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The University of Manchester

LATEST2

LIGHT ALLOYS TOWARDS ENVIRONMENTALLY SUSTAINABLE TRANSPORT: 2ND GENERATION

EPSRC
Engineering and Physical Sciences Research Council

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By utilising multi-materials in new design solutions, the research will enhance lightweighting in the transport sector with consequent reductions in emissions.

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THE LATEST2 PROGRAMME VISION

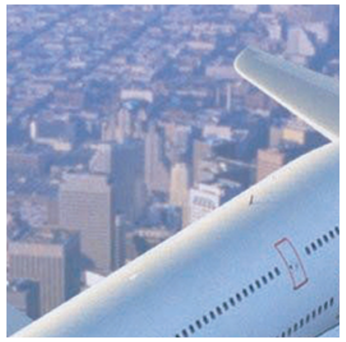
The LATEST2 Programme Grant, awarded by the Engineering and Physical Sciences Research Council (EPSRC), will provide important core funding for the long term development of a centre of excellence in light alloy research, building on Manchester's recognised capability in this field. The investment in the LATEST2 Programme Grant is expected to exceed £9.0 million over the next 5.5 years, including initial funding of £5.6 from the EPSRC supplemented by a £1.0 million investment from The University of Manchester and pledged leveraged funding from our industrial partners.

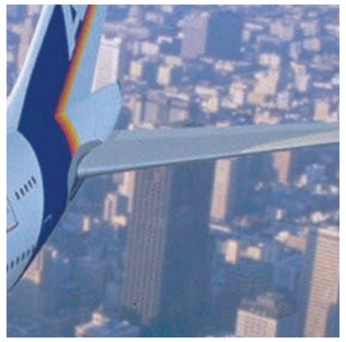
The project is aimed at providing the basic research required to facilitate a step change in high-performance, light alloy, design solutions in the transport sector. The Programme is carefully tailored to the needs of industry and will deliver the supporting underpinning research needed to maintain global competitiveness in the realignment of the manufacturing sector towards sustainable transport technologies. The Programme will also be pivotal in maintaining a throughput of trained personnel needed by UK manufacturing in this critical area.

INTRODUCTION FROM THE MANAGEMENT TEAM

By the year 2050, the UK is committed to reduce its CO_2 emissions by 80% of current levels to avoid the implications of global warming and to reduce our unsustainable dependence on fossil fuels.
As a consequence of European directives, automotive manufacturers must also comply with a 130 CO_2 g/km average fleet limit in the near future, and this will soon fall to 80 g/km. Aerospace and automotive manufacturing are critical to the UK economy having a turnover of £30 billion and employing 600,000 people directly and within the supply chain. A sustained research effort is thus required to maintain the UK's global competitiveness in these sectors, encourage the expansion of the manufacturing base and to support the move towards a low carbon economy.

In order to reach these ambitious emission reduction targets, applications for light alloys within the transport sector are projected to double in the next decade. However, in many cases the properties and cost of the materials and manufacturing processes are inhibiting progress in weight reduction. In addition, the introduction of new renewable technologies, such as hydrogen and biofuels, as well as hybrid and electric drive trains, will present further challenges in materials engineering.





RECENT STUDIES

European Automotive Manufacturers have shown that polymer composites are too expensive for structural applications in large volume vehicle production. First generation Al and Mg body structures already in production are cheaper and give similar weight savings (~ 40%) and a favourable lifecycle CO_2 footprint, but only if a high level of recycling is achieved.
In the future more substantial weight savings will only become possible, at an acceptable cost, by the introduction of stronger higher performance alloys in more efficient designs that combine the best attributes of more advanced Al and Mg alloys with composites, laminates, and cheaper steel products in multi-material structures. Furthermore, advanced computer-based design tools allow, as never before, the optimisation of component architectures for increased mass efficiency. This alone can dramatically reduce component weight if the challenges of manufacturing more complex components can be overcome. In the aerospace sector, new higher performance Ti and Al alloys will be substituted into existing airframe designs to achieve incremental weight savings for many years to come.

More importantly, they will play a key role in future multi-material designs, where they will be increasingly required to work with composites and to be manufactured into more efficient, mass optimised designs, as well as in multi-material and graded structures

This 'road map' for the transport industry presents challenges to the materials community, with important fundamental research required to address issues such as:

- How do we make more complex shapes in light alloys, Al, Mg and Ti, which typically have low formability, while achieving the required microstructure, texture, surface finish and, hence, in-service and cosmetic properties?
- How do we join different materials, such as Al and Mg, with composites, laminates, and steel to produce more mass efficient and cost-effective designs?
- How do we protect multi-material structures and their interfaces from environmental degradation?
- How can we make new manufacturing technologies less energy intensive and increase sustainability?

THE LATEST2 TEAM

The LATEST2 team is comprised of eight academic investigators within the School of Materials at Manchester. The Team has extensive experience of processing, modelling, microstructure and texture control, surface engineering, corrosion control, joining and forming of light alloys and related materials for transport applications. The Programme will enable the investigators to function as a flexible, interdisciplinary research team that can respond rapidly to new innovations. The Team is supported by colleagues within the School of Materials and beyond, enabling new expertise to be drawn in as required.

GEORGE THOMPSON OBE, FRENG
LATEST2 PRINCIPAL INVESTIGATOR/ PROGRAMME DIRECTOR
PROFESSOR OF CORROSION SCIENCE AND ENGINEERING

George Thompson is Deputy Head of School and Head of Research for the School of Materials. His research interests are largely focused on the corrosion and protection of light alloys, with applications in the architecture, automotive, aerospace, lithography and packaging sectors, and electronic materials. He collaborates extensively with scientist in the UK, Europe, Japan and America.

In his work on material/property/performance relationships, extensive use is made of electrochemical, electronoptical, surface analytical and surface structural probing to understand the influence of the material bulk, near-surface and surface properties on corrosion and its control. Environmentally friendly coatings, with incorporated nanoparticles, with self-healing abilities are of particular interest.

CURRENT RESEARCH PROJECTS

- Understanding the Influence of Alloying Elements on the Performance of Aluminium Alloys
- New Anodizing Procedures for Aluminium Aerospace Alloys
- Protection of Aluminium Alloys by Sol-Gel Coatings with Incorporated Nanoparticles
- Mechanisms of Formation of Anodic Titania Nanotubes
- Characterisation and Performance of Friction Stir Welded Aluminium Alloys
- New Routes to Light Alloy Characterisation and Degradation Mechanisms using Low Voltage Scanning Electron Microscopy and Serial Sectioning (3XuM)
- Surface Modification of Magnesium Alloys for Corrosion Control

The experience of the LATEST2 team will enable rapid response to new innovations, overriding obstacles to the implementation of light materials in the transport sector.

PHILIP PRANGNELL
LATEST2 DEPUTY PROGRAMME DIRECTOR
PROFESSOR OF MATERIALS ENGINEERING

Phil Prangnell is a founder member of the Manchester £6M Portfolio Partnership in **Light Alloys towards Environmentally Sustainable Transport** (LATEST). He is also co-director of Sheffield-Manchester Centre for Doctoral Training (CDT) in metallic materials. His research activities are focused on studying advanced thermomechanical processing and joining techniques for light alloys. In particular, he is interested in understanding and modelling interactions between phase transformations, deformation microstructures, and industrial processes. He has worked extensively with the aerospace and transport industries on the materials issues involving the development of novel welding techniques for light alloys, as well as forming processes, for aerospace applications.

CURRENT RESEARCH PROJECTS

- Material interactions during friction stir processing and welding
- Thermal management in friction stir welding, including hybrid welding
- Optimisation of friction stir (FSSW) and ultrasonic spot (USW) welding for aluminium automotive alloys
- Friction joining of dissimilar materials for application to multi-material structures
- Control of interfacial reaction in welding dissimilar materials
- Topographic and surface engineering for metal to composite joining
- Microstructure control during additive layer manufacturing
- The formation and stability of nanocrystalline alloys by severe deformation processing

PETE BATE
LATEST2 CO-INVESTIGATOR
PROFESSOR IN MECHANICAL MATERIALS ENGINEERING

Pete Bate's research centres on the relationship between the microstructure and plastic behaviour of metals, particularly to relatively high strains characteristic of metal forming. Specific areas of interest include the modelling of plastic deformation and microstructural development, including finite element analysis coupled with crystal plasticity, the role of crystallographic texture and microstructure in plastic anisotropy, and high temperature, 'superplastic', deformation. In addition, he has interests in aspects of recrystallisation and grain growth and interactions between phase transformations and texture.

CURRENT RESEARCH PROJECTS

- Optimising superplastic forming
- Modelling crystal plasticity in hexagonal materials (Mg, Ti).
- The fundamentals of superplasticity: solute effects & dynamic grain growth
- The effects of orientation clustering and texture colonies on formability
- Texture development in Ti

The LATEST2 is enhanced by focused, international collaborations with academic and industry to facilitate low cost manufacturing routes.

DR. MICHAEL PREUSS
LATEST2 CO-INVESTIGATOR
SENIOR LECTURER IN MATERIALS PERFORMANCE

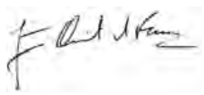
Michael Preuss is Deputy Director of the Rolls-Royce Nuclear University Technology Centre, Theme leader for High Temperature Materials within the University of Manchester Aerospace Research Institute (UMARI) and has been recently awarded a prestigious EPSRC Leadership Fellowship to work on irradiation growth and creep in zirconium cladding material from 2011.

He leads a fast expanding research group focusing on fundamental and applied metallurgical issues and residual stresses in high temperature materials, components and friction welding. He has strong links to the aerospace and nuclear industries in the area of nickel-base superalloys, titanium and zirconium alloys. He makes extensive use of synchrotron and neutron facilities in his research and collaborates with ISIS (UK) and the ILL (France).

CURRENT RESEARCH PROJECTS

- Deformation mechanism in advanced polycrystalline nickel base superalloys
- Deformation mechanisms in CP Ti and two phase Ti alloys
- Variant selection in Ti alloys
- Flow forming of high strength Ti alloys
- Residual stress characterisation in:
  Corrosion mechanisms in Zr alloys for nuclear application
  Irradiation induced growth and creep in zirconium alloys
- Linear and rotational friction welding of high performance alloys
- Diffraction Contrast Tomography for studying deformation mechanisms in polycrystalline materials

DR. JOÃO QUINTA DA FONSECA
LATEST2 CO-INVESTIGATOR AND OUTREACH ACADEMIC CHAMPION
LECTURER IN MATERIALS PERFORMANCE

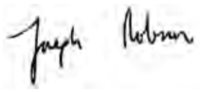


Joao Fonseca's research focuses on fundamental aspects of metal deformation, including polycrystalline plasticity modelling, and characterising deformation by synchrotron X-ray and neutron diffraction and surface strain mapping. He has used crystal plasticity models to predict inter-granular strain partitioning. Industrially-funded projects include the effect of crystal plasticity on cleavage fracture in pressure vessels the development of strain mapping techniques and texture evolution).

CURRENT RESEARCH PROJECTS

- Musicale modelling of fracture
- Full-field strain mapping for studying strain localisation in forming
- Deformation mechanisms in hexagonal metals
- Texture evolution alloys
- In-situ deformation studies using image correlation
- Effects of microstructure on the deformation mechanisms

DR JOE ROBSON
LATEST2 CO-INVESTIGATOR
SENIOR LECTURER IN PHYSICAL METALLURGY



Joe Robson has expertise in thermodynamic and kinetic modelling of phase transformations during rapid transient processes, such as welding, and has led major projects in this area in collaboration with industrial partners. Models he has developed have been transferred to industrial R&D applications in the UK and Germany. He also has a large activity in understanding and optimising microstructural development during thermomechanical processing of wrought magnesium alloys.

CURRENT RESEARCH PROJECTS

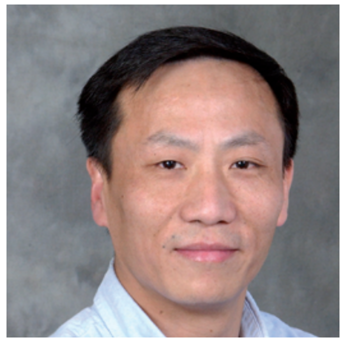
- Modelling Heterogeneous Precipitate Evolution in Complex Alloys
- Friction Stir Welding – Integrated Modelling
- Designed Microstructures for Wrought Magnesium Alloys
- Fundamentals of Superplasticity in Magnesium Alloys

PETER SKELDON
LATEST2 CO-INVESTIGATOR
PROFESSOR OF CORROSION SCIENCE AND ENGINEERING

Peter Skeldon's research extends over the field of surface treatments of light metals, particularly for corrosion resistance and surface functionality. Application areas relate to architectural, engineering, automotive, aerospace, electronics, nanotechnology and biomedical sectors. Fundamental studies concern interrelationships of alloy microstructure, formation mechanisms of coatings and coating performance - special interest lies in growth of anodic oxides - barrier-types, porous types and more complex types produced under dielectric breakdown.

CURRENT RESEARCH PROJECTS

- Growth mechanisms of porous anodic films.
- PEO coating technologies for light metal alloys.
- Corrosion and protection of magnesium alloys.
- Ionic transport in amorphous and crystalline films.
- Conversion treatments for light metal alloys.
- Laser surface treatment of aluminium and magnesium alloys



DR XIAORONG ZHOU
LATEST2 CO-INVESTIGATOR
SENIOR LECTURER IN CORROSION SCIENCE AND ENGINEERING

Xiaorong Zhou's research interests lie in corrosion control of light alloys, with emphasis on surface and interface characterization from the nanoscale upward, allowing detailed understanding of relationships between forming, joining and prediction of corrosion susceptibility, and protection mechanism. His work is validated by innovative electron microscopy approaches enabling the progress of corrosion to be followed, and susceptible regions in the microstructure, i.e. near-surface altered layers, defined three-dimensionally. He has published over 100 papers, and received the Kape Medal of the IMF (2001).

CURRENT RESEARCH PROJECTS

- Understanding the microstructure evolution in near-surface layers on fabricated aluminium and selected alloys
- Corrosion control of welded light alloys
- Control of cosmetic corrosion of automotive alloys
- Development of environmentally-friendly coatings
- Critical aspects in the adhesive bonding and painting of aluminium alloys
- Cold gas spray coatings
- Influence of shot/laser peening on surface integrity
- Nanotomography for understanding materials degradation

The Academic Team is supported by an Administrative Team comprising the Programme Manager, Outreach Administrator and Programme Administrative Assistant.

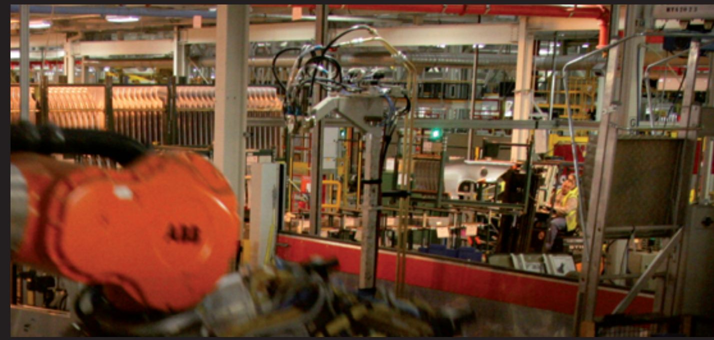
THE RESEARCH PROGRAMME

The LATEST2 aims to facilitate a step change in weight reduction in transport, by developing the science base required to overcome critical issues inhibiting progress towards, second generation, light alloy, multi-material designs. We hope to accelerate the exploitation of new transformative, low energy, environmentally-compliant manufacturing processes, by providing solutions to the important materials challenges and predictive capabilities required by industry. This will require the development of an enhanced fundamental scientific understanding and modelling capability in key areas.

The future direction of the transport industry requires more geometrically complex designs with a lower part count and the efficient utilisation of more expensive, lighter alloys. At the same time, industry will have to cope with the difficulties presented by the introduction of less formable, higher performance and more recycled materials. These conflicting requirements require a better understanding of the fundamental issues controlling forming, joining and surface engineering light alloy products, as well as the development of more reliable predictive models, and the optimisation and introduction of new techniques and technologies.

The research will be supported by exciting new approaches to materials analysis, modelling and simulation to facilitate more rapid industrial optimisation, while maintaining cost competitiveness and recyclability. A focus on the use of low energy manufacturing routes, and recycled materials, will be an important aspect of the research - to ensure a competitive cost base - as well as a low environmental footprint.

The Programme will be advanced through three principal interacting Themes as illustrated opposite.



THEME 1 CONQUERING LOW FORMABILITY

- Forming high performance light alloys & tailored panels
- Advanced Forming Processes & techniques
- Graded materials
- Modelling micromechanics of deformation
- Forming limits
- Surface finish

THEME 2 JOINING ADVANCED ALLOYS AND DISSIMILAR MATERIALS

- Joining for multi-material high performance light alloy structures
- Joining dissimilar material combinations
- Modelling interface reactions, weld microstructures and performance

SIMULATION & MODELLING RECYCLABILITY

THEME 3 SURFACE ENGINEERING FOR LOW ENVIRONMENTAL IMPACT

- In service protection & cosmetic control
- Surface engineering for adhesion (e.g. composite to metal bonding)
- Fundamentals of micromechanisms at all length scales

OUTPUT & TECHNOLOGY TRANSFER

Enabling knowledge for manufacturing advanced light alloy materials and their interfacing in multi-material systems, with more complex, mass efficient, design architectures

THEME 1 CONQUERING LOW FORMABILITY FOR OPTIMISED DESIGN ARCHITECTURES

We aim to develop the currently lacking scientific base required to optimise, energy efficient, routes for forming advanced light alloy materials - to cost effectively achieve the more complex shapes required by industry in these difficult materials. A key ambition is to develop predictive models and intelligently optimise innovative techniques for extending formability in higher strength – lower ductility, materials and recycled alloys.

This is a challenging task that first requires a step back to fully understand the deformation mechanics of hexagonal metals (HCP) e.g. Ti, Mg, before implementation in crystal plasticity models that capture the influences of microstructural and texture heterogeneity that cause strain localisation and limit formability. The Theme will then extend modelling to describe advanced warm forming processes and other novel approaches to increasing formability through, for example, exploiting material property and temperature gradients, as well as simultaneous phase transformations.

The research is aimed at developing the fundamental science required to underpin the following application areas:

- Extending shape capabilities in conventional cold forming medium strength alloys
- Selection and optimisation of new warm forming operations (e.g. quick plastic forming) for high strength Al-Al alloys
- Energy efficient, warm forming of HCP materials (Mg, Ti)
- Forming more economic roll cast and recycled materials
- Extending formability by through thickness (e.g. cast laminated) or in plane property gradients (e.g. laser/ FSP treated)
- Improving formability by exploiting differential thermal gradients and phase transformations
- Microstructure optimisation of additive layer manufacturing higher performance aerospace.

THEME 2 JOINING ADVANCED ALLOYS AND DISSIMILAR MATERIALS

Theme 2 will concentrate on developing the underpinning science required to support cost effective, routes for joining second generation light alloys and multi-material structures. Severe problems requiring urgent solution include; poor weldability of high strength alloys, interfacial reaction between dissimilar metals, thermal damage, distortion and residual stress.

The dissimilar material combinations required by industry, e.g. Al-steel, Mg-Al, metals to metal-polymer laminates and Ti to composites, are very difficult to join by traditional fusion welding methods.

We thus aim to focus on new transformative low energy friction joining processes, for dissimilar metal combinations, and advanced surface engineering to facilitate composite to metal joining (Theme 3), thereby maximising impact. Solid state friction welding techniques are highly efficient and have the advantage of far greater weldability and reduce the risk of interfacial reaction when welding dissimilar materials. New advances in welding technology with proven potential for success are targeted, such as friction stir spot welding (FSSW), and high power ultrasonic spot welding (USW), in conjunction with selected fusion welding techniques.

The research has been targeted at under pinning the following application areas:

- Energy efficient point joining of Mg and Al in automotive bodies (e.g. by USW and FSSW, with and without adhesives)
- Friction welding advanced alloys for aerospace structures with new welding techniques and greater microstructure and texture control.
- Friction welding dissimilar metallic product combinations with similar flow stresses, requiring control of intercalation and interfacial reaction (e.g. Mg HP-die castings to wrought Al sheet by)
- Friction welding dissimilar metallic hard to soft material combinations, requiring control of bond formation and interfacial reaction (e.g. Al to galvanised steel, Ti to Al).
- Low heat input fusion welding dissimilar materials - controlling interface reaction with fusion welding techniques.
- Joining metals to hybrid materials / laminates - where the core material is thermally and pressure
- Novel solutions for surface engineering to facilitate bonding polymer matrix composites to metals –theme 3.

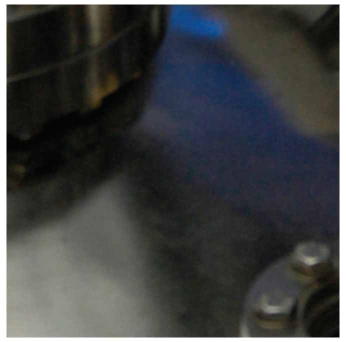
THEME 3 SURFACE ENGINEERING FOR LOW ENVIRONMENTAL IMPACT AND INTERFACE DESIGN

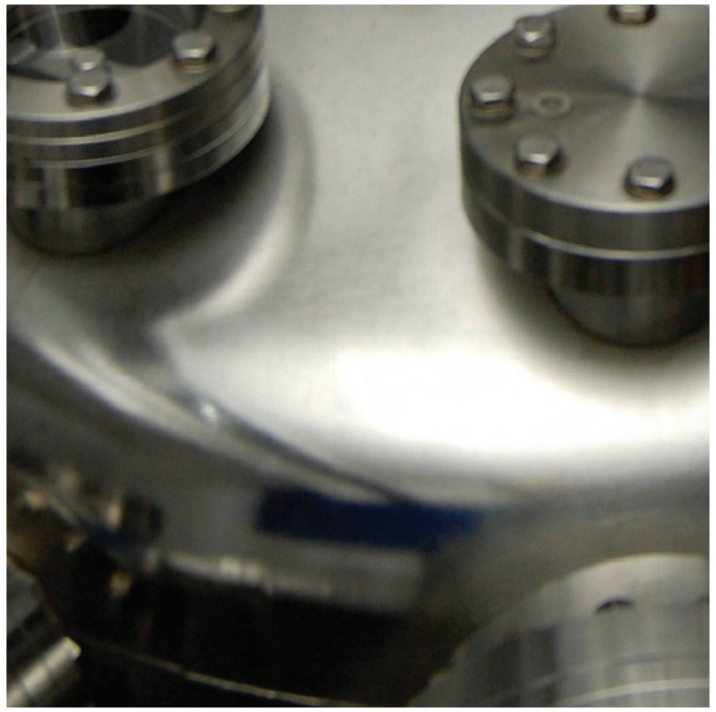
The aim of Theme 3 is to develop the scientific understanding required to underpin and explore creative, new, environmentally-compliant and economically viable solutions to; i) enhance surface properties and performance, ii) facilitate joining of dissimilar materials (e.g. metals to composites) and iii) the manufacture of hybrid materials (i.e. low density core metal skin laminates) and to protect multi-material structures, thus facilitating the introduction of more efficient designs.

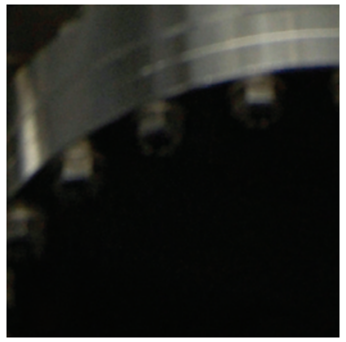
For light alloys, controlled corrosion is a vital aspect of many surface treatments, where local variations in microstructure impact significantly on uniformity. Importantly, microgalvanic effects are decisive in determining performance in service. Consequently, major inputs to this theme are, understanding the roles of local subsurface microstructures, textures and surface roughening, developed through forming and joining, on surface engineering.

The research is aimed at supporting the following application areas:

- The use of more recycled material, by understanding the impact on surface engineering for in-service performance
- Development of environmentally-friendly, economic coating routes for advanced light alloys across the transport sector
- Prevention of cosmetic corrosion in automotive closure panels by control of process-surface activated corrosion
- The development of self healing and 'smart' coating technologies
- Designing versatile surface treatment and finishing procedures to support the use of advanced forming and joining approaches for advanced light alloys
- The development of targeted surface treatments for protecting welded joints between dissimilar materials
- Surface engineering for enhanced bonding metals in hybrid materials/ laminates and to polymer matrix composites.







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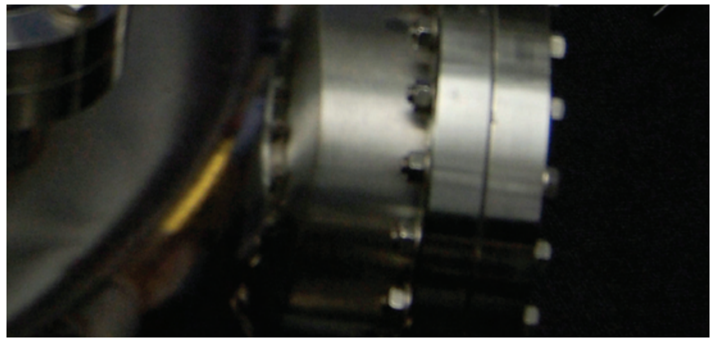

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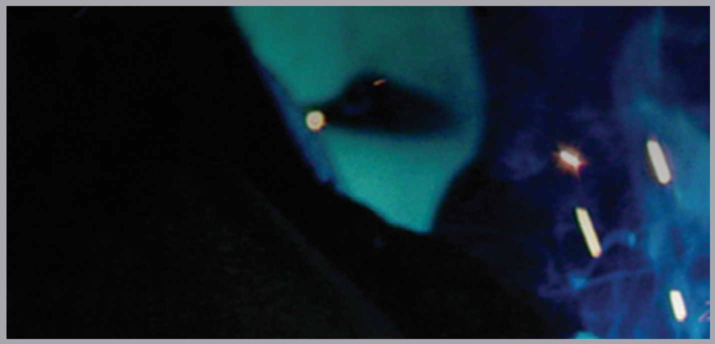
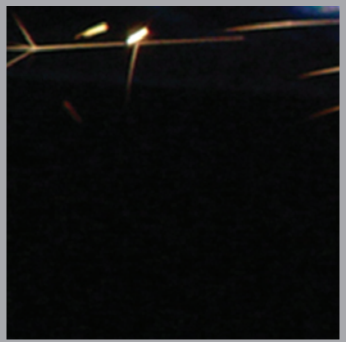




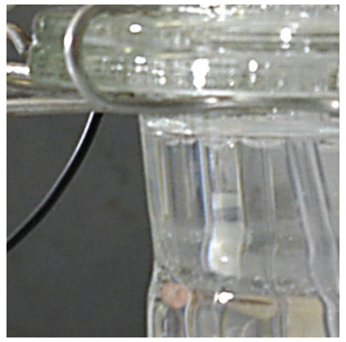
Joining is a critical technology in reducing the environmental footprint of transport and presents many exciting scientific challenges, with the potential for a high impact and payback to UK manufacturing from the development of transformative technologies and innovative ideas.

STATE-OF-THE-ART FACILITIES

The research is supported by an extensive suite of state-of-the-art facilities, which will be further expanded through the EPSRC's and The University of Manchester's investment in this Programme.

Current facilities include state-of-the-art analytical tools, such as high resolution scanning and transmission electron microscopes and surface analysis instruments, as well as equipment for process simulation. Recent notable investments focus on exciting new 3D microstructural characterisation methods, including X-ray tomography, nanoscale serial sectioning using dual ion beam tomography, forming and friction joining research and the development of techniques for in-situ analysis of simulated processes. Members of the Team are also involved in the development of large scale facilities for materials research (e.g. Diamond Light Source) and will use these tools to validate the models to be developed within the proposed work.

We intend to continue our role in developing cutting edge techniques by investments, in new equipment, including a subnanometre resolution (0.8 nm SE) SEM which will be the first in the UK, and surface and texture analysis facilities with in-situ strain mapping.



SOCIETY AND SUSTAINABILITY

The LATEST2 Programme aims to underpin developments vital to the future commercial success of the UK transport manufacturing sector and its supply chain.

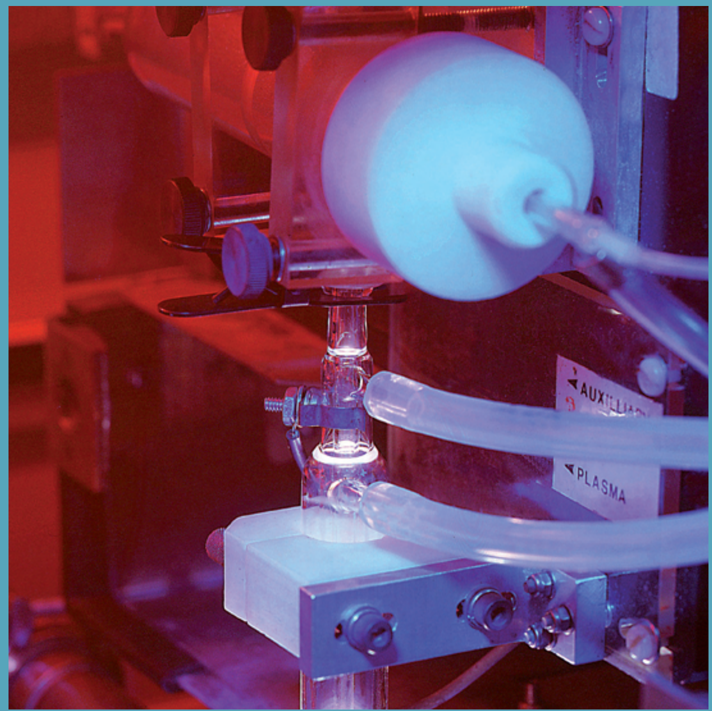
The research has been targeted to maximise impact by providing a step advance in the science base required in the move towards more efficient, lower emission products, essential to maintaining global competitiveness. The project will also facilitate significant indirect benefits in terms of maintaining the knowledge base, increasing the throughput of trained engineers, improving the environment by combating global warming, and increasing public awareness of research to cultivate future generations of engineers.

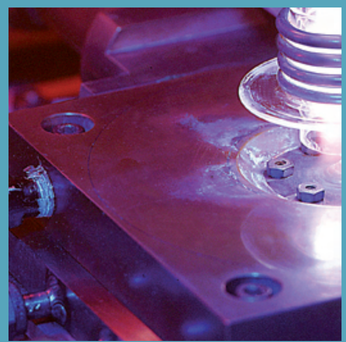
LATEST2 is targeted to maximise impact by providing a step advance in the science base required to implement efficient lower emission products.

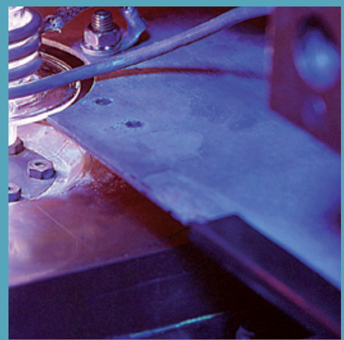
FILLING THE SKILLS GAP - HIGHER LEARNING AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

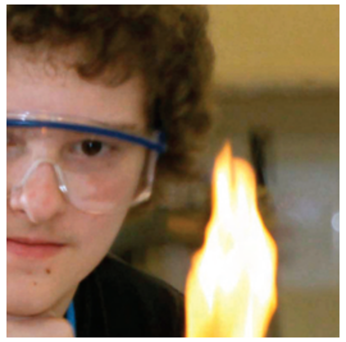
A high priority for the Programme is to address the skills gap in metallurgical and corrosion science training. We aim to attract high quality students and researchers – thus developing a future generation skills base for academia and industry. Strategic alignment with the CDT in Metallic Materials Systems, in partnership with Sheffield University, will give access to high quality research training, with a structured PhD programme, allowing enhanced core and transferable skills teaching. This will help provide globally competitive and innovative material's engineers needed by the UK manufacturing sector.

LATEST2 will also provide CPD in light alloys, in collaboration with our industrial partners, building on the Manchester Materials Masters Programme.









EXTERNAL ENGAGEMENT

The programme aims to promote networking and dissemination and to provide an advocacy role for engineering and the physical sciences.

ACADEMIC AND INDUSTRIAL ENGAGEMENT

The LATEST2 Team is committed to developing effective strategic relationships with industrial and academic organisations as well as to regional, national and international stakeholders.

At time of going to press collaboration agreements have already been signed with the following key External Partners:

AIRBUS UK, Alcoa Europe, Bridgnorth Aluminium Ltd, CSIRO, GKSS Research Centre, Innoval Technology Ltd, Jaguar LandRover, Keronite Ltd, Magnesium Elektron Ltd, Meridian Business Development UK, NAMTEC, Norton Aluminium, Novelis Global Technology Centre, Rio Tinto Alcan, Rolls-Royce Plc, TWI

The Programme will look to build further on these collaborations with other world class research centres and industrial partners. LATEST2 aims to promote networking and dissemination through a light alloys seminar series, international scientific meetings, an annual conference, via our website and Newsletter.

PUBLIC ENGAGEMENT

The LATEST2 team is committed to developing an effective outreach programme, to engage with the wider public in the challenges associated with providing lower carbon emissions within the transport sector.

A key goal is to improve awareness of materials engineering and light metallic materials with a focus on applications for transportation. Following previous successes, we will promote the importance of materials research through national frameworks for engagement by working with organisations such as the Smallpiece Trust, the Industrial Trust, EDT and Nuffield Science Bursary Scheme, as well as HEI STEM initiatives, focusing efforts on summer schools, workshops and science fairs (e.g Headstart, Physics at Work, National Science Week and Tech Challenge). In order to raise public awareness of the 'real world' applications of metallic materials, we will also work with regional institutions such as the Manchester Museum of Science and Industry, to highlight applications of light metals in transport and provide hands-on training and CPD for teachers, careers advisors and students.

By providing specialist science communication training for our PhD students, we will encourage our students to become ambassadors for Materials Engineering and become involved in public engagement activities.

CONTACT US

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The LATEST2 Team is focused on supporting the transport sector, in terms of delivering the underpinning, materials engineering research required to address key challenges in light weighting and sustainability, as well as by providing a dynamic environment for higher learning and external engagement.

A key aim for the Programme is to ensure there is a future generation skills base for academia and industry in metallurgical and corrosion science delivered through the highest quality research and higher learning programmes.

LATEST

ENVIRONMENTAL
LOGO TO BE ADDED

www.manchester.ac.uk/latest2
latest2@manchester.ac.uk