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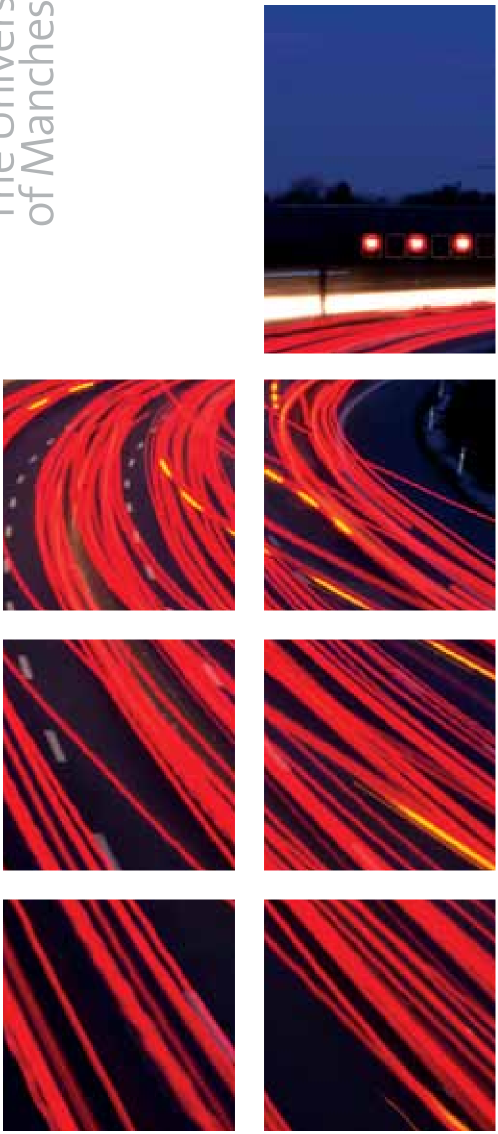
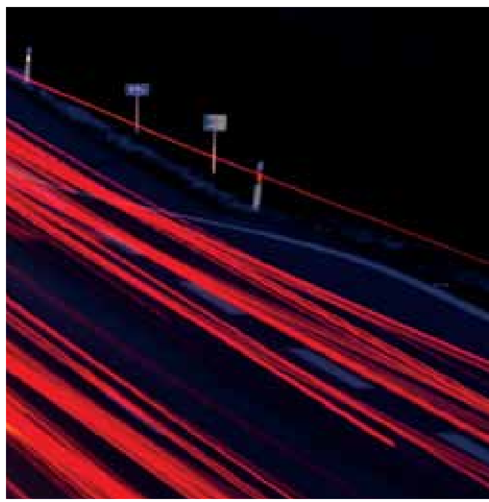
LATEST 2

LIGHT ALLOYS TOWARDS ENVIRONMENTALLY SUSTAINABLE TRANSPORT: 2ND GENERATION





EPSRC
Engineering and Physical Sciences Research Council

WINTER ISSUE 2011

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

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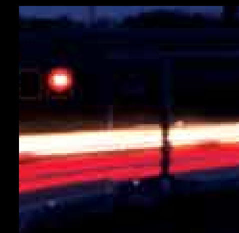
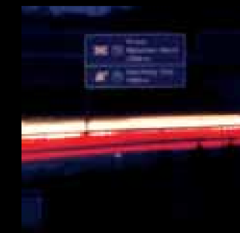
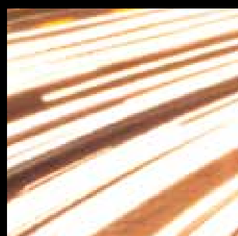
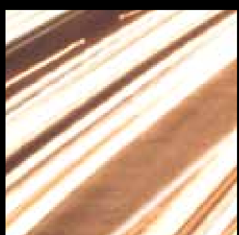
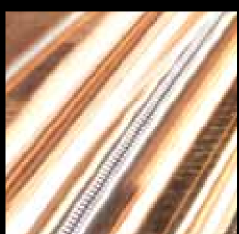










Welcome to the Winter 2011 first edition of the LATEST2 (Light Alloys Towards Environmentally Sustainable Transport: 2nd Generation) Newsletter, which provides an insight into the developing interdisciplinary lightweight multi-materials research funded by the EPSRC (Engineering and Physical Sciences Research Council) taking place within the School of Materials at The University of Manchester. I look forward to sharing future advances in both our research and outreach activities in forthcoming editions.

Are you interested in collaborating or finding out more about LATEST2? Please visit our website at www.manchester.ac.uk/latest2

The LATEST2 Programme has gained a great deal of momentum since the launch and now comprises over 50 live research projects. A large number of recruits are now undertaking research on the Programme at PhD and Postdoctoral level, and the team has been further strengthened with the appointment of a LATEST2 Research Fellow, namely Dr Michele Curioni. On behalf of the whole of the LATEST2 Management Team, I would like to warmly welcome all the new additions to the LATEST2 Team.

As part of the LATEST2 Team's commitment to knowledge transfer and our "IMPACT" strategy, in 2011, the team has run eight LATEST2 internal Researcher Symposia and two International Conferences on relevant research topics; the most recent Conference is featured in The Conference Corner in this issue.

These activities have helped strengthen collaborations with existing partners and identify new opportunities and key stake holders to help drive the research and the industrial impact forward. To date, LATEST2 has hosted 12 scientific visitors from Australia, Chile, China, Colombia and Italy.

LATEST2 has also made an "IMPACT" on over 5,000 pupils and members of the general public achieved through an extensive outreach programme, the outreach team has participated in over 12 major events including science fairs, summer schools, as well as a whole host of school and college visits. Some examples of these activities are featured in the IMPACT News article in this issue.

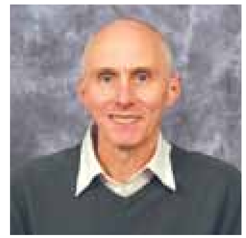
GEORGE THOMPSON OBE, FRENG
PROGRAMME DIRECTOR/PRINCIPLE INVESTIGATOR/THEME LEADER
LATEST2 PROGRAMME GRANT

MEET THE MANAGEMENT TEAM

The LATEST2 Management team is comprised of eight academic investigators within the School of Materials at The University of Manchester, and three administrative support staff. The Team is supported by colleagues within the School of Materials and beyond, enabling new expertise to be drawn in as required.

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

PROFESSOR PHILIP PRANGNELL
LATEST2 DEPUTY PROGRAMME DIRECTOR/ PRINCIPLE INVESTIGATOR/THEME LEADER
PROFESSOR OF MATERIALS ENGINEERING

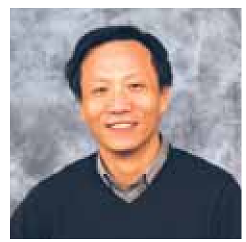


PROFESSOR PETER SKELDON
LATEST2 CO-INVESTIGATOR
PROFESSOR OF CORROSION SCIENCE AND ENGINEERING

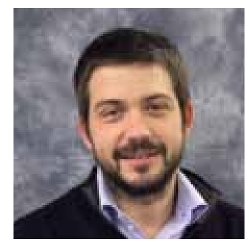
DR JOE ROBSON
LATEST2 CO-INVESTIGATOR
SENIOR LECTURER IN PHYSICAL METALLURGY

DR JOÃO QUINTA DA FONSECA
LATEST2 CO-INVESTIGATOR/THEME LEADER/OUTREACH ACADEMIC CHAMPION
SENIOR LECTURER IN MATERIALS PERFORMANCE

PROFESSOR MICHAEL PREUSS
LATEST2 CO-INVESTIGATOR
PROFESSOR OF METALLURGY



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



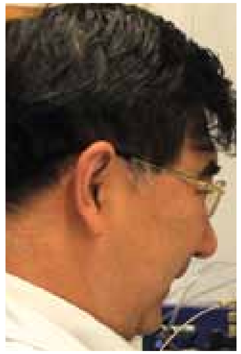
DR MICHELE CURIONI
LATEST2 CO-INVESTIGATOR/ RESEARCH FELLOW

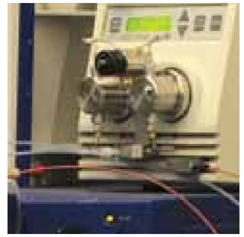
SUSAN C. DAVIS
LATEST2 PROGRAMME PROJECT MANAGER

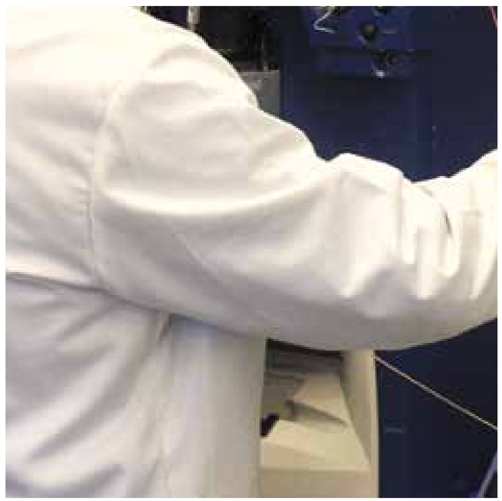
CACIA PERCIVAL
LATEST2 PROGRAMME ADMINISTRATIVE ASSISTANT

MAX ROWE
LATEST2 OUTREACH ADMINISTRATOR

RESEARCH IN FOCUS







The investment in the LATEST2 Programme Grant is expected to exceed £9.0 million over a 5.5 year period, including initial funding of £5.6 million from the EPSRC supplemented by a £1.0 million investment from The University of Manchester and pledged leveraged funding from our industrial partners. The LATEST2 Programme 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, lightweight, 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 research is supported by exciting new approaches to materials analysis, modelling and simulation to facilitate more rapid industrial optimisation and is advanced through three principal interacting themes as illustrated.

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

THE ASSESSMENT AND QUANTITATIVE MEASUREMENT OF FORMABILITY IN ALUMINIUM ALLOYS USING DIGITAL IMAGE CORRELATION (DIC)

The aim of the research on formability in LATEST2 is to understand the interplay between microstructural parameters (grain size and distribution, second phase particle distribution, texture, etc.) and the formability of different light alloys. Key to this work is the ability to assess the degree of anisotropy in the material by measuring r-values and building forming limit diagrams (FLDs). In the past, these have been measured by measuring the deformation on grids etched on the surface. These methods, however, provide limited spatial resolution and cannot be used to measure the evolution of deformation during straining, which often provides valuable clues. To overcome these limitations, the testing in LATEST2 will make use of state-of-the-art digital image correlation (DIC) techniques. DIC is a non-contact optical method of measuring full-field surface deformation. With DIC it is possible to make time resolved, in-situ measurements of the full 2D deformation tensor. Since the technique is essentially magnification independent, it can be used to measure deformation development at different scales, opening up the possibility of observing directly how microstructural features affect local deformation.

The formability tests will make use of a 3D version of the method, developed by LaVision, Göttingen. Two sets of images of the surface of the specimen are recorded at pre-determined time intervals during testing, using two digital high-speed cameras. These images are then filtered, calibrated and cross-correlated to give deformation data i.e. strains and their distribution and inhomogeneity. Our setup provides a strain resolution of 0.002 with sub mm spatial resolution. Figure 1 shows the setup in our lab. for a LaVision image correlation system and an Erichsen 145/60 Hydraulic sheet forming press.

Figure 1. Materials Science Centre, The University of Manchester. Experimental setup including an acquisition computer system and a Hydraulic sheet forming press

a) Computer system for data acquisition and analysis. b) Ring LED light source. c) High-speed cameras. d) Specimen clamped over the punch. e) Forming press. f) Acquisition system for mechanical data.

DIC will be used to compile forming limit diagrams for different materials. FLDs are usually determined by the Nakazima or the Marciniak tests in accordance with ISO 12004. The principle of the Nakazima test uses a hemispherical punch to deform wasted specimens of different widths until failure. The maximum characteristic deformations achievable (before failure) of the different shapes of specimens are determined and thus define the forming limit curve of a material. Figure 2 shows the camera views of a specimen before and after deformation as well as the strain distribution over a typical Nakazima test sample.

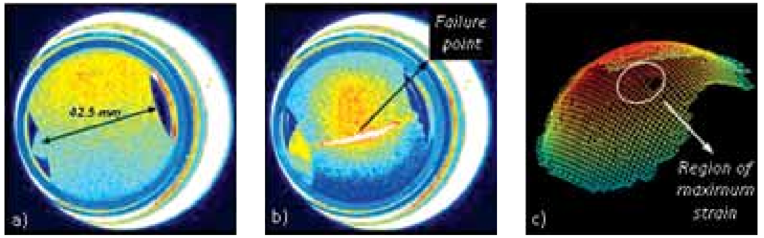


Figure 2.
a) non-deformed;
b) deformed specimen;
and c) strain distribution of the deformed sample

The data, in here, true strains, obtained and calculated by the DIC method are usually presented in a 2D diagram with perpendicular axes where the vertical and horizontal axes give the major and minor principal strains, respectively. This allows the determination of formability limits in different processes such as stretch forming, deep drawing or the combination of both. Figure 3 below shows a typical forming limit diagram for aluminium alloys.

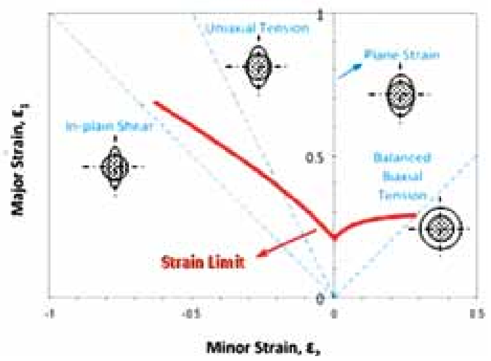


Figure 3. Shows typical forming limit diagram for aluminium alloys, the red curve delineates the onset of local necking, above which a successful deformation is attainable. Four strain paths/straining modes (the dashed lines and the vertical axis) are also shown on the diagrams to guide the user. The non-deformed state of an element of the sheet, dotted circle; and the deformed state, unfilled circle and ellipses elongated along the major axis are observable.

FOCUS ON CONTROLLING INTERMETALLIC REACTIONS IN DISSIMILAR JOINING

DISSIMILAR JOINING IS THUS A KEY TECHNOLOGY AREA FOR ENABLING INCREASED FUEL EFFICIENCY IN TRANSPORT

New design concepts for light weight vehicles involve multi-material structures, as they provide the best compromise solution between mass reduction, performance, and cost. Such designs allow materials to be used more efficiently and will involve combining light alloys with high strength steels and composites. Dissimilar joining is thus a key technology area for enabling increased fuel efficiency in transport.

LATEST2 has identified the control of intermetallic reaction between metal alloys like steel and aluminium as one of its foremost basic science challenges that will have a major impact in allowing greater versatility in joining dissimilar materials and more efficient joint design. This is because intermetallic reaction causes embrittlement of joints and is a severe problem that prevents industry from using most welding technologies to assemble multi-material structures. The LATEST2 team is currently studying and modelling reaction rates, between different material combinations, in solid state friction and rapid thermal-cycle fusion welding processes.

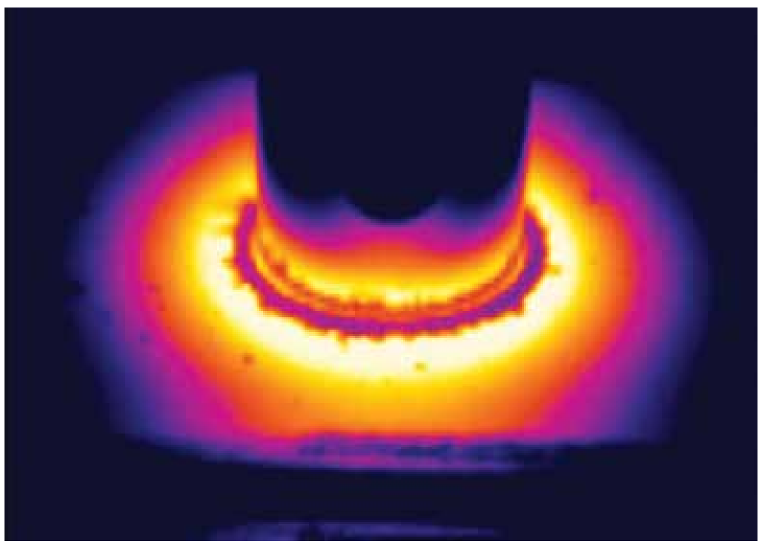


Figure 1. Thermal imaging of the temperature field during friction spot welding aluminium to steel

Three main approaches are being pursued to control the level of reaction, and minimise the thickness of intermetallic layers formed at the join-line; including, coatings that physically separate the weld interface from the dissimilar material couple, diffusion barriers and the use of inhibitors. An example of such a concept in practice would be to design the zinc coating on automotive steels to contain a reaction inhibitor, sufficiently effective that conventional fusion welding processes would become possible for aluminium and steel joints. This would reduce production costs by removing the need for highly specialised welding processes, which themselves have process windows that are restricted by the requirement to reduce intermetallic formation.

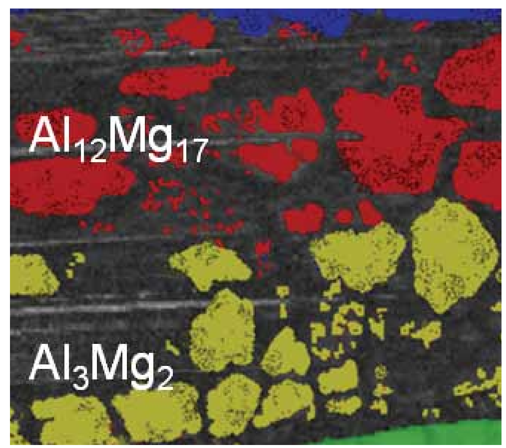


Figure 2. Phase mapping of the intermetallic reaction layer between aluminium and magnesium

In parallel with this work, LATEST2 is investigating alternative joining technologies like friction stir spot and ultrasonic welding with the aim of reducing the weld cycle time to be more compatible with industrial production and increasing weld performance.

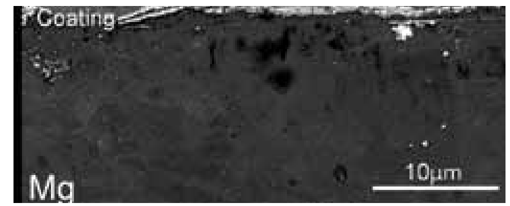


Figure 3. A diffusion barrier coating in a magnesium and aluminium ultrasonic weld

A NEW PERSPECTIVE ON CORROSION OF MULTIMATERIAL COMPONENTS

When metal structures are exposed to aqueous or humid environments, local events proceed on the surface. The events involve metal oxidation, releasing electrons within the metal, whereas other events consume electrons by reducing dissolved oxygen or hydrogen ions from the aqueous phase. Overall, the two reactions (anodic and cathodic) are balanced to preserve electroneutrality; thus, the conditions under which the balance is achieved determine the corrosion rate of the metallic structure.

On practical aluminium or magnesium alloys, the anodic and cathodic events also generate localized pH changes that locally modify the corrosion conditions. Thus, the corrosion process results from equilibrium between the anodic and cathodic reactions, pH changes, diffusion of reaction products and electrochemical potential. On multimaterial components, the balance that determines the corrosion behaviour is generally attained under conditions remote from that typical of each individual material. The increasing use of multimaterial components for lightweight solutions requires precise understanding of the long term corrosion issues to feedback information to alloy and surface treatment designers to secure safety, durability and acceptable aesthetic appearance.

Fortuitously, corrosion events produce a characteristic electrochemical signature, i.e. transient fluctuations of electrochemical potential and galvanic current. Study of these transients, termed electrochemical noise analysis, provides invaluable information on the size and frequency of corrosion events, and the overall anticorrosion performance of the surface. Importantly, it is the only available technique that extracts such information without disturbing the freely corroding surfaces.

Within LATEST2, electrochemical noise analysis is being developed to its full potential and extensively applied to the study of light alloys and multimaterial components and their protection systems. A unique, in-house graphical-interface software enables routine analysis, including i) practical evaluation of the anticorrosion performance of anodic oxides, ii) practical evaluation of corrosion inhibitor effectiveness and iii) elucidation of the effects of alloying addition on the type and morphology of corrosion on aluminum alloys. The use of electrochemical noise analysis has rapidly provided information to tune the anodizing condition for aerospace components, enabling the development of cycles requiring more than 50% less energy and providing enhanced anticorrosion performance (Figure 1).

Further, within LATEST2, uniquely, a theoretical basis for extending electrochemical noise analysis to studies of multimaterial components has been developed (Figure 2) and, now, the complex material-environment interactions that take place following coupling can be investigated. Invaluable information will be fed back for alloy selection, component design (including forming and joining), and surface treatment.

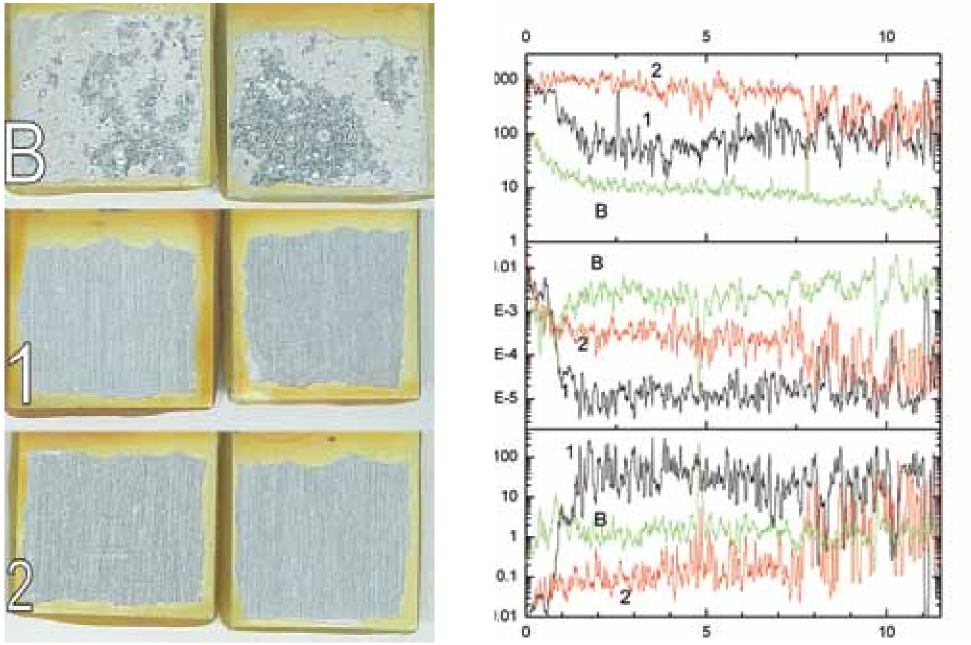


Figure 1. Surface appearance of anodized AA2024T3 specimens after immersion for 12 days in 3.5% NaCl and associated time evolution of noise impedance, average charge of corrosion events and frequency of corrosion events. (b) typical aerospace anodizing cycle in sulphuric-tartaric acid electrolyte , (1) and (2) energy saving anodizing cycles (1) in sulphuric tartaric acid electrolyte (2) as (1) but with addition of cerium nitrate. Cycles 2 and 1 provide better protection compared with (b), indicated by higher noise impedance and lower average charge of corrosion events.

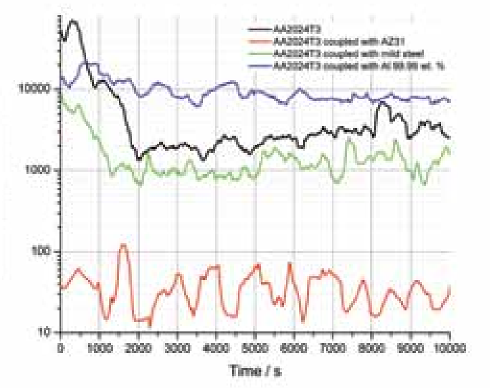
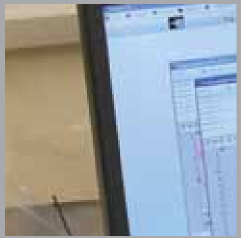


Figure 2. Time evolution of the noise resistance of AA2024T3 specimens coupled with AA2024T3 aluminium alloy (taken as reference), AZ31 magnesium alloy, mild steel and high purity aluminium. Galvanic coupling with high purity aluminium is beneficial (increase in noise resistance), conversely galvanic coupling with steel decreases slightly the noise resistance, indicating possible corrosion issues. Coupling with AZ31 is detrimental as evident from the significantly lower noise resistance and severe issues are anticipated both on AA2024T3 and AZ31.



RECENT PUBLICATIONS

ELECTROCHEMICAL NOISE ANALYSIS ON DISSIMILAR ELECTRODES: THEORETICAL ANALYSIS
M. CURIONI, R.A. COTTIS, M. DI NATALE AND G.E. THOMPSON
Electrochimica Acta 56 (2011) 10270-10275

EFFECT OF EXTRUSION CONDITIONS ON MICROSTRUCTURE, TEXTURE, AND YIELD ASYMMETRY IN MG–6Y–7GD–0.5WT% ZR ALLOY
J.D. ROBSON, A.M. TWIER, G.W. LORIMER AND P. ROGERS
Materials Science and Engineering A 528 (2011) 7247-7256

EFFECT OF PRECIPITATE SHAPE ON SLIP AND TWINNING IN MAGNESIUM ALLOYS
J.D. ROBSON, N. STANFORD AND M.R. BARNETT
Acta Materialia 59 (2011) 1945-1956

A COMBINED APPROACH TO MICROSTRUCTURE MAPPING OF AN AL–LI AA2199 FRICTION STIR WELD
A. STEUWER, M. DUMONT, J. ALTENKIRCH, S. BIROSCA, A. DESCHAMPS, P.B. PRANGNELL AND P.J. WITHERS
Acta Materialia 59 (2011) 3002–3011

MATERIAL INTERACTIONS IN A NOVEL PINLESS TOOL APPROACH TO FRICTION STIR SPOT WELDING THIN ALUMINUM SHEET
D. BAKAVOS, Y. CHEN, L BABOUT AND P. PRANGNELL
Metallurgical and Materials Transactions A 42 5 (2011) 1266-1282

ULTRASONIC SPOT WELDING OF ALUMINIUM TO STEEL FOR AUTOMOTIVE APPLICATIONS – MICROSTRUCTURE AND OPTIMISATION
P. PRANGNELL, F. HADDADI AND Y. C. CHEN
Materials Science and Technology 27 3 (2011) 617–624

MICROSTRUCTURE SIMULATION AND BALLISTIC BEHAVIOUR OF WELD ZONES IN FRICTION STIR WELDS IN HIGH STRENGTH ALUMINIUM 7XXX PLATE
A. SULLIVAN, C. DERRY, J.D. ROBSON, I. HORSFALL AND P.B. PRANGNELL
Materials Science and Engineering A 528 (2011) 3409–3422

NEAR-SURFACE DEFORMED LAYERS ON ROLLED ALUMINIUM ALLOYS
X. ZHOU, Y. LIU, G.E THOMPSON, G. SCAMANS, P. SKELDON AND J. HUNTER
Metallurgical and Materials Transactions A 42 (2011) 1373-1385

DISCONTINUITIES IN THE POROUS ANODIC FILM FORMED ON AA2099-T8 ALUMINIUM ALLOY
Y. MA, X. ZHOU, G.E. THOMPSON, M. CURIONI, X. ZHONG, E. KOROLEVA, P. SKELDON, P. THOMSON AND M. FOWLES
Corrosion Science 53 (2011) 4141-4151

A SILANOL-BASED NANOCOMPOSITE COATING FOR PROTECTION OF AA-2024 ALUMINIUM ALLOY
E. GONZALEZ, J. PAVEZ, I. AZOCAR, J.H. ZAGAL, F. MELO, X. ZHOU, G.E. THOMPSON AND M.A. PAEZ
Electrochimica Acta 56 (2011) 7586-7595

GLASS-LIKE CE_XO_Y SOL-GEL COATINGS FOR CORROSION AND PROTECTION OF ALUMINIUM AND MAGNESIUM ALLOYS
N. C. ROSERO-NAVARRO, M. CURIONI, Y. CASTRO, M. APARICO, G.E. THOMPSON AND A. DURAN
Surface and Coatings Technology 206 (2011) 257-264

ANODIC FILM FORMATION ON AA 2099-T8 ALUMINIUM ALLOY IN TARTARIC-SULPHURIC ACID
Y. MA, X. ZHOU, G.E. THOMPSON, M. CURIONI, T. HASHIMOTO, P. SKELDON, P. THOMSON AND M. FOWLES
Journal of the Electrochemical Society 158 (2011) C17-22 Also selected for publication in The Virtual Journal of Nanoscale Science & Technology, 22, Issue 26 (2010), published by the American Institute of Physics and the American Physical Society.

IMPACT NEWS

The LATEST2 team has been very active participating in a wide range of outreach events in 2011, working with established programmes and also taking part in some brand new and exciting initiatives. This article will highlight a few examples.

[redacted]

In March 2011, we hosted a stand as part of the University's Science Fair for National Science and Engineering Week. Over 700 local school pupils attended over three days and were enthralled with our copper plating experiment as they got to see their drawings etched into steel before their eyes!

In June, we hosted the 4th 'Engineering Materials' Residential Summer School in conjunction with the Smallpiece Trust. Forty five Year 10 students stayed at the University for four days and took part in a wide range of activities, talks and external visits designed to foster their interest in Materials Science and give them some hands on experience of the subject. The summer school was a great success with many students feeding back they would now consider studying the subject when they wouldn't have previously.

In July, we ran a number of our 'Build a Beam' challenge workshops for the Headstart Summer School and Dragonfly Day. The workshop tasks students with building the lightest, stiffest and most environmentally friendly composite beam for aerospace applications. We are currently working on a new initiative to host a regional 'Build a Beam' competition for local secondary schools.

In August, LATEST2 had a stand at the inaugural Jodrell Bank Summer Science Festival. The week long event was designed to showcase to the public the research undertaken at The University of Manchester and inspire children about science. The LATEST2 stand featured a number of interactive activities that captivated and entertained the audience, whilst raising awareness of Materials Science and we thoroughly enjoyed interacting with over 2,000 people that attended during the week!

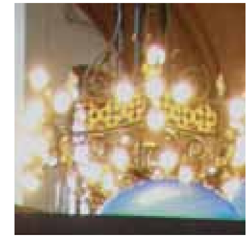
Over the summer a number of LATEST2 academic staff supervised students as part of the Nuffield Bursary Scheme. The scheme is for local A-Level students who are looking to gain some practical experience of science work. The students are set an assignment which lasts for four–six weeks where they have to perform experiments and write up their findings. We had a number of great projects this year with a few of them even resulting in academic publication.

In September, we attended the Physics at Work event at the Cavendish Laboratory in Cambridge where both staff and visitors alike had great fun attempting to build paper aeroplanes from tissue, cardboard and paper; an activity designed to demonstrate issues in materials selection for aerospace.

The LATEST2 Outreach "IMPACT" Strategy aims to reach:

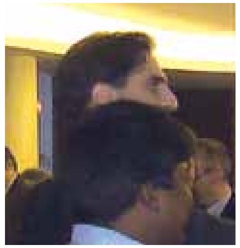
INDUSTRY
MATERIAL SCIENTISTS
PUPILS
ACADEMIA
COMMUNITY
TEACHERS & CAREER ADVISORS

[redacted]



If you would like to find out more about the LATEST2 Outreach Programme or are interested in collaborating in future outreach events please contact our Outreach Administrator, Mr Max Rowe max.rowe@manchester.ac.uk

CONFERENCE CORNER



On November 24th 2011, LATEST2 hosted its second major conference on the "Challenges for Joining Light Weight Dissimilar Materials for Automotive Applications". This one day event was held at The University of Manchester and brought together industry representatives across the automotive supply chain and members of academia and research institutions. The event comprised presentations as well as a poster session showcasing some of the current work by LATEST2 PhD and Post-doctoral Researchers and provided plenty of opportunity for networking and discussion.

The presentations were all of an extremely high standard and found to be very interesting and thought provoking. Special thanks go to the speakers namely, Dr Ian Norris, TWI Ltd, UK. Dr Frank Balle, University of Kaiserslautern, Germany. Dr Paul Briskham, The University of Coventry, UK. Mr Andrew Blows, Jaguar LandRover, UK. Professor Philip Prangnell, The University of Manchester, UK. Dr Alberto Echeverria Zubiria, Lortek, Spain. Professor Stewart Williams, Cranfield University, UK. Dr Cyrille Bezencon, Novelis, Switzerland. Dr Jorge Dos Santos, GKSS, Germany. Dr Richard Hewitt, Warwick Manufacturing Group, UK. Dr Michele Curioni, The University of Manchester, UK.

The event attracted over 60 delegates from the UK, Spain, Germany, Italy and Switzerland and has acted as a catalyst for potential new collaborations.

If you missed the event and you are interested in finding out more then please e-mail susan.davis@manchester.ac.uk or visit the LATEST2 website at www.manchester.ac.uk/latest2

ALUMINIUM SURFACE SCIENCE & TECHNOLOGY VI INTERNATIONAL SYMPOSIUM, SORRENTO, ITALY

27th – 31st May 2012

The ASST Symposia are now recognised as a key event bringing together aluminium companies, industrial end users, instrument manufacturers and researchers from the international scientific community. The scope of this years symposium encompasses all aspects of aluminium surface generation, characterisation, modification, performance and development as well as multi-materials design and performance.

30th January 2012
Early bird registration deadline

30th April 2012
Registration deadline

For more information please visit
www.asst2012.org

Interested in attending or sponsoring this event? Please contact latest2@manchester.ac.uk

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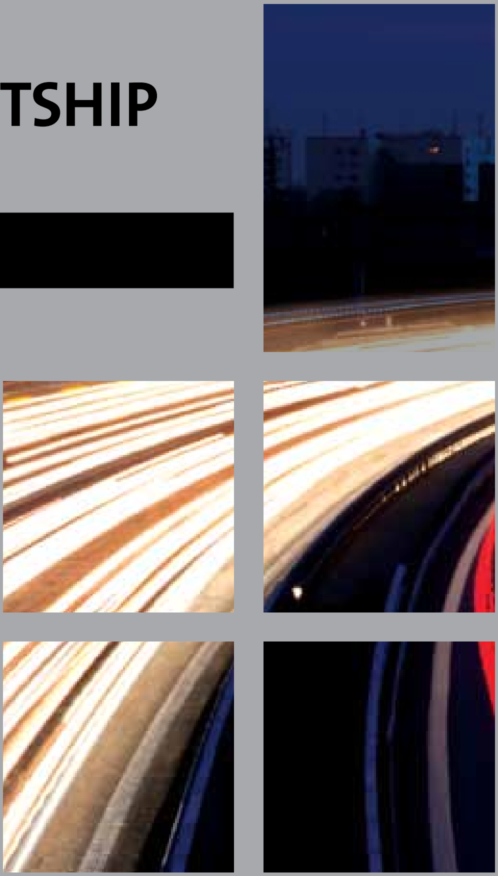

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