

The Future Liquid Metal Engineering Hub

REPORT 2019



Welcome

Dear Friends,

It gives me great pleasure to welcome you to the Future LiME Hub's 2019 report.

The Future LiME Hub was launched in November 2015 with sponsorship from the EPSRC, industrial companies and the host university, Brunel University London. The Future LiME Hub is a national centre of excellence in liquid metal engineering based at Brunel University London in collaboration with our four Spokes of Imperial College London and the universities of Oxford, Leeds and Manchester.

We are now over half way through the programme and the past 12 months have been full of activity. The overarching focus for the Future LiME Hub remains centred on our vision of full metal circulation, and working to ensure that our fundamental research is not only advancing, but is also transferable to the wider industry, highlighted by our extensive and growing connections with our industrial partners.

This report provides you with an overview of the Hub's research themes, along with some highlights of the Hub's activities of the past year. We have continued to strive for research excellence, having taken significant steps forward in the areas of heterogeneous nucleation, grain initiation and grain refinement. We have also achieved major advances in the development of the multi-purpose high shear technology and its applications in industrial processes. We have been working ever closely with our industrial partners, supporting them through direct collaboration and through a number of new Innovate UK funded programmes. Alongside our research programme, we have continued to extend our national and international reach. We have supported the academic research community by hosting the 11th International Conference on Magnesium Alloys and Their Applications in July 2018, and launched a call for proposals for external feasibility studies to be carried out over the next year. As well as developing research collaborations with our partners, we have sought to support industry through active participation at a number of industry-led events, e.g. the Aluminium Federation and Council for Aluminium in Building co-hosted Aluminium Recycling Industry Workshop. Our efforts, as a national hub, to support and develop the national landscape have included organising a Hub Convention, to bring other EPSRC critical mass programmes, the Advanced Propulsion Centre, the Aerospace Technology Institute, and industry experts together with the Future LiME Hub to explore and take forward cross-sector synergies.

We welcome you, as always, to join us from both academic and industrial sectors for national and international collaborations through appropriate mechanisms at all levels. With your support, help and participation, we can continue to work to turn our dream of full metal circulation into a reality for our future generations.

Yours faithfully,

Professor Zhongyun Fan

Director of the Future LiME Hub



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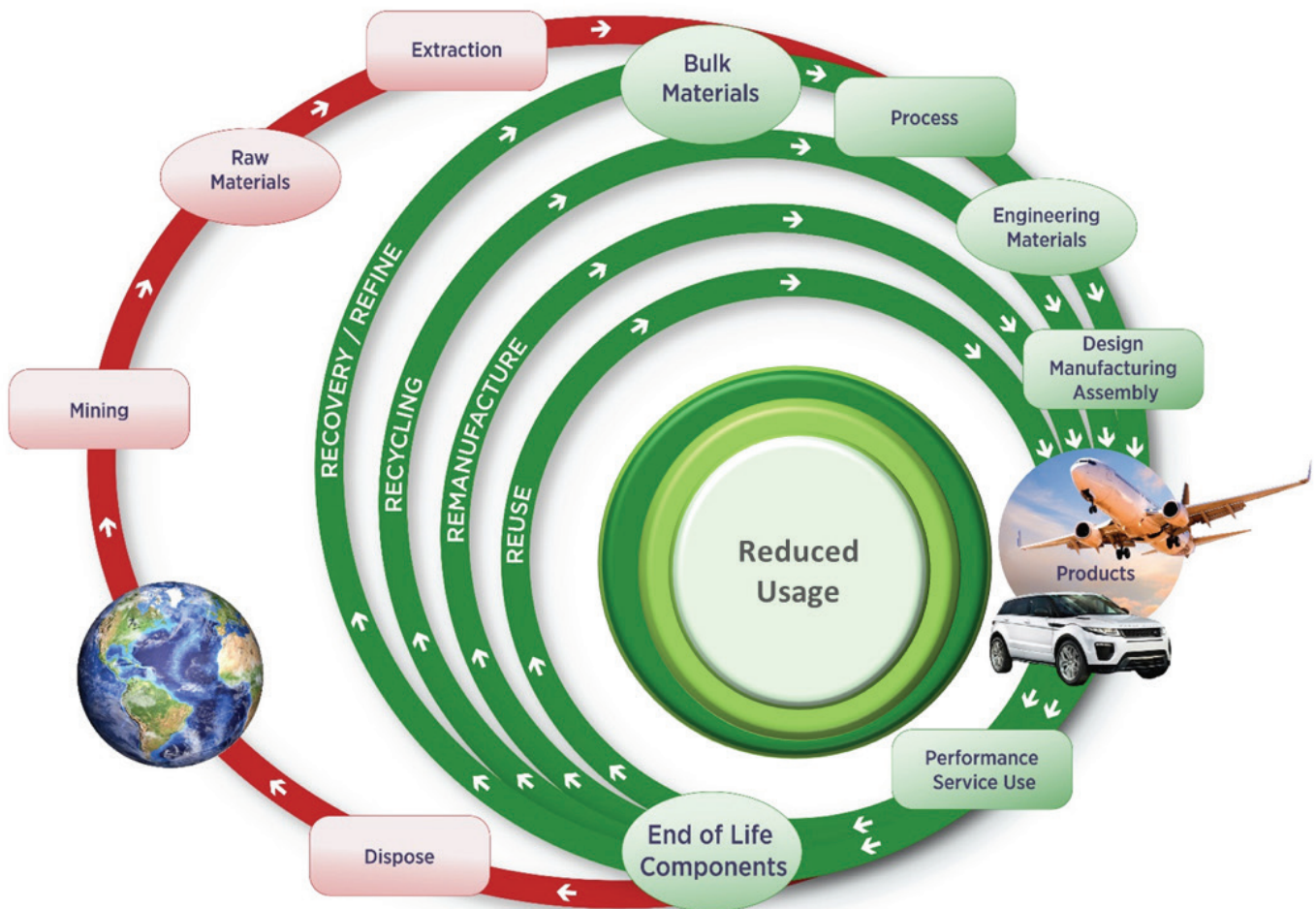
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Introduction

Metallic materials are the backbone of the manufacturing industry and metal casting, and play a pivotal role in fuelling economic growth. Metal castings are used in over 90% of all manufactured goods and in nearly all manufacturing machinery.

The UK metal casting industry adds £2.6bn/year to the UK economy, employs 30,000 people and produces 1.14MT of metal castings. It underpins the competitive position of every sector of UK manufacturing across automotive, aerospace, defence, energy and general engineering. However, the industry faces severe challenges, including having been “hollowed-out” over the past 30 years, increasing energy and material costs, tightening environmental regulations, shortage of skilled people and fierce competition from the emerging economies.

Therefore, together with the EPSRC, we have established the Future Liquid Metal Engineering Hub (Future LiME Hub) to address these challenges. The Hub’s core research activities are based within BCAST at Brunel University London and our academic Spokes at Oxford, Leeds and Manchester universities and Imperial College London. We have identified closed-loop recycling of metallic materials, which is an integral part of our long term vision for full metal circulation, as the single greatest challenge and opportunity facing the global manufacturing industry, formulating our dynamic Future LiME Hub research programme in concert with our ever-expanding industrial partnerships. The research programme’s six research themes are summarised in the ‘research themes’ section later in this report.



Schematic illustration of the Future LiME Hub's vision for full metal circulation.

ED&I in the Future LiME Hub

The LiME Hub has always endeavoured to promote the equality and diversity of its research staff, as evidenced by the higher than average number of female staff members and PhD students associated with the Hub's research.

Currently, 18% of the research staff and 28% of the PhD students within the LiME Hub are female, which compares favourably with the WES statistics (www.wes.org.uk) that show only 5% CEng registrations are from females. The minority ethnicities described within the BAME framework are highly represented among the researchers working within the LiME Hub: 78% of the research staff and 100% of the PhD students.

Inequality in female representation within the STEM sector, especially in engineering, is well documented and recruitment of qualified females is difficult. However, the Hub has continued to actively recruit suitable female candidates where possible. As part of its ED&I strategy, the Hub is actively engaged with the IOM3 and Hub researchers are encouraged to take part in the IOM3 Women in Engineering activities as part of their network building, and to participate in the mentoring

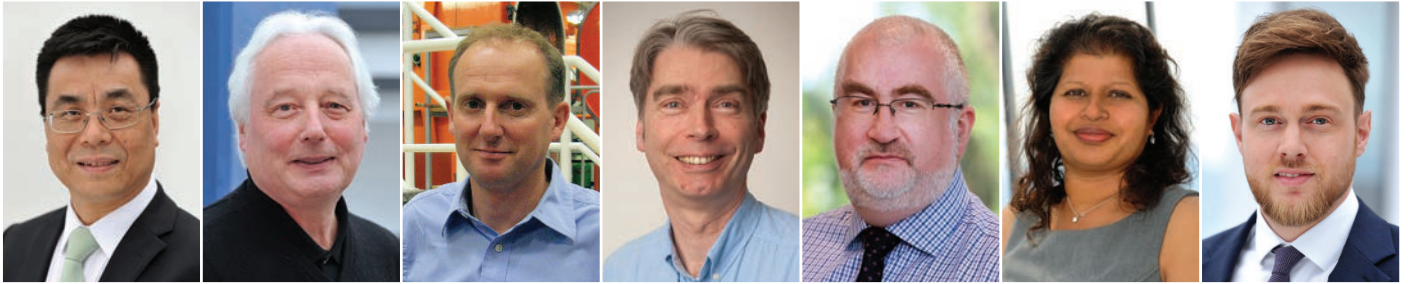
programme. Recently, an IOM3 International Women in Engineering day was attended by a number of the Hub personnel.

Building upon the well-developed ED&I provision of the individual Hub and Spoke institutions, the LiME Hub is currently strengthening its own comprehensive ED&I strategy. The strategy will include pathways to encourage equality and inclusivity in both gender and BAME, through promotion of gender-neutral language in advertisements for research staff positions and studentships, ensuring equality in attending conferences and participating in Hub events, signposting gender and BAME specific development opportunities, and mixed shared workspaces to promote inclusion, among others. In addition, innovative routes have been considered to develop a more gender inclusive dialogue within the Hub to encourage retention of female staff and students and ensure their progression where feasible.



LiME Hub researchers at the LiME Creativity@home event held in September 2018.

Management and Governance



The Hub management structure:

Professor Fan, as Director and PI of the Hub, takes the overall responsibility for driving the Hub vision and delivering the aims and objectives of the Hub programme, supported by a newly appointed Deputy Director (Professor Geoff Scamans) and a Hub Management Group (HMG), and advised by a refreshed International Advisory Board (IAB) and a new Industrial Advisory Panel (IAP). Professor Fan is assisted by a Hub Manager and a Hub Administrator.

The **Hub Management Group (HMG)**, chaired by Professor Fan (Director), includes Professors Scamans (Deputy Director), Grant (Oxford Spoke – policy lead) and Mullis (Leeds Spoke - research integrity lead), and Drs Stone (researcher development lead), Mendis (ED&I lead) and Jones (Hub Manager). The HMG is designed to support the Director to deliver the aims and objectives of the Hub. The purpose of the HMG is to ensure the successful execution of the Hub's research and outreach programmes through effective coordination of the Hub and its Spokes.

The **International Advisory Board (IAB)** is an advisory body set by the HMG, which advises the Hub on its scientific research direction and technical approaches and benchmarks the Hub's scientific research quality from an international perspective.

To reflect the dynamic nature of the Hub, IAB membership has been refreshed for 2019, with new members selected from leading international authorities in solidification research. The refreshed IAB consists of eight members, of which two are female and six are male.

As part of the new membership arrangements, at least one new or replacement member is added to the IAB each year, and one or two additional people may be invited to attend specific meetings as invited IAB members.

The last IAB meeting was held on 23 July 2018 at Beaumont Estate, Old Windsor, UK, prior to the 11th International Conference on Magnesium Alloys and Their Applications (Mg2018), hosted by the LiME Hub and BCAST. The next IAB meeting will be held at the same venue in October 2019.

Prior to April 2019, the Future LiME Hub was advised by an **Industrial Steering Panel (ISP)**, with the last ISP meeting held at Brunel University London on 16 January 2019, which advised the Hub on the industrial relevance of its research activities. Although its membership has been dynamic, and has served the purpose of supporting the development of industrial research and its impact well, the ISP had gradually become somewhat inward looking. To ensure the widest industrial impact of the Hub, the HMG has reshaped and re-purposed the ISP, and now includes members from the aerospace sector and the broader UK high value manufacturing and materials research landscape. The new body has been renamed the **Industrial Advisory Panel (IAP)**. The purpose of the new IAP is to advise the Hub on the wider industrial relevance of the LiME Hub research activities and provide effective mechanisms to deliver industrial impact of the Hub's research in a broader range of sectors. The next IAP meeting will be held in October 2019 at Beaumont Estate, Old Windsor, UK.



2018 IAB members at the last IAB meeting held in July 2018.



Hub and ISP members at the last ISP meeting held in January 2019.

The reshaped IAP has the following members:

Dr Mark White

Former Chief Technologist at JLR (Chair, independent)

Dr Bernie Rickinson

Former CEO, IOM3 (Independent member)

Ms Philippa Oldham

Head of National Network Programmes, Advanced Propulsion Centre (Independent member)

Professor Sam Turner

CTO, Catapult Centres (Independent member)

Dr Pam Murrell

CEO, CMF (Independent member)

Mr Alex Hickson

Head of Technology, Aerospace Technology Institute (Independent member)

Mr Henry Dickinson

MD, Norton Aluminium (Independent member)

Dr Mike Clinch

CTO Innoval Technology (Independent member)

Professor Martin Jarrett

Technology VP Constellium (Industrial collaborator)

Dr Paul Blake

Research Engineer, JLR (Industrial collaborator)

Mr Keith Denholm

Engineering and Technology Director, Grainger & Worrall (Industrial collaborator)

Mr Mike Bond

Director of Advanced Materials Technology, Aeromet (Industrial collaborator)

Mr Anthony Evans

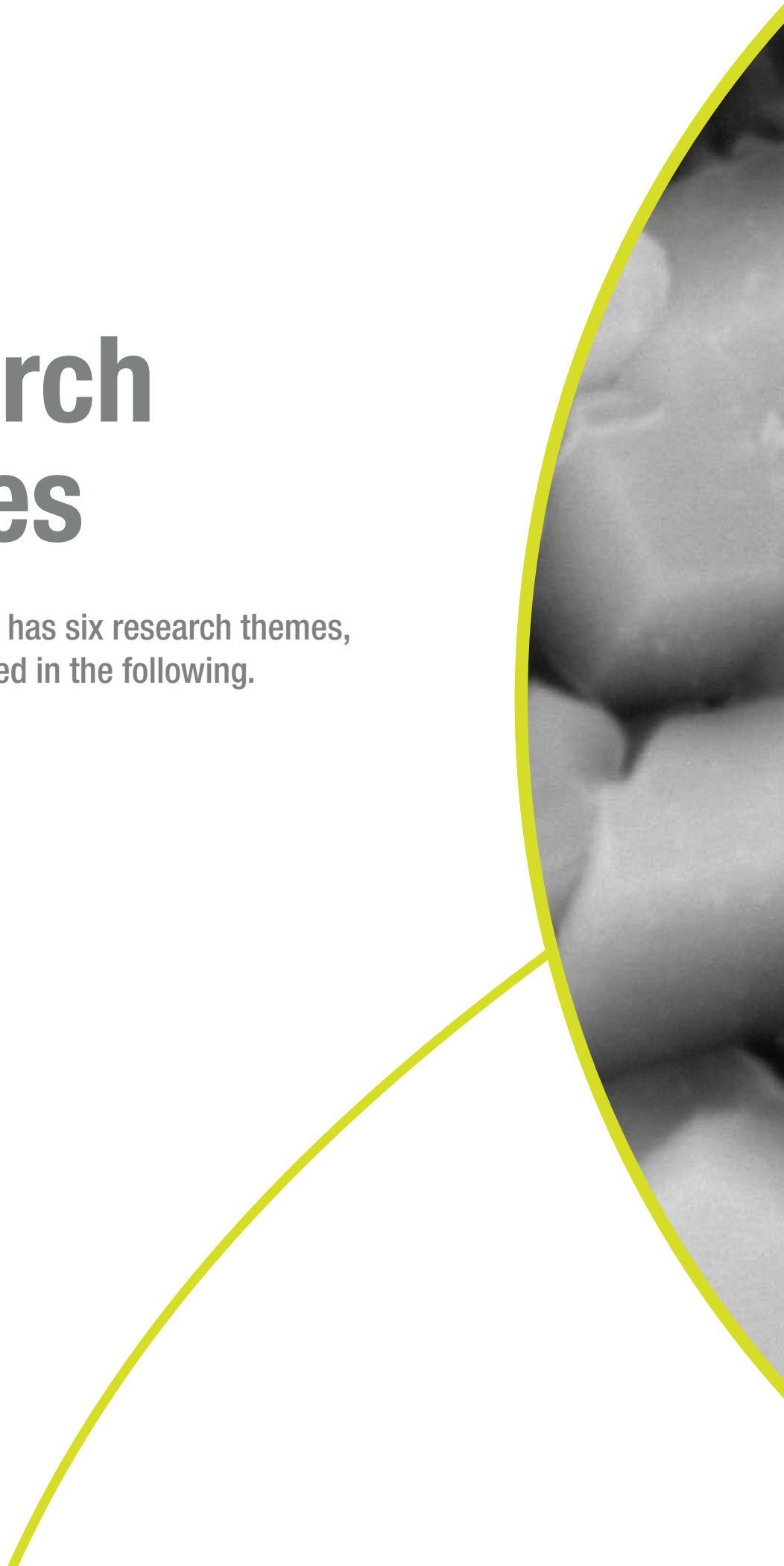
MD, Sarginsons (Industrial collaborator)

Mr Andy Smith

Chief Engineer, Gordon Murray Design (Industrial collaborator)

Research Themes

The Future LiME Hub has six research themes, which are summarised in the following.





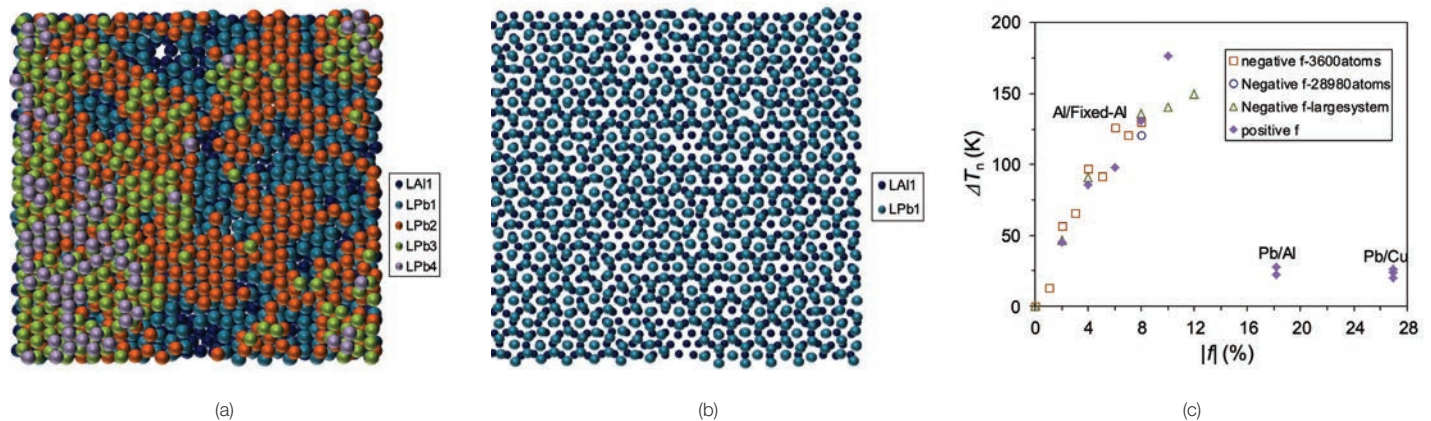
www.lime.ac.uk

Research Theme 1: Understanding the atomistic mechanisms of heterogeneous nucleation

Z. Fan, X.R. Zhou, P.S. Grant, C.M. Gourlay, Q.M. Ramasse, H. Men, H. Tetlow, B. Jiang, C.M. Fang, Y. Wang, F. Wang, Z.P. Que, J. Xia, T. Hashimoto, E. Liotti, G. Zeng and S.H. Wang

Aims and key objectives

- To understand the phenomenon of prenucleation and the effect of lattice misfit, chemical interaction and surface roughness on prenucleation;
- To understand the atomistic mechanism of heterogeneous nucleation;
- To understand the exact mechanisms for both grain refinement and poisoning (e.g., Zr, Si, etc.) in relation to the commercial Al-Ti-B grain refiners;
- To identify the chemical and physical nature of interfacial segregation at the solid/substrate interface;
- To understand the effect of interfacial segregation at the solid/substrate interface on the substrate potency for heterogeneous nucleation;
- To understand the mechanisms for heterogeneous nucleation of intermetallics benchmarked by the mechanisms for heterogeneous nucleation of solid solutions;
- To validate theoretical predictions of the atomistic modelling by providing experimental evidence.



1. (a) Precursor and (b) coincidence site lattice (CSL) at the interface during heterogeneous nucleation in liquid Pb/solid Al; and (c) undercooling for heterogeneous nucleation as a function of lattice misfit, f . These indicate that prenucleation is a general phenomenon, and the CSL mechanism facilitates heterogeneous nucleation dramatically in systems with large f , via a structural templating mechanism.

Summary of key progress

- 1 We have pioneered the new concept of prenucleation, which is defined as substrate surface induced atomic ordering in the liquid at temperatures above the nucleation temperature. We found that prenucleation is promoted by reducing temperature, lattice misfit or atomic surface roughness, and by having an attractive chemical interaction between the substrate and the liquid.
- 2 We found that heterogeneous nucleation occurs within 3 atomic layers through a structural templating mechanism: the 1st layer accommodates lattice misfit through the formation of an edge dislocation network; the 2nd layer twists by an angle to reduce strain energy via the formation of a screw dislocation network; and the 3rd layer is almost perfect and provides a template for further crystal growth.
- 3 We have validated the new 3-layer nucleation mechanism by experimental observation of the physical twist of the nucleated crystal relative to the substrate.
- 4 After more than 70 years industrial practice, we have for the first time elucidated the grain refining mechanism of commercial A-5Ti-1B grain refiner: the formation of a monolayer of (112) Al_3Ti 2-dimensional compound (2DC) on the (0001) TiB_2 surface.
- 5 We have uncovered the mechanism for Zr-poisoning of commercial Al-5Ti-1B grain refiner: dissolution of the (112) Al_3Ti 2DC and formation of Ti_2Zr 2DC on the (0001) TiB_2 surface by replacing some of the Ti atoms on the (0001) TiB_2 surface by Zr.
- 6 We have established the concepts of structural and compositional templating for heterogeneous nucleation of intermetallic compounds (IMCs). We have also developed practical approaches to provide both structural and compositional templating for heterogeneous nucleation of IMCs.
- 7 We have found that heterogeneous nucleation of IMCs is inherently more difficult than that of simple solid solutions. It has been confirmed that the nucleation undercooling for IMCs is tens of K while that for solid solutions is usually a fraction of a degree.
- 8 We have established the chemical and physical nature of elemental segregation of Fe (Mn), Ni, and Si at the TiB_2/Al interface.
- 9 We have established the chemical and physical nature of elemental segregation of Y, Ca, and Sn at the MgO/Mg interface.

Potential long-term impact:

- Heterogeneous nucleation is a wide-spread phenomenon in both natural and industrial processes. New insights obtained from this theme may have significant impact on other research fields, such as ice formation for climate control, protein crystallisation in life science and mineral crystallisation in pharmaceutical processes.
- The Hub's research on heterogeneous nucleation has the potential to rewrite the textbook on this subject.

Selected impacts:

- 1 The paper by Men and Fan (Metallurgical and Materials Transactions A, 49 (2018), 2766-2777) has been selected by Advances in Engineering (<https://advancesENG.com>) as a key scientific article contributing to excellence in science and engineering research.
- 2 Plenary lecture: Z. Fan, A new framework for understanding heterogeneous nucleation and grain refinement, the 6th Decennial International Conference on Solidification Processing (SP17), Old Windsor, UK, 25-28 July 2017.
- 3 Plenary lecture: Z. Fan, An overview on recent advances in understanding early stages of solidification, the 7th International Conference on Solidification and Gravity (SolGrav-2018), Miskolc, Hungary, 3-7 September 2018.
- 4 Invited lecture: C.M. Gourlay, Heterogeneous nucleation mechanisms in solder joints, the 6th Decennial International Conference on Solidification Processing (SP17), Old Windsor, UK, 25-28 July 2017.
- 5 Invited lecture: P.S. Grant, Nucleation of intermetallics in a model Al-Fe alloy by x-ray radiography, the 7th International Conference on Solidification Science and Processing (ICSSP-7), Trivandrum, India, 19-22 November 2018.
- 6 Invited lecture: P.S. Grant, Synchrotron x-ray radiography measurement of intermetallic compound selection and growth during Al-alloy solidification, TMS 2017, California, USA.
- 7 Keynote lecture: C.M. Gourlay, Nucleation and growth of Al-Mn-(Fe) intermetallics in AZ91 alloy, International Conference on Magnesium (ICM-6), Shengyang, China, 23-26 September 2017.
- 8 Invited lecture: C.M. Fang, Prenucleation on oxide particles in Al- and Mg-alloys: An ab initio MD study, the 7th International Conference on Solidification Science and Processing (ICSSP-7), Trivandrum, India, 19-22 November 2018.
- 9 Invited lecture: H. Men, A molecular dynamics study on heterogeneous nucleation, the 7th International Conference on Solidification Science and Processing (ICSSP-7), Trivandrum, India, 19-22 November 2018.

Selected publications:

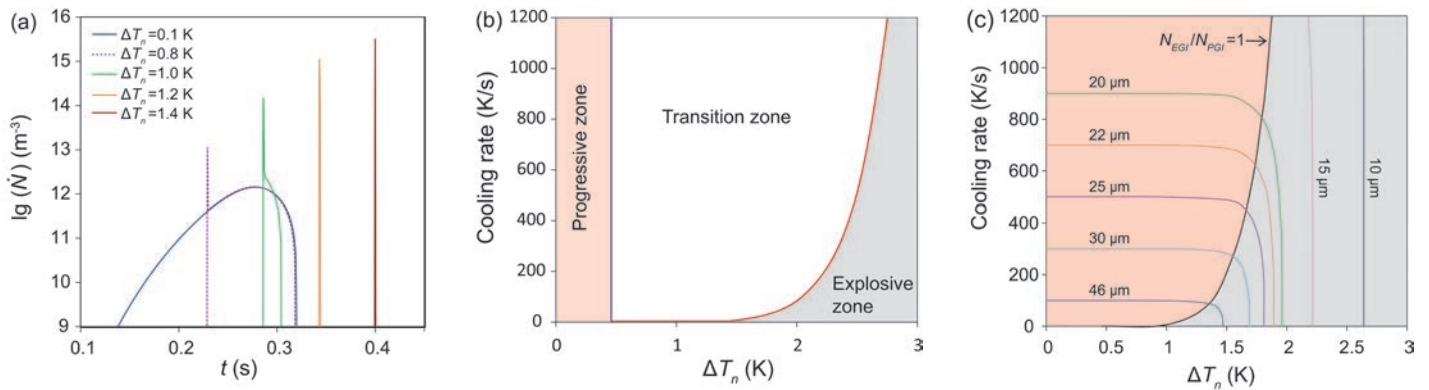
- 1 H. Men, Z. Fan: Prenucleation induced by crystalline substrates, Metallurgical and Materials Transactions A, 49 (2018), 2766-2777.
- 2 C.M. Fang, H. Men, Z. Fan: Effect of substrate chemistry on prenucleation, Metallurgical and Materials Transactions A, 49 (2018), 6231-6242.
- 3 B. Jiang, H. Men, Z. Fan: Atomic ordering in the liquid adjacent to an atomically rough solid surface, Computational Materials Science, 153 (2018), 73-78.
- 4 Y. Wang, C.M. Fang, L. Zhou, T. Hashimoto, X. Zhou, Q.M. Ramasse, Z. Fan: Mechanism for Zr poisoning of Al-Ti-B based grain refiners, Acta Materialia, 164 (2019), 428-439.
- 5 Z. Fan, Y. Wang, Y. Zhang, T. Qin, X.R. Zhou, G.E. Thompson, T. Pennycook, T. Hashimoto: Grain refining mechanism in the Al/Al-Ti-B system, Acta Materialia, 84 (2015), 292-304.
- 6 G.S. Peng, Y. Wang, Z. Fan: Competitive heterogeneous nucleation between Zr and MgO particles in commercial purity magnesium, Metallurgical and Materials Transactions A, 49 (2018), 2182-2192.
- 7 G. Zeng, J. Xian, C.M. Gourlay: Nucleation and growth crystallography Al_3Mn_5 on B2-Al(Mn, Fe) in AZ91 magnesium alloy, Acta Materialia, 153 (2018), 364-376.
- 8 E. Liotti, C. Arteta, A. Zisserman, A. Liu, V. Lempitsky, P.S. Grant: Crystal nucleation in metallic alloys using x-ray radiography and machine learning, Science Advances, 4 (2018), eaar4004.
- 9 Y. Wang, Z.P. Que, Y. Zhang, Z. Fan: Effect of interfacial segregation on heterogeneous nucleation, Proceedings of the 6th Decennial International Conference on Solidification Processing, Ed. Z. Fan, Brunel University London, 2017, pp. 56-60.
- 10 Z.P. Que, Y.P. Zhou, Y. Wang, Z. Fan: Composition templating for heterogeneous nucleation of intermetallic compounds, Proceedings of the 6th Decennial International Conference on Solidification Processing, Ed. Z. Fan, Brunel University London, 2017, pp. 158-161.

Research Theme 2: Understanding grain initiation and grain refinement during solidification

Z. Fan, H.B. Nadendla, H. Assadi, P.S. Grant, C.M. Gourlay, F. Gao, B. Jiang, Z.P. Que, S.Z. Lu, Y. Wang, G. Peng, H.T. Li, J. Xia, E. Liotti and G. Zeng

Aims and key objectives

- To understand the grain initiation behaviour during solidification as a function of size and size distribution of nucleant particles, alloy composition and solidification conditions;
- To understand the interaction between heterogeneous nucleation and grain initiation and its consequences on grain refinement;
- To understand the mechanisms for heterogeneous nucleation and grain refinement by native oxide particles;
- To understand competition for heterogeneous nucleation between different types of nucleant particles and its consequences on grain refinement;
- To develop new approaches to grain refiner development;
- To develop new grain refiners for engineering applications.



2. Solidification behaviour of Mg-1Al alloys containing nucleant particles with varying nucleation undercooling (from 0.1 K to 1.4 K).

(a) Calculated grain initiation rate as a function of time. (b) Calculated grain initiation map. (c) Calculated grain refinement map.

The nucleant particles are assumed to have a number density of 10^{17} m^{-3} and a log-normal size distribution ($d_0 = 0.07 \text{ }\mu\text{m}$ and $\sigma = 0.45$).

Summary of key progress

- 1 We have pioneered the concepts of progressive grain initiation (PGI) and explosive grain initiation (EGI) and their consequences on grain refinement.
- 2 We have developed the concepts of grain initiation maps and grain refinement maps to map grain initiation and grain refinement behaviour as functions of the physical nature of nucleating particles, alloy composition and solidification conditions.
- 3 We have identified a new approach to grain refinement, i.e., more significant grain refinement can be achieved by delaying heterogeneous nucleation rather than promoting it. This is in direct contrast to the conventional grain refinement theory.
- 4 We have developed a universally applicable approach to grain refinement: dispersing the native oxide particles by high shear melt processing either prior to or during solidification processing.
- 5 We have found that intensive melt shearing either prior to or during solidification processing can achieve effective grain refinement without the need of grain refiner addition.
- 6 We have developed an Al-Nb-B based grain refiner for grain refining of Al-Si based alloys, which cannot be grain refined by the currently available Al-Ti-B based grain refiners due to the Si-poisoning effect. The new grain refiner has been licenced to industry for commercial production.
- 7 We have expanded liquid metal engineering approaches developed for Mg- and Al-alloys to electronic solder joints. We have developed new approaches to the grain refinement of solders and a method to harness heterogeneous nucleation to control tin orientations in electronic interconnections.

Potential long-term impact:

- Over the last 70 years, for grain refinement the community has been searching for solid particles that can promote heterogeneous nucleation by decreasing the nucleation undercooling. Our research suggests that for more significant grain refinement we need to go in the opposite direction, i.e., delaying heterogeneous nucleation by increasing the nucleation undercooling.
- One of the major implications from our research is that, once appropriately dispersed, the native solid particles in alloy melts are adequate for grain refinement of any light alloys, suggesting that we do not need the addition of any grain refiner for grain refinement. This may change the industrial practice for metal casting forever.

Selected impacts:

- 1 Charles Hatchett Medal: H.B. Nadendla, for the development of Al-Nb based grain refiners, IOM3, London, 2016.
- 2 Charles Hatchett 2016 Lecture: H.B. Nadendla, Niobium for Aluminium Cast Parts in Automotive Components, the Royal Society of Chemistry, London, 13 July 2016.
- 3 Plenary lecture: Z. Fan, Heterogeneous nucleation, grain initiation and grain refinement of Mg-alloys, the 11th International Conference on Magnesium Alloys and Their Applications (Mg18), Old Windsor, UK, 24-27 July 2018.
- 4 Plenary lecture: Z. Fan, A new framework for understanding heterogeneous nucleation and grain refinement, the 6th Decennial International Conference on Solidification Processing (SP17), Old Windsor, UK, 25-28 July 2017.
- 5 Invited lecture: Y. Wang, Effect of interfacial segregation on heterogeneous nucleation, the 6th Decennial International Conference on Solidification Processing (SP17), Old Windsor, UK, 25-28 July 2017.
- 6 Invited lecture: P.S. Grant, The dynamics of nucleation and growth in solidifying alloys studied by X-ray radiography and automated computer vision, the 7th International Conference on Solidification Science and Processing (ICSSP-7), Trivandrum, India, 19-22 November 2018.
- 7 Invited lecture: C.M. Gourlay, Heterogeneous nucleation mechanism in solder joints, the 6th Decennial International Conference on Solidification Processing (SP17), Old Windsor, UK, 25-28 July 2017.
- 8 Technology transfer: H.B. Nadendla, the patented Al-Nb-B grain refiner has been licensed to Norton Aluminium for production and supply of Al-Nb-B based grain refiners, 2017.
- 9 Best Paper Award: G. Zeng, C.M. Gourlay, TMS Light Metals Division Magnesium Technology Award, 2018.
- 10 Press attention: "Grain refiner breakthrough for magnesium alloys", Creamer Media's Engineering News, 8th April 2016.

Selected publications:

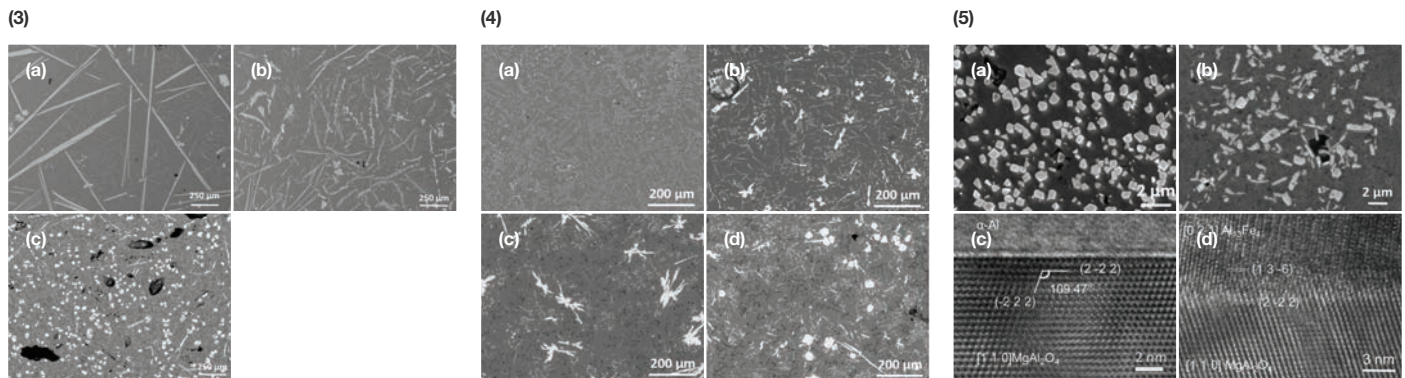
- 1 Z. Fan, F. Gao, L. Zhou, S.Z. Lu: A new concept for growth restriction during solidification, *Acta Materialia*, 152 (2018), 248-257.
- 2 G.S. Peng, Y. Wang, Z. Fan: Competitive heterogeneous nucleation between Zr and MgO particles in commercial purity magnesium, *Metallurgical and Materials Transactions A*, 49 (2018), 2182-2192.
- 3 L. Bolzoni, M. Xia, H.B. Nadendla: Formation of equiaxed crystal structures in directionally solidified Al-Si alloys using Nb-based heterogeneous nuclei, *Scientific Reports*, 6 (2016), 39554.
- 4 E. Liotti, S. Kumar, Z. Guo, C. Bi, T. Connolley, P.S. Grant: The spatial and temporal distribution of dendrite fragmentation in solidifying Al-Cu alloys under different conditions, *Acta Materialia*, 121 (2016), 384-395.
- 5 M.J. Balart, J.B. Patel, F. Gao, Z. Fan: Grain refinement of deoxidized copper, *Metallurgical and Materials Transactions A*, 47 (2016), 4988-5011.
- 6 E. Liotti, C. Arteta, A. Zisserman, A. Liu, V. Lmpitsky, P.S. Grant: Crystal nucleation in metallic alloys using x-ray radiography and machine learning, *Science Advances*, 4 (2018), eaar4004.
- 7 H. Shang, Z. Ma, S. Belyakov, C.M. Gourlay: Grain refinement of electric solders: the potential of combining solute with nucleant particles, *Journal of Alloys and Compounds*, 715 (2017), 471-485.
- 8 Y. Wang, G. Peng, Z. Fan: Grain refinement of Mg and its alloys by inoculation of in situ MgO particles, *Magnesium Technology 2017*, TMS, 2017, pp. 99-106.
- 9 B. Jiang, Z. Fan: Grain initiation: progressive vs. explosive, *Proceedings of the 6th Decennial International Conference on Solidification Processing*, Ed. Z. Fan, Brunel University London, 2017, pp. 61-65.
- 10 Z. Fan: Heterogeneous nucleation, grain initiation and grain refinement of Mg-alloys, *Proceedings of the 11th International Conference on Magnesium Alloys and Their Applications*, Eds. Z. Fan, C.L. Mendis, Brunel University Press, 2018, pp. 7-17.

Research Theme 3: Understanding the formation of Fe-containing intermetallic compounds (Fe-IMCs) during solidification

Z. Fan, A.M. Mullis, H.B. Nadendla, P.S. Grant, C.M. Gourlay, S. Ji, I.C. Stone, C.L. Mendis, X.R. Zhou, Z.P. Que, Y. Wang, C.M. Fang, J. Xia, H.T. Li, F. Gao, A. Dinsdale, P.C. Bollada, E. Liotti, G. Zeng, J. Yu and L. Zhou

Aims and key objectives

- To understand the nucleation behaviour of Fe-IMCs during solidification;
- To understand the effect of structural templating and compositional templating on heterogeneous nucleation of Fe-IMCs;
- To understand the growth behaviour of Fe-IMCs during solidification through both phase field modelling and in situ observation;
- Development of both chemical and physical approaches to the refinement of Fe-IMCs in the solidified microstructure.



3. Optical and scanning electron microscopy (SEM) images showing that different alloying elements segregated on one type of in situ oxide have different effects on the heterogeneous nucleation of Fe-IMCs: (a) Al₄Fe₈Si₁Mg alloy, with (b) 1000 ppm Zr, (c) 1000 ppm Y.

4. SEM images showing that the same alloying elements segregated on different in situ oxides have different effects on the heterogeneous nucleation of Fe-IMCs: (a) Al₄Fe₄Si alloy, with (b) 1000 ppm Y; and (c) Al₄Fe₄Si₂Mg alloy, with (d) 1000 ppm Y.

5. (a) SEM image showing the in situ MgAl₂O₄ particles in Al-Fe-Si-Mg alloy, (b) SEM image showing the in situ Al₂O₃ particles in Al-Fe-Si alloy, (c) the high resolution transmission electron microscopy (HRTEM) image of MgAl₂O₄ with the incident electron beam paralleled to <1 1 0> zone direction showing that this MgAl₂O₄ particle is faceted on {1 1 1} planes, (d) HRTEM image showing the MgAl₂O₄/Al₁₃Fe₄ interface with the incident electron beam paralleled to <1 1 0> of MgAl₂O₄ and [0 2 1] of Al₁₃Fe₄, revealing an orientation relationship (OR) between the oxide and Al₁₃Fe₄: (2 -2 2) MgAl₂O₄// (1 3 -6) Al₁₃Fe₄ and [1 1 0] MgAl₂O₄// 3.4° [0 2 1] Al₁₃Fe₄.

Summary of key progress

- 1 We have established the concepts of structural and compositional templating for heterogeneous nucleation of Fe-IMCs.
- 2 We have also developed practical approaches to provide both structural and compositional templating for heterogeneous nucleation of Fe-IMCs.
- 3 We have confirmed that heterogeneous nucleation of IMCs is inherently more difficult than that of simple solid solutions. We found that the nucleation undercooling for Fe-IMCs is tens of degrees while that for solid solutions is usually a fraction of a degree.
- 4 We have established the chemical and physical nature of elemental segregation of Fe (Mn), Ni, and Si at the TiB₂/Al interface. Such knowledge enables the manipulation of heterogeneous nucleation of IMCs.
- 5 We have established a clearer picture of the solidification sequence of Fe-containing Al-alloys as a function of alloy composition and solidification conditions.
- 6 We have developed a physical approach to control the size and spatial distribution of Fe-IMCs as second phase particles in DC cast Al-alloy billets.
- 7 We have developed a phase-field model for intermetallic compounds including faceted interface morphologies and expanded the phase-field model for IMCs to include arbitrary sub-lattice thermodynamic descriptions of the phases, including an anti-trapping current for use with sub-lattice phases.
- 8 We have built the understanding of intermetallic growth crystallography in AZ-series Mg alloys.
- 9 We have developed a method to observe in situ the formation of wFe-IMCs during solidification using synchrotron x-ray radiography.

Potential long-term impact:

Our research has the potential to fundamentally change the metals industry from the current primary metal based industrial configuration to a secondary metal based industrial configuration.

Selected impacts:

- 1 Invited lecture: A.M. Mullis, Simulation of intermetallic solidification using phase field techniques, the 7th International Conference on Solidification Science and Processing (ICSSP-7), Trivandrum, India, 19-22 November 2018.
- 2 Invited lecture: A.M. Mullis, Phase-field modelling of intermetallic solidification, TMS 2018, Phoenix, Arizona, USA, 11-15 March 2018.
- 3 Invited lecture: Z. Fan, Structural and compositional templating for heterogeneous nucleation, Frontiers in Solidification, TMS Symposium in Honor of Michel Rappaz, TMS, Nashville, USA, 15-17 February 2016.
- 4 Plenary lecture: Z. Fan, A new framework for understanding heterogeneous nucleation and grain refinement, the 6th Decennial International Conference on Solidification Processing (SP17), Old Windsor, UK, 25-28 July 2017.
- 5 Keynote lecture: C.M. Gourlay, Nucleation and growth of Al-Mn-(Fe) intermetallics in AZ91 alloy, International Conference on Magnesium (ICM-6), Shenyang, China, 23-26 September 2017.
- 6 Invited lecture: P.S. Grant, Synchrotron x-ray radiography measurement of intermetallic compound selection and growth during Al-alloy solidification, TMS 2017, San Diego, California, USA, 26 February-2 March 2017.
- 7 Invited lecture: P.S. Grant, The dynamics of nucleation and growth in solidifying alloys studied by X-ray radiography and automated computer vision, the 7th International Conference on Solidification Science and Processing (ICSSP-7), Trivandrum, India, 19-22 November 2018.
- 8 Plenary lecture: Z. Fan, An overview on recent advances in understanding early stages of solidification, the 7th International Conference on Solidification and Gravity (SolGrav-2018), Miskolc, Hungary, 3-7 September 2018.

Selected publications:

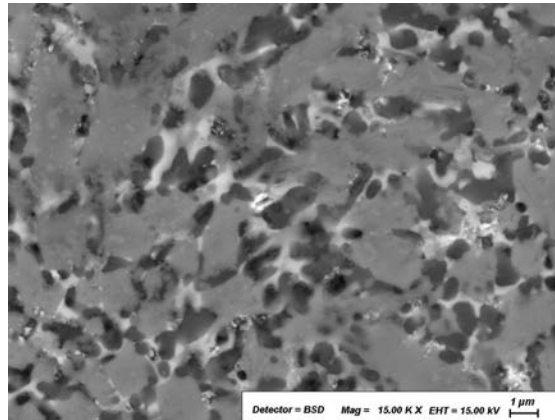
- 1 Z. Que, Y. Wang, Z. Fan: Formation of the Fe-containing intermetallic compounds during solidification of Al-5Mg-2Si-0.7 Mn-1.1 Fe alloy, *Metallurgical and Materials Transactions A*, 49 (2018), 2173-2181.
- 2 Z. Fan, Z.P. Que, Y. Wang, B. Jiang: Structural and compositional templating for heterogeneous nucleation, in *Frontiers in Solidification*, TMS Symposium in Honor of Michel Rappaz, Eds. W. Kurz et al, 2016, pp. 17-21.
- 3 C.M. Fang, A. Dinsdale, Z.P. Que, Z. Fan: Intrinsic defects in and electronic properties of θ -Al₁₃Fe₄: An ab initio DFT study, *Journal of Physics: Materials*, 2 (2019), 015004.
- 4 A.M. Mullis, P.C. Bollada, P.K. Jimack: Simulation of intermetallic solidification using phase field techniques, *Transactions of the Indian Institute of Metals*, 71 (2018), 2617-2622.
- 5 A.T. Dinsdale, C.M. Fang, Z. Fan, A.V. Khvan: The critical assessment of data for Al-Fe based intermetallic phases formed during solidification of aluminium alloys, *Proceedings of the 6th Decennial International Conference on Solidification Processing*, Ed. Z. Fan, Brunel University London, 2017, pp. 171-174.
- 6 J. Wang, X. Zhou, G.E. Thompson, J.A. Hunter, Y. Yuan: Microstructure evolution in the near-surface region during homogenization of a twin-roll cast AlFeMnSi Alloy, *Metallurgical and Materials Transactions A*, 47 (2016), 4268-4275.
- 7 P.C. Bollada, P.K. Jimack, A.M. Mullis: Faceted and dendritic morphology change in alloy solidification, *Computational Materials Science*, 144 (2018), 76-84.
- 8 G. Zeng, J.W. Xian, C.M. Gourlay: Nucleation and growth crystallography of Al₈Mn₅ on B2-Al(Mn,Fe) in AZ91 magnesium alloys, *Acta Materialia*, 153 (2018), 364-376.
- 9 C.B. Basak, H.B. Nadendla: Influence of Cu on modifying the beta phase and enhancing the mechanical properties of recycled Al-Si-Fe cast alloys, *Scientific Reports*, 7 (2017), 5779.
- 10 S. Feng, E. Liotti, S. Kumar, A. Mahadevegowda, K. O'Reilly, P.S. Grant: An in situ method to estimate the tip temperature of secondary Fe-rich intermetallics using synchrotron X-ray radiography, *Scripta Materialia*, 149 (2018), 44-48.

Research Theme 4: Development of closed-loop recyclable high performance light alloys

S. Ji, G.M. Scamans, I.T.H. Chang, H.B. Nadendla, C.L. Mendis, Z. Fan, F. Gao, X. Zhu, M. Rahimian, S. Amirkhanlou, S. Khorsand, G. Salloum-Abou-Jaoude, N. Hou, X. Dong, H. Yang, Y. Zhang, Q. Cai and U. Amin

Aims and key objectives

- To understand the mechanisms for high tolerance to impurities (i.e., variation of level of impurities without causing significant variation in mechanical properties);
- To develop the design principles for developing closed-loop recyclable high performance light alloys;
- To develop Al-alloys that have high strength and good ductility, are closed-loop recyclable and are suitable for high pressure die casting for automotive applications;
- To develop Al-alloys that have high strength at high temperature, are closed-loop recyclable and are suitable for high pressure die casting for automotive applications;
- To develop Al-alloys that have high modulus, are closed-loop recyclable and are suitable for automotive applications;
- To develop wrought Al-alloys that have high strength, high ductility, high thermal conductivity and good extrudability and are closed-loop recyclable and suitable for automotive applications.



6. The microstructure of a multi-component eutectic alloy (Al-Cu-Mg-Si-Ni-Mn-Fe-Ag-Sn-Zr-Ca-Ti-Zn) showing a fine and uniformly distributed multi-phase mixture.

Summary of key progress

- 1 We have successfully developed an Al-Mg-Si based HPDC alloy with high strength and acceptable ductility for both automotive and aerospace applications. This alloy has now been patented and licensed to an industrial company for production and supply of arm-rests for civil aircraft seats.
- 2 We have developed a high strength high ductility Al-alloy (DB1 alloys) for low pressure die casting of automotive chassis components through the leveraged LEAAST project funded by Innovate UK. BCAST and Sarginsons (industrial collaborator) were awarded the 2017 Innovation Award by CMF for the development of the DB1 alloy.
- 3 We have developed a high modulus Al-TiB₂ based alloy for automotive applications. This alloy provides a modulus of 94 GPa, representing a 30% increase in modulus.
- 4 We have developed a high temperature Al-alloy for automotive powertrain applications. Compared with the base alloy, the new alloy has a ten-fold increase in fatigue life at 200 °C.
- 5 We have further developed the HSA6 alloy (a high strength 6xxx Al-alloy) to provide improved strength, increased crash worthiness and high thermal conductivity for electric vehicle applications. This was the foundation for the STEP AI Prosperity Partnership project (£4.4M) funded by the EPSRC and Constellium in 2018.
- 6 We have developed an effective process for recycling of A20X alloy for aerospace applications. This has led to a significant research grant from Aeromet for further development of this process (in progress).

Potential long-term impact:

Our research has the potential to fundamentally change the metals industry from the current primary metal based industrial configuration to a secondary metal based industrial configuration.

Selected impacts:

- 1 Cast Metals Federation 2017 Innovation Award: S. Ji, X. Dong, for the development of a high strength and high ductility aluminium alloy, 2017.
- 2 Frank Fitzgerald Medal and Travel Award: A. Valizadeh, Institute of Materials, Minerals and Mining (IOM3), 2018.
- 3 C.L. Mendis: Outstanding Reviewer Award, Journal of Alloys and Compounds, 2018.
- 4 S. Ji, Z. Fan, D. Watson: patent, A super ductile die cast aluminium alloy, UK patent application No, 1205655.2, 2016.
- 5 S. Ji, Z. Fan: A Casting Al-Mg-Zn-Si based aluminium alloy for improved mechanical performance, patent, WO 2016034857 A4, 2016.
- 6 I.T.H. Chang, Z. Fan, Q. Cai: patent, A recycle-friendly high strength cast Al-alloy, UK patent application under preparation, 2019.
- 7 Plenary lecture: Z. Fan, Casting a brighter future for Magnesium in the next 20 years, International Conference on Magnesium (ICM-6), Shenyang, China, 23-26 September 2017.
- 8 Invited lecture: I.T.H. Chang, Mapping of phase field of FCC solid solution on CoCrFeMnNi high entropy alloy using diffusion couple approach, the 1st International Conference on High-Entropy Materials, Taiwan, 6-9 November 2016.
- 9 Press attention: "Novel research on cast aluminium products wins international award", Aluminium International Today, 17 August 2016.
- 10 Press attention: "Impressive project from start to finish", Foundry, 2018.

Selected publications:

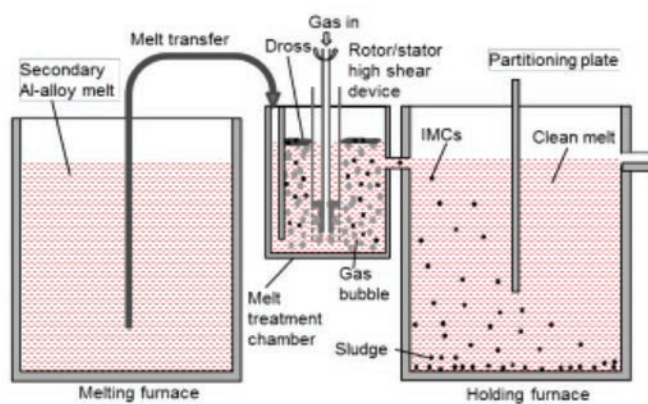
- 1 S. Amirkhanlou, S. Ji, Y. Zhang, D. Watson, Z. Fan: High modulus AlSiMgCu/Mg₂SiTiB₂ hybrid nanocomposite: Microstructural characteristics and micromechanics-based analysis, Journal of Alloys and Compounds, 694 (2017), 313-324.
- 2 I.T.H. Chang, Q. Cai, X. Zhu, Y. Zhang, F. Gao, Z. Fan: Refinement of eutectic microstructure in quaternary Al-Cu-Si-Mg alloys, Proceedings of the 6th Decennial International Conference on Solidification Processing, Ed. Z. Fan, Brunel University London, 2017, pp. 406-409.
- 3 M. Rahimian, S. Ji, P. Blake, D. Watson, Z. Fan: Microstructural transition and elevated temperature tensile properties of modified Al-Si-Cu-Mg alloys, Light Metals 2017, 2017, pp. 419-425.
- 4 S. Amirkhanlou, Y. Zhang, S. Ji, Z. Fan: Young's modulus of Al-Si-Mg-Cu based alloy under different heat treatment processes, Light Metals 2017, 2017, pp. 335-342.
- 5 Y. Zhang, S. Ji, Z. Fan: Improvement of mechanical properties of Al-Si alloy with effective grain refinement by in-situ integrated Al₂TiB-Mg refiner, Journal of Alloys and Compounds, 710 (2017), 166-171.
- 6 S. Ji, F. Yan, Z. Fan: A high strength aluminium alloy for high pressure die casting, Light Metals 2016, 2016, pp. 207-210.
- 7 X. Dong, Y. Zhang, S. Ji: Enhancement of mechanical properties of high silicon gravity die cast Al-Si-Mg alloys refined by Al-3Ti-3B master alloy, Materials Science Engineering A, 700 (2017), 291-300.
- 8 M. Rahimian, S. Amirkhanlou, P. Blake, S. Ji: Nanoscale Zr-containing precipitates: a solution for significant improvement of high temperature strength in Al-Si-Cu-Mg alloys, Materials Science Engineering A, 721 (2018), 328-338.
- 9 X. Dong, H. Yang, X. Zhu, S. Ji: High strength and ductility aluminium alloy processed by high pressure die casting, Journal of Alloys and Compounds, 773 (2019), 86-96.
- 10 X. Zhu, P. Blake, K. Dou, S. Ji: Strengthening Al-Mg and Al-Mg-Mn alloys with Fe as a beneficial element, Materials Science Engineering A, 732 (2018), 240-250.

Research Theme 5: Development of the multi-purpose high shear technology and its application to metal casting processes

Z. Fan, G.M. Scamans, S. Ji, I.C. Stone, H. Assadi, D.G. Eskin, H.B. Nadendla, C.L. Mendis, Y. Huang, J.B. Patel, H.T. Li, Y. Zhang, J. Lazaro-Nebreda, X. Yang, N.S. Barekar, K. Al-Helal, G.S.B. Lebon and K. Dou

Aims and key objectives

- To develop the multi-purpose high shear technology for melt conditioning prior to metal casting;
- To develop an effective melt purification process for converting scrap aluminium into high performance engineering alloys;
- To develop the melt-conditioned direct chill (MC-DC) casting process for high quality wrought alloy billets;
- To develop the melt-conditioned twin roll casting (MC-TRC) process for high quality light alloy sheets;
- To develop the melt-conditioned high pressure die casting (MC-HPDC) process for high quality light alloy components.



7. Schematic illustration of the multi-purpose high shear melt conditioning technology for efficient melt cleanliness and enhanced casting performance.



8. Recovery and recycling of secondary aluminium scrap by HSMC with greater tolerance to impurity elements.

Summary of key progress

- 1 We have developed a multi-purpose high shear technology for melt conditioning prior to metal casting. It has been confirmed that high shear melt conditioning can lead to degassing, de-drossing, de-ironing and dispersing solid particles and gas bubbles.
- 2 Application of the high shear melt conditioning technology to recycling has led to the successful development of an effective melt purification process for converting scrap aluminium into high performance engineering alloys.
- 3 We have successfully developed the melt-conditioned direct chill (MC-DC) casting process for high quality wrought alloy billets. The MC-DC casting process can deliver grain refinement without grain refiner addition and can eliminate the conventional energy intensive homogenisation process prior to extrusion. This technology has been patented and licensed to an industrial company for billet production.
- 4 We have successfully developed a melt-conditioned twin roll casting (MC-TRC) process for high quality light alloy sheets. The MC-TRC process has overcome the long-standing problem of centreline segregation and provides TRC strip with fine and uniform microstructure. It has been demonstrated that MC-TRC Mg-alloy strip can be directly stamped without any prior thermomechanical processing. This process is currently under industrial trials with our industrial partners.
- 5 We have also successfully developed a melt-conditioned high pressure die casting (MC-HPDC) process for high quality light alloy components. It has been confirmed that the MC-HPDC process is capable of producing components with significantly reduced performance variation, which has been a long-standing challenge facing the die casting industry.

Potential long-term impact:

This research has the long-term potential to deliver a brand new metal casting industry, which is simplified, more optimised, more resource efficient and environmentally friendly.

Selected impacts:

- 1 Patent: Z. Fan, S. Ji, I.C. Stone: Purifying alloy melts, WO 2016146980 A1, 2016.
- 2 Technology transfer: The patented MC-DC casting technology has been licensed to MEL (UK) for commercial production and supply of high quality magnesium billets.
- 3 Industrial trials: The patented MC-DC casting technology is under industrial trials with Constellium (UK), Arconic (USA) and Chinalco (China); the patented MC-TRC technology with Federal Mogul (USA) and VW (Germany).
- 4 Invited lecture: J.B. Patel, Development of the multi-purpose high shear mixing technology for continuous processing of Al- and Mg-alloys, the 6th Decennial International Conference on Solidification Processing (SP17), Old Windsor, UK, 25-28 July 2017.
- 5 Plenary lecture: Z. Fan, Casting a brighter future for magnesium in the next 20 years, the 6th International Conference on Magnesium, Shenyang, China, 23-26 September 2017.
- 6 Keynote lecture: S. Ji, Lightweight materials for high pressure die castings in automotive applications, International Conference on Materials Science and Environment Protection (MSEP2017), Wuhan, China, 24-26 March 2017.
- 7 Keynote lecture: H.B. Nadendla, Advances in development of grain refiner for high performance lightweight Al-Si castings, International Conference on Materials, Minerals and Energy, (PMME2016), Ongole, India, 29-30 July 2016.
- 8 Invited lecture: G.M. Scamans: Removing iron from aluminium using high shear melt processing, Workshop of European Aluminium's Innovation Hub, Aachen, Germany, 21 June 2017.
- 9 Press attention: "Academic research into casting is helping vehicle-makers and their suppliers to bridge a knowledge gap", Automotive Manufacturing Solutions, 25 May 2016.
- 10 Press attention: "Headline News Brunel University unveils new metal processing centre", The Manufacturer, 18 June 2018.

Selected publications:

- 1 J.B. Patel, X. Yang, C.L. Mendis, Z. Fan: Melt conditioning of light metals by application of high shear for improved microstructure and defect control, *Journal of Metals*, 69 (2017), 1071-1076.
- 2 X. Yang, Y. Huang, N.S. Barekar, S. Das, I.C. Stone, Z. Fan: High shear dispersion technology prior to twin roll casting for high performance magnesium/SiCp metal matrix composite strip fabrication, *Composites Part A: Applied Science and Manufacturing*, 90 (2016), 349-358.
- 3 M. Tong, J.B. Patel, I.C. Stone, Z. Fan, D.V. Browne: Identification of key liquid metal flow features in the physical conditioning of molten aluminium alloy with high shear processing, *Computational Materials Science*, 131 (2017), 35-43.
- 4 H.T. Li, P. Zhao, R. Yang, J.B. Patel, X. Chen, Z. Fan: Grain refinement and improvement of solidification defects in direct-chill cast billets of A4032 alloy by melt conditioning, *Metallurgical and Materials Transactions B*, 48 (2017), 2481-2492.
- 5 N.S. Barekar, S. Das, X. Yang, Y. Huang, O.E. Fakir, A.G. Bhagurkar, L. Zhou, Z. Fan: The impact of melt conditioning on microstructure, texture and ductility of twin roll cast aluminium alloy strips, *Materials Science and Engineering: A* 650 (2016), 365-373.
- 6 E. Lordan, J. Lazaro-Nebreda, Y. Zhang, Z. Fan: Effective degassing for reduced variability in high-pressure die casting performance, *Journal of Metals*, 71 (2018) 824-830.
- 7 K. Al-Helal, J.B. Patel, Z. Fan: Melt conditioning twin roll casting with thermo-mechanical treatment of recycled AA6111 alloy, *Journal of Metals*, (2018), 1-8.
- 8 Y. Zhang, J.B. Patel, J. Lazaro-Nebreda, Z. Fan: Improved defect control and mechanical property variation in high-pressure die casting of A380 alloy by high shear melt conditioning, *Journal of Metals*, 70 (2018), 2726-2730.
- 9 Y. Zhang, S. Wang, E. Lordan, Y. Wang, Z. Fan: Improved mechanical properties of high pressure die cast Al9Si3Cu alloy via dislocation enhanced precipitation, *Journal of Alloys and Compounds*, 785 (2019), 1015-1022.
- 10 Y. Zhang, J.B. Patel, Y. Wang, Z. Fan: Variation improvement of mechanical properties of Mg-9Al-1Zn alloy with melt conditioned high pressure die casting, *Materials Characterization*, 144 (2018), 498-504.

Research Theme 6: Realising the impact of LiME Hub research through industrial collaborative research projects

G.M. Scamans, Z. Fan, S. Ji, I.C. Stone, Y. Huang, B. McKay, D.G. Eskin, H.B. Nadendla, I.T.H. Chang, H. Assadi, C.L. Mendis, J.B. Patel, H.T. Li, Y. Zhang, X. Yang, N. Barekar, N. Hou, X. Zhu, M. Rahimian, S. Amir Khanlou, J. Lazaro-Nebreda, E. Karakulak, T. Li, Z. Niu, K. Al-Helal, I. Anza, D. Liu, E. Bagherpour, Z. Li, A. Prabakar, S. Nammi, L. Hinton and A. Miranda

Aims and key objectives

- To maximise the impact of the Hub's research outputs to realise the full potential economic benefit to the UK economy;
- To scale up the technology concepts developed by the Hub research team to higher technology readiness levels (TRLs);
- To strengthen the R&D capability of the automotive supply chain through government funded industrial collaborative projects;
- Promote knowledge exchange between industry and academia.



9. Carbon aluminium automotive hybrid structures (CAAHS) structure developed using BCAST's casting and processing facilities.

Summary of key progress

- 1 Establishing industrial research fellowships co-funded by the Hub and industry.** This mechanism is particularly suitable for supporting companies with medium and long-term challenges. So far, we have set up 6 industrial research fellowships: 3 with JLR, 2 with Constellium and 1 with Sapa. Establishment of industrial fellowships with Aeromet, Grainger and Worrall, MPQ and Chinalco is in progress.
- 2 Development of strategic industrial partnerships.** Based on a shared vision, we have been developing long-term strategic research partnerships with industrial companies. For example, Constellium co-funded an RA with the EPSRC Centre - LiME in 2011, founded the Constellium UTC at Brunel in 2016, established the Constellium R&D Centre for Automotive Structures at Brunel in 2018, and co-funded with EPSRC the STEP AI programme (£4.4M) under the Prosperity Partnership scheme in 2018.
- 3 Supporting industrial research through Innovate UK funded industry-led collaborative research projects.** Through such projects, we either scale-up the technology concepts developed by the Hub or deploy the Hub's expertise and facilities to support industrial research. Over the last 3 years, we have developed 9 such projects working with a large number of industrial companies.
- 4 Building "The LiME Technology Playground" as a platform to support industrial R&D.** This is the mechanism by which we make the Hub's expertise and facilities available to the wider manufacturing community, particularly to SMEs. It works in two distinct ways: (1) companies try out their ideas in the Hub using our expertise and/or facilities; and (2) companies work with us closely to generate new ideas. Both ways have proven to be effective by a number of successful cases.

Selected impacts:

- 1 Invited Lecture: G.M. Scamans, Upcycling end-of-life auto Al scrap into “new” sheet and other products, Metal Bulletin’s 25th International Recycled Aluminium Conference, Warsaw, Poland, November 2017.
- 2 Aluminium Industry Award: G.M. Scamans, for outstanding and sustained contribution to the development of the global aluminium industry, particularly aluminium recycling, Aluminium Federation, 2018.
- 3 Constellium Innovation Gold Award: G.M. Scamans, Z. Fan, for outstanding contributions to the development of the HSA6 alloy and their application in the automotive industry, Constellium, 2018.
- 4 Liddiard Memorial Lecture: G.M. Scamans, Aluminium from Cans to Cars: Recycling the Future, London Materials Society, IOM3, 3 May 2018.
- 5 Technology transfer: S. Ji, Z. Fan, The patented high strength HPDC Al-alloy was licensed to an industrial company for the production and supply of arm-rests for civil aircraft seats. 2016.
- 6 Technology transfer: Z. Fan et al, The patented MC-DC casting technology has been licensed to a UK company for commercial production of Mg-alloy billets, 2018.
- 7 Press attention: “Brunel unveils new metals processing centre”, Manufacturing Management, 22 June 2018.
- 8 Press attention: “University-industry partnership to accelerate aluminium component development”, Automotive Industry, USA, Issue May 2016.
- 9 Press attention: “Brunel team working to develop next-generation light, thin-walled aluminium die-cast parts”, Green Car Congress, 12 May 2017.
- 10 Press attention: “Novel research on cast aluminium products wins international award”, Aluminium International Today, 17 August 2016.

Industrial grant awards (May 2018 – September 2019):

- The Future Metallurgy Centre - AMCC III, Research England UKRPIF (£16M)
- STrain Enhanced Precipitation Aluminium-alloys (STEP Al), EPSRC and Constellium (£4.5M)
- Development of MC-DC Casting Technology for A6xxx Alloys, Shandong Huaya Alloy Materials (£150k)
- Lightweight Innovative Battery Enclosures using Recycled Aluminium Technologies (LIBERATE), Innovate UK (£500k)
- Protocols and Strategies for Extending the Useful Life of Major Capital Investments and Large Industrial Equipment (LEVEL-UP), European Commission (£610k)
- Aluminium Reduced Cost Hybrid Parts (ARCH), Innovate UK (£280k)
- Microstructural Characterization of 3xxx Heat Exchanger Material, Hydro Aluminium (£150k)



10. Jaguar iPace pictured behind aluminium ingots produced within the Innovate UK funded Recycled Aluminium Through Innovative Technology (REALITY) project.

Outreach

The Future LiME Hub has been full of outreach activities in the last year, with the following presenting some highlights.





Academic outreach



Professor Fan opening the Mg2018 conference.

The LIME Hub has, and continues to reach out to the wider academic community through extensive dissemination of its research outcomes, and through organising and participating in a range of knowledge transfer and community-building activities.

Mg2018

It was a great honour for the Future LiME Hub and BCASST to host and organise the 11th International Conference on Magnesium Alloys and Their Applications, Mg2018, which was held at the Beaumont Estate, Old Windsor, UK, on 24-27 July 2018, and chaired by the Hub Director, Professor Fan. Magnesium Alloys and Their Applications is the longest running conference series dedicated to the development of magnesium alloys and processes for structural and other applications. Mg2018 was an opportunity to bring together scientists, engineers and users from academia and industry to examine the recent developments and advances in both the established and emerging fields in magnesium, in relation to both the fundamental science and the application of magnesium alloys. Mg2018 also provided the opportunity for the Hub to showcase its own research and pioneering vision for magnesium on the international stage.

The week-long conference was attended by 222 delegates and featured 140 oral presentations. All presentations provided the opportunity to reflect on the magnesium research performed to date and consider research areas to focus on to make magnesium the material of choice in the future. Mg2018 also hosted the inaugural Karl Kainer Lecture, a new addition to the conference series. The Karl Kainer Lecture will be given by an individual who has made an outstanding contribution to the science and technology of magnesium alloys and their applications.

Hub attendance at international conferences

In 2018 and 2019 Hub members participated at numerous international conferences. As well as individual members attending meetings of specific interest, the Hub approaches key major conferences in a coordinated manner, to maximise reporting of research outcomes to the broadest possible audience. Members of the Hub attended and presented at the 5th International Conference on Advances in Solidification Processes (ICASP-5). This event took place in Salzburg, Austria, June 17-21, 2019, and was selected by the Hub for its importance in the solidification and casting community. The organisation committee recorded 220 registered participants and a total of 187 contributions. Among them, Hub members had a substantial impact with a total of 18 contributions (2 highlight talks, 12 oral presentations and 4 posters). Hub members also attended the 7th International Conference on Solidification and Gravity on 3-6 September 2018, in Miskolc - Lillafüred, Hungary. This conference was chosen for its focus on the investigation and simulation of a wide range of solidification processes. Hub members showcased key advances in the Hub's research by giving a total of 10 oral presentations, ranging from understanding the early stages of solidification to the effect of the high shear process on grain refinement.



Professor Hari Babu Nadendra with GIAN students at the National Institute of Technology Manipur.



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Global Initiative for Academic Networks

The Indian Government approved a new programme titled Global Initiative of Academic Networks (GIAN) in Higher Education aimed at utilising the international talent pool of scientists and entrepreneurs, to encourage their engagement with the institutes of Higher Education in India. Professor Hari Babu Nadendra, a Hub co-investigator, joined the GIAN programme and attended the National Institute of Technology Manipur, Manipur, India, on 23-29 December 2018. He delivered a one-week workshop on advanced metals and materials to 150 students, including second year undergraduates, PhDs and junior faculty academics.



Suwaree Chankitmongk presenting her PhD research at the Solidification and Gravity conference.

Forthcoming activities

In July 2019, the Hub launched a call for proposals for **feasibility studies** open to all UK academics eligible to apply for EPSRC grants, as a direct platform for the academic community to engage with the LiME Hub to address the grand challenges facing UK industry. The call encouraged proposals with radical ideas in the wider field of solidification science and technologies, covering a broad range of metallic materials (metals other than aluminium and magnesium) for applications in industries beyond the automotive sector. The feasibility studies will be carried out during the next year.

The Hub will host a **UK Solidification Workshop** on 24-25 October 2019, aiming to facilitate collaboration and knowledge transfer among solidification researchers in academia and industry. If you are interested in attending this event, please visit the following link: <https://www.lime.ac.uk/?portfolio=uk-solidification-workshop-2019>.

Industrial outreach

The Hub has a continuous and strategic approach to engaging with UK industry by leading and actively participating in workshops, forums and events; by roadmapping exercises; and by engaging new stakeholders through supporting industry-led projects that apply the Hub's research in new directions.

Aluminium Recycling Industry Workshop

In September 2019, the LiME Hub featured at the Aluminium Recycling Industry Workshop co-hosted by the Aluminium Federation (ALFED) and the Council for Aluminium in Building (CAB). The LiME Hub Deputy Director, Professor Geoff Scamans, contributed his recognised expertise in recycling of aluminium in the automotive sector, with which the Hub is already aligned, and sought to understand the requirements for recycling in the construction industry. A cross-mapping exercise identified that while there is a clear difference in the lifecycle of a car and that of a building, there is considerable synergy between the recycling requirements of the two sectors. Each shares the same end-of-life recycling goals and both are working towards closed-loop recycling. The Hub is aiming to develop strategic partnerships and collaborations with construction industry companies and their supply chains to broaden the impact of the Hub's closed-loop recycling research and technology development.

Other networking activities

The Deputy Director also represented the Hub at **Shaping the High-Level Collaborative R&D Programme for the Foundation Industries** workshop held by Innovate UK and UK Research & Innovation in September 2019. The first tranche of this funding will support feasibility studies, but all studies must be across at least two of the five materials sectors including metals. The Hub will raise awareness of these funding opportunities among its existing and potential new industrial stakeholders, to seek to broaden its sector alignment and its impact.

In December 2018, the High Value Manufacturing (HVM) Catapult hosted its second **UK Manufacturing Forum**, at which the LiME Hub was represented by the Hub Manager, Dr Mark Jones. The Forum including roadmapping activities and a discussion of the HVM Catapult 'Anchoring Innovation' programme. The LiME Hub is supporting the programme by providing case studies of key developments and supporting a deep review of the Catapult's strategic objectives.

Engaging new stakeholders through supporting industry-led research

Based on the LiME Hub's fundamental research, our partner Constellium has introduced innovative and ground-breaking high strength aluminium extrusion alloys for use in light-weight crash resistant vehicle structures such as crash management systems. The Hub is supporting two new projects – Aluminium for Ultra Low Emission Vehicles (AI-ULEV) and Lightweight Innovative Battery Enclosures using Recycled Aluminium TEchnologies (LIBERATE) – which both contribute to the acceleration towards zero emission vehicles through further development of this aluminium alloy technology to reduce the cost of battery enclosures and their

integration into vehicle structures. The AI alloy extrusions are 100% recyclable and can both form the protective structures and provide novel thermal management systems to control battery operating temperatures to precise levels.

Our partners in the AI-ULEV project are Constellium, Gordon Murray Design, and Innoval Technology, and the partners in the LIBERATE project are Constellium, BMW, Volvo, Impression Technologies, Grainger & Worrall, Innoval Technology, Warwick Manufacturing Group. These groupings include the engagement of OEMs new to the Hub's research outcomes and technology developments.

The AI-ULEV project is based on an extrusion intensive battery enclosure design whereas the LIBERATE project is based on the combined use of extrusions, sheet and castings, and a key component of both is the down-selection of joining technologies that can provide the required integrity aligned with mass-manufacture at low cost. Validation of the technology will be through Gordon Murray Design i-Stream vehicles in the AI-ULEV project and through BMW and Volvo vehicles in the LIBERATE project.

On completion of the projects there will be physical demonstrators, a report showing the emissions reduction the technology can achieve on implementation, a detailed system costing showing the commercial payback period, and performance results demonstrating the viability of the technology. The projects represent key steps to a full future UK supply chain and the technology has a clear route to market, with end customers and OEMs, and discussions are already in place with both the APC and the inward investment arm of the UK government.

The projects draw directly from the fundamental research within the LiME Hub on aluminium alloy casting, processing and property development, and its recycling technologies.

Forthcoming activities

The Hub will be hosting an **Aluminium in Aerospace Networking Event** to take place at Brunel University London on 28 November 2019. The purpose of this event is to explore opportunities to develop and exploit the alloys and processing technology under development in the Future LiME Hub for application in the aerospace industry, for example in more efficient lightweight wing structures using Near Net Shape (NNS) castings.

Analysis of the potential for synergy between the automotive and aerospace industries identified at the LiME Hub Convention (described in the next section) will be the platform for an **Automotive and Aerospace Workshop** to be hosted by the Hub, with the support of the Aerospace Technology Institute (ATI) and Advanced Propulsion Centre (APC) early next year.

For more information please
contact the LiME Team at
lime@brunel.ac.uk



Scrap aluminium from multiple sources.



The High Value Manufacturing Catapult roadmapping workshop.

Acting as a national Hub



Cameron Pleydell-Pearce introducing the EPSRC SUSTAIN Hub at the LiME Hub Convention.

As a national leader in Liquid Metal Engineering, the Hub influences and supports the national research agenda and innovation landscape, works with other centres and stakeholders, and drives forward public engagement.

Hub Convention

In August 2019, the Future LiME Hub hosted a Hub Convention. The LiME Hub brought together its own members, senior industry experts and senior members of other EPSRC critical mass programmes to discuss the UK's national metals-related research landscape. The opening session, dedicated to outlining the LiME Hub's fundamental research and technology developments, stimulated discussions on the requirements for alloy development from an aerospace and automotive perspective and the demands for recycling of scrap. In addition, it was recognised that there was an opportunity for the EPSRC SUSTAIN Hub (hosted by Swansea University) to take advantage of the LiME Hub's advances in nucleation theory by applying the same principles to steel, thus broadening the national impact of our research.

In the second session, presentations were given on behalf of the UK aerospace, automotive, and high value manufacturing sectors, each providing a current status and strategic view for the future. Clear overlaps emerged, and to take this forward, the LiME Hub will be leading, with the support of the Aerospace Technology Institute (ATI) and the Advanced Proposition Centre (APC), an **Aerospace and Automotive Workshop** scheduled for February 2020 to cross map materials and processing needs and to encourage cooperation between the two sectors.

The third and final session of the day consisted of presentations from other EPSRC critical mass programmes, with a discussion that followed identifying clear collaborative potential between the EPSRC LiME and Metrology Hubs and the EPSRC LightForm programme, including the potential for cross-programme supervision of PhDs.



John Forde presenting on behalf of the Aerospace Technology Institute at the LiME Hub Convention.

For more information
please contact the
LiME Team at
lime@brunel.ac.uk

Open day

In October 2018, the Hub and BCAST hosted an open day to showcase their solidification and casting research and the purpose of the Advanced Metals Casting Centre (AMCC) and Advanced Metals Processing Centre (AMPC) research scale up facilities. The audience were also informed about the strategic industrial collaborations with companies such as Jaguar Land Rover and Constellium, and the impact that support from major funding bodies (such as HEFCE/ Research England and Innovate UK) has had on strengthening collaboration and delivering impact. Professor Fan described the Hub's vision and the ambitious plans for the future. The AMCC and AMPC facilities were opened to visitors to understand further the innovative capabilities of the equipment.

Forthcoming activities

The Hub is working with the experts in the Brunel University London Science, Technology, Engineering, and Mathematics (STEM) Centre to develop new material for a Royal Institution approved workshop on sustainability and metals. The workshop will initially be targeted at year 9 students, and will be followed by a more advanced workshop for the Inspire Girls' summer school event aimed at female students who are making crucial choices on decisions for applications to UCAS. In the same vein, the Hub will be hosting an open day for school students which will include an accessible overview of the Hub's research and the importance of liquid metal engineering to the closed-loop economy, and be shown around the state-of-the-art laboratory and scale-up facilities.

The LiME Training Centre

During the 2018/2019 academic year, the Liquid Metal Engineering (LiME) Training Centre continued to deliver four intensive modules, covering the basic scientific knowledge on physical metallurgy, metal processing, materials characterisation, and materials and process modelling, taught to our PhD research students and postdoctoral research fellows who join us with varying academic backgrounds.



Professor Isaac Chang
Head of LiME Training Centre

This year, we organised a seminar entitled “Building in the good. ORBIT and the impact of technology on society” for our research students and fellows. It was delivered by Martin De Heaver from the Observatory for Responsible Research and Innovation in ICT (ORBIT) to introduce the responsible research innovation (RRI) concept and to provide examples of how to apply RRI principles to research. There are plans to review the existing taught modules and to develop more advanced courses. For example, we intend to consolidate the topic of solidification science/technology into a distinct in-depth module on solidification processing that will be directly relevant to all of the Hub’s researchers. In addition, three potential new modules have been identified for advanced research students and research fellows to be developed and delivered for future training activities. These will take the researchers to the forefront of current knowledge. The topics include Advanced Materials & Process Modelling, Advanced Materials Characterisation, Microstructural Evolution and Phase Transformation in the Solid State during Thermomechanical Processing.

A total of four PhD students have been recruited during the 2018-19 academic year. Two students are supported by Brunel University London and two students are sponsored by industrial companies including Jaguar Land Rover and Constellium. The research projects focus on both fundamental and applied aspects of physical metallurgy. They cover a wide range of topics, including big data analytics of thermomechanical processing of aluminium alloys, diffusion bonding and joining, high pressure die casting of aluminium alloys and high-resolution transmission electron microscopy of advanced automotive aluminium alloys.

PhD’s promote their work

Our PhD students have also been actively promoting their work at both student focused conferences, including the National Student Conference in Metallic Materials, held in Sheffield in July 2018 and at the Brunel University London Postgraduate Conference also held in July 2018, and at a number of international conferences.

Our students’ research has been recognised too. In particular, we congratulate PhD student AIREZA VALIZADEH who was awarded the IOM3 Frank Fitzgerald Medal and Travel Award in October 2018 for his research in developing an advanced bonding method to join aluminium and steel.

Creativity@home

In September 2018 the LiME Hub hosted the first of its Creativity@home workshops to focus on research efficiency and effectiveness. Working with an external facilitator, Hub members took part in a Belbin workshop. The Belbin Team Role theory characterises the behaviours of individuals and identifies strengths and weaknesses in relation to working in teams. Prior to the workshop, individuals completed an online survey to establish their lead Team Role type. The results were compiled into reports and presented to members at the workshop. The workshop provided Hub members with the opportunity to discover their own Belbin Team Role type(s) and gain an understanding of the Team Role type(s) of colleagues within their teams and the wider Hub more generally. This activity aimed to enhance individual team working, and to identify how to harmonise the Hub’s teams with one another.

After assessment of their Team Roles, each team was asked to present as a group how their team contributes to the Hub’s overall full metal circulation vision (illustrated in the Introduction to this report). This encouraged each of the teams and their members to consider how they can enhance the research efficiency and effectiveness of their team going forwards.



Dr Chamini Mendis delivering a taught module to LiME researchers.

For more information on the LiME Training Centre please contact Prof Isaac Chang Head of LiME Training Centre

isaac.chang@brunel.ac.uk
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PhD students at the National Student Conference in Metallic Materials.



Alireza Valizadeh being awarded the IOM3 Frank Fitzgerald Medal and Travel Award.



The Hub's alloy development team working on the Belbin Team Role activity at the Creativity@home workshop.

Prestige



Professor Geoff Scamans receiving the Gold Medal from the Institute of Materials, Minerals and Mining (IOM3).

Hub Deputy Director receives prestigious award

Professor Geoff Scamans, has been awarded the Gold Medal by The Institute of Materials, Minerals and Mining (IOM3). The IOM3's Gold Medal is a premier award presented to a company, team or individual who has made a significant contribution to the industrial application of materials. The award was presented at a gala dinner at the Science Museum in London on 11th July to mark the IOM3's 150th anniversary. The award recognises a remarkable record of internationally acclaimed, multidisciplinary research that spans several decades and every element of the materials cycle. The award acknowledges Geoff's tireless campaigning for sustainable manufacturing and the efficient use of materials, especially aluminium, which has developed into a core part of the Future LiME Hub's fundamental and applied programmes and has been inculcated in our vision of full metal circulation.

The award acknowledges that progress has been made towards the realisation of full metal circulation for metals like aluminium and magnesium and that this has been achieved through bringing together the joint efforts of academia, industry, government and society. This has enabled the LiME Hub to take a leadership role on behalf of the UK and this is reflected in the development of an extensive outreach programme. This is best exemplified through collaborative R&D programmes funded through Innovate UK of which the AI-ULEV and LIBERATE projects are the most recent examples. These collaborative projects span applications from transportation to construction, packaging and energy with a core theme of full metal circulation. These have delivered major technological advances, including the development of high-performance alloys with excellent mechanical properties and structural integrity that can be fabricated using 100% recycled content.

Prof Z. Fan

Chairman of the MPMD Symposium in Honour of David StJohn at TMS 2019, USA

Chairman of the 11th International Conference on Magnesium Alloys and Their Applications, 2018, UK

Member of International Scientific Committee, International Conference on Magnesium Alloys and Their Applications, since 2012

Member of International Scientific Committee, International Conference on Advanced Solidification Processes (ICASP), since 2011

Member of International Scientific Committee, International Light Metals Technology Conference (LMT), since 2011

Member of International Scientific Committee, International Conference on Solidification and Gravity (SolGrav), since 2008

Member of International Scientific Committee, International Conference on Solidification and Solidification Processing (ICSSP), since 2006

Member of International Scientific Committee, International Conference on Semisolid Processing of Alloys and Composites (S2P), since 2004

Prof G.M. Scamans

Gold Medal – IOM3 Awards 2019, Premier Awards

Prof I.T.H. Chang

Member of Editorial Board – Journal of Materials Chemistry and Physics

External Examiner- MSc course in Advanced Engineering Materials for School of Materials, University of Manchester

Dr Y. Huang

Committee Member – Global Congress on Advanced Ceramics and Composite Materials, Malaysia, 2019

Committee Member – 5th International Conference and Expo on Ceramics and Composite Materials, UK, 2019

Committee Member – 5th International Conference on Materials Science and Technology, Canada, 2019

Committee Member – 31st European Congress on Nanotechnology and Materials Engineering, Hungary, 2018

Editorship – Advances in Materials

Dr S. Ji

Member of Technical Committee, NFE035 Light Metals and Their Alloys, BSI International, UK, since 2017

Member of Technical Committee, ISO/TC 079/SC07 'Aluminium and Cast Aluminium Alloys', ISO, since 2017

Member of Technical Committee, ISO/TC 079/SC06 'Wrought Aluminium and Aluminium Alloys', ISO, since 2017

Member of Technical Committee, ISO/TC 079/SC05 'Magnesium and Alloys of Cast or Wrought Magnesium', ISO, since 2017

Member of Organising Committee, Materials Chemistry – 6th International Science and Chemistry Conference, since 2018

Dr C.L. Mendis

Committee Member – TMS Magnesium Committee 2019

2018 Outstanding Reviewer for Journal of Alloys and Compounds

Member of Technical Committee, TMS Mg, since 2007

Member of Awards Sub-Committee, TMS Mg, since 2018

Member of Publications Sub-Committee, TMS Mg, since 2017

Dr C.M. Gourlay

Rosenhain Medal and Prize – IOM3 Awards 2019, Awards for Personal Achievement

Member of the Board of Associate Editors, Journal of Crystal Growth, since 2015

Member of the Editorial Board, Journal of Materials Science: Materials in Electronics, since 2018

Organising Committee Member, Emerging Interconnect and Pb-free Materials for Advanced Packaging Technology Symposium, TMS Annual Meeting & Exhibition, 2018

Prof P.S. Grant

Promoted to Pro Vice Chancellor (Research), University of Oxford

Dr E. Liotti

Promoted to Lecturer in the Department of Materials, University of Oxford

Grant awards

Project	Investigator	Sponsor	Value (£)	Duration
Integrated Computational Process Engineering with Focus on Aluminium Extrusion	Zhongyun Fan	Constellium	£60,000	May 2018 – Apr 2022
Understanding the Role of Melt Conditioning and the Effect of Various Grain Refiners on the DC Cast Billet Microstructure and Subsequent Extrusion Product	Zhongyun Fan	Constellium	£27,765	July 2018 – June 2022
Development of MC-DC Casting Technology for A6xxx Alloys	Zhongyun Fan	Shandong Huaya Alloy Materials Co. Ltd.	£156,528	Aug 2018 – Apr 2020
Aluminium Reduced Cost Hybrid Parts (ARCH)	Shouxun Ji	Innovate UK	£277,915	Aug 2018 – Jan 2021
Sustainable Coatings by Rational Design	Xiaorong Zhou	EPSRC/AkzoNobel	£5,000,000	Nov 2018 – Oct 2023
STEP Aluminium (EPSRC)	Zhongyun Fan	EPSRC	£2,249,252	Dec 2018 – Nov 2023
STEP Aluminium (Constellium)	Zhongyun Fan	Constellium	£2,218,670	December 2018 – November 2023
Grain Refiner Technology for Lightweight Magnesium Alloys	Hari Babu Nadendla	Innovate UK	£31,872	Jan 2019 – Mar 2019
An Open Innovation Ecosystem for Upscaling Production Processes of Lightweight Metal Alloy Composites (LIGHTME)	Brian McKay	European Commission	£696,048	Jan 2019 – Jan 2023
ICASE Studentship – V de Stefano	Chamini Mendis	Constellium	£27,765	Feb 2019 – Jan 2023
NSIRC Studentship: M Khairy	Hari Babu Nadendla	TWI Ltd	£42,000	Mar 2019 – Mar 2022
Aluminium Alloy Development using TRC	Zhongyun Fan	Mahle Engine Systems UK Ltd	£15,948	June 2019 – July 2019
Lightweight Innovative Battery Enclosures using Recycled Aluminium Technologies (LIBERATE)	Zhongyun Fan	Innovate UK	£300,610	July 2019 – June 2021
Microstructural Characterization of 3xxx Heat Exchanger Material	Xiaorong Zhou	Hydro Aluminium	£150,000	Sept 2019 – Aug 2022
Protocols and Strategies for Extending the Useful Life of Major Capital Investments and Large Industrial Equipment (LEVEL-UP)	Isaac Chang	European Commission	£613,098	Oct 2019 – Sept 2023
The Future Metallurgy Centre – AMCC III	Zhongyun Fan	Research England	£16,000,000	Apr 2020 – Mar 2021
Non-Equilibrium Solidification, Modelling For Microstructure Engineering Of Industrial Alloys (NEQUISOL IV)	Andrew Mullis	European Space Agency (AO-2009-0829)	£442,538	Under contract negotiation

Invited lectures

Z. Fan, Invited Lecture, An Overview on Recent Advances in Understanding Early Stages of Solidification, 7th International Conference on Solidification and Gravity (SG18), Lillafüred, Hungary, September 2018

Z. Fan, Invited Lecture, Recent Advances in Understanding Heterogeneous Nucleation, Grain Initiation and Grain Refinement, 7th International Conference on Solidification Science and Processing (ICSSP-2018), Trivandrum, India, November 2018

Z. Fan, Plenary Lecture, Heterogeneous Nucleation, Grain Initiation and Grain Refinement of Mg-Alloys, 11th International Conference on Magnesium Alloys and Their Applications (Mg2018), Old Windsor, UK, July 2018

Y. Huang, Invited Lecture, A Revisit to Theories of Grain Boundary Migration and a New Approach to Solute Effect, 10th International Conference on Processing & Manufacturing of Advanced Materials Processing, Fabrication, Properties, Applications (THERMEC 2018), Paris, France, July 2018

S. Ji, Invited Lecture, Reinforcement of Nano-Particles in Aluminium Piston Alloys for Improved Properties at Elevated Temperatures, 6th International Conference on Nanomanufacturing (nanoMan2018), London, UK, July 2018

H.B. Nadendla, Invited Lecture, Effect of Varied Nb/B Ratio in Al-Nb-B Master Alloys on the Grain Refinement of Al-Si Alloys, X International Congress and Exhibition "Non-Ferrous Metals and Minerals", Krasnoyarsk, Russia, September 2018

C.M. Fang, Invited Lecture, Prenucleation on Oxide Particles in Al-And Mg-Alloys: An Ab Initio MD Study, 7th International Conference on Solidification Science and Processing (ICSSP-2018), Trivandrum, India, November 2018

H. Men, Invited Lecture, A Molecular Dynamics Study on Heterogeneous Nucleation, 7th International Conference on Solidification Science and Processing (ICSSP-2018), Trivandrum, India, November 2018

J.B. Patel, Invited Lecture, Developments in Application of High Shear Melt Conditioning (HSMC) Technology to Mg Alloys, 11th International Conference on Magnesium Alloys and Their Applications (Mg2018), Old Windsor, UK, July 2018

Y. Huang, Invited Lecture, Nano-crystalline and Ultrafine-grained Materials, 10th Pacific Rim International Conference on Advanced Materials and Processing (PRICM10), Xian, China, August 2019

Y. Huang, Invited Lecture, Deformation of a High Purity Magnesium Single Crystal In The C-axis (0001) Direction, 3rd Conference & Exhibition on Light Materials (LightMAT 2019), Manchester, UK, November 2019

G.M. Scamans, Invited Lecture, Continuous Casting of Aluminium Automotive Body Sheet, European Working Group Meeting on Aluminium Continuous Casting Technology, Düsseldorf, Germany, April 2019

G.M. Scamans, Invited Lecture, Automotive Body Sheet from End-of-Life Aluminium, CRU World Aluminium Conference 2019 "Sustainability and Recycling", London, UK, April 2019

G.M. Scamans, Invited Lecture, Aluminium Surfaces under the Knife, Symposium: "Past, Present and Future of Corrosion and Light Metal Surface Science", Trondheim, Norway, May 2019

G.M. Scamans, Invited Lecture, Aluminium from Cans to Cars - Forming the Future, Impression Technologies HFQ Partner Network Consultation Workshop, London, UK, June 2019

Y. Huang, Keynote Speaker, Characterization and Performance of Metal Matrix Particular Nanocomposites Fabricated by High Shear Solidification, 5th International Conference and Expo on Ceramics and Composite Materials, London, UK, June 2019

Z. Fan, Keynote Speaker, Recent Advances in Understanding Early Stages of Solidification, TMS 2019, An MPMD Symposium in Honor of David StJohn, Texas, USA, March 2019

H. Assadi, Keynote Speaker, Modelling of Materials Processes and Microstructures, 2018 International Conference on Materials Science and Manufacturing Engineering (MSME 2018), Paris, France, November 2018

H. Assadi, Invited Lecture, Modelling and Simulation of Cold Spray Deposition, 5th Cold Gas Spray Summer School 2019, Barcelona, Spain, June 2019

S. Ji, Keynote Speaker, Development of Al-Si-Cu-Mg Based Aluminium Alloys for Automotive Powertrain at Elevated Temperatures, 2019 International Conference on Metals and Alloys (CMA 2019), Beijing, China, August 2019

H.B. Nadendla, Invited Lecture, Processing and Properties of Infiltration and Grown Bulk MgB₂ Superconductor, 11th International Workshop on Processing and Applications of Superconducting Bulk Materials (PASREG 2019), Prague, Czech Republic, August 2019

S. Ji, Invited Lecture, An Overview on Stiffness Improvement of Cast Aluminium Systems, 9th International Light Metals Technology Conference (LMT2019), Shanghai, China, October 2019

A.M. Mullis, Invited Lecture, Development of an Anti-Trapping Current for Phase-Field Models using Arbitrary CALPHAD Thermodynamics, THERMEC' 2018, International Conference on Processing and Manufacture of Advanced Materials, Paris, France, July 2018

A.M. Mullis, Invited Lecture, Simulation of Intermetallic Solidification using Phase-Field Techniques, 7th International Conference on Solidification Science and Processing (ICSSP-2018), Trivandrum, India, November 2018

A.M. Mullis, Invited Lecture, Phase-field Modelling of Intermetallic Solidification, TMS 2018 147th Annual Meeting, Arizona, USA, March 2018

C.M. Gourlay, Invited Lecture, EBSD Studies of Intermetallic Growth in AZ91 Solidification, 11th International Conference on Magnesium Alloys and Their Applications (Mg2018), Old Windsor, UK, July 2018

P.S. Grant, Invited Lecture, The Nucleation of Intermetallic Compounds in a Model Al-Fe Alloy Studied by X-Ray Radiography, 7th International Conference on Solidification Science and Processing (ICSSP-2018), Trivandrum, India, November 2018

X. Zhou, Invited Lecture, The Combined Effect of Intermetallic Phases and Anodizing Parameters on the Integrity of Anodic Films on Aluminium Alloys, 3rd International Symposium on Anodizing Science and Technology (AST2019), Hyogo, Japan, June 2019

P.S. Grant, Invited Lecture, In situ Characterization of Dynamic Phenomena during Materials Synthesis, Materials Research Society Fall Meeting, Boston, USA, December 2019

P.S. Grant, Keynote Speaker, Solidification Processing of Light Metals and Alloys, TMS Annual Meeting, Texas, USA, March 2019

P.S. Grant, Plenary Lecture, 15th International Symposium Functionally Graded Materials, Kitakyushu, Japan, August 2018

P.S. Grant, Plenary Lecture, 9th International Conference on Advanced Materials and Processing (ICAMP-9), Shenyang, September China, 2018

P.S. Grant, Plenary Lecture, 7th International Conference on Solidification Science and Processing (ICSSP-2018), Trivandrum, India, 2018

P.S. Grant, Plenary Lecture, Royce Institute for Advanced Materials - Shaping the future, UK, 2018

C.M. Gourlay, Keynote Speaker, Nucleation and Growth Twinning in Al-Mn-Fe Intermetallic Solidification in Mg Alloys, 5th International Conference on Advances in Solidification Processes (ICASP5-CSSCR5), Salzburg, Austria, June 2019

C.M. Gourlay, Invited Lecture, Nucleation and Cyclic Twinning of Tin Droplets on Single Crystal Intermetallic Compounds, TMS Annual Meeting & Exhibition, Texas, USA, March 2019

C.M. Gourlay, Invited Lecture, Deformation and Defect Formation in Partially Solid Alloys, MPMD Symposium in Honor of David StJohn, TMS Annual Meeting & Exhibition, Texas, USA, March 2019

Publications

Peer Reviewed Journal Articles

M. Razavi, Y. Huang

A Magnesium-based Nanobiocomposite Processed by a Novel Technique Combining High Shear Solidification and Hot Extrusion
Recent Patents on Nanotechnology, 13 (2019), 38-48
DOI: 10.2174/1872210513666181231122808

J. Wang, H. Yang, Z. Liu, S. Ji, R. Li, J. Ruan

A Novel Fe₄₀Mn₄₀Cr₁₀Co₁₀/SiC Medium-Entropy Nanocomposite Reinforced by the Nanoparticles-Woven Architectural Structures
Journal of Alloys and Compounds, 772 (2019), 272-279
DOI: 10.1016/j.jallcom.2018.09.050

S. Amir Khanlou, S. Ji

A Review on High Stiffness Aluminium-Based Composites and Bimetallics
Critical Reviews in Solid State and Materials Sciences, (2019), 1-21
DOI: 10.1080/10408436.2018.1485550

W. Yang, S. Ji, R. Zhang, J. Zhang, L. Liu

Abnormal Grain Refinement Behaviour in High-Pressure Die Casting of Pure Mg with Addition of Zr as Grain Refiner
JOM, 70 (2018), 2555-2560
DOI: 10.1007/s11837-018-3087-6

C.M. Fang, Z. Fan

An Ab Initio Study on Stacking and Stability of TiAl₃ Phases
Computational Materials Science, 153 (2018), 309-314
DOI: 10.1016/j.commatsci.2018.07.011

X. Huang, X. Dong, L. Liu, P. Li

An Improved Modified Embedded-Atom Method Potential to Fit the Properties of Silicon at High Temperature
Computational Materials Science, 153 (2018), 251-257
DOI: 10.1016/j.commatsci.2018.07.001

M. Razavi, Y. Huang

Assessment of Magnesium-Based Biomaterials: From Bench to Clinic
Biomaterials Science, 7 (2019), 2241-2263
DOI: 10.1039/C9BM00289H

B. Jiang, H. Men, Z. Fan

Atomic Ordering in the Liquid Adjacent to an Atomically Rough Solid Surface
Computational Materials Science, 153 (2018), 73-81
DOI: 10.1016/j.commatsci.2018.06.00

S. Amir Khanlou, S. Ji

Casting Lightweight Stiff Aluminum Alloys: A Review
Critical Reviews in Solid State and Materials Sciences, (2019), 1-16
DOI: 10.1080/10408436.2018.1549975

B. McKay, A. Miranda

Characterization and Selection of MWCNTs for High Thermal Conductivity Applications
In preparation

C.M. Fang, H. Men, Z. Fan

Chemical Effect of Substrates on Prenucleation
Metallurgical and Materials Transactions A, 49A (2018), 6231-6241
DOI: 10.1007/s11661-018-4882-y

N. Liu, C. Chen, I. Chang, P. Zhou, X. Wang

Compositional Dependence of Phase Selection in CoCrCu_{0.1}FeMoNi-Based High-Entropy Alloys Materials (Basel, Switzerland), 11 (8) (2018), 1290
DOI: 10.3390/ma11081290

X. Zhang, X. Zhou, J. Nilsson, Z. Dong, C. Cai

Corrosion Behaviour of AA6082 Al-Mg-Si Alloy Extrusion: Recrystallized and Non-recrystallized Structures
Corrosion Science, 144 (2018), 163-171
DOI: 10.1016/j.corsci.2018.08.047

L. J. Yin, S.H. Zhang, H. Wang, X. Jian, X. Wang, X. Xu, M.Z. Liu and C.M. Fang

Direct Observation of Eu Atoms in AlN Lattice and the First-Principles Simulations
Journal of the American Ceramic Society, 102 (2019), 310-319
DOI: 10.1111/jace.15912

H. Hajipour, A. Abdollah-zadeh, H. Assadi, E. Taheri-Nassaj, H. Jahed Effect of Feedstock Powder Morphology on Cold-Sprayed Titanium Dioxide Coatings

Journal of Thermal Spray Technology, 27 (8) (2018), 1542-1550
DOI: 10.1007/s11666-018-0782-3

M.M. Moradi, H.J. Aval, R. Jamaati, S. Amir Khanlou, S. Ji

Effect Of SiC Nanoparticles on the Microstructure and Texture of Friction Stir Welded AA2024/AA6061
Materials Characterization, 152 (2019), 169-179
DOI: 10.1016/j.matchar.2019.04.020

X. Dong, X. Zhu, S. Ji

Effect of Super Vacuum Assisted High Pressure Die Casting on the Repeatability of Mechanical Properties of Al-Si-Mg-Mn Die-Cast Alloys
Journal of Materials Processing Technology, 266 (2019), 105-113
DOI: 10.1016/j.jmatprotec.2018.10.030

L. Li, S. Ji, Q. Zhu, Y. Wang, X. Dong, W. Yang, S. Midson, Y. Kang

Effect of Zn Concentration on the Microstructure and Mechanical Properties of Al-Mg-Si-Zn Alloys Processed by Gravity Die Casting
Metallurgical and Materials Transactions A, 49 (2018), 3247-3256
DOI: 10.1007/s11661-018-4684-2

E. Lordan, J. Lazaro-Nebreda, Y. Zhang, Z. Fan

Effective Degassing for Reduced Variability in High-Pressure Die Casting Performance
JOM 71 (2019) Issue 2, 824-830
DOI: 10.1007/s11837-018-3186-4

Q. Yuan, Y. Huang, D. Liu, M. Chen

Effects of Solidification Cooling Rate on the Corrosion Resistance of a Biodegradable β -TCP/Mg-Zn-Ca Composite
Bioelectrochemistry, 124 (2018), 93-104
DOI: 10.1016/j.bioelechem.2018.07.005

G. Liu, S. Khorsand, S. Ji

Electrochemical Corrosion Behaviour of Sn-Zn-xBi Alloys Used for Miniature Detonating Cords
Journal of Materials Science & Technology, 35 (2019), 1618-1628
DOI: 10.1016/j.jmst.2019.03.026

- Y. Wang, G.S.B. Lebon, I. Tzanakis, Y. Zhao, K. Wang, J. Stella, T. Poirier, G. Darut, H. Liao, M.P. Planche
Experimental and Numerical Investigation of Cavitation-Induced Erosion in Thermal Sprayed Single Splats
Ultrasonics Sonochemistry, 52 (2019), 336-343
DOI: 10.1016/j.ultsonch.2018.12.008
- O. Adole, N. Barekar, L. Anguilano, T. Minton, A. Novytskyi, B. McKay
Fibre/Matrix Intermetallic Phase Formation in Novel Aluminium-Basalt Composites
Materials Letters, 239 (2019), 128-131
DOI: 10.1016/j.matlet.2018.12.079
- Q. Cai, C.L. Mendis, F. Wang, I.T.H. Chang, Z. Fan
Formation of Nanoscale Anomalous Eutectic in Al-Cu-Si-Mg Quaternary Eutectic Alloy by Suction Casting
Scripta Materialia
Submitted
- X.X. Dong, S. Amirkhanlou, S. Ji
Formation of Strength Platform in Cast Al-Si-Mg-Cu Alloys
Scientific Reports, (2019)
DOI: 10.1038/s41598-019-46134-7
- D.G. Eskin, I. Tzanakis, F. Wang, G.S.B. Lebon, T. Subroto, K. Pericleous, J. Mi
Fundamental Studies of Ultrasonic Melt Processing
Ultrasonics Sonochemistry, 52 (2019), 455-67
DOI: 10.1016/j.ultsonch.2018.12.028
- X. Dong, H. Yang, X. Zhu, S. Ji
High Strength and Ductility Aluminium Alloy Processed by High Pressure Die Casting
Journal of Alloys and Compounds, 773 (2018), 86-96
DOI: 10.1016/j.jallcom.2018.09.260
- A.G. Bhagurkar, A. Yamamoto, L. Wang, M. Xia, A. R. Dennis, J.H. Durrell, T.A. Aljohani, H.B. Nadendla, D.A. Cardwell
High Trapped Fields in C-doped MgB₂ Bulk Superconductors Fabricated by Infiltration and Growth Process
Scientific reports, 8 (1) (2018), 13320
DOI: 10.1038/s41598-018-31416-3
- Y. Zhang, S. Wang, E. Lordan, Y. Wang, Z. Fan
Improve Mechanical Properties of High Pressure Die Cast Al₉Si₃Cu Alloy via Dislocation Enhanced Precipitation
Journal of Alloys and Compounds, 785 (2019), 1015-1022
DOI: 10.1016/j.jallcom.2019.01.278
- Y. Zhang, J.B. Patel, J. Lazaro-Nebreda, Z. Fan
Improved Defect Control and Mechanical Property Variation in High-Pressure Die Casting of A380 Alloy by High Shear Melt Conditioning
JOM, 70 (2018), 2726-2730
DOI: 10.1007/s11837-018-3005-y
- J. Xian, M. Mohd Salleh, S. Belyakov, T. Su, G. Zeng, K. Nogita, H. Yasuda, C.M. Gourlay
Influence of Ni on the Refinement and Twinning of Primary Cu₆Sn₅ in Sn-0.7Cu-0.05Ni
Intermetallics, 102 (2018), 34-45
DOI: 10.1016/j.intermet.2018.08.002
- J. Wang, H. Yang, H. Huang, J. Ruan, S. Ji
In-Situ Mo Nanoparticles Strengthened CoCrNi Medium Entropy Alloy
Journal of Alloys and Compounds, 798 (2019), 576-586
DOI: 10.1016/j.jallcom.2019.05.208
- C.M. Fang, A. Dinsdale, Z.P. Que, Z. Fan
Intrinsic defects in and electronic properties of θ -Al₁₃Fe₄: an ab initio DFT study
JPhys Materials, 2 (2019) 015004
DOI: 10.1088/2515-7639/aaf5d7
- G.S.B. Lebon, A. Dybalska, H. Assadi, H.T. Li, J.B. Patel, Z. Fan
Large Eddy Simulation of High-Shear Processing of Liquid Metals
Applied Mathematical Modelling
Submitted
- X.S. Huang, X.X. Dong, L.H. Liu, P.J. Li
Liquid Structure of Al-Si Alloy: A Molecular Dynamics Simulation
Journal of Non-Crystalline Solids 503-504 (2019), 182-185
DOI: 10.1016/j.jnoncrysol.2018.09.047
- P. Mair, N. Lauth, C.L. Mendis, M. Bechly, N. Hort
Mechanical and Corrosion Properties of Two Precipitation-Hardened Mg-Y-Nd-Gd-Dy Alloys with Small Changes in Chemical Composition
JOM, 71 (2019), 1426
DOI: 10.1007/s11837-019-03359-1
- Y. Wang, C.M. Fang, L. Zhou, T. Hashimoto, X. Zhou, Q.M. Ramasse, Z. Fan
Mechanism for Zr Poisoning of Al-Ti-B Based Grain Refiners
Acta Materialia, 164 (2019), 428-439
DOI: 10.1016/j.actamat.2018.10.056
- K. Al-Helal, J.B. Patel, Z. Fan
Melt Conditioning Twin Roll Casting with Thermo-Mechanical Treatment of Recycled AA6111 Alloy
JOM, 71 (5) (2019), 1714-1721
DOI: 10.1007/s11837-018-3189-1
- Y. Huang, J. Li, L. Zhou
Mg-3Zn-0.5Zr/HA Nanocomposites Fabricated by High Shear Solidification and Equal Channel Angular Extrusion
Materials Science and Technology, 34 (15) (2018), 1868-1879
DOI: 10.1080/02670836.2018.1495880
- J. Wang, H. Yang, J. Ruan, Y. Wang, S. Ji
Microstructure and Properties of CoCrNi Medium-Entropy Alloy Produced By Gas Atomization and Spark Plasma Sintering
Journal of Materials Research, 34 (12) (2019), 2126-2136
DOI: 10.1557/jmr.2019.96

- G. Liu, S. Ji
Microstructure, Dynamic Restoration and Recrystallization Texture of Sn-Cu after Rolling at Room Temperature
Materials Characterization, 150 (2019), 174-183
DOI: 10.1016/j.matchar.2019.02.032
- A. Miranda, N. Barekar, B.J. McKay
MWCNTs and Its Use in Al-MMCs for Ultra-High Thermal Conductivity Applications: A Review
Journal of Alloys and Compounds, 774 (2019), 820-840
DOI: 10.1016/j.jallcom.2018.09.202
- A. Khvan, D.G. Eskin, K. Starodub, A. Dinsdale, F. Wang, C.M. Fang, V. Cheverikin, M. Gorshenkov
New Insights into Solidification and Phase Equilibria in the Al- A_{13} Zr System: Theoretical and Experimental Investigations
Journal of Alloys and Compounds, 743 (2018), 626-638
DOI: 10.1016/j.jallcom.2018.02.023
- G.S.B. Lebon, G. Salloum-Abou-Jaoude, D.G. Eskin, I. Tzanakis, K. Pericleous, P. Jarry
Numerical Modelling of Acoustic Streaming During the Ultrasonic Melt Treatment of Direct-Chill (DC) Casting
Ultrasonics Sonochemistry, 54 (2019), 171-182
DOI: 10.1016/j.ultsonch.2019.02.002
- G.S.B. Lebon, H.T. Li, J.B. Patel, H. Assadi, Z. Fan
Numerical Modelling of Melt-Conditioned Direct-Chill Casting
Computational Materials Science
In press
- R.H. Buzolin, C.L. Mendis, D. Tolnai, E.P. da Silva, K.U. Kainer, N. Hort, H.C. Pinto,
On The Influence of Solution and Ageing Treatments on the Microstructure of ZK40 Alloys Modified with Ca, Gd, Nd and Y Additions
Practical Metallography, 55 (4) (2018), 268-287
DOI: 10.3139/147.110518
- J. Wang, P. Andrews, C. Butler, E. McAlpine, G.M. Scamans, X. Zhou
Optical Cleanliness Measurement Methods for Aluminium Sheet Surfaces
Surface and Interface Analysis, (2018), 1-10
DOI: 10.1002/sia.6566
- Q. Cai, C.L. Mendis, I.T.H. Chang, Z. Fan
Optimisation of Mechanical Properties of Al-Cu-Si-Mg Hypoeutectic Alloys through Control of Distribution of Ultrafine Eutectic Network
JOM
Submitted
- I. Fartushna, M. Mardani, A. Khvan, V. Cheverikin, D. Ivanov, A. Kondratiev, and A. Dinsdale
Phase Equilibria in the Ce-Co-Fe-System at 900 °C
Journal of Alloys and Compounds, 756 (2018), 644-649
DOI: 10.1016/j.jallcom.2018.06.261
- P. Maier, M. Bechly, C.L. Mendis, N. Hort
Precipitation Hardening on Mechanical and Corrosion Properties of Extruded Mg10Gd Modified with Nd and La
Metals, 8 (8) (2018), 640
DOI: 10.3390/met8080640
- C.M. Fang, Z. Fan
Prenucleation at the Interface between MgO and Liquid Magnesium: An Ab Initio Molecular Dynamics Study
Metallurgical and Materials Transactions A
Submitted
- G. Lin, D. Liu, M. Chen, C. You, Z. Li, Y. Wang, W. Li
Preparation and Characterization of Biodegradable Mg-Zn-Ca/MgO Nanocomposites for Biomedical Applications
Materials Characterization, 144 (2018), 120-130
DOI: 10.1016/j.matchar.2018.06.028
- A.T. Miranda, L. Bolzoni, N. Barekar, Y. Huang, J. Shin, S.H. Ko, B.J. McKay
Processing, Structure and Thermal Conductivity Correlation in Carbon Fibre Reinforced Aluminium Metal Matrix Composites
Materials & Design, 156 (2018), 329-339
DOI: 10.1016/j.matdes.2018.06.059
- Y. Zhang, S. Amirkhanlou, S. Ji
Reinforcement of TiB₂ Nanoparticles in Aluminium Piston Alloys for High Performance at Elevated Temperature
Nanomanufacturing and Metrology, 1 (4) (2018), 248-251
DOI: 10.1007/s41871-018-0027-6
- X. Zhu, P. Blake, K. Dou, S. Ji
Strengthening Die-Cast Al-Mg and Al-Mg-Mn Alloys with Fe as a Beneficial Element
Materials Science and Engineering A, 732 (2018), 240-250
DOI: 10.1016/j.msea.2018.07.005
- R.A. Seraj, A. Abdollah-zadeh, S. Dosta, H. Canales, H. Assadi, I.G. Cano
The Effect of Traverse Speed on Deposition Efficiency of Cold Sprayed Stellite 21
Surface and Coatings Technology, 366 (2019), 24-34
DOI: 10.1016/j.surfcoat.2019.03.012
- X. Zhu, H. Yang, X. Dong, S. Ji
The Effects of Varying Mg and Si Levels on the Microstructural Inhomogeneity and Eutectic Mg₂Si Morphology in Die-Cast Al-Mg-Si Alloys
Journal of Materials Science, 54 (7) (2019), 5773-5787
DOI: 10.1007/s10853-018-03198-6
- X. Zhu, P. Blake, S. Ji
The Formation Mechanism of Al₆(Fe, Mn) Phase in Die-Cast Al-Mg Alloys
CrystEngComm, 20 (27) (2018), 3839-3848
DOI: 10.1039/C8CE00675J

- R. Nikbakht, S.H. Seyedein, S. Kheirandish, H. Assadi, B. Jodoin
The Role of Deposition Sequence in Cold Spraying of Dissimilar Materials
Surface and Coatings Technology, 367 (2019), 75-85
DOI: 10.1016/j.surfcoat.2019.03.065
- H. van Gog, W.F. Li, C.M. Fang, R.S. Koster, M. Dijkstra, M.A. van Huis
Thermal Stability and Electronic and Magnetic Properties of Atomically Thin 2D Transition Metal Oxides
NPJ 2D Materials and Applications (Nature), 3 (18) (2019)
DOI: 10.1038/s41699-019-0100-z
- K. Al-Helal, I.T.H. Chang, J.B. Patel, Z. Fan
Thermomechanical Treatment of High-Shear Melt-Conditioned Twin-Roll Cast Strip of Recycled AA5754 Alloy
JOM, 71 (6) (2019), 2018-2024
DOI: 10.1007/s11837-018-3190-8
- X. Yang, J.B. Patel, Y. Huang, C.L. Mendis, Z. Fan
Towards Directly Formable Thin Gauge AZ31 Mg Alloy Sheet Production by Melt Conditioned Twin Roll Casting
Materials and Design, 179 (2019), 107887
DOI: 10.1016/j.matdes.2019.107887
- G.S.B. Lebon, I. Tzanakis, K. Pericleous, D.G. Eskin, P.S. Grant
Ultrasonic Liquid Metal Processing: The Essential Role of Cavitation Bubbles in Controlling Acoustic Streaming
Ultrasonics Sonochemistry, 55 (2019), 243-255
DOI: 10.1016/j.ultsonch.2019.01.021
- A. Dinsdale, C.M. Fang, Z.P. Que, Z. Fan
Understanding the Thermodynamics and Crystal Structure of Complex Fe Containing Intermetallic Phases Formed on Solidification of Aluminium Alloys
JOM, 71 (2019), 1731-1736
DOI: 10.1007/s11837-019-03380-4
- A. Dybalska, D.G. Eskin, J.B. Patel
Validation of the Physical Simulations of a Stirred Molten Metal Using Particle Image Velocimetry Data
JOM, 70 (7) 2018, 1256-1260
DOI: 10.1007/s11837-018-2924-y
- Y. Zhang, J.B. Patel, Y. Wang, Z. Fan
Variation Improvement of Mechanical Properties of Mg-9Al-1Zn Alloy with Melt Conditioned High Pressure Die Casting
Materials Characterization, 144 (2018), 498-504
DOI: 10.1016/j.matchar.2018.08.007
- F. Wang, Z. Fan
Characterization of AlN Inclusion Particles Formed in Commercial Purity Aluminium
Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science, 50 (5) (2019), 2519-2526
DOI: 10.1007/s11661-019-05150-y
- C.B. Basak, A. Meduri, H.B. Nadendla
Influence of Ni in High Fe Containing Recyclable Al-Si Cast Alloys
Materials & Design, 182 (2019), 108017
DOI: 10.1016/j.matdes.2019.108017
- M. Balart, F. Gao, J.B. Patel, F. Miani
Effects of Superheat and Solute Additions on the Grain Size in Binary Copper Alloys
Metallography, Microstructure, and Analysis, 8 (4) (2019), 566-572
DOI: 10.1007/s13632-019-00559-8
- J. Wang, H. Yang, Z. Liu, R. Li, J. Ruan, S. Ji
Synergistic Effects of WC Nanoparticles and MC Nanoprecipitates on the Mechanical and Tribological Properties of Fe₄₀Mn₄₀Cr₁₀Co₁₀ Medium-Entropy Alloy
Journal of Materials Research and Technology, 8 (4) (2019), 3550-3564
DOI: 10.1016/j.jmrt.2019.06.031
- S. Ji, F. Amirkhanlu, A. Mostaed, R. Beanland
Atomic Structure and Interface Chemistry in a High-Stiffness and High-Strength Al-Si-Mg/TiB₂ Nanocomposite
Materials Science and Engineering A, 763 (2019), 138072
DOI: 10.1016/j.msea.2019.138072
- J. Wang, H. Yang, H. Huang, J. Ruan, S. Ji
Microstructure and Mechanical Properties of SiC Whisker Reinforced CoCrNi Medium Entropy Alloys
Materials Letters, 254 (2019), 77-80
DOI: 10.1016/j.matlet.2019.07.033
- E. Bagherpour, Y. Huang, Z. Fan
Assessment of Self-Piercing Riveted Joints Using the Analytic Hierarchy Process
Metals, 9 (7) (2019), 760
DOI: 10.3390/met9070760
- J.Y. Wang, J.H. Fang, H.L. Yang, Z.L. Liu, R.D. Li, S.X. Ji, Y. Wang, J.M. Ruan
Mechanical properties and wear resistance of medium entropy Fe₄₀Mn₄₀Cr₁₀Co₁₀/TiC composites
Transactions of Nonferrous Metals Society of China, 29 (7) (2019), 1484-1494
DOI: 10.1016/S1003-6326(19)65055-7
- K. Al-Helal, J. Lazaro-Nebreda, J.B. Patel, G.M. Scamans, Z. Fan
Melt Conditioned Direct Chill (MC-DC) Casting of AA-6111 Aluminium Alloy Formulated from Incinerator Bottom Ash (IBA)
Recycling 4 (3) (2019), 37
DOI: 10.3390/recycling4030037
- A.M. Mullis, P.C. Bollada, P.K. Jimack
Simulation of Intermetallic Solidification Using Phase-Field Techniques
Transactions of the Indian Institute of Metals, 71 (2018), 2617-2622
DOI: 10.1007/s12666-018-1428-3
- X. Zhang, X. Zhou, J.-O. Nilsson, Z. Dong, C. Cai
Corrosion Behaviour of AA6082 Al-Mg-Si Alloy Extrusion: Recrystallized and Non-recrystallized Structures
Corrosion Science, 144 (2018), 163-171
DOI: 10.1016/j.corsci.2018.08.047

- M.C. Veale, P. Seller, M. Wilson, E. Liotti
 HEXITEC: A High-Energy X-ray Spectroscopic Imaging Detector for Synchrotron Applications Synchrotron Radiation News, 31 (6) (2018), 28-32
 DOI: 10.1080/08940886.2018.1528431
- A.M. Mullis, P.C. Bollada, P.K. Jimack
 Development of an Anti-Trapping Current for Phase Field Models Using Arbitrary CALPHAD Thermodynamics
 Materials Science Forum, 941 (2018), 2337-2342
 DOI: 10.4028/www.scientific.net/MSF.941.2337
- P.C. Bollada, P.K. Jimack, A.M. Mullis
 A Numerical Approach to Compensate for Phase Field Interface Effects in Alloy Solidification
 Computational Materials Science, 151 (2018), 338-350
 DOI: 10.1016/j.commatsci.2018.04.050
- A. Piglione, B. Dovggy, C. Liu, C.M. Gourlay, P. Hooper, M. Pham
 Printability and Microstructure of the CoCrFeMnNi High-entropy Alloy Fabricated by Laser Powder Bed Fusion
 Materials Letters, 224 (2018), 22-25
 DOI: 10.1016/j.matlet.2018.04.052
- T. Gu, C.M. Gourlay, T. Britton
 Evaluating Creep Deformation in Controlled Microstructures of Sn-3Ag-0.5Cu Solder
 Journal of Electronic Materials, 48 (1) (2018), 107-121
 DOI: 10.1007/s11664-018-6744-1
- S. Belyakov, J. Xian, G. Zeng, K. Sweatman, T. Nishimura, T. Akaiwa, C.M. Gourlay
 Precipitation and Coarsening of Bismuth Plates in Sn-Ag-Cu-Bi and Sn-Cu-Ni-Bi Solder Joints
 Journal of Materials Science: Materials in Electronics, 30 (1) (2018), 378-390
 DOI: 10.1007/s10854-018-0302-8
- Z. Ma, H. Shang, A. Daszki, S. Belyakov, C.M. Gourlay
 Mechanisms of beta-Sn Nucleation and Microstructure Evolution in Sn-Ag-Cu Solders Containing Titanium
 Journal of Alloys and Compounds, 777 (2019), 1357-1366
 DOI: 10.1016/j.jallcom.2018.11.097
- E. Liotti, C. Kirk, I. Todd, K. Knight, S. Hogg
 Synchrotron X-ray and Neutron Investigation of the Structure and Thermal Expansion of the Monoclinic Al₁₃Cr₂ Phase
 Journal of Alloys and Compounds, 781 (2019), 1198-1208
 DOI: 10.1016/j.jallcom.2018.12.132
- T. Su, C. O'Sullivan, T. Nagira, H. Yasuda, C.M. Gourlay
 Semi-solid Deformation of Al-Cu Alloys: A Quantitative Comparison between Real-time Imaging and Coupled LBM-DEM Simulations
 Acta Materialia, 163 (2019), 208-225
 DOI: 10.1016/j.actamat.2018.10.006
- E. Liotti, M. Wilson, A. Lui, S. Feng, T. Connolley, P.S. Grant
 In-situ Multi-Elemental Mapping by Synchrotron X-rays Fluorescence Spectroscopy during Solidification of an Al-Pt-Er Alloy
 In preparation
- S. Feng, E. Liotti, A. Lui and P.S. Grant
 The Nucleation of Intermetallic Compounds in a Model Al-Fe Alloy Studied by X-Ray Radiography
 In preparation
- Z. Hong, A. Morrison, H. Zhang, S.G. Roberts, P.S. Grant
 Development of a Novel Melt Spinning Based Processing Route for Oxide Dispersion Strengthened Steels Metallurgical and Materials Transactions A, 49 (2018), 604-612
 DOI: 10.1007/s11661-017-4398-x
- T.L. Lee, J. Mi, S.B. Ren, J.F. Fan, S. Kabra, S.Y. Zhang, P.S. Grant
 Modelling and Neutron Diffraction Characterization of the Interfacial Bonding of Spray Formed Dissimilar Steels
 Acta Materialia 155 (2018), 318-330
 DOI: 10.1016/j.actamat.2018.05.055
- G.S.B. Lebon, I. Tzanakis, K. Pericleous, D.G. Eskin, P.S. Grant
 The Essential Role of Cavitation Bubble Fraction in Controlling Acoustic Streaming: Relevance to Ultrasonic Liquid Metal Processing
 Ultrasonics Sonochemistry, 55 (2019), 243-255
 DOI: 10.1016/j.ultsonch.2019.01.021
- A. Lui, P.S. Grant, K.A.Q. Oâ..Reilly
 The Role of Grain Refiner in the Nucleation of Al-Fe Intermetallic Phases during Solidification of an Aluminium Alloy
 Metallurgical and Materials Transactions A
 Submitted
- D. Herlach, S. Burggraf, M. Reinartz, P.K. Galenko, M. Rettenmayr, Ch.-A. Gandin, H. Henein, A. Mullis, A. Ilbagi, J. Valloton
 Dendrite Growth in Undercooled Al-rich Al-Ni Melts Measured on Earth and in Space
 Physical Review Materials, 3 (2019), 073402
 DOI: 10.1103/PhysRevMaterials.3.073402
- P.C. Bollada, P.K. Jimack, A.M. Mullis
 Multiphase Field Modelling of Alloy Solidification
 Computational Materials Science
 In press
- A.M. Mullis, P.C. Bollada, P.K. Jimack
 Simulation of Intermetallic Solidification using Phase-field Techniques
 Transactions of the Indian Institute of Metals, 71 (2018), 2617-2622
 DOI: 10.1007/s12666-018-1428-3
- P.C. Bollada, P.K. Jimack, A.M. Mullis
 Numerical Approach to Compensate for Phase-field Interface Effects in Alloy Solidification
 Computational Materials Science, 151 (2018), 338-350
 DOI: 10.1016/j.commatsci.2018.04.050
- L. Peng, G. Zeng, T.C. Su, H. Yasuda, K. Nogita, C.M. Gourlay
 Al₈Mn₅ Particle Settling and Interactions with Oxide Films in Liquid AZ91 Magnesium Alloys
 JOM, 71 (7) (2019), 2235-2244
 DOI: 10.1007/s11837-019-03471-2

Conference Proceedings

C.M. Fang, Z. Fan

A Comparative Study of Prenucleation on Zr and MgO Substrates by Ab Initio MD Simulations

In Proceedings of The 11th International Conference on Magnesium Alloys and Their Applications, 24 to 27 July 2018, Old Windsor, UK ed. Z. Fan, C.L. Mendis, 41-50

I. Tzanakis, G.S.B. Lebon, T. Subroto, D.G. Eskin, K. Pericleous
Acoustic Cavitation Measurements and Modelling in Liquid Aluminium
In Light Metals 2019, The Minerals, Metals & Materials Series, 996 (2019), 1533-8

DOI: 10.1007/978-3-030-05864-7_193

G. Salloum-Abou-Jaoude, D.G. Eskin, G.S.B. Lebon, C. Barbatti, P. Jarry, M. Jarrett

Altering the Microstructure Morphology by Ultrasound Melt Processing During 6XXX Aluminium DC-Casting

In Light Metals 2019, The Minerals, Metals & Materials Series, (2019), 1605-10

DOI: 10.1007/978-3-030-05864-7_203

X.L. Yang, C.L. Mendis, J.B. Patel, Y. Huang, Z. Fan

Development of Melt-Conditioned Twin-Roll Casting (MC-TRC)

Process for Thin Gauge Mg Alloy Strip Production

In Proceedings of The 11th International Conference on Magnesium Alloys and Their Applications, 24 to 27 July 2018, Old Windsor, UK ed. Z. Fan, C.L. Mendis, 69-75

J.B. Patel, H.T. Li, X.L. Yang, Y. Zhang, Z. Fan

Developments in Application of High Shear Melt Conditioning (HSMC) Technology to Mg Alloys

In Proceedings of The 11th International Conference on Magnesium Alloys and Their Applications, 24 to 27 July 2018, Old Windsor, UK ed. Z. Fan, C.L. Mendis, 18-25

Z. Fan

Heterogeneous Nucleation, Grain Initiation and Grain Refinement of Mg-Alloys

In Proceedings of The 11th International Conference on Magnesium Alloys and Their Applications, 24 to 27 July 2018, Old Windsor, UK ed. Z. Fan, C.L. Mendis, 7-17

Y. Zhang, J.B. Patel, Z. Fan

Improvement on Variation of Mechanical Properties of AZ91 Alloy by Melt Conditioned High Pressure Die Casting (MC-HPDC)

In Proceedings of The 11th International Conference on Magnesium Alloys and Their Applications, 24 to 27 July 2018, Old Windsor, UK ed. Z. Fan, C.L. Mendis, 93-99

H.T. Li, J.B. Patel, Z. Fan

Melt Conditioned Direct-chill (MC-DC) Casting of Mg Alloys

In Proceedings of The 11th International Conference on Magnesium Alloys and Their Applications, 24 to 27 July 2018, Old Windsor, UK ed. Z. Fan, C. Mendis, 107-114

E. Bagherpour, Y. Huang, Z. Fan

Microstructural Investigation of the Assessed High Strength Al6082

Self-Piercing Riveted Joints

In Proceedings of Twenty-seventh International Conference on Processing and Fabrication of Advanced Materials (PFAM-XXVII), 27 to 29 May 2019, Jönköping, Sweden

J. Lazaro-Nebreda, J.B. Patel, G.M. Scamans, Z. Fan

Multi-purpose High Shear Melt Conditioning Technology for Effective Melt Quality and for Recycling of Al-Alloy Scrap

In Proceedings of the 16th International Conference on Aluminium Alloys (ICAA16), 17-21 June 2018, Montreal, Canada

G.S.B. Lebon, H.T. Li, J.B. Patel, H. Assadi, Z. Fan

Numerical Modelling of Melt Conditioned Direct-chill (MC-DC) Casting of AZ31 Magnesium Alloy

In Proceedings of The 11th International Conference on Magnesium Alloys and Their Applications, 24 to 27 July 2018, Old Windsor, UK ed. Z. Fan, C. Mendis, 100-106

K. Dou, E. Lordan, Y.J. Zhang, A. Jacot, Z. Fan

Numerical Simulation of Fluid Flow, Solidification and Defects in High Pressure Die Casting (HPDC) Process

In IOP Conference Series: Materials Science and Engineering, 529 (1) (2019) 012058

DOI: 10.1088/1757-899X/529/1/012058

A. Dybalska, D.G. Eskin, J.B. Patel

Optimal Stator Design for Oxide Films Shearing Found by Physical Modelling

In Minerals, Metals and Materials Series, (2019), 181-192

DOI: 10.1007/978-3-030-05728-2_17

T. Subroto, D.G. Eskin, I. Tzanakis, G.S.B. Lebon, A. Miranda, K. Pericleous

Optimization of Ultrasonic Cavitation Processing in the Liquid Melt Flow

In IOP Conference Series: Materials Science and Engineering, 529 (2019), 012050

DOI: 10.1088/1757-899X/529/1/012050

S.H. Wang, F. Wang, Y. Wang, Q.M. Ramasse, Z. Fan

Segregation of Ca at the Mg/MgO Interface and its Effect on Grain Refinement of Mg Alloys

In IOP Conference Series: Materials Science and Engineering, 529 (2019) 012048

DOI: 10.1088/1757-899X/529/1/012048

H.T. Li, J.B. Patel, Z. Fan

Solidification Mechanisms of Melt Conditioned Direct-chill (MC-DC) Casting

In Proceedings of the 16th International Conference on Aluminium Alloys (ICAA16), 17-21 June 2018, Montreal, Canada

J. Lazaro-Nebreda, J.B. Patel, I.T.H. Chang, I.C. Stone, Z. Fan
Solidification Processing of Scrap Al-Alloys Containing High
Levels of Fe
In IOP Conf. Series: Materials Science and Engineering, 529 (2019),
012059
DOI: 10.1088/1757-899X/529/1/012059

X. Zhu, S. Ji
The Formation of Al₆ (Fe, Mn) Phase in Die-Cast Al-Mg Alloys
In IOP Conference Series: Materials Science and Engineering, 529 (1)
(2019), 012011
DOI: 10.1088/1757-899X/529/1/012011

I. Tzanakis, G.S.B. Lebon, D.G. Eskin, M. Hyde, P.S. Grant
Investigation of Acoustic Streaming and Cavitation Intensity in Water
as a Liquid Metal Analogue
In Proceedings of the ASME 10th International Symposium on
Cavitation (CAV2018)

A.M. Mullis, N. Haque
Direct Observation of Dendrite Fragmentation in the Solidification of
Undercooled Melts
In Proceedings of the 5th International Conference on Advanced
Solidification Processes, 17-21 June 2019, Salzburg, Austria
IOP Conference Series: Materials Science & Engineering, 529: 012020

P.C. Bollada, H. Men, C.M. Fang, P.K. Jimack, Z. Fan, A.M. Mullis
A Novel Route to the Coupling of Molecular Dynamics and Phase-Field
Simulations of Crystal Growth
In Proceedings of the 5th International Conference on Advanced
Solidification Processes, 17-21 June 2019, Salzburg, Austria
IOP Conference Series: Materials Science & Engineering, 529: 012032



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