yellow cakes, which are naturally radioactive as a consequence of the high content of K-40.
6. Research Highlights

6.1 Biomaterials and Tissue Engineering

“Dip and Dry” Anti-inflammatory Biomaterial Coatings, Mirren Charnley, Kathryn Fairfull-Smith, Saubhik Haldar, Richard Elliott, Sally L. McArthur, Nicholas H. Williams & John W. Haycock.

There is an increase in the use of implantable medical devices for the repair of soft and hard tissue in the developed world. However, many of these devices can initiate an acute inflammatory response, triggered by both the initial injury and by the presence of biomaterial itself. Acute inflammation has been associated with implant degradation and “stress cracking”, which can lead to failure of the device, such as restenosis after stent implantation or failure of electronic devices such as pacemakers\[3\] and defibrillators. The aim of the present work conducted between John Haycock’s group and Nick Williams in Chemistry was to immobilise short melanocyte-stimulating hormone (MSH) anti-inflammatory peptide sequences onto a model surface using resorcinarenes, which are known to attach to a wide variety of hydrophilic materials. The first stage comprised the biological evaluation of a synthetic MSH peptide attached to different linking tethers (poly(ethylene glycol), PEG 350, octanoic acid or cholesterol) for the ability to inhibit inflammatory signalling. Findings showed that a glycine-lysine-proline-D-valine sequence inhibited inflammatory signalling most effectively when attached to a PEG 350 tether. The second stage comprised of synthesising the MSH peptide attached to resorcinarene groups via a PEG tether and immobilising it onto glass coverslips. X-ray photoelectron spectroscopy (XPS) indicated the presence of a surface attached peptide. The ability of the immobilised peptide to inhibit inflammatory signalling was then determined by culturing RN22 Schwann neuronal cells and human dermal fibroblast cells on functional surfaces and measuring an NF-κB/p65 inflammatory transcription factor activation. Significant inhibition of inflammatory signalling was observed in cells cultured on functional surfaces. In conclusion, this work supports the development of new approaches enabling the rapid immobilisation of short biologically active peptides, with the potential for generating a ‘dip and dry’ approach for altering the surface properties of biomaterial and medical devices [72].
The influence of octahedral tilting on the microwave dielectric properties of $A_2B_3O_12$ hexagonal perovskites ($A=$Ba, Sr) \cite{182} Ritesh Rawal, Andrew J. McQueen, Lisa J. Gillie, Neil C. Hyatt, Emma E. McCabe, Antonio Feteira, Ian M. Reaney and Derek C. Sinclair.

The constant demand for miniaturisation of electronic circuitry in applications such as mobile telecommunications has led to the development of 'high relative permittivity' ($\varepsilon_r$) ceramics ($\varepsilon_r > 30$) for microwave dielectric resonators and filters. These materials are required to have high permittivity, low dielectric losses and exhibit negligible temperature variation of the resonant frequency ($\tau_f = 0$ ppm/K). $\tau_f$ is related to the temperature dependence of the permittivity ($\varepsilon_r$) and the linear thermal expansion coefficient of the material ($\alpha_T$), by the equation $\tau_f = -1/2(\varepsilon_r + \alpha_T)$. To date, most microwave dielectric ceramics are predominantly based on 3C-type AB0$_3$ perovskites, such as Ba(Zn$_{1/3}$Ta$_{2/3}$)O$_3$ ($\varepsilon_r \sim 30$), with crystal structures based exclusively on cubic close packing (ccp) of AO$_3$ layers. Recently, we have been investigating the potential of hexagonal perovskites such as $A_2B_3O_{12}$ as alternative dielectric materials.

The crystal structure of 12R-type $A_2B_3O_{12}$ perovskites can be described as consisting of ccp perovskite blocks, three corner-sharing octahedra thick, separated by layers of vacant octahedra; successive blocks are shifted by a $\frac{1}{2}$ <01-10>$_{\|}$ vector. Figure 6.2.1 (a). The space group adopted is either R$\bar{3}$m if the octahedra are untitled (Glazer notation, a$a^3a^3$) or R$\bar{3}$ if octahedral tilting is present. In this case, the tilt system of the ccp blocks can be described as a$a^3a$. Rietveld refinement of room temperature (RT) Neutron Diffraction (ND) data reveals 12R-type hexagonal perovskites Ba$_3$LaNb$_3$O$_{12}$ (BLN) and Sr$_3$LaNb$_3$O$_{12}$ (SLN) to adopt space group R$\bar{3}$ with tilted NbO$_6$ octahedra, Figures 1 (b) and (c). The tilt angle at room temperature is ~ 4° for BLN and ~ 9° for SLN. The presence of an octahedral tilt transition (T$_{\text{tilt}}$) at 465 K in BLN from R$\bar{3}$ to R$\bar{3}$m has been discovered from a combination of high temperature ND data and fixed frequency permittivity measurements. Figure 6.2.2. T$_{\text{tilt}}$ is estimated to be much higher at ~ 720 K for SLN. The large difference in the RT temperature coefficient of the resonant frequency ($\tau_f$), -100 ppm/K for BLN compared to -5 ppm/K for SLN, is attributed to the closer proximity of T$_{\text{tilt}}$ to RT for BLN. $\tau_f$ in these 12R-type hexagonal perovskites can therefore be tuned by controlling the tolerance factor (e.g. the size of A-site cation) and therefore T$_{\text{tilt}}$ in a manner similar to that used for many Ba- and Sr-based 3C-type AB0$_3$ perovskites. This is the first report in the literature \cite{182} of the influence of an octahedral tilt transition on the dielectric properties of hexagonal perovskites.

The origin(s) of the giant permittivity effect in CaCu$_3$Ti$_4$O$_{12}$ (CCTO) is one member of a family of A'A'3Ti$_4$O$_{12}$ phases with the cubic Im3 structure. In CCTO, the three dimensional TiO$_6$ corner sharing octahedral framework is substantially tilted (a$a^3a^3$). Glazer notation to accommodate the size difference of the Ca$^{2+}$ and Cu$^{2+}$ ions which are ordered on the A- and A'-sites in a ratio of 1:3, respectively, see inset in Figure 6.2.3. The Ca$^{2+}$ ions occupy a body centred arrangement in a doubled perovskite-type cubic cell, whereas the Cu$^{2+}$ ions are located on the face and edge centres of the cell. Due to its unusual perovskite-related structure, the electrical properties of CCTO single crystals, thin films and ceramics have attracted considerable attention in recent years. In each case, the effective permittivity, $\varepsilon_{\text{eff}}$ (where $\varepsilon_{\text{eff}} = C/\varepsilon_o$, where C is the measured capacitance at radio frequencies corrected for sample geometry and $\varepsilon_o$ is the permittivity of free space) near room temperature (RT) has been reported to exceed 10,000 and to exhibit little temperature dependence in the range ~150 – 400 K, Figure 6.2.3. This has made CCTO a potential candidate for capacitor-based applications. It is now generally accepted that the intrinsic (or relative) permittivity ($\varepsilon_r$) of CCTO is ~ 100 and therefore the giant $\varepsilon_{\text{eff}}$ is an extrinsic effect; however, much debate remains about the mechanism(s) responsible for this phenomenon. In particular, it is unclear whether the high $\varepsilon_{\text{eff}}$
arises from the same polarisation mechanism(s) in each case or whether different mechanisms dominate the various forms of CCTO.

We have undertaken an Impedance Spectroscopy (IS) study of CCTO single crystals to complement our previous studies on CCTO ceramics in an attempt to resolve this issue \[95\]. IS is a useful technique to characterise electrically heterogeneous materials and can, in many circumstances, be used to identify and separate intrinsic (eg. bulk) and extrinsic (eg, grain boundary, non-ohmic electrode contact) effects. A particular useful but often under-utilized parameter in the analysis of IS data is the time constant or relaxation time, $\tau$. This parameter depends only on the permittivity and conductivity of a particular component (or region) as it is geometry-independent; this makes it particularly useful when comparing data collected on samples of different physical forms, eg single crystals, thin and thick films and ceramics with various ceramic microstructures. From our IS results the magnitude and temperature dependence of $\tau$ associated with the giant permittivity effect ($\tau_2$) are different for the single crystal compared to the ceramic, Figure 6.2.4. This demonstrates the origin of

![Figure 6.2.3: Typical permittivity versus temperature profile for CCTO single crystals with Au metal electrodes. Inset shows the crystal structure of CCTO. Green octahedra are TiO$_6$ units, red, blue and black spheres represent Oxygen, Calcium and Copper atoms, respectively.](image)

![Figure 6.2.4: Arrhenius-type plot of $\tau_2$ for single crystal (filled symbols) and ceramic (open symbols) CCTO.](image)
6.3 Glasses, Cements and Waste Immobilisation

A compendium of viscosity models was given including recent data on viscous flow model based on network defects in which thermodynamic parameters of configurons - elementary excitations resulting from broken bonds - were found from viscosity-temperature relationships (Figure 6.3.1) [M.I. Ojovan. Viscosity and Glass Transition in Amorphous Oxides, Advances in Condensed Matter Physics, 2008, Article ID 817829, 23 pages (2008)].

The viscosity is a continuous function of temperature whereas the glass-liquid transition is accompanied by explicit discontinuities in the derivative parameters such as the specific heat or thermal expansion coefficient. Glass-liquid transition phenomena were described including the configuron model of glass transition which shows a reduction of Hausdorff dimension of bonds at glass-liquid transition (Table 6.3.1) [M.I. Ojovan. Configurons: thermodynamic parameters and symmetry changes at glass transition. Entropy, 10, 334-364 (2008)].

It was concluded that transitions in disordered media from glassy to liquid states are universal and reflect changes in the bonding system. Because of that the configuron model of glass transition can be used to provide insights on embrittlement of materials composed of microcrystalls at low temperatures as well as on such natural phenomena as quick sand formation. In all such cases formation of additional bonds between elementary particles which constitute the material e.g. microcrystalls or sand grains leads to their solid-like behaviour at lower temperatures or denser packing.

**Table 6.3.1: Viscosity and bond geometries of amorphous materials.**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>( T &lt; T_g )</th>
<th>( T &gt; T_g )</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>Solid (glassy)</td>
<td>Liquid (melt)</td>
</tr>
<tr>
<td>Hausdorff dimension of bonds</td>
<td>( D=3 )</td>
<td>( D=2.55\pm0.05 )</td>
</tr>
<tr>
<td>Viscosity</td>
<td>Continuous decreasing function of temperature</td>
<td>Activation energy high</td>
</tr>
<tr>
<td></td>
<td>Activation energy low</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 6.3.1: Temperature behaviour of viscosity of amorphous materials.](image)
6.4 Magnetics

Organic Spintronics, N A Morley and M R J Gibbs.

Organic spintronics is an exciting new research area, which studies the spin transport within organic semiconductors. There are two different types of organic semiconductor, small molecules (e.g. tris 8-hydroxyquinoline aluminium (Alq3)) and polymers (e.g poly(3-hexyl thiophene) (P3HT)), both of which have been studied in spintronic devices. The basic spintronic device is the spin-valve, which consists of two different magnetic electrodes, with a non-magnetic transporting layer between them. A current is applied to the bottom magnetic electrode, which injects spin carriers into the non-magnetic layer, which are then extracted by the top magnetic electrode. The magnitude of the resistance across the device depends on the direction of the electrode's magnetisation. This difference in resistance as a function of magnetic field is known as the magnetoresistance (MR) (Figure 6.4.1).

In collaboration with Dr Martin Grell (Dept. Of Physics, University of Sheffield), spin-valves containing the polymers RR-P3HT and RRa-P3HT were studied [6.4.1]. It was found that the interface played a big role in the injection and extraction of the spin carriers to and from the polymer [6.4.2]. It was also found that the solvent used to spin coat the polymer onto the bottom electrode affected the magnitude of the MR of the spin-valve. The largest MRs measured at 300K, were for the P3HT layers which were spin-coated with solvents with boiling points higher than 150K, as it allowed the P3HT to form a crystalline layer [6.4.3]. In collaboration with Dr Alan Drew and Dr Bill Gillin (Queen Mary, University of London), the spin transport in Alq3 spin-valves has been studied, using low energy muons [6.4.4,5]. This involved using the muons to measure the spin diffusion length within the Alq3. It was also found that the MR of the devices depended on the additional layers added at the interfaces between the magnetic electrode and the Alq3 layer.

Figure 6.4.1: MR of the 80 nm RR-P3HT device prepared with xylene as solvent. Arrows represent the direction of each electrode magnetization. Inset: I-V characteristics of the device.

Thin MagnetostRICTive Films, N A Morley and M R J Gibbs.

Thin magnetostriuctive films are of great interest for use in Magnetic Microelectrical Mechanical systems (MagMEMS) such as sensors and actuators. The ongoing research has studied two different highly magnetostriuctive thin films: FeCo [6.4.5] and FeGa [6.4.7-9]. The magnetostriiction constant along the <100> direction in single crystals of FeGa increases with Ga concentration, with the peak magnetostriiction constant of 230ppm occurring at x=19. For further increases in Ga, the magnetostriiction constant decreases due to the appearance of the D03 phase.

For the FeGa films, a specially commissioned deposition system from Kurt J Leskers, was purchased [6.4.7]. The deposition system consists of a dc magnetron to sputter the Fe and a high temperature evaporator to evaporate the Ga. This gives good control of the composition of the FeGa films. It was found that all the films fabricated had (110) texture out of plane, with the thicker films having columnar growth. In collaboration with Dr Tad Szumiata (Radom University, Poland), conversion Mossbauer spectroscopy (CMOS) measurements were made to determine that none of the films contained any D03 structure. It was found that the magnetostriction constant depended on the fabrication parameters, i.e. magnetron power, chamber pressure and Ga rate and seemed to be independent of the calculated magnetostriiction constants from the bulk single crystal values.

Figure 6.4.2: Effective saturation magnetostriiction constant ($\lambda_{eff}$) as a function of Ga composition for Fe$_{100-x}$Ga$_x$ thin films varying $R_{Ga}$ ($\triangle$), varying $P_{Fe}$ (●), varying $P_{Ar}$ (▲). The plotted lines are calculated saturation magnetostriiction for isotropic (solid) or textured (dashed) films.

References:
Magnetic Spin torque driven devices, G Hrkac.

Gino Hrkac investigates Spin Transfer Effects in Magnetic Nanometre Scale Devices in an active field with applications in direct current driven nanometre scale microwave oscillators and high density, low power nanomagnetics simulations. He combines basic electromagnetic theory with finite element method based on a response surface model for the optimization of the pole tip shape of single pole write heads. This work was presented as an invited talk at the latest The Magnetic Recording Conference TMRC in Tuscaloosa, Alabama 2009. He also has filed a patent (US-Patent Application: 07/27/2009 "Magnetic Storage Device", Serial Number 12/509,540).

Figure 6.4.3: (left) (a) SEM and (b) AFM image of point contact. (c) Low frequency power spectra measured at $H = 0.21 T$ for several applied currents. The field and film geometry is shown in the inset of (c). (right) (a) Color map of experimental power spectral density (PSD) as a function of current for $H = 350 mT$. Solid squares represent results of micromagnetics simulations. (b) Top view of vortex magnetisation probe obtained from simulation. (c) In-plane component of magnetisation represented in a graylevel (black for $m_y = +1$, white for $m_y = -1$) for the entire simulation area. Also shown are the contact and the vortex orbit.

Figure 6.4.4: Finite element mesh of the pole tip region and objective function as function of the number of field evaluations during global optimization of the geometry.


Global geometry optimization for magnetic recording heads, Thomas Schrefl.

Geometrical optimization is an important tool for the optimization of magnetic devices. Its main purpose is to concentrate the magnetic field in a well defined area, whereby a sharp field gradient shall separate the region of high field from the rest. One way to achieve geometric optimization is to combine finite element micromagnetics simulation with general purpose optimization software. In this work Thomas Schrefl combined the micromagnetics method with a global optimization method based on a response surface model for the optimization of the pole tip shape of single pole write heads. Within the framework of this method at each iteration step a response surface model of the objective function, the product of write field with the field gradient, is constructed in the current search region. The surface model is used to find the next best trial step. For the current optimal point the true objective function is evaluated and the result of the computation is used to refine the response surface. This optimization techniques works for non-differential as well as for stochastic objective functions. By creating a hierarchical decomposition of the parameter space, the global minimum can be found. The pole tip shape and write gap strongly influence the characteristics of the write field. Optimization is necessary, in order to design writers for magnetic recording at densities beyond 6 Tbit/in². Using a head that is perfectly adjusted to the switching properties of the media may help to push recording towards higher densities without the need of energy assist technology. In this work he focused at writer designs for exchange spring or composite media. Here the optimal write field angle is in about 20 degrees. In order to optimize the pole tip region of the writer. The free parameters for the optimization are trailing angle, the distance between the pole tip and the trailing shield, the side angle, and the shield thickness. This work was presented at the latest The Magnetic Recording Conference TMRC in Tuscaloosa, Alabama 2009. He also has filed a patent (US-Patent Application: 07/27/2009 "Magnetic Storage Device", Serial Number 12/509,540).
Anti-ferromagnetic domains in metallic thin films, Thomas Schrefl and Julian Dean.

Julian Dean a Postdoctoral researcher with Prof Thomas Schrefl developed in this project a quantitative methodology for indirect mapping of anti-ferromagnetic (AF) domains at the nanometer scale in metallic thin films used for spin electronic devices. The methodology is based on the development of micromagnetic simulations for AF thin films exchanged biased to an amorphous ferromagnetic layer using a new surface integral technique. The development of the algorithm was possible due to links with experimental input and comparison with micromagnetic and structural data from Lorentz and analytical TEM, respectively provided by Amit Kohn at Oxford University. Fingerprint micromagnetic studies have been created, including their temporal temperature evolution with applied magnetic field. This has allowed the correlation between microstructure and micromagnetic properties to observed experimentally phenomena, most notably the importance of grain thickness, interlayer exchange and intergranular importance on exchange bias, training effects and 360° domain wall formation. This work will be published in Applied Physics Letters and Physical Review B and was presented at the latest Joint Intermag/MMM conference in Washington DC.


Alexander Goncharov is a Postdoctoral researcher with Prof Thomas Schrefl has developed a new framework for large-scale micromagnetic simulations, where traditionally used methods for fast field evaluations (FFT, FMM, H-matrices) become infeasible is developed. In the new method the Kronecker product approximation of the pointfunction demagnetizing tensor is used. The clear advantage of this technique can be seen as follows. If in large-scale three-dimensional simulations one space dimension is discretized by N cells, then a total number of cells is N^3. Standard algorithms will scale with a total number of cells squared giving N^6 for the full N^3 x N^3 matrix. The Kronecker approximation allows us to store only O(N^2) entries, which is less than the order of the original matrix. The advantage of this type of approximation compared to other techniques is its superlinear compression property.

Kronecker product approximation can be applied to complex geometries such as magnetic recording head by using a hierarchical tensor structure or by wrapping the whole geometry into the cartesian grid. Hierarchical tensor can be seen as a hierarchical matrix on a tensor product grid where each matrix block represented in a tensor form, but admissible blocks are stored in the Kronecker format. This new technique allows to reduce the memory usage for numerical calculations from GBits down to MBits or even KBits. Meaning that simulations that are normally done on computer clusters can be done on stand-alone machines. This new method was presented by Alexander Goncharov as an invited talk at the latest Joint Intermag/MMM conference in Washington DC.

Calcite crystallization on self-assembled monolayers, Colin Freeman, John Harding (Sheffield) David Quigley, Mark Rodger (Warwick), Dorothy Duffy (UCL).

We show that recent developments in the ability of simulation methods to study long timescale processes (metadynamics) permit the direct simulation of crystallization. This makes it possible to predict the orientation of crystals grown on self-assembled monolayers. In contrast to previous studies, the method allows for dynamic treatment of the organic component and the inclusion of explicit surface water without the need for computationally intensive interfacial energy calculations or previous knowledge of the interfacial structure. The method is applied to calcite crystallization on carboxylate terminated alkanethiols arrayed on Au (111). We demonstrate that a dynamic treatment of the monolayer is sufficient to reproduce the experimental results of Joanna Aizenberg’s group (Harvard) without the need to impose epitaxial constraints on the system – compare the bottom left and top right configurations in the diagram. We also observe an odd-even effect in the variation of selectivity with organic chain length (top and bottom right), reproducing experimentally observed orientations in both cases. The analysis of the ordering process in our simulations suggests a cycle of mutual control in which

Figure 6.4.5: Shows the simulated Fresnel image of a 360° domain wall formation as a function of field and waiting time. This highlights many features observed experimentally such as the magnetisation ripple, the width of the domain walls and the shape and structure.
both the organic and mineral components induce complementary local order across the interface, leading to the formation of a critical crystalline region. We can also show the importance of solution chemistry, in particular the effect of pH, in controlling the ionization of the monolayer and thus the crystallisation behaviour.

Figure 6.4.6: Top left: starting configuration with amorphous CaCO₃. Bottom left: Rigid template: crystals with (00.1) orientation. Top right: Flexible template: crystals with (01.2) orientation. Bottom right: Length of molecules in template changed by one CH₂ unit but still flexible; poor crystallisation with (11.6) orientation.
6.5 Metallurgy

High-speed machining of titanium alloys, M Jackson, M Thomas and S Turner (AMRC).

A traditional metallurgical approach has been applied to the high-speed machining of aero-structural titanium alloys. If component manufacturers are to meet the supply demands of the aerospace industry, machining at high speeds is a critical requirement. Traditional surface integrity practice applied by mechanical engineers characterizes macroscopic features such as surface tearing, chip smearing and general deformation of grains in the direction of cutting. Until now, there has been very little emphasis placed on the subsurface microstructural response during high-speed machining processes. Collaborative research between the Department of Engineering Materials and the Advanced Manufacturing Research Centre (AMRC) determined the microstructural damage arising during the high speed milling operation. High speed milling trials were performed at the AMRC on near-α alloy Ti-834. Microstructural characterisation was performed at the Department of Engineering Materials.

Figure 6.5.1 shows the effect of the high degree of subsurface plastic strain imparted on Ti-834, during milling at a speed of 200 m per.min. The plastic strain is principally accommodated by dislocation slip of the alpha phase to sub-surface depths of 30 μm. The slip bands (regions of intense dislocation density) can be observed using scanning electron microscopy due to electron channelling contrast. Such microstructural features are concerning, as they have been reported to be crack initiation sites during fatigue loading.

From the disorientation map and corresponding stereographic projections in Figure 6.5.2, two observations can be made. The first is that multiple slip systems are activated during milling; the second is that there is variation in slip intensity, including slip band spacing, between neighbouring grains. Grains C and D are of similar crystallographic orientation and show the highest intensity of slip, with the slip band traces closely aligned with the machining direction. It is evident from the trace analysis that slip has occurred along the basal plane; in both cases, the grains have a Schmid factor approaching 0.5 for {0 0 0 2}[1 1 _2 0] basal slip. Additionally, slip traces aligned with the {1 0 _1 1} crystallographic plane can be observed in grain C, corresponding to the activation of a secondary slip system, {1 0 _1 1}[1 1 _2 0] pyramidal slip, which has a Schmid factor of 0.46. For more details with regard to deformation modes please refer to Meurig Thomas, Sam Turner, Martin Jackson. Microstructural damage during high-speed milling of titanium alloys, Scripta Materialia 62 (2010) 250-253.

As the near-surface micro-texture has a direct effect on slip band characteristics in the alpha phase following high-speed milling, a better understanding of the upstream thermomechanical processing of the near-surface micro-texture could potentially aid downstream machining operations. A combinatorial improvement in forging practices and milling tool parameters, via the development of through-process models by mechanical and metallurgical engineers at Sheffield will eventually permit much high production rates (>200 m min⁻¹) of aero-structural titanium components.
Application of combined discrete/finite element multiscale method for modelling of magnesium redistribution during hot rolling of aluminium. Michal Krzyzanowski and W Mark Rainforth.

The hot rolling of aluminium results in the formation of a nanocrystalline surface layer, which comprises three main features, namely, nanoscale fragmented oxide particles mechanically mixed from the original surface into the metal; a fine subgrain structure, and a significant difference in chemical composition to the bulk. Understanding the mechanisms of formation of such layers is difficult as it takes place in fractions of a second inside the roll bite. It is known that the tribological conditions at the roll/stock interface during processing, such as state of lubrication, position of the neutral point, roughness of the rolls and the roll speed, are key variables in the surface layer formation. Therefore, the most appropriate route in understanding is to model the interaction of the surface of the metal with the work roll. Numerical modelling of the stock surface layer formation has been carried out on the rolling of the Al-Mg-Mn aluminium alloy AA3104 using a two-high laboratory mill. The results of a parallel experimental programme have demonstrated that the structure, morphology and the filiform corrosion susceptibility of the subsurface layer appears to be strongly dependent on both the depth of the Mg enrichment formed during reheating and redistribution of this near-surface metallic element during hot rolling. The numerical problem is effectively a matter of discrete rather than continuum numerical analysis. The applied combined finite-discrete element method merges finite element tools and techniques with discrete element-based transient dynamics, contact detection and contact interaction solutions. Linking of the modelling scales is based on transferring of the corresponding boundary conditions from the macro model to the representative cell, considered as the meso-level model. This meso-model consists of a large number of deformable bodies that interact with each other. Each individual discrete element is of a general shape and size, and can be discretised into finite elements to analyse deformability and diffusion. The transfer processes in the thin surface layer are described by the system of diffusion and the motion equations for particles integrated in time. The numerical analysis indicated that, under the rolling conditions, the redistribution of Mg content can arise mainly due to one or a few of the following reasons, namely: by removal of some of the thin oxide layer by abrasion and adhesion to the work roll surface; by intermixing of the small oxides (Mg) into the subsurface layer of a few microns depth; and by diffusion. Further analysis should be carried out to validate the modelling approach and to establish the predominant mechanisms of the surface layer formation and influence of the key hot rolling parameters.
6.6 Nanomaterials and Nanoengineering


As part of the NanoLAB Basic Technology Nanorobotics programme we have developed a mechanical triboprobe miniaturized to fit inside a TEM. The TEM tribological probe can be used for nanofriction and nanofatigue testing of individual nanostructures, with 3D control of the loading direction and simultaneous TEM imaging of the nanoobjects. Using the TEM triboprobe a technique to quantify in real-time the microstructural changes occurring during mechanical nanoscale fatigue of ultrathin surface coatings has been developed. It is demonstrated that fracture of 10-20nm thick amorphous carbon films by a single nanoscale shear impact results in the formation of <10nm diameter amorphous carbon filaments. Failure of the same carbon films after cyclic nanofatigue, however, results in the formation of carbon nanostructures with a significant degree of graphitic ordering, including a carbon onion [214].

Welding of individual nanoobjects using nanoscale solder, B J Inkson and Y Peng.

One of the central challenges for the bottom-up construction, integration and repair of nanoscale systems is to develop reliable methods of joining individual nanoobjects together and to substrates. In this work we have developed a new nanoscale electrical welding technique, using nanovolumes of metal solder, which radically improves the spatial resolution, flexibility and controllability of welds between individual nanowires and nanoobjects. At the weld sites, nanoscale volumes of a chosen metal are deposited using a sacrificial nanowire, which ensures that the nanoobjects to be bonded retain their structural integrity.

We demonstrate by welding both similar and dissimilar materials, that the use of nanoscale solder is clean, controllable and reliable, and ensures both mechanically strong and electrically conductive contacts. The use of solder to bond the nanoobjects together also offers the opportunity to tailor the weld’s mechanical and functional properties by controlling the chemistry, structure and volume of solder material used, and nanoscale weld resistances of just 20Ω have been achieved by using Sn [175].

Figure 6.6.1: Real-time imaging of the nanoscale tribology of carbon thin films.

Figure 6.6.2: (a) Method for welding nanostructures together using nanovolumes of solder (b) Nanowriting using welded nanowires.
Polymer composites research has continued to focus on the fields of self-sensing and self-healing of composite damage and in the study of group-interaction modelling to predict polymer and composite properties from their chemical constituents. Work on plasma polymerisation for surface functionality control is also on-going. In association with the Department of Mechanical Engineering, and through the Composite Systems Innovation Centre (CSIC), work is also on-going in the field of nanocomposites and on biodegradable and recycled polymers for both structural and packaging applications. Highlights in two areas, those self-sensing and self-healing and of group interaction modelling are given below.

**Self-sensing and self-healing**

The self-sensing work has concentrated on two principle techniques, these being optical self-sensing and electrical self-sensing of damage in composites. The well established electrical sensing work has progressed in the use of flexible printed circuit board to deliver the contacts necessary to enable the localised resistance of the composite to be determined. This has facilitated more-rapid manufacture of self-sensing composite and has the potential, given further work to enable deployment of the sensor system in a production environment.

Optical self-sensing, using e-glass reinforcing fibres, is a new departure for the research group and has shown significant promise. The use of reinforcing fibres as light-guides is not new, however, in the past it has been necessary to employ a specially selected low refractive index resin to enable the fibres to guide light. Unfortunately these resins are generally unsuitable for use in structural composites, as they are designed primarily as optical adhesives. In our work, we have used conventional resin blending techniques, and readily available additives to modify a commercial aerospace approved resin system, such that its refractive index is sufficiently low that the fibres can guide light. Using commercially available woven glass cloth, we have successfully manufactured composite panels using this resin and shown them to be capable of sensing damage to the composites structure (Figure 6.7.1).

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Work on the solid-state self-healing resin system is continuing with studies to improve the processibility of the resin, by reducing its viscosity, and also to improve the repeat healing capability by minimising resin shrinkage during repeated heating cycles. Work is also continuing to investigate the healing of new resin systems whose chemistry differs significantly from the anhydride or amine cured epoxies that we have healed to date.

**Group Interaction Modelling**

The Polymers and Composites group is pioneering work in the field of Group Interaction Modelling which predicts polymer properties from molecular structure in a fraction of the time required for tradition methods. Dr Joel Foreman and Dr David Porter have developed the method to predict strain rate and temperature dependent properties from dynamic mechanical measurements of the secondary phase transitions that occur in viscoelastic polymers. The predicted properties of a typical aerospace epoxy resin matrix are used as input for a finite element prediction of the impact a fibre failure has on surrounding fibres. This information is then used to predict the statistical propagation of fibre failure events through a typical composite system. The method is currently being developed into the dedicated software programs GIProps and FFC (www.gimprops.com).

The Group Interaction Modelling method is also being extended within the department to predict the properties of many different kinds of polymers. Previously, amorphous, isotropic thermosets such as epoxy resins have been studied but the technique is being developed to predict the properties of semi-crystalline, orthotropic polymers such as Ultra-High Molecular Weight Polyethylene. Additionally, we are investigating how to incorporate extremely high strain rate impact events, the influence of moisture on properties and the prediction of properties as a function of cure schedule.

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**Figure 6.7.1:** Self-sensing composite produced using a modified commercial epoxy resin system and commercial woven e-glass fabric. a) before impact showing full transmission across the panel width and b) showing reduced transmission in the centre of the panel following an impact event.

**Figure 6.7.2:** The compressive modulus and yield stress of a 50:50 blend of two amine cured epoxy resins (TGDDM and TGAP cured with DDS) as a function of strain rate. The experimental values compare extremely well with those predicted by Group Interaction Modelling.
Surface cleaning is an important step of most manufacturing processes. It is essential in the manufacture of steel components that are prone to formation of mill-scales, pigmented films and rust spots during prior processing and in-process storage. Well known cleaning treatments include mechanical (abrasive blasting and tumbling), chemical (molten salt, acid etching or pickling), electrochemical (electrolytic acid pickling or alkaline cleaning), solvent and emulsion cleaning processes. To enhance cleaning efficiency, individual treatments are combined into hybrid and multistage procedures. New cleaning technology based on electrolytic plasma processing (EPP) was studied in ref [6.8.1]. The method relies upon intensification of conventional electrolytic alkaline cleaning by a plasma discharge that is initiated at the surface of a cathodically polarised workpiece (Figure 6.8.1). Plasma processes enhance cathodic reduction with thermally and mechanically activated removal of contaminants. A risk of decrease in mechanical properties can be mitigated by the application of the pulse current mode. A specially designed and instrumented EPP facility was used, which allowed for an adjustable inter-electrode gap, controlled sample movement, electrolyte temperature and flow as well as independent control of the pulse frequency f and duty cycle d from DC to 32 kHz.

It was observed (Figure 6.8.2) that the pulse current EPP cleaning leads to a decrease in the surface roughness of treated samples, compared with both the untreated and the DC treated specimens. Moreover, the roughness decreases with an increase in frequency and a decrease in duty cycle.

SEM observations of the original surface morphology, revealed partly contaminated grinding ridges, whereas EPP-cleaned surface featured by a crater-like morphology due to discharge events accompanying the cleaning process (Figure 6.8.3). With an increase in frequency and a decrease in duty cycle of the pulsed current, the feature size reduced, making the surface profile particularly suitable for subsequent coating treatments.

The cleaning quality was estimated by glow discharge optical emission spectroscopy (GDOES). Typical surface profiles of oxygen for the untreated and EPP treated surfaces are presented in Figure 6.8.4. The untreated sample shows a near surface broad peak oxygen profile attributed to residual oxide scale resulting from the sample manufacturing and storage. The breadth of the O peak and extended tail profile indicated an effect due to surface roughness, where the surface material in valleys was sputtered at a lower rate than the asperities. The EPP cleaned surfaces had a significantly lower subsurface O profile indicating that the EPP process had successfully removed or reduced surface oxides, which together with reduced surface roughness, resulted in a
lower near-surface O content. It is also evident that the pulse current EPP cleaning treatment is as effective in removing surface oxide as the DC process. These compositional changes are likely to be responsible for slight enoblement of the surface corrosion potential, which is attributable to an increased rate of cathodic processes, as revealed by potentiodynamic corrosion tests.

Mechanical tests have demonstrated negligible reduction in hardness and no reduction in toughness due to hydrogen embrittlement induced by EPP treatments. At the same time, rotating bending beam fatigue tests indicated a noticeable reduction in fatigue life, which could however be offset by a shot peening pre-treatment. Overall, optimal process parameters for pulse current EPP cleaning were identified at $\delta = 0.8$ and $f = 100$ to 10000 Hz.

Reference:

Plasma assisted electrochemical treatments provide new possibilities in surface modification of various materials including light weight alloys. However, their large-scale application is still restricted, mainly due to poor understanding of the process mechanism and consequent limitations in the process control and automation. This problem can be resolved if the frequency response (FR) of the system is known and applied for process diagnostics. A research discussed in ref [172] was dedicated to FR measurements during PEO of Al in the small signal mode corresponding to small perturbations of voltage signal around large DC values (Figure 6.8.5).

The study was carried out during PEO of Al at DC voltages which were varied from 450 to 600V. The FR obtained is a frequency dependent admittance of the PEO electrolyser; this complex number is represented by a modulus and a phase angle (Figure 6.8.6). It was shown that, under potentiostatic conditions, the modulus evolution strongly correlates with the average current value; therefore, it bears insufficient amounts of independent information. The FR phase angle measured within this study was never obtained before. Depending on the frequency, it varies between 0 and 70 deg in the capacitive domain. One of the most notable features of this characteristic is low values at 500 to 5000 Hz when microdischarges appear during PEO. The other feature is a correlation with the coating growth. As a result, a new diagnostic tool was developed and shown to be effective for evaluation of microdischarges and surface properties during the treatment, thus decreasing the uncertainty in the system. 

Figure 6.8.4: GDOES profiles of iron and oxygen in untreated and EPP treated steels.

Figure 6.8.5: Voltage and current waveforms for PEO treatment of Al.

Figure 6.8.6: Temporal dependencies of FR components at $U = 500$ V (a) – admittance modulus and (b) – phase angle.
The effect of superfinishing and PVD/CVD coatings on torque and temperature of SAE52100 rolling element ball bearings under starved lubrication conditions, J. Eichler, A. Matthews, G.L. Doll, A. Leyland.

Investigation into the rolling contact behaviour of coated and uncoated counterfaces under lubrication starvation conditions has been carried out. Cr$_2$N and WC/a-C:H coatings deposited by PVD and hybrid PVD-CVD processes respectively were tested. In addition, the effect of vibratory superfinishing on rolling contact, both in isolation and as a surface pre-treatment prior to PVD coating was investigated. The results illustrate the benefits provided by surface modifications under these extreme operating conditions and their ability to delay the onset of catastrophic bearing failure in the event of lubrication starvation. The findings of this investigation were presented at the Society of Vacuum Coaters (SVC 2009) conference held in Santa Clara, California, USA, May 2009 [92]. The main findings from this paper are summarised below.

The raceways from thrust ball bearings (shown below in Figure 6.8.7) were modified with either chromium nitride (Cr$_2$N), tungsten carbide/amorphous hydrogenated carbon (WC/a-C:H), or vibratory superfinishing. Superfinishing was also used as a surface treatment before the deposition of a PVD coating to produce a ‘duplex’ surface treatment.

The treated raceways were re-assembled into thrust bearings and initially lubricated with a solution of ISO VG10 mineral oil and hexane. After evaporation of the volatile solvent, a film of lubricant with repeatable thickness remains on the components of the bearing. The bearings were loaded to 6.2 kN (maximum Hertzian contact stress of approximately 1 GPa) and rotated at 4000 RPM until the frictional torque exceeded 1 Nm or the raceway temperature exceeded 110°C. The bearing lives were analysed using a Weibull statistical method.

As illustrated in Figure 6.8.8, the bearings exhibited a rapid increase in torque as the speed and load were increased. After approximately one minute the torque decreases to a plateau level where it remains until failure commences. This ‘running-in’ process results in a reduction of the temperature gradient. The onset of failure is indicated by a sharp increase in torque, followed by a delayed increase in heat generation.

In this investigation, the WC/a-C:H coating offered the best performance under lubrication starvation conditions (as shown in Figure 6.8.9). This coating is likely to function as a barrier to adhesive interactions between the raceway and rolling element, thereby increasing bearing life.

Evidence of carbonaceous material on the rolling elements was found. This transferred material is likely to act as a solid lubricant, delaying bearing failure under boundary lubricated conditions. The performance of the superfinished specimens was unexpectedly low. Superfinishing alone did not provide an appreciable improvement in performance and it also reduced the performance of the WC/a-C:H coating when used as a surface pre-treatment. The superfinished substrate topography is unlikely to have caused poor coating adhesion. However, the modified raceway surface will result in a larger contact area which could increase the spin of the rolling elements, increasing frictional torque and shear stress in the coating. Experimentation with the ceramic media size, type and process duration is likely to yield better results and will be the subject of future investigations.
Degradation of a C/CrC PVD coating after annealing in Ar+H2 at 700°C studied by Raman spectroscopy and transmission electron microscopy, Z Zhou, IM Ross, WM Rainforth, A Cavaleiroa, A Ehiassarianb, P Hovsepianb (aMechanical Engineering Department, University of Coimbra, 3030-788 Coimbra, Portugal, bMaterials Engineering Research Institute, Sheffield Hallam University, Sheffield, S1 1WB UK).

Recently, there has been increasing interest in the development of nano-composite carbon based coatings due to their excellent tribological properties. These coatings typically consist of an amorphous carbon phase (a-C:H, but could be diamond like carbon) and a hard crystalline metal or metal carbide phase (usually Ti, Ta, W and Cr carbides). The prevailing synthesis methods to produce the coatings have been to sputter metal targets in a mixture of hydrocarbon (e.g. C2H2, CH4) and inert gas (usually Ar). Despite the reduction of internal stresses by alloying with transition metals, the large amount of hydrogen, up to 20-50at%, incorporated in the resultant coatings undermines the coatings’ thermal stability. Nanoscale hydrogen free C/Cr coatings have been produced by unbalanced magnetron sputtering of graphite and Cr metal targets with structure and properties strongly dependent on the substrate bias voltage. The coatings evolve from an amorphous (-65V to -95V) through an ‘onion-like’ carbon structure (-120V) to nanoscale multilayer structure (-350V and -450V) and finally a uniform fine grain structure (-550V). The current work looked at the thermal stability of a hydrogen free C/CrC coating. The coating was deposited by unbalanced magnetron sputtering of graphite and Cr metal targets in a non-reactive argon atmosphere with high ion irradiation conditions. The coating possessed a nanocomposite structure with amorphous carbon embedded in a metastable NaCl (B1) structure CrC matrix, Figure 6.8.10. Chromium carbides are well known to have three stable phases of Cr3C2, Cr7C5 and Cr23C6. It is believed that a stable CrC with NaCl (B1) structure cannot be produced on the basis of Hagg’s empirical rules, \( r_c/r_{me} < 0.59 \), where \( r_c \) is the single bond radius of carbon and \( r_{me} \) is the considered transition metal \( (r_c/r_{Cr} = 0.61) \). The nanometre amorphous carbon clusters formed layers within the CrC matrix, producing a self-assembled multilayer structure. Degradation was evaluated by annealing at 600 and 700°C in Ar+5%H2 atmosphere for 30 minutes. Microstructures of the as-deposited and annealed coating were characterised using Raman spectroscopy and cross sectional transmission electron microscopy coupled with electron energy filtered mapping. Raman spectroscopy suggested the presence of graphitic carbon in the coating after annealing, together with a trace of Cr2O3 associated with coating growth defects, Figure 6.8.11. TEM investigation of the cross sections of annealed coating revealed regions of C enrichment at the very top (~40nm) and bottom (~10nm) of the coating, which was confirmed by Raman spectroscopy. However, the central region of the coating retained its composite C/CrC multilayer structure, Figure 6.8.12. Tentative mechanisms of the coating degradation, in particular the C enrichment are proposed in reference [6.8.2].

Reference:

7.1 Publications 2008


7.2 Publications 2009


147. Y Liu and A R West “Ho-doped BaTiO$_3$: Polymorphism, phase equilibrium and dielectric properties of BaTi$_{1-x}$Ho$_x$O$_{3-x/2}$: 0 < x < 0.17”, J Euro Ceram Soc, 29 (2009) 3249-3257.


162. L Miranda, D C Sinclair, M Hernando, A Varela, A Wattiaux, K Boulahya, J M Gonzalez-Calbert and M Parras “Mn-rich BaMn$_{1-x}$Fe$_{x}$O$_{3-x/2}$ perovskites revisited: structural, magnetic, and electrical properties of two new 5H polotypes”, Chem Mater, 21 (2009) 5272-5283.


194. A Sittichochromechaiwut and G C Reilly “Development of a culture system to modulate tissue engineered bone formation by varying loading conditions”, Proc 7th Int Conf Manufacturing Research (ICMR09), University of Warwick, UK, 8th-10th September 2009, pp.6.


221. G Yang, G Møbus, P A Bingham and R J Hand

222. M Yang, P M Rodger, J H Harding and S L S Stipp

223. B Zalinska, M Mirsaneh and I M Reaney

224. X Zeng, F Liu, A G Fowler, G Ungar, L Cseh, G H Mehl and J E Macdonald

225. S Zhang

226. S Zhang, L Yuan and J Yu

PhD Awards, 2008

1. **Vincent Aerts**, "Influence of interfacial morphology on the strength of bonded joints". Supervisor: Prof F R Jones.

2. **Wenting Zhang**, "Self healing epoxy resins and composites". Supervisors: Dr S A Hayes and Prof F R Jones.

PhD Awards, 2009

1. **Mohamed Mohamed Zaky Ahmed**, "The development of thick section welds and ultra-fine grain aluminium using friction stir welding and processing". Supervisor: Dr B P Wynne.

2. **Simon G Bance**, "Data storage and processing using magnetic nanowires". Supervisor: Prof T Schrefl.

3. **Michael Blackmore**, "Strain path effects on Timetal 834 under hot working conditions". Supervisor: Dr B P Wynne.


8. **Fathi El Fallagh**, "3D analysis of indentation damage by FIB tomography and TEM". Supervisor: Dr B J Inkson.


11. **Ian Hickman**, "Chromium segregation and the effect on crystallisation processing green soda-lime-silica glass". Supervisor: Prof J M Parker.


13. **Feng Liu**, "Complex supramolecular self-assembly of T- and X-shaped amphiphiles". Supervisors: Dr X Zeng and Prof G Ungár.


15. **Nima Nasseri**, "Microstructure and crystallographic texture evolution in TIMETAL 6-2-4-6 billet". Supervisors: Dr B P Wynne and Prof W M Rainforth.


20. **Anuphan Sittichokechaiwut**, "Dynamic mechanical stimulation for bone tissue engineering". Supervisor: Dr G Möbus.


22. **Yun Wu**, "Li-doped CoO: Structure and properties". Supervisor: Prof A R West.

23. **Muhamad Azizi Mat Yajid**, "Chemical mapping techniques for nanoscale multilayer coatings". Supervisor: Dr G Möbus.


9. Current Research Sponsors

The Department of Engineering Materials is very grateful to the organisations listed below for their material support of our research. Our level of research activity would have been impossible without their generous contributions.

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White Rose Consortium
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WRAP (Waste and Resources Action Plan, UK Government)
Wuhan Iron and Steel Company (WISCO)
Yorkshire Forward
York Pharma

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**GRAND TOTAL** 50,817,521.08
11. Department Highlights, 2009

11.1 Personal Highlights, 2009

Dr Dan Allwood

- Visited the Advanced Light Source synchrotron in Berkeley, California 7th-14th December 2008, with Dr Matthew Bryan, Dr Tom Hayward and Placiede Fundi. They had five days of beamtime to perform magnetic transmission X-ray microscopy measurements of magnetic nanostructures. These included imaging of interacting magnetic domain walls in patterned Ni80Fe20 nanowires of the type being developed for data storage and sensor applications. While there, Dan Allwood gave a seminar presentation, "Patterned nanoscale magnetic field sources".
- Attended the 35rd Magnetism and Magnetic Materials conference in Austin, Texas 10th - 14th November 2008. He gave an invited talk, "Magnetic positioning of nerve cells".
- Gave an invited talk, "Magneto-optical Kerr effect measurements of magnetic thin films and nanostructures", at the Institute of Physics Magnetism Group Postgraduate Workshop on 9th July 2008, at The University of Manchester.
- Attended the European Congress and Exhibition on Advanced Materials and Processes (EUROMAT), Glasgow, UK (7th - 10th September 2009).
- Has been running a project with post-16 students at King Edward VII School every Wednesday afternoon from October 2008 on next-generation magnetic hard drive materials. The project is designed to allow students to use computer modelling to perform research and learn from the model outcomes. One project aim is to produce a peer-reviewed research paper that includes the students as authors.

Asif Bashir

- Research visit to Seagate Technologies Ireland, 26th February 2009.
- Visited the Technical University of Vienna and St. Polten University of Applied Sciences, Austria, 2nd, 11th March 2009, to conduct research with groups in Austria. This visit was funded by the "Exchange Excellence Scheme", awarded by the University of Sheffield.
- Visited Seagate Technologies, Londonderry on 6th July 2009 with Professor Thomas Schreff and David Hahn to discuss project ideas for magnetic recording up to 2.5 Tbit/in2.
- Attended IEEE Magnetics Society meeting at the University of Cardiff, 9th July 2009, and presented a talk, "Microwave-assisted multilayer magnetic recording for 3Tbit/in2".
- Visited Corus Steel, Scunthorpe, 29th July 2009, to attend a poster prize ceremony.
- Research visit to St. Polten University of Applied Sciences, Austria, 11th-17th October 2009.

Dr Alison Beck

- Presented “Positive ion mass spectrometry detection from the atmospheric pressure plasma treatment of polymers”, co-authored with Y Aranda Gonzalez (Hiden Analytical Ltd), A Pilkington, A Yerokhin and A Matthews, at the International Symposium on Plasma Chemistry (ISPC19), July 2009, Bochum, Germany.
- Co-authored “Influence of Implementation of Composite Materials in Civil Aircraft Industry on Reduction of Environmental Pollution and Greenhouse Effect”, with Alma Hodzic, Constantinou Soutis, Chris W Wilson, which was presented at Trends in Aerospace Manufacturing (TRAM09), Sheffield

Dr Paul Bingham

- Gave an Invited Presentation, “Modified iron phosphate glasses for waste immobilisation: advantages and limitations” at the 12th Conference on the Physics of Non-Crystalline Materials in Iguassu Falls, Brazil, 6th-11th September. He also presented a poster, “Speciation of sulphur in silicate glasses by X-ray absorption and X-Ray emission spectroscopies”. The Crystalisation conference series took place after the PNCS conference and Dr Bingham, as a representative of the University of Sheffield, contributed a short presentation on Prof Peter James, in memory of whom a special session of the conference had been organised.
- Attended Materials Science and Technology 2009 (MS&T’09), 25th-29th October, Pittsburgh, USA with postgraduate student, Mohamed Salem and Daniel Reid. Dr Bingham’s presentation, “An overview of recent UK glass development for ILW and HLW immobilisation”, was particularly well received and generated considerable discussion and debate. Mohamed Salem gave a presentation, “The effect of processing conditions and cooling rate on API-70 and X-100 grade steels” and Daniel Reid presented a paper at the “Materials Solutions for the Nuclear Renaissance” symposium at the conference, “Synthesis and structures of Gd2(Zr2-xCex)O7: A model ceramic system for plutonium disposition”.

Dr Matthew Bryan

- Visited the Advanced Light Source synchrotron in Berkeley, California 7th-14th December 2008, with Dr Dan Allwood, Dr Tom Hayward and Placiede Fundi. They had five days of beamtime to perform magnetic transmission X-ray microscopy measurements of magnetic nanostructures. These included imaging of interacting magnetic domain walls in patterned Ni80Fe20 nanowires of the type being developed for data storage and sensor applications. While there, Dan Allwood gave a seminar presentation, “Patterned nanoscale magnetic field sources”.
Emeritus Prof Hywel Davies

- Visited the South China University of Technology in Guangzhou (Canton), 10th-15th April 2009, where, in a formal ceremony conducted by Prof Min Zhu, Vice President for Research, he was appointed Consulting Prof in the School of Materials Science and Engineering. Prof Davies presented two research lectures in the Department of Metallic Materials Science and Engineering, entitled: "Influence of refractory metal additions on the magnetic properties of nanocomposite hard magnets" and "High glass forming ability for Cu-Hf-Ti alloys with small additions of Y and Si".
- Presented an invited lecture, "The Future of Nanocomposite Magnets for Practical Exploitation", at a Symposium on Materials for a Sustainable Future, Birmingham University, 11th September.
- Prof Davies attended a dinner at Birmingham University to celebrate jointly Prof Rex Harris’ 70th birthday and Prof Ray Smallman’s 80th birthday.
- Chaired the first session of a Symposium on Bulk Amorphous and Nanocrystalline Materials as part of programme for the 2009 E-MRS Fall Meeting held at Warsaw University of Technology in Poland on 14th-18th September. He also presented an invited lecture, "The Influence of Heterogeneous Nucleation on the Prediction of Glass Formability in Metallic Materials", co-authored with Dr Ignacio Figueroa, Mr John Plummer and Dr Iain Todd.

Dr Joel Foreman

- Attended a conference (Composites 2009, 1st-3rd April) and gave a presentation, "Modelling the Yield Properties of a Trifunctional Epoxy Resin Based Composite".
- Attended Thermosets 2009, Berlin, October, with Prof Frank Jones.

Emeritus Prof Fergus Gibb

- Continued as a member of the Committee on Radioactive Waste Management, whose remit is to provide advice to the Government and the Nuclear Decommissioning Authority on matters relating to nuclear wastes.
- Attended the Micro Analysis, Processes and Time (MAPT) Conference, Edinburgh 31st August-2nd September where he Chaired the session on "Mineralogy of Nuclear Waste”. This was an international conference jointly organised by The Mineralogical Society of Great Britain, the Deutsche Mineralogische Gesellschaft, the Societe Français de Mineralogie et de Crystallographie and the International Association of Geoanalysts.
- As a member of the Government’s advisory committee on Radioactive Waste Management (CoRWM), participated in a joint meeting of CoRWM and the US Nuclear Waste Technical Review Board to discuss "matters of mutual interest relating to nuclear waste management and disposals".

Prof Mike Gibbs

- Attended the Programme Committee Meeting for INTERMAG 09, Sacramento, January. He was involved in refereeing digests in the areas of magnetic sensors and soft magnetic materials.
- Was elected to the grade of Senior Member of the IEEE (Institute of Electrical and Electronic Engineers), the citation reading that this is “in recognition of professional standing”.
- Session chair at INTERMAG 09, Sacramento, USA.
- European Advisory Committee for INTERMAG 2014.
- Invited to join the Editorial board of IEEE Magnetics Letters.
- Hosted 3-month visit from Prof Ji-Bing Sun, Heibei University of Technology, China.

Dr Russell Goodall

- Recorded an invited online lecture on the Mechanical Properties of Metals, for the European Space Agency as part of the European FP6 IMPRESS Project. This lecture can be accessed on: http://streamiss.spaceflight.esa.int/Prg=production &dm=1&PID=impresslect.
- Attended meetings of the management committee for the FP7 European Integrated project IMPRESS, looking at TiAl intermetallics for turbine blades, in Les Diablerets, Switzerland and Budapest, Hungary.
- Attended EUROMAT 09 is Glasgow, where he had contributed to a keynote lecture and poster presentation.
Dr Russell Hand
- Was appointed chair of Technical Committee 6 (Mechanical Properties of Glasses) of the International Commission on Glass.
- Gave an invited lecture entitled "Silicate glasses: hydration, chemistry and defects" (co-authored by Damir Tadjiev) EFONGA workshop "Glass surfaces and stress corrosion mechanisms at the nanoscale", held in Montpellier, France, 23rd–25th February 2009.
- Gave an invited talk "Interaction of glasses with a GDF environment" at the RWIN XI meeting held in Sheffield, UK, 23rd April 2009.
- Attended the Society of Glass Technology Annual Meeting in Lancaster, 16th-18th September 2009 where he gave an oral presentation entitled "The (near surface) mechanical properties of durable and non-durable silicate glasses" (co-authored by Damir Tadjiev).

Prof John Harding
- Was the senior organiser of a symposium "Molecular biomimetics and materials design" at the 2009 Fall Meeting of the Materials Research Society at Boston, 30th November - 4th December 2009 where Colin Freeman presented a paper, "Simulating orientational specificity in the growth of calcite on self-assembled monolayers". Prof Harding and Colin Freeman presented three posters; two in the area of biomineralisation and one in the area of ferroelectrics on the role of defects in BaTiO3 (together with Hung-Ru Chen, Ben Lui Bin and Prof Derek Sinclair).
- Organised a symposium on the theme of Biominerals and Biomineralization at the MRS Fall Meetings (Boston) in December 2009 and presented a couple of posters at the meeting.
- Gave five invited talks at conferences:
  - "Nucleation and growth: a multiscale problem" (keynote: ICNAM May 2009), Bahrain.
  - "Simulating the role of amorphous and crystalline phases in biomineralisation" (Max Planck Workshop – BioAmorPhys; Schloss Neuhausen, June 2009.
  - "What can simulation contribute to the understanding of biomineralisation?" (13th IACIS International Conference on Surface and Colloid Science; New York, June 2009).
  - "Simple models for metal-ceramic interfaces" (CECAM Workshop, Zurich, July 2009).
  - "Controlling crystal growth using organic molecules, biomolecules and arrays" (238th ACS National Meeting and Exposition; Washington, August 2009).
- Gave invited lecture at TU Eindhoven "The challenge of biomaterials to simulation".
- Overall organiser of the CCP5 International Summer School in Molecular Simulation (Sheffield, July 2009) and gave some lectures thereat.

Dr John Haycock
- Was appointed as the new Director of the University Centre for Biomaterials and Tissue Engineering in 2009, taking over from Prof Sheila MacNeil, who was its director from 2003. John's first few tasks in 2010 will be to re-vamp the centre with a new website, re-focus the future direction the centre and start a new programme of themed seminars.
- Was appointed as the Associate Director of the Kroto Research Institute at the end of 2009. The primary role of the AD is to assist the Director (Prof. Steve Banwart) in research policy and implementation and to represent the interests of staff in the Kroto Research Institute at board meetings.
- Was appointed as an external examiner for another year at the University of Manchester for the M.Res (Hons) postgraduate degree in TERM (Tissue Engineering and Regenerative Medicine). This is a 1-year research and taught degree programme run by the Medical School at Manchester.
- Ran an Expertissues short course at the University of Oxford with Prof. Paul Hatton (Dental School, Sheffield) on the subject of "Biological and Biomimetic Scaffold Materials" in June 2009. This was a residential course for 50 delegates, which had a number of external invited speakers including Prof. Anthony Hollander (Bristol University) and Dr David Knight (Oxford University and Director of Oxford Biomaterials Ltd). Practical workshops and design problems were also integrated in to the programme.
- Was elected to the UK TCES (Tissue and Cell Engineering Society) Executive Committee at the TCES Annual Meeting (which was held at the University of Glasgow in June 2009).
- Gave invited talks:
  - "Confocal and 2-Photon Microscopy for 3D Skin and Nerve Models", at the Expertissues course on "Preclinical Models and Imaging" in Radstadt, Salzburg, Austria (Organised by the Ludwig Boltzman Institute, Vienna, Austria), March 2009.
  - "Scaffolds and Surface Modification for Bioengineering Peripheral Nerve", at the Expertissues short course on 'Biological and Biomimetic Scaffold Materials' at the University of Oxford, June 2009.
  - "Creating Biological Structures and Function with Scaffolds and Surface Chemistry", at the UKSAF (UK Surface Analysis Forum) Annual Meeting at the University of Nottingham, June 2009.
  - "Bioengineering Nerves and the Fabrication of Bioactive Surfaces" at the SHIC (Sheffield Health Innovation Centre) at the University of Sheffield, October 2009.
  - "Bioreactors for Peripheral Nerve Tissue Engineering", at the University of Keele short course on "Bioreactors", November 2009.
Dr Simon Hayes

Dr Tom Hayward
- Visited the Advanced Light Source synchrotron in Berkeley, California 7th-14th December 2008, with Dr Dan Allwood, Dr Matthew Bryan and Placide Fundi. They had five days of beamtime to perform magnetic transmission X-ray microscopy measurements of magnetic nanostructures. These included imaging of interacting magnetic domain walls in patterned Ni80Fe20 nanowires of the type being developed for data storage and sensor applications.
- Gave an invited seminar at the Cavendish Laboratory, University of Cambridge, "Domain Walls: Nanoscopic Magnetic Field Sources".
- Attended the European Congress and Exhibition on Advanced Materials and Processes (EUROMAT), Glasgow, UK (7th-10th September 2009) and presented a talk, "Switchable Nanomagnetic Atom Mirrors" and a poster, "Coupled Domain Wall Structure in Planar Magnetic Nanowires".
- Attended Condensed Matter and Materials Physics (CMMP) conference, University of Warwick, UK (15th-17th December 2009) and presented a talk, "Design and characterisation of a switchable nanomagnetic atom mirror" and a poster, "Direct imaging of domain wall interactions in NiFe planar nanowires".

Prof Andy Howe
- Was a participant at a Materials Prioritisation Panel, Swindon, 12th February 2009.
- Was "Opponent" to V Savran's PhD defense "Austenite formation in C-Mn steel" at TUDelft, 23rd February 2009.
- Attended the IMMPETUS Colloquium, Sheffield, 7th-8th April 2009.
- Was Expert Member of the European Commission/RFCS annual TGS6 meeting, "Physical metallurgy and design of new generic steel grades", Portugal, 5th-7th May 2009.
- Attended the IPTME Research Day, Loughborough University, Leicester, 9th June 2009.
- Was participant at the HEFCE/Impact of Research (REF) discussion day, London, 13th July 2009.
- Attended the M2i Conference, "Materials to innovate industry and society", Noordwijkerhout, Netherlands, 7th-8th December 2009.

Dr Gino Hrkac
- Was invited to give four invited talks on magnetic spintronics one at the American Physical Society Meeting in the USA, one at NIMS in Japan and two at UNAM in Mexico.
- "Current driven vortex oscillations in metallic nano contacts", co-authored with T Schrefl, Q Mistral, M van Kampen, Joo-Von Kim, T Devolder, P Crozat, C Chappert, L Lagae, at the American Physical Society APS meeting March 2009.
- Given 5 contributed talks at international conferences (Intermag, MMM, Jems) and published 17 papers (3 first author and 14 joint publications).
- Was awarded the Royal Society University Research Fellowship, Fundamentals of spin-torque induced magnetisation dynamics, Award 2009-2014 (PI GBP 421,275).
- Was awarded the EPSRC Bridging the Gaps, Pump-Priming Award, Ferrofluid-based microscale dosage device Award 2008 (PI, GBP 4,800).

Dr Beverley Inkson
- Gave an invited talk to the Dept of Physics, The University of Exeter, February 2009, entitled "Nanomaterials in Motion".
- Gave an invited talk to MATEIS, INSA de Lyon, and the Tribology Department, Ecole Centrale de Lyon, Lyon, France, March 2009, "Dynamical testing of Nanomaterials in TEM".
- Gave an invited talk to the Department of Mechanical Engineering, The Indian Institute of Science (IISc), Bangalore, India, August 2009, "Dynamical analysis of Nanomaterials".

- "Research in to Tissue and Bioengineering", at the University of Durham (Biophysical Sciences Research Institute), November 2009.
- John’s group attended the TCES Annual Meeting at the University of Glasgow in June 2009, with talk and poster presentations given on scaffolds for nerve tissue engineering and the use of stem cells for nerve repair.
- Was invited to lead a discussion group (together with Dr Gwen Reilly) on the subject of 'Tissue Engineered Models as Alternatives to Animal Testing' at the Medical Innovation Forum held at Harrogate International Centre in December 2009.
- Was invited to become an editor for a Methods in Molecular Biology book entitled 3D Cell Culture, by the original creator of the MiMB series Prof. John Walker. MiMB books are recognised worldwide as essential academic method texts and over 200 different book topics have been published to date. Much of 2009 was devoted to the creation of 3D Cell Culture which, after the goodwill of 56 authors contributing 20 chapters, is now with the publishers at Humana Press (New York).

Engineering Materials. The University Of Sheffield
• Gave an invited lecture to the Advanced School on Nanofabrication and Nanomanipulation, IOP EMAG Conference, Sheffield, September 2009, “Introduction to Focused Ion Beam Microscopy”.

• Dr Inkson, Aiden Lockwood and Dr David Deivasagayam have had an active collaboration with Dr M S Bobji and group at the Department of Mechanical Engineering, Indian Institute of Science (IISc), Bangalore India. Exchange visits in March and August 2009 have been funded by a joint NanoLAB-IISc UKIERI NanoBALLS project.

• Dr Inkson and Aiden Lockwood hosted a collaborative visit from Dr Lucille Joly-Pottuz and Dr Laurent Gremillard, MATEIS, INSA de Lyon, France 6th-7th July 2009 to work on the nanoscale mechanical properties of zirconia.

• Dr Inkson organised the “Mechanical Characterisation using in-situ Methods Symposium”, at the international EUROMAT 2009 conference, Glasgow, UK, 7th-10th September.

• Robert Milne gave an oral presentation, “Cyclic mechanical testing of aluminium nanostructures”.

• Dr Inkson organised a one-day joint IOM3 and UK NanoFIB Network meeting “NanoFIB 2009: Advances in Focused Ion Beam microscopy”. The meeting was held on 16th March at Wadham College, Oxford and attracted over 50 researchers and exhibitors. Dr Mark Jepson chaired a session, and a poster presentation was given by F Elfallagh and B J Inkson, “3D analysis of crack morphologies in silicate glass using FIB tomography”.

Dr Martin Jackson

• Presented two papers, “Surface Conditioning of Aerospace Titanium Alloys” and “Thermomechanical Processing of high Strength Landing Gear Forgings” at Aeromat 2009 (Dayton, Ohio).

Dr Mark Jepson

• Made a research visit to Harvard University to make use of their Helium Ion Microscope in August 2009. Dr Jepson also gave seminar at Harvard University’s Nanoscale Science and Engineering, “Secondary electron dopant imaging in the scanning electron microscope and helium ion microscope”.

• Visited the Carl Zeiss facility in Peabody, Massachusetts in August 2009.

• Visited University College London on two occasions to make use of their triple-beam FIB. These visits were funded by the Engineering and Physical Sciences Research Council.

• Gave a poster presentation, “Progress towards site-specific dopant profiling in the scanning electron microscope”, co-authored with B J Inkson, R Beanland, C J Humphreys and C Rodenburg.

Emeritus Prof Frank Jones

• Appeared on the Naked Scientist Radio Show to discuss his work on self-healing materials and can be heard on http://www.thenakedscientists.com/HTML/content/interviews/interview/1045/.

• In February, he attended the International Conference on Hi-Tech Materials (ICHTM-09) held at The Indian Institute of Technology, Kharagpur, India. This IIT is the first and the most senior of the Indian Institutes. He was invited to present a paper, “Smart self-healing composites”, to a conference including more that 34 international delegates. The paper was co-authored with Dr Simon Hayes, Wenting Zhang, Dr Leon Hou and Mohammed Jamil. Prof Jones also chaired a session at the conference on various aspects of conducting polymers.

• Also in February, Prof Jones hosted a workshop, “Polymers that help themselves”, co-organised with the IRC in Polymers (Leeds University) Polymer Centre for the Polymer Innovation Network, on Self-healing Polymers and Composites. He presented an introduction on “Self-sensing Damage for Heal”. Other speakers came from Holland and Bristol.

• Attended the 17th International Conference on Composite Materials in Edinburgh in August. He gave the opening plenary lecture at the meeting, “From Atoms to Aeroplanes – Towards a Design Methodology for Composite Materials”. The opening lecture was The Scala Award Lecture which he had received in 2007 from the International Committee on Composite Materials. He was presented with a certificate for the Scala Award and his entitlement to the title “World Fellow of ICCM”. This was the largest international conference on composite materials ever held. Prof Jones co-Chaired the mini symposium on Interfaces and Interphases in Composite Materials. There were three sessions and an interactive poster session arranged to present work on interfacial aspects in composite materials. Prof Jones chaired the first session of the interfaces and interphases mini symposium, together with Prof N Ikuta from the Shonan Institute in Japan. Within the interfaces mini symposium a collaborative paper with Prof Jones was presented. Arran Wood presented the paper co-authored with Profs J F Watts, P A Smith, University of Surrey, Dr Edith Maeder and S L Gaoof the Liebnitz Institute of Polymer Research, Dresden. Dr Zheng Liu was also a co-author of the paper, “Interfacial Properties of Glass Fibres in Nanoparticulate Reinforced Polyester Resin”.

• Other papers presented were:
  − Mohammed Jamil, “Development of Self-Healing Resin Matrices for Composites”, within the smart composites application mini symposium, co-authored with Prof Jones.
  − Dr Joel Foreman, in the Damage Mechanics and Multi-scaled Modelling session, “Rate Dependent Multi-scale Modelling of a Fibre Reinforced Composite”. The paper was co-authored with Prof David Porter (Visiting Prof in the Department) and Dr Shabnam Behzadi, Prof Paul Curtis (Visiting Prof) and Prof Jones.
  − Cheng Cheng Wang, “The Role of the Thermal Induced Residual Stresses in a Single Fibre Thermoplastic Model Composite”, co-authored with Prof Jim Thomason from the University of Strathclyde and Prof Jones.
Aiden Lockwood

- Was awarded an EPSRC/University of Sheffield Doctoral Prize Fellowship. This will be to develop his work on Dynamical Testing of MEMS structures in the NanoLAB from October 2009-October 2010.
- Was awarded an Outstanding Student Poster Prize at the IOP EMAG 2009 conference for his poster of the paper A J Lockwood, M S Bobji, R J T Bunyan and B J Inkson, "MEMS nanostructure deformation and nano-contact adhesion by in-situ TEM nanoindentation.

Dr Plato Kapranos

- Spent 5 days on a visit to the Faculty of Metals Engineering and Industrial Computer Science, AGH University of Science and Technology, Krakow. During his stay he carried out experiments using as feedstock M2 tool steel produced by GFM and by Sprayforming, with his Polish colleagues, Prof Dutkiewicz and Dr Solek. He also made a presentation to the faculty of Engineering, "Processing materials in the semi-solid state".
- Visited ASCAMM Technological Research Centre at Cerdanyola del Vallés, Barcelona, October 2009 and made a presentation to their research staff, "Thixoforming - Past, Present and Future?" and discussed future collaboration on Semi-Solid Processing of Metal Alloys. During the same trip, he also attended a COST-THIXOSTEEL 451, Management Committee meeting, organised by Prof Dr Antonio Form, Director of the Light Alloys and Surface Treatments Design Center (CDAL), Technical University of Catalonia in Vilanova i la Geltrú and discussed further collaboration between the institutions within the COST Short Term Scientific Missions (STSM) of which he is the managing co-ordinator.

Prof Sheila MacNeil

- Gave invited presentations as follows:
  - "Polymers and bugs and skin - an interdisciplinary approach to developing antibacterial polymers for wound healing", KREBS Institute, Sheffield, 27th January 2009.
  - "Designing synthetic scaffolds to take the place of human dermis for soft tissue reconstruction", Tissue and Cell Engineering Society, Glasgow, 8th, 10th June 2009.
  - "Development of Biopolymers for Tissue Engineering and Wound Healing Purposes", Controlled Release Society Copenhagen, 18th-22nd July 2009.
  - "Development of biomaterials for tissue engineering and wound healing", Swinburne Institute of Technology, 13th October 2009.
  - "Tissue engineering of skin and other epithelial tissues including cornea", CSIRO Sydney, 10th November 2009.
  - "Clinical experiences with tissue engineered skin", The O'Brian Institute, St Vincent's Hospital Campus, Melbourne, 26th November 2009.
  - "Tissue engineering of skin from in vitro to in vivo to commercialisation", Deakin University, Geelong, Victoria, Australia 28th November 2009.
  - "Tissue engineering of skin and biomaterials for wound healing", Auckland University, Faculty of Life Sciences, 11th December 2009.

Dr Steve Matcher

- Presented with M Bonesi "Measurement of Microvascular Apparent Pulse Wave Velocity Using Doppler Optical Coherence Tomography" at the European Conference on Biomedical Optics, Munich, 15th-18th June 2009. Dr Matcher also presented "Optical Coherence Tomography", at the Optical Technologies and Measurement Network Meeting, NPL, 24th-25th June 2009.

Prof Allan Matthews

- Attended the 17th International Conference on Wear of Materials (WoM 2009), 19th-23rd April, Las Vegas and presented a keynote paper, "Aspects of tribological coating design and selection", co-authored with K Holmberg, S Franklin and A Leyland. Prof Matthews chaired the session "Wear of thin films and coatings, surface engineering for wear control".
• Attended the 52nd Society of Vacuum Coaters Annual Technical Conference (SVC 2009), 9th-14th May, Santa Clara, USA with Dr John Eichler and presented a poster paper, “The effect of superfinishing and PVD/CVD coatings on torque and temperature of SAE52100 rolling element ball bearings under starved lubrication conditions”, co-authored with G L Doll and A Leyland. Prof Matthews also chaired a Technology Forum Breakfast on “Tribological Coatings”.

• Hosted a visit by Professor Lyubov Snizhko from Dnepropetrovsk (Ukraine) visited the RCSE from 24th August to 4th October, within the EPSRC “Bridging the Gaps” Visiting Scholar scheme, to work on the project on Mathematical modelling of growth processes for anodic oxide films on Al and Mg.

Dr Günter Möbus
• Gave an invited lecture at the Materials Department of Oxford University about “Modern Electron Tomography”, 13th March 2009.
• Attended the workshop “Understanding Materials through Electron Microscopes: Realising the Potential”, 22nd-24th April 2009 at Imperial College in London, and gave an invited talk about “Unsolved problems in imaging”.
• Attended the MRS spring meeting, San Francisco, 13-17th April 2009 gave an oral presentation, “Hybrid Electron Tomography”, co-authored with Z Saghi, T Gnanavel, W Guan, and X Xu.
• Attended the EELS-workshop “Edge 2009”, a four-yearly meeting of the electron energy loss spectroscopy community, Banff, Canada, 17th-22nd May 2009, and gave an oral presentation, “Electron Tomography and EELS”, co-authored with W Guan, Z Saghi and T Gnanavel.

Dr Nicola Morley
• Became a member of the UK Magnetics Society Committee.

Dr Eric Palmiere
• At the request of the Materials Society (MatSoc), Dr Palmiere recently organised a trip to the local company Sheffield Forgemasters International Limited, for Materials Science and Engineering undergraduates. The trip was hosted by Dr Jesus Talamantes-Silva (who is a former member IMMPEUS and a University of Sheffield graduate), and was designed to give students an insight into the manufacture and processing of steels and also a chance to relate theoretical knowledge from lectures (particularly the Industrial Materials Processing module) with real applications in industry. Those in attendance, mainly second years, found the trip thoroughly interesting and an invaluable experience.

Prof John Parker
• Visited Ghana, at the invitation of British Council, 14th-18th November. The purpose of this visit was to provide support for two AKTPs involving industrial partners making glazed ceramic cooking ware and roof tiles working in conjunction with the Institute of Industrial Research (CSIR) in Accra. AKTPs (African Knowledge Transfer Partnerships) follow a similar pattern to KTPs in the UK and have only recently been introduced into Ghana. The final day of the visit centred around a one day conference organised by British Council and aimed at promoting the programme to a wider audience; approximately 100 people attended including the Deputy Minister for Trade and Industry. I was left with a strong impression of an enthusiastic and friendly group of people working innovatively but within tight constraints such as limited access to equipment. A number of opportunities for joint research, exchange programmes and student recruitment presented themselves and will be followed up.
• Received a Service Excellence Award at the 3rd Services excellence Awards Ceremony to recognise and celebrate the high levels of service provided from staff from across the organisation.

Dr Yong Peng
• Attended the Ion Beam Centre Training Course, and Ion Beam Centre Workshop, 30th March to 3rd April 2009, Surrey University, followed by joint experimental sessions on their equipment.

Tony Pilkington
• Attended the 2nd HSS-Forum “Smart Solutions for the Future of Metal Cutting”, Quellenhof, Aachen, Germany, 20th-21st January. The conference covers a diverse range of topics concerned with the technology of HSS manufacture, HSS metallurgy, metalworking, cutting tool manufacture and surface coatings.

John D Plummer

Prof Mark Rainforth
• On completion of 3 year role as President of the Royal Microscopical Society, was elected Vice President and International Secretary.
- Attended the 17th International Conference on Wear of Materials (WoM 2009); 19th-23rd April, Las. Three papers were presented and subsequently published, “Wear mechanisms experienced by a work roll grade high speed steel under different environmental conditions”, co-authored with N Garza-Montes-deOca, “Wear study of retrieved alumina hip replacements”, co-authored with A Rana, P Zen and B J Inkson, and “Application of combined discrete/finite element multiscale method for modelling of Mg redistribution during hot rolling of aluminium”, co-authored with M Krzyzanowski. In addition, as a member of the WoM steering committee, attended review meetings of the 17th meeting and planning meetings for the 18th Conference in 2011.
- Gave a Plenary Lecture at the Homi Bhabha Centenary Conference in Mumbai, India (2nd-5th December), “Recent Step Changes in Microscopy - a Revolution in Our Ability to Understand Material Microstructure”. The conference, “Science and Technology at the Frontiers” attracted just short of a 1000 people. Homi Bhabha is an iconic figure in India and internationally known for both his research and leadership, elected an FRS by the age of 31. The conference, which celebrated his life, opened by CN Yang (Physics Nobel Laureate), with other talks included the UNESCO Director, the Astronomy Royal, Sergio Bertolucci (Director of CERN, also Physics Nobel Laureate), the Director of the Office of the French High Commissioner for Atomic Energy, the Head of the Cavendish and many others. Prof Rainforth, who gave the only Materials based talk, also visited the Bhabha Atomic Research Centre, which has three operational research nuclear reactors.
- Gave two invited lectures at EuroMAT 2008, Glasgow, “Hydrothermal Degradation of Tetragonal Zirconia Polycrystals For Prosthetic Devices: Effect of Al2O3 and La2O3 Additions” and “High temperature tribological behaviour of high hardness, nano-scale multilayer coatings”.
- Attended the International Society for Technology in Arthroplasty. 22nd Annual ISTA Congress in Kona, Hawaii and presented a talk, “Advanced microscopy of alumina-on-alumina hip prostheses: in vivo and in vitro studies”.
- Gave invited lecture at the 2009 HIPIMS conference, Sheffield, “High temperature degradation mechanisms of multilayer coatings”.
- Appointed to the Technical Opportunities Panel (TOP) of the EPSRC.
- Acted as a panel member for the Austrian competence centre COMET –K2 XTribology.

Prof Ian M Reaney
- Was awarded the “Best KTP” building EPSRC-funded research for 2008.
- Was awarded Outstanding for KTP “Glass Ceramics and Dielectrically Loaded Antennas”.
- Gave Invited talks:
  - at the Advanced Ceramics and Composites, Daytona Beach, USA, January 2009.
  - at the Ceramics and Glass Symposium, PACRIM 2009, Vancouver, May.
  - at the Pennsylvania State University, July 2009.
  - at the MRS meeting, Cancun, Mexico, August 2009.
- Attended a study visit to the University of Aveiro, Portugal, April-September 2009
- Reviewed “SMARTPie”, an academic/industrial piezoelectric large grant from the Dutch Government, as an International Expert.

Dr Gwendolen Reilly
- Chaired a special “European Society for Biomechanics” session at the World Congress on Regenerative Medicine, Leipzig, Germany on Biomechanics in Regenerative Medicine, 29th-31st October. She also presented a poster, “Human Mesenchymal Stem Cell Responses to Steady and Oscillatory Fluid Flow in a Porous Scaffold” for which the first author was Biomedical Engineering MEng student Amos Matsiko.
- Gave an invited seminar at the University of Keele, “Mechanical signal transduction in bone tissue engineering” and at the University of Aveiro, Portugal, “Bone tissue engineering at the University of Sheffield”.
- Attended the Bone Research Society conference in London, UK and co-authored two papers, “ATPase activity and ATP release in osteoblast cultures” in collaboration with researchers from the Mellonby Centre for Bone Research and “Short bouts of dynamic compressive loading stimulate mineralized matrix production by human mesenchymal stem cells (hMSC) on 3-D polyurethane scaffolds”.

Dr Cornelia Rodenburg
- Was invited to present “Quantitative dopant mapping in semiconductors using the ORION plus”, co-authored with M A E Jepson, B J Inkson and X Liu, at Carl Zeiss’s 1st Crossbeam/Orion workshop, Dresden, April 2009.
- See http://www.microscopy-analysis.com/meeting-reports/1st-european-crossbeam-and-helium-ion-microscope-user-workshop.pdf
- Visited the Carl Zeiss Innovation Centre in Dresden, Germany to carry out Helium Ion Microscopy in April 2009 and August 2009.

Ms Zineb Saghi
• Attended the Microscopy Congress 2009 in Graz, Austria, 31st August-4th September 2009 and presented a paper, “Prospects of Atomic Electron Tomography using Aberration Corrected TEM”, co-authored with I M Ross and G Möbus.

Prof Thomas Schrefl
• Was invited to give one keynote talk and four invited talks on advanced numerical methods and recording simulations. Furthermore he filed one patent on magnetic storage devices.
• Invited talks:
  − “Micromagnetic Finite Element Simulation Including Spin Torque Currents”, Algoritym 2009, Vysoke Tatry, Podbanske, 16th March 2009
  − “Global geometry optimization of magnetic recording heads”. International Workshop on Multiscale Simulation of Magnetic Materials, University of Konstanz, 9th December 2009.
• US-Patent Application: 07/27/2009 “Magnetic Storage Device”, Serial Number 12/509,540. The application was jointly done with the Vienna University of Technology and The University of Sheffield. This was a joint invention by Dieter Suess Dieter, Muhammad Asif Bashir, and Thomas Schrefl.

Emeritus Prof John H Sharp
• Attended the Fred Glasser Cement Science Symposium, Aberdeen, 17th-19th June 2009, in honour of Prof Glasser’s 80th birthday. He is well known in Sheffield over forty years as an examiner at all levels from B Eng to PhD. Prof Sharp was the Facilitator for Theme 2: “Novel Cement Systems (Sustainability)”, which involved contact beforehand with the speakers and chairing the session.
• Attended the Installation Dinner of the Worshipful Company of Constructors in the Drapers Hall in London, 14th October, where he was the principal guest and responded to the toast to the guests and proposed a toast to the Worshipful Company and its new Master. The new Master is Dr Christine Rigden (formerly Bland), who is the first Lady Master of the Company and graduated from the Department with a PhD around 1990. Prof Sharp took the opportunity to emphasise the country’s need for more well-qualified engineers and to ask the Worshipful Company to encourage more talented young women to take up engineering studies at University and to enter the relevant industries.

Prof Derek Sinclair
• Visited the Physics Academy of Sciences of the Czech Republic, Prague, March 2009 with Prof Ian Reaney, to discuss on-going collaborations with Stanislav Kamba and Jan Petzel on Raman and Tershertz spectroscopic studies of complex perovskites.
• Visited the Chemistry Department at the Universidad Complutense de Madrid, July 2009, to discuss on-going collaborations with the group of José Calbet-Gonzalez on crystallographic studies of hexagonal perovskites.
• Was Chairman of the EPSRC Materials Panel Meeting, October 2009.
• Gave invited talks:
  − “The time constant – the forgotten man of impedance spectroscopy”, at the 33rd International Conference on Advanced Ceramics and Composites (American Ceramic Society), Daytona Beach, Florida, USA.
  − “Slicing through perovskite space: the search for new/improved dielectrics”. Departmental Seminar, Chemistry Departments, St Andrew’s University.
  − “What are the dielectric properties of CaCu3Ti4O12?” European Materials Research Society (E-MRS), Strasbourg, France, 8th-11th June 2009.
  − “Structure-composition-dielectric property relationships in titanate-based perovskites”, Department Seminar, Department of Physics, Universidad Complutense de Madrid, Spain, 1st July 2009.
  − “Unravelling the electrical properties of ACu5Ti4O32 perovskites”, Polar Solids UK meeting, Open University, 17th-18th December 2009.
Tim Swait
- Gave a presentation, "Identification of interfacial and interphasic failure in composites of plasma polymer coated fibres" at the Deformation and Fracture of Composites 10 conference held in Sheffield. He also submitted a paper of the same title in the special issue of Composites Part A, which covers the conference.

Damir Tadjiev
- Attended the 8th Pacific Rim Conference on Ceramic and Glass Technology, 31st May - 5th June 2009, Vancouver, BC, Canada and gave a presentation, "Near surface mechanical properties of mixed alkaline earth silicate glasses", co-authored with Dr Russell J Hand.

Dr Richard Thackray
- Was Chairman of the Iron and Steel Society of the IOM3.
- Member of the Sustainable Development Group of the IOM3.
- President of the Sheffield Metallurgical and Engineering Association.
- Member of the Association for Iron and Steel Technology.
- Member of the World Steel Association University Working Group.
- Editorial Board, Ironmaking and Steelmaking.
- Chairman of the Organising Committee for Thermomechanical Processing Conference, TMP 2012.
- Member of the Scientific Advisory Panel for ECSC large grant "The Waste of the World".

Dr Karl Travis

Prof Goran Ungar
- Gave a talk, "Complex Multicolour Tiling Patterns by Self-Assembly of X-Shaped Polyphilic Molecules" at the Materials Research Society Conference in Boston 1st-5th December 2008. At the conference Hybrid Materials in Tours, France, 15th-19th March, he presented a lecture on "Tangential, axial and helical alignment of liquid crystal columns in nanochannels", co-authored with M A Shcherbina, X B Zeng, M Prehm, C Tschierske and M Steinhart. There he also presented a poster on LC-coating gold nanoparticles.
- Attended the annual meeting of the Eurocores SONS network SCALES with Dr Xiangbing Zeng, 6th-8th July. The meeting was held in Warsaw but organised by Sheffield. Prof Ungar gave a talk, "Critical behaviour in multicolour LC honeycombs", while Dr Zeng talked about "New thermotropic cubic phases in T-shaped molecules".
- Attended the 40th Anniversary Conference of the British Association for Crystal Growth in Bristol, 6th-8th September, and gave a keynote lecture, "Self-Poisoning in Polymer Crystallization".
- Gave an invited talk at the Annual Meeting of the Korean Society of Industrial Chemistry, 15th October.
- Delivered the Distinguished Lecturer Series talk, "Soap Froth, Beehives and Patterns of Molecular Self-Assembly" at Seoul National University, 21st October. Spending his sabbatical at Seoul National University, the top University in Korea, he appeared on the homepage of that University (www.useoul.edu).
- Gave a keynote lecture, "Making Soft Matter Obey Order" at the Global Research Forum at Seoul National University, 13th November. He was one of the two overseas guest speakers, the other being the Nobel Laureate Alan Heeger.

Dr Alexey Yerokhin
- Attended the 36th International Conference on Metallurgical Coatings and Thin Films (ICMCTF 2009), 27th April - 1st May, San Diego, with Konstantinos Kanakis, Glen Cassar and Po-Jen Chu and gave nine presentations (4 oral, 5 poster) authored or co-authored with the Sheffield Surface Engineering Team.
- Hosted a visit to the RCSE by Dr Evgeny Parfenov from Ufa (Russia). 10th-17th September to work on the project on "Frequency Response Analysis of Plasma Assisted Electrochemical Processes" sponsored by President of Bashkortostan Award for Young Scientists scheme.

Dr Xiangbing Zeng
- Gave a talk, "New thermotropic cubic phases in t-shaped molecules", co-authored with F Liu and G Ungar, at the Annual British Liquid Crystal Society Conference held in Bristol in March 2009. Dr F Liu and Dr M Shcherbina each presented a poster, the former on new cylinder mesophases in amphiphiles, the latter on the structure of a unique six-stranded helical liquid crystal.

Dr Shaowei Zhang
- Gave two invited seminars, "High Temperature Aerospace Materials" and "Low Temperature In-situ Synthesis of Ceramics/Refractories", respectively, at Wuhan University of Science and Technology, 10th-14th September 2009.
### 11.2 Events, 2009

#### 11.2.1 The Composites Group

Organised the 10th Deformation and Fracture of Composites Conference (DFC10) during April. The Conference was attended by approximately 100 delegates who came from all over the world to the meeting. The DFC10 Conference was Co-Chaired by Prof Costas Soutis, Dr Alma Hodzic and **Prof Frank Jones**. This is the fourth time that the Composites Group has organised the DFC Programme. The DFC Conference was spun out of the Deformation and Fracture Conference on Polymers, the so-called Churchill Meeting some years ago, and the Composites Section became an independent conference some twenty years ago. The conference moved around the UK but has found a home at Sheffield in the recent past. This conference was highly successful and was used for many friends to recognise the retirement of Prof Jones after his 65th Birthday. A mini-conference on "Interfaces and Interphases in Composite Materials" was held which spanned much of the first day. Prof Jones gave the opening plenary lecture, "Defining interfaces and interphases". Dr Daniel Wagner from the Weizmann Institute in Israel provided an invited lecture on "Nanotube and Nanocomposite Mechanics: a guide to the perplexed".

Members of the research group gave papers in the conference:
- Tim Swait, "TOF-SIMS study of interphase failure in plasma-polymer coated glass fibre composites", co-authored with Prof Costas Soutis and Prof Frank Jones.
- Peter Bailey, "Novel interlayers for self healing sandwich structures" co-authored with Dr Simon Hayes who gave a talk on "Self-sensing composites for structural health monitoring".
- Dr Joel Foreman, "Hierarchical modelling of composite strength as a function of strain rate", co-authored with Prof Frank Jones, Prof David Porter (a Visiting Professor in the Department) and Dr Shabnam Behzadi, a former student who is currently working for the Gurit Company on the Isle of Wight.

The conference also featured a very strong poster session:
- Aidah Jumahat (who is a joint student with the Department of Mechanical Engineering), "Analysis of compression failure of unidirectional carbon fibre toughened resin composites".
- Dr Alison Beck with posters "Life cycle assessment to optimise aerospace composite" and "The assessment of sustainability of composite materials".
- Ann Van Ho, "The effect of nanoclay on the morphology and thermal properties of epoxy and toughened epoxy resins". Ann Van Ho is a former MSc Student who is currently a joint PhD Student with Mechanical Engineering and the Department of Engineering Materials.
- Jack Howarth, "Recycling of Carbon Fibre Composites".
- Most importantly, Mohammed Jamil Suzeren won the poster competition with his poster, "The development of self-healing matrices for composite materials".

#### 11.2.2 EUROMAT 2009

The European congress on advanced materials and processes was held in Glasgow, 7th - 10th September 2009. Euromat meetings are held every two years and are sponsored by the Federation of European Materials Societies. They have become the prime events in Europe for gatherings of academics and industrialists with an interest in materials science and technology.

The meeting comprised 66 symposia scattered across 6 main topics covering main areas of materials science and engineering.

There were many representatives from the Department. The RCSE participation involved 4 delegates, 1 highlight talk, 4 oral and 3 poster presentations.

Dr Aleksey Yerokhin chaired a session in Symposium C55 "Plasma Electrolytic Oxidation (Micro-Arc Oxidation) Surface Coatings".

**Highlight:**
- A Yerokhin, E V Parfenov and A Matthews, "Modelling plasma electrolytic oxidation process using frequency response data".

**Oral Presentations:**
- E V Parfenov, A Yerokhin, A Matthews and R R Nevyanntseva, "Frequency response analysis as a new tool for plasma assisted electrochemical processes characterisation".
- L O Snizhko, A Yerokhin, N L Gurevina, D O Misnyankin and A Matthews, "Voltastatic Studies of Plasma Electrolytic Oxidation of Al".
- P-J Chu, A Leyland and A Matthews, "Detailed Microstructural Characterization of the Plasma Electrolytically Oxidized Titania Coating on Titanium".
- G Cassar, A Yerokhin, A Leyland and A Matthews, "Triode–Plasma Diffusion Treatments to Improve the Tribological Performance of Titanium Alloys".

**Poster Presentations:**
- A Pilkington, H X Cheng, A Yerokhin and A Matthews, "Microabrasive Wear Resistance of PEO Treated Aluminium Alloy".
- K Kanakis, S Banfield, J Housden, A Matthews and A Leyland, "Structure, mechanical and tribological properties of thick CrNx coatings deposited by plasma-assisted electron-beam PVD".
- Y N Kok, G Cassar, J Hardy, R Johns, A Ollerenshaw, M Russell, A Matthews and A Leyland, "A study of the effect of shot-peening and roller burnishing on the rotating-bending fatigue performance of threaded components".
11.2.3 The Research Groups of Dr John Haycock, Prof Sheila MacNeil and Dr Gwendolen Reilly

Presented a number of talks and posters at the UK Tissue and Cell Engineering Society (TCES) held at Glasgow University 8th-10th July. Prof MacNeil gave an invited talk, “Designing synthetic scaffolds to take the place of human dermis for soft tissue reconstruction”. Other Sheffield presentations included:

- R Kaewkhaw, “Adipose-derived stem cells for peripheral nerve repair”.
- C Murray-Dunning, “The use of aligned polymer microfibers in peripheral nerve engineering”.
- T Sun, “Investigation of the biological activity of TGF-B1 during re-epithelialisation using a computational modelling approach”.
- N Green, “Development and characterisation of a tissue engineered oesophagus”.
- C M G Marques, “Investigation of the impact of wounding and inflammation on melanoma migration in a 3D skin model”.
- J Shepherd, “Use of a tissue engineered model of bacterial infection of human skin to develop responsive polymers to reduce bacterial burden of infected wounds”.
- M V Flores-Merino, “Nano-domain detection in poly (vinyl pyrrolidinone) hydrogels”.
- G Reilly, “Mechanical responses of bone tissue formation in 3D engineered constructs via primary cilia”.

11.2.4 IAEA Workshops

Radioactive Waste Predisposal Management

The Ministry of Environment and Natural Resources of Moldova hosted the IAEA Workshop on Radioactive Waste Processing and Storage held in Chisinau from 23rd-27th March 2009. The IAEA Workshop was actually an attempt to combine both theoretical lectures and practical exercises intended to select appropriate routes and equipment to deal with radioactive wastes before disposal. Lectures and exercises were led by IAEA staff members Z Drace, V Kurghinyan, J Raicevic and invited lecturers – experts in field: M Ojovan (ISL, UK) and M Mateeva (NRA, Bulgaria).

Yerevan, Armenia

The IAEA regional workshop on Modular Design of Processing and Storage Facilities for Small Volumes of Low and Intermediate Level Radioactive Waste and Disused Sealed Radioactive Sources was held in Yerevan, Armenia from 29th June to 3rd July 2009. Kumar Samanta (IAEA), Borislava Batandjieva (Bulgaria), Alena Zavazanova (Slovak Republic) and Michael Ojovan (United Kingdom) participated in the Workshop as invited lecturers with the aim to provide key lectures according to the agenda, agreed by the IAEA and the national counterpart (ANRA), supervise, moderate, guide and coordinate the three-day exercises and evaluate the outcomes of the exercises and participate in the panel discussions at the end of the workshop. The Workshop was attended by 20 participants from 8 countries (Albania, Armenia, Bulgaria, Estonia, Lithuania, Hungary, Macedonia, Romania and Slovenia). The work- shop was opened by Armen Amirjanyan, Director of the Nuclear and Radiation Safety Centre of ANRA, Kumar Samanta (WTS, IAEA) and Vladimir Kurghinyan (TC Project Manager, IAEA). The IAEA presented the scope and objectives of the workshop that is the first to be organised by the IAEA in English after the pilot regional workshop held in Russian language in Moldova in March 2009. In addition, two presentations on current waste management practices in Armenia were made by the representatives of Aida Avetisyan (ANRA) and Nelli Aghajanyan the Armenian NPP, Metsamor.

Expert Mission to China Institute of Atomic Energy and China National Nuclear Corporation

China’s main supply of electricity by nuclear power is about 2% with eleven nuclear power reactors in commercial operation by January 2008. There are 5 new power plants under construction and government approval for several more to be constructed. Plans to develop a civil nuclear power programme were initiated in 1970. The early development in technology had been sought from France, Canada and Russia. The country aims to become self-sufficient in reactor design, construction and develop a full fuel cycle from production to disposal. China has significant resources of uranium, circa 70,000 TU, from which to produce nuclear fuel which will be sufficient to fulfill the mainland nuclear programme for the short term. The anticipated power capacity is 20 GWe by 2010 and 40 GWe by 2020. China has a reprocessing strategy to recover the uranium and plutonium for reuse in new nuclear fuel. In 2007 the Chinese Government gave approval for three state owned corporations to own and operate nuclear power plants: China National Nuclear Corporation (CNNC), China Guangdong Nuclear Power Holding Corporation (CGNPC) and China Power Investment Corporation (CPI). CNNC has the overall responsibility for the management of the waste generated from the nuclear industry in China. CNNC is regulated by the National Nuclear Safety Administrated (NNSA) for approval of siting, construction and operation of repositories. The CNNC is one of the largest state owned nuclear companies and has over 300,000 employees. China may have plans for a total of five regional LLW/HLW facilities depending on capacity requirements. There are already two sites in existence at Lanzhou in the north-west and Bailong in south China for industrial-scale disposal of LLW and ILW. The Chinese government strategy is to vitrify HLW, followed by encapsulation and final disposal in a geological repository.

11.2.5 IMMPETUS

The 11th IMMPETUS Colloquium took place at Halifax Hall, The University of Sheffield, 7th and 8th April 2009. It was attended by a total of 79 delegates, 19 external delegates from industry and academia and 60 from The University of Sheffield. The annual IMMPETUS colloquium gives an opportunity to our researchers, many of whom are PhD students at different stages of their research, to present their work.
There were 5 sessions for the 25 oral presentations and 3 poster sessions for 25 posters covering a wide range of topics on the thermomechanical processing of metals, with plenty of opportunity for discussion and one-to-one interaction. The dinner on the first evening was held at The Edge, The University of Sheffield and gave an important opportunity for people to meet informally and to foster mutual interests.

Panel Discussion
• As in previous years the panel discussion took place on the second day after lunch. The Panel is made up of members of the IMMPETUS Industrial Steering Committee who are invited to answer questions on the chosen topic which this year was "Metals Research in a Changed Industrial Economy".

Mike Frolish Prize
• This year the prize was awarded to Mr Moises Talamantes-Silva for his oral presentation on "Finite Element Modelling and Microstructural Evolution of High Integrity Forgings".

Poster Session
• The poster session was sponsored this year by Siemens VAl and Corus plc. Mr Mick Steeper from Siemens VAI and Chairman of the IMMPETUS Industrial Steering Committee awarded the 1st prize to Mr Sinan Al-Bermani for his poster "Microstructural Evolution in Electron Beam Melted Ti-6Al-4V" and the 2nd Prize was awarded to Mr Gael Reyes Zaragoza for his poster "Aluminium Foam for Heat Transfer Applications".

IMMPETUS hosted the following visits:
• 13th March 2009, Dr T Mukherjee, Group Director, Technology and Integration, Corus Group and Dr D Bhattacharjee who is to be the new Director for R & D based in Ijmuiden from April 2009. The visit commenced with a presentation by Prof Panos Tsakiropoulos with Academic members of IMMPETUS in attendance and Prof Allan Matthews, HoD of Engineering Materials and Prof Rob Dwyer-Joyce, HoD of Mechanical Engineering. Drs Mukherjee and Bhattacharjee were then given a tour and presentations on current research in each of the three Departments which form IMMPETUS.
• 16th March 2009, Prof Katagerman and Dr Hoekstra from the Materials Innovation Centre from The Netherlands. The meeting had been organised by Dr Iain Todd to look at ways to collaborate with IMMPETUS in the future and had been a successful meeting.
• 30th and 31st March in Swansea University, Electron Backscatter Diffraction Meeting 2009 sponsored by RMS and IOM3. Five members of IMMPETUS attended the meeting: Dr Brad Wynne, Dr Krzysztof Muszka, Mr Pete Davies, Mr Meurig Thomas and Miss Xiaqing Jiang. Dr Brad Wynne gave a presentation on "Can EBSD quantify size and shape of macrozones in titanium alloys?".
• 10th June 2009, Dr Yvon Millet, the new Timet Director of Research for Europe and Dr Matt Thomas (ex-IMMPETUS PhD Student) who is in the Research and Development Section at Timet, Witton Birmgham. Dr Brad Wynne gave a presentation, "Ti and IMMPETUS" and a tour was given of IMMPETUS facilities followed by presentations from Dr Peter Davies, Mr Nima Nasseri, Dr Magda Lopez-Pedrosa and Mr Meurig Thomas.

TMS (The Minerals, Metals and Materials Society), 15th-19th February 2009, San Francisco. Members of IMMPETUS attended the 138th annual TMS conference, San Francisco, 15th-19th February 2009. Prof Panos Tsakiropoulos, Dr Martin Jackson, Dr Ignacio Figueroa, Dr Michael Blackmore, Mr Dave Randman, Mr John Plummer, Mr Meurig Thomas, Mr Robert Deffely and Mr Sinan Al-Bermani attended. IMMPETUS has a very strong presence at TMS, the standard of work delivered was excellent and the conference was enjoyed by all.

On 6th March 2009 a Seminar and Tour of IMMPETUS took place for all Research Staff and Students. This was hosted by Prof Panos Tsakiropoulos (Director of IMMPETUS) and he gave a presentation on IMMPETUS covering its background, publications, KMSI, website, attendance at conferences, file exchange area and Colloquium. The aim of the seminar was to highlight facilities in IMMPETUS and ensure that all research staff and students are aware of these and assist them in the future with any queries they may have with regards to the institute.

5th European Rolling Conference (ERC5) The 5th European Rolling Conference took place from 23rd-25th June 2009 at The Institute of Materials, Minerals and Mining, London. The series of European Rolling Conferences began in 1996, and is now established as the principal forum for rolling practitioners on the continent. The 5th European Rolling Conference (ERC5), sponsored by Siemens VAI Metal Technologies and covers an audience that embraces the whole metals rolling community. Flat and long products rolling, hot and cold rolling and ferrous and non-ferrous rolling are all included. Mr Mick Steeper who is the Chairman of the IMMPETUS Industrial Steering Committee was a member of the Organising Committee of this conference. Dr Richard Thackray and Dr Michal Krzyzanowski represented IMMPETUS at this event. Dr Michal Krzyzanowski gave a presentation, "Oxide scale modeling in hot rolling: assumptions, numerical techniques, examples of prediction", co-authored with Prof W M Rainforth.
SMEA Conference and Exhibition took place on 7th and 8th July 2009 at The Edge, The Endcliffe Village, The University of Sheffield and the theme for the conference this year was “Alloys for Critical Applications”. This was the eighteenth in a series of conferences organised by the Sheffield Metallurgical and Engineering Association (SMEA). The aim of the conference was to explore recent developments in the manufacture, evaluation and application of alloy steels, nickel-based superalloys and light metal components for critical engineering applications. Five technical sessions focused on nuclear energy, aerospace, energy supply chain and transport applications. The following academic and research members of IMMPETUS attended: Prof Panos Tsakiropoulos, Prof Mark Rainforth, Dr Iain Todd, Dr Richard Thackray (Chairman of SMEA), Dr Russell Goodall, Dr Martin Jackson, Dr Krzysztof Muszka, Mr Lin Sun, Mr Amir Nanpazi, Dr Paul Nnamchi and Mr Sinan Al-Bermani.

The following presentations were given:

- Dr Martin Jackson, “Thermomechanical processing of high strength titanium alloys used in landing gear”.
- Prof Panos Tsakiropoulos, “Alloys beyond nickel based superalloys”.

Dr Richard Thackray chaired the session “Energy Supply Chain”.

The Celebrity Lecture which was held on the first evening at The Auditorium, The University of Sheffield was given by Dr Graham Honeyman, Chief Executive, Sheffield Forgemasters International on “Out of the black into the blue”.

11.2.6 MRS’09 Symposium on Scientific Basis for Nuclear Waste Management

One of the most successful Materials Research Society (MRS) conferences, the 33rd MRS’09 Symposium on Scientific Basis for Nuclear Waste Management, was held this year in Saint Petersburg, Russia, 24th-29th May 2009.

Drs Boris Burakov and Albert Aloy were the two main promoters and active organisers who contributed to the overall success of the conference. The topics considered at conference were: Transnational programmes, Advanced materials, Radionuclide migration, Geological disposal, Glass waste forms, Ceramic waste forms and High level waste and spent fuel. Each of these topics was covered by excellent overview papers as well as research contributions such as those presented by of John Vienna on glass formulations (USA), Elie Valcke on bitumen (Belgium), Neil Hyatt on ceramics (UK), Boris Burakov on self-glowing crystals (Russia), Thorsted Geissler on corrosion of wasteforms (Germany), Willie Meyer on graphite (South Africa), Kari Whittle on radiations damage (Australia), Thierry Advocat on spent fuel (France), Neil Hyatt, Michael Ojovan (members of conference organising committee) and Martin Stennett presented several scientific papers based on ongoing research on ceramics and glasses at ISL.

A great success of ISL was the recent MRS decision to appoint Neil Hyatt as the principal organiser – Chairman of Scientific Organising Committee of MRS Symposia on Scientific Basis for Nuclear Waste Management. He is taking over this post from Professor Lars Verme from Sweden.

11.2.7 NanoLAB

New NanoLAB Projects

- Dr B Inkson and Dr G Möbus have been awarded a Basic Technology Translation Grant from the EPSRC. This 4-year project, from July 2009 - June 2013 is in collaboration with the Departments of Electronic and Electrical Engineering, Dentistry and the University of Nottingham. The Translation grant will enable the exploitation of the new NanoLAB Nanotesting Technology and associated patents. Collaborative work with Industry and Academia will focus on developing the fields of dynamical nanotribology, in-situ nanodevice testing and TEM tomography.
- Dr Möbus and Dr Inkson have been awarded an EPSRC grant for, “Building Ceramic Metamaterials from Nanoparticles: A combined Modelling, Tomography and In-situ Loading Study”. The three-year project is in collaboration with Cranfield University, Shrivenham campus (Dr Sayle), and the University of Bath (Prof Parker).

NanoLAB in the news

- The work of Dr Yong Peng and Dr Beverley Inkson on nanoscale electrical testing and fabrication of nanostructures has been highlighted in the press. The paper Y Peng, A G Cullis, B J Inkson, Appl Phys Lett, 93, 183112 (2008), “Accurate electrical testing of individual gold nanowires by in-situ SEM nanomanipulators”, was selected for the Virtual Journal of Nanoscale Science and Technology as a current Nanotechnology highlight.
- The development of a new technique to weld nanostructures using nanovolumes of solder described in Y Peng, A G Cullis, B J Inkson, Nano Lett, 9, 1, 91-96 (2009), "Bottom-up construction by welding individual nanoobjects using nanoscale solder”, has been highlighted as high impact news in over 50 website articles, several newspapers, and chosen for a press release by the University. The work has been filed as both a UK and international patent.
11.2.8 Electron Microscopy and Analysis Group, EMAG2009 Conference

G Möbus, T Walther and I Ross (Department of Electronic and Electrical Engineering) were local organ- isers of the Institute of Physics, Electron Microscopy and Analysis group, EMAG2009 conference, held at Sheffield University in the Octagon Centre, 9th-11th September 2008. G Möbus chaired one of the 6 conference sessions on nanofabrication.

5 oral presentations by NanoLAB members were given:

- Yong Peng, "Nanoconstruction by welding individual metallic nanowires together using nanoscale solder", co-authored with A G Cullis and B J Inkson.
- T Gnanavel, "Electron beam fabrication of ferromagnetic nanostructures".
- Wei Guan, "A multipurpose miniaturised nanomanipulation system for in-situ TEM studies", co-authored with A Lockwood, X Xu, B J Inkson and G Möbus.

12 poster presentations by NanoLAB members included:

- A J Lockwood, B J Inkson and MS Bobji, "Deformation of polysilicon nano-sized structures evaluated by in-situ TEM nanoindentation".
- K Briston, A G Cullis and B J Inkson, "Development of a novel SEM nanogripper".
- C Rodenburg, M E Jepson, B J Inkson, X Liu and D C Bell, "Dopant contrast in the Helium Ion Microscope: contrast mechanisms and quantification".
- M A E Jepson, K Khan, B J Inkson and C Rodenburg, "The effect of oxidation and contamination on SEM dopant contrast".
- B J Inkson, Y Peng, M A E Jepson, C Rodenburg and X Liu, "Comparison of multilayered nanowire imaging by SEM and Helium Ion Microscopy".
- R J Milne, A J Lockwood and B J Inkson, "In-situ TEM deformation of aluminium nanopillars".
- X Mu, Y Peng, T Gnanavel, B J Inkson and G Möbus, "Nanoporous structures from anodisation of non-planar aluminium surfaces".
- W Xie, G Möbus and S Zhang, "Carbon nanotube to SiC nanorod conversion in molten salt studied by EELS and aberration corrected HRTEM".
- M Azizi Mat Yajid and G Möbus, "Nanostructured reactive metallic multilayers".
- Z Saghi, W Guan, T Gnanavel, X Xu and G Möbus, "hybrid tomography".
- T Gnanavel, G Möbus, S Kumar, S Cook, J Tsai and M I Ojovan, "Irradiation induced transformation in ceramics".
- B D Medford, N Berdunov, D Laird, B L Rogers, P Beton (U Nottingham), A J Lockwood, T Gnanavel, W Guan, J Wang, G Möbus and B J Inkson, "A novel tripod driven platform for in-situ positioning of samples and electrical probes in a TEM".

11.2.9 Advanced School on Nanofabrication and Nanomanipulation

G Möbus, T Walther and I Ross also organised an "Advanced School on Nanofabrication and Nanomanipulation" immediately preceding the EMAG conference on 8th September 2009, held in Mappin Hall. Five external and internal lectures were combined with three experimental demos of Focused Ion Beam microscopy, nanomanipulation in SEM, and FEGTEM analysis of FIB prepared specimens. In addition to the organisers, Mark Jepson, Yong Peng, Kevin Briston, and T Gnanavel contributed with demonstrations and assistance to organisation. B J Inkson presented a lecture, "Introduction to Focused Ion Beam systems" while G Möbus presented a lecture, "Nanomanipulation".

11.2.10 NTEC 2008 Module X Session

The Nuclear Technology Education Consortium (NTEC, www.ntec.ac.uk) held the postgraduate MSc Core Module 10 on "Processing, storage and disposal of nuclear wastes". This module introduced basic approaches on nuclear materials management as well as scientific fundamentals of nuclear waste processing and disposal. The Core Module 10 consists of pre-course assignment, one week direct teaching, post-module assignment and examination.

The direct teaching week for 2008-2009 was held from 15th-19th December 2008 in the University of Manchester. Module lectures were given by Michael Ojovan (module convenor) and John Roberts, Ed Butler of National Nuclear Laboratory, Paul Abraitis of Environment Agency, and Mick Bacon of HM Nuclear Installations Inspectorate (NII), Health and Safety Executive (HSE). 14 attending and two distance learning students were involved in the teaching week activities.

From September 2008 the NTEC Core Module 10 is available in distance learning (DL) format. In 2008/9 five DL students from Austria (IAEA), Canada, Ireland, United Arab Emirates and UK took this module using Internet. The DL module contains the same syllabus as its counterpart delivered by direct teaching, has the same learning outcomes and is delivered once per annum at a fixed time in order to facilitate the concept of a "virtual classroom".
11.2.11 Skills Week 2008

This year our first year MSE and BSTE students participated in a ‘Skills Week’ which took place in Week 7 of the first Semester from the 10th to 14th November 2008. It was based around two industrial visits but included additional activities aimed at developing transferable skills and introducing career planning.

Some of our speakers took Careers in Materials as their theme, including: David Arthur (IOM3), Adam Mannis (UKCME), Judith Everett (Careers Service), Stephen Curran (Smith and Nephew), and Rebecca Creighton (NAMTEC). We also ran a topical presentation on Plagiarism (given by Dr Russell Hand) to illustrate what is and particularly what is not acceptable in writing reports, a session on Report Writing presented by Alice Lawrence of the English Language Training Centre and a session on Personal Development Plans presented by Dr John Parker. The final presentation was given by Carl Hitchens. He demonstrated how Materialise use state-of-the-art computing techniques to aid in the rapid manufacture of implants for reconstructive surgery.

For the industrial element of “Skills Week” we visited Guardian (Goole, Flat Glass Manufacturers) and JRI (Sheffield). An additional visit to Corus is planned for the second semester. We are grateful to all these host companies for access to their facilities and for providing staff for guided tours and introductory talks. For many of our students this was their first opportunity to see large-scale industrial operations. The students were asked to take notes during the visits and subsequently submit a short report giving details on the company background, manufacturing output, customer base and opportunities for Materials graduates.

A particularly successful event was a series of presentations made by the students themselves. The MSE students were presented with a list of artifacts and asked to consider ways in which they could lower the carbon footprint of one of them. Examples from the list of artifacts included: an aircraft wing, a pair of running shoes and a combat helmet. The BSTE students were asked to select a human tissue from a list that included, for example, a heart valve and skin. They were asked to weigh the pros and cons of using artificial and natural materials for the construction of surgical implants for repair of the damaged tissue. The students worked in small groups and gathered their information from various sources. At the end of Skills Week, each group had just 10 minutes in which to present their case to a panel of academic judges. All groups gave excellent presentations showing a great deal of enthusiasm and a healthy degree of competitiveness! The winning group comprised: Harry Matthews, Matthew Whitworth, Jamie Williams, Yen-Ju Wu and Matthew Yeow, all from the Aerospace Materials course.

11.2.12 Training and Seminar on Ceramics and Glasses to Immobilise Radioactive wastes, South Africa, 30th October - 15th November 2009

The use of nuclear energy for the electricity generation is a viable option, however it poses a problem when it comes to the management of nuclear waste. South African Nuclear Energy Corporation (Necsa) and Centre for Applied Radiation Science and Technology (CARST) of the North West University have organised a Training course and a Seminar on Ceramics and Glasses to Immobilise Radioactive Wastes from 30th October to 15th November 2009.

The State-owned corporation Necsa was established as a public company to undertake and promote research and development in the field of nuclear energy and radiation sciences and technology. Necsa main operations are at Pelindaba site and Vaalputs Radioactive Waste Disposal Facility. In South Africa conversion, enrichment and fuel fabrication plants produced radioactive waste until 1997. Presently waste is produced as a result of the decommissioning of these facilities. Eskom’s Koeberg nuclear power plant produces spent fuel and operational radioactive waste. Necsa’s Safari research reactor at Pelindaba produces spent fuel and operational waste. Radioactive waste is produced from radioisotopes production activities at Necsa. The iThemba LABS also produces radioactive waste. Historically waste has been produced by various research activities. Radioactive wastes are also produced from various applications of radioactive materials in industry and the medical sector. Naturally occurring radioactive waste materials (NORM) are produced by various facilities in the mining and minerals processing industry.

The CARST was established in 1998 between the University of North-West and South African electricity generating and supply utility (Eskom), National Nuclear Regulator (NNR), iThemba Laboratory for Accelerator Based Sciences, Pebble Bed Modular Reactor Group (PBMR), National Research Foundation (NRF) and Necsa. The Centre currently offers a two-year Master-degree course in Applied Radiation Science and Technology.

The programme of Training and Seminar included training sessions on ceramic and glass manufacture for nuclear waste immobilisation and presentations given by national (W Meyer, M Andreoli, J Topkin, J Badenhorst of Necsa, H Van der Linde and N. Mumba of CARST) and international experts (B Burakov, V Gribova and M Petrova of KRI, Russia, O Batyukhnova of SIA Radon, Russia, and M I Ojovan of ISL, UK), student project presentations by CARST students, and field trips to Vaalputs Radioactive Waste Disposal Facility and to Steenkampskaal rare earth element mine which is a unique monazite-analogue site.
12. Maps of University Precincts and City Centre
Research in Progress 2010

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Every effort has been made to ensure the accuracy of the information given in this publication. However, the university reserves the right to make changes.