CURRICULUM VITAE (November 2009)

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CAREER / EDUCATION

2006–	Professor, Dept of Metallurgy of Materials, University of Birmingham, Birmingham, UK; holder of Chair in Materials Science and Engineering.
2005–2006	Professor, Department of Materials, Imperial College, London, UK.
2002–2005	Professor and Canada Research Chair, Dept of Materials Engineering, The University of British Columbia, Vancouver, British Columbia, Canada, V6T 1Z4.
1994–2002	Assistant Director of Research, Rolls-Royce University Technology Centre, Dept of Materials Science & Metallurgy, University of Cambridge, Pembroke Street, Cambridge CB2 3QZ, UK; also Official Fellow & College Lecturer in Materials Science & Engineering, Emmanuel College, 1999-2002; Director of Studies in Physical Sciences 1999-2002, Admissions Tutor 2000-2002.
1990–1994	Lecturer in Physical Metallurgy, Department of Materials, Imperial College, London, UK.
1987–1990	Studied for a Ph.D. at the Department of Materials Science and Metallurgy, University of Cambridge, under the supervision of Dr. H.K.D.H. Bhadeshia, on an SERC/CASE award sponsored by the Central Electricity Generating Board. Title of thesis 'The Characterisation and Modelling of Multipass Steel Weld Heat-Affected Zones', submitted in September, 1990.
1984–87	Studied at Corpus Christi College, University of Cambridge, under the Natural Sciences Tripos. Papers in Mathematics, Physics, Chemistry, Crystalline Materials, Crystalline State, History & Philosophy of Science, graduating in Materials Science & Metallurgy.
1987	B.A. in Materials Science & Metallurgy, graduated with top first; awarded the Goldsmiths Company's Medal and Prize, and a Foundation Scholarship at Corpus Christi College.
1977-83	Dulwich College, London SE21 7LD, UK
1982/83	'A' levels: (with grades) Mathematics A1, Further Mathematics A1, Physics A, Chemistry A

RESEARCH EXPERTISE

The materials science and engineering of structural materials, particularly those for high temperature applications. The design, structure & constitution, mechanical behaviour and processing of these materials and components made from them; also the inter-relationship between these topics. A strong emphasis on the numerical analysis of these phenomena using both purpose-built software and commercial codes. Validation of numerical models using targetted experimentation using novel techniques. Microstructural instabilities in these systems as a consequence of phase transformations and damage accumulation, both during service and during processing.

SIGNIFICANT CONTRIBUTIONS TO ORIGINAL RESEARCH AND LEARNING

A. Micromechanics of Deformation of Single Crystal Superalloys

Fundamental research carried out systematically over more than a decade has elucidated the physical mechanisms responsible for the mechanical behaviour of single crystal superalloys under loading conditions relevant to the gas turbine, the effects of service exposure and the role played by interaction with the environment due to oxidation. See for example the series of related articles [J21, J28, J37, J40, J68, J70, J72]. Recently, this work has culminated in the first composition-dependent theory for creep deformation in these materials; this has allowed us to propose new grades of single crystal superalloy which should be close to those which are optimal – these are now being tested. This work is highly relevant to practical applications; for example it has become commonplace for the turbine blading of modern jet and land-based (electricity-generating) engines to be cast in single crystal form, such that the grain boundaries are eliminated completely. The potencies of the various factors contributing to the high temperature performance have been rationalised, quantified and introduced into a unified theory. This work is enabling gas turbine designers to improve the performance characteristics of their engines.

B. Numerical Modelling of Microstructural Instabilities in Structural Alloys

The properties of structural alloys are compromised by phase transformations and microstructural instabilities that can occur during extended periods of service. A second portfolio of research [J20, J25, J33, J47, J48, J53] has been concerned with rationalising, modelling and providing insights into the mechanisms responsible for these effects, particularly (i) the precipitation of topologically closed-packed phases and (ii) the rafting effect. Recent work [J59, J62, J73] has used quantum-mechanical modelling to deduce, for the first time, the role played by Re in superalloy metallurgy, which until now has been highly controversial. Very recently, my group has been studying the factors controlling the failure of thermal barrier coatings (TBCs) placed on these materials during thermal cycling [J74], so that compatibility of alloy, bond coat and TBC can be assured. Emphasis has been placed on quantifying the relevant phenomena using computer-based numerical modelling. This work is highly relevant to the practical application of materials in high temperature systems, since extended periods of high temperature service are required.

C. Process Simulation of Manufacturing Operations

I have developed numerical models for the manufacturing processes of interest to industry, and shipped them to the collaborating industrial concerns *via* processes of technology transfer. I have placed great emphasis on the interfacing of models for phenomena occurring on the continuum and microstructural scales, believing this to be the major technical challenge in the field. Such work is reported in [J16, J30, J32, J36, J39, J46, J51]. Highlights include (i) the simulation of the welding of the compressor assembly for Rolls-Royce's Trent series of aeroengines, and the validation of the computed results using neutron diffraction studies at NRC's Chalk River facility in Ontario, see [J16] (ii) modelling of the investment casting process used for the fabrication of superalloy single crystal blading, see [J32], including heat transfer effects to account for interactions between molten metal, shell, susceptor and baffle arrangement and microstructure evolution to enable grain selector geometries to be optimised and (iii) simulation of the important processes related to the production of turbine discs, for example the cogging and closed-die forging operations, see [J30, J57]. This research is highly topical. The industry is placing great emphasis on numerical simulations of manufacturing processes as a means of enabling (i) the proper evaluation of conceptual designs, (ii) a greater expectation of manufacturing 'right-first-time', (iii) reductions in the

time-to-market for new products, (iv) a better understanding of the physical processes occurring during processing. In my opinion, training of highly qualified persons in these areas is sorely needed.

D. Validation by Experiment of Numerical Models
Experience has shown that when constructing models of the type outlined in the previous section, a limited number of experimental tests are required for the purpose of verification and calibration. My strategy has been to match the needs of the modelling to the optimum choice of experimental technique. Thus, my research has involved the use of targetted experimentation, often with very specialised equipment and sometimes in collaboration with experts around the world. Transmission electron microscopy has been used extensively to test and validate models for the micromechanics of deformation in these materials [J21, J37, J47, J67]. Neutron and synchrotron methods have been used to test predictions for the state of residual strains and stresses in structural alloys [J27, J29, J35, J43, J52], to help build up a complete picture of the patterns of stress and distortion to be expected from processing. The extended X-ray absorbtion fine structure method (EXAFS) – using a tuned synchrotron – has been exploited to assess our theoretical predictions that rhenium is not prone to clustering in superalloys [J73]. More recently, atom probe tomography has been used to test models for phase transformations in these materials, and papers are emerging from my collaboration with Mike Miller of Oak Ridge National Laboratory [J79].

F. University/Industry Collaborations in Materials Technology for Gas Turbine Applications
In my present position at the University of Birmingham, I have established (and act as Director of) the Partnership for Research in the Simulation of Manufacturing and Materials – PRISM^2 – set up in collaboration with Rolls-Royce plc and the ESI Group. Its focus is a Materials Modelling Laboratory housed in the Interdisciplinary Research Centre (IRC) on Birmingham's campus. This new activity complements efforts of mine between 1994 and 2002 when I was responsible with others for the establishment of a University Technology Centre (UTC) in the Department of Materials Science & Metallurgy at the University of Cambridge, which continues to this day under the sponsorship of Rolls-Royce. The following responsibilities arise:

- to liaise with industry collaborators, in order to define and fund research projects of strategic, long-term importance;
- to manage such projects within the University environment, such that proper outcomes are achieved, and thus to train personnel who might be employed by collaborating companies;
- to assist in the transfer of technology from the University to the industrial partner;
- to disseminate the outcomes of the research in the learned journals and at international conferences.

These activities have been very successful, as can be judged by the research output, the quantity of research income and the continuing support of the industrial sponsors. Of particular interest to the author has been the care and diligence required to balance the conflicting requirements of academia and industry. In the United Kingdom and elsewhere, these activities are considered to be models for the way in which co-operation between industrial concerns and our universities can be achieved successfully.

MAJOR TEACHING ACTIVITIES

At the University of Birmingham since 2006, my major contributions have been to teach classes to graduate students as part of our EngD programme on 'Materials for High Performance Applications'.

At Imperial College between 2005 to 2006 I gave a course (17 lectures) to the second year class of 80 students on 'Thermodynamics and Microstructure Evolution'. As part of the MEng programme on Aerospace Materials, I gave a 24 lecture course on 'High Temperature Materials' to the fourth year class. I contributed also to a fourth year course on 'Materials Modelling'.

At the University of British Columbia (UBC) during the period 2002 to 2005, I taught a major third year course on the 'Thermodynamics of Materials', consisting of 36 lectures; for this and to promote computer-based learning, I developed 5 computer-based tutorial sessions in which thermodynamic problems were tackled by computer-based software. For a fourth year elective/graduate programme, I developed a course

on 'Materials for High Temperature Applications' consisting of 24 lectures and 5 computer-based modelling exercises – partly based upon my textbook 'The Superalloys: Fundamentals and Applications' which was published by Cambridge University Press in 2006. For these two courses, I received some of the highest teaching assessment grades given by the UBC students. Furthermore, I led a successful 'Design Study' on 'Materials for Jet Engines' which proved very popular. Finally, in collaboration with Dr Olivera Kesler, I co-developed a graduate course on 'Materials Solutions for Clean and Sustainable Energy'.

At the University of Cambridge during the period 1994 to 2002, I lectured regularly to second and third year undergraduate students. The courses were concerned with 'Fracture Mechanics', 'Deformation Processing', 'Structural Alloys' and 'Mechanical Behaviour of Materials'. I was involved also in the teaching (with Harry Bhadeshia, Lindsay Greer and others) of a course within a graduate programme on Materials Modelling, leading to the MPhil degree. I was actively involved with supervising undergraduate students in Materials Science at all levels, both in laboratory classes and supervisions, the latter for Emmanuel College.

During the period 1990 to 1994, I gave three lecture courses to final year students at Imperial College. The first two were concerned with 'Structural Metallic Materials', 'Welding and Joining'. The third, conceived and developed by me, was a new course 'Modelling of Materials Behaviour' given to MEng students. In addition, I gave a 18 lecture course to second year students on numerical analysis. I was engaged widely in the teaching of undergraduate students in tutorials and practical classes.

PERSONAL/PROFESSIONAL DEVELOPMENT

In November 2003, whilst at the University of British Columbia, I took a 1 week 'Management Programme' which consisted of content on (i) leadership and change in the academic context, (ii) effective working with creative groups of teams, (iii) human resource management and the legal framework, (iv) financial management and budgetary control and (v) managing and leading change.
During July 2005, whilst at Imperial College London, I took the week-long 'Senior Leadership Development Programme' which was given in collaboration with University College London. Topics included individual leadership style, the leader's role in managing change, promoting equality and diversity, learning from key incidents and personal development planning and the impact of psychological preference on communication within teams.

TRAINING OF HIGHLY QUALIFIED PERSONNEL

During my 18 years in academia, I have been successful in graduating a significant number of PhD students, all of whom have gone on to good positions in industry, science or commerce. For example, Harald Slinde (1990-1993) graduated with a thesis on 'The Laser Welding of Steel' (now a Scientific Officer at the Norwegian Institute of Standards). Taner Akbay (1991-1994), thesis title 'Reaustenitisation in Steel' (now a chief scientist at Mitsubishi Materials Corporation in Japan). Martin Jackson (1994-1997) graduated with a thesis on 'Characterisation and Modelling of Phase Transformations in Superalloys' (now a patent attorney in intellectual property, London). Nirundorn Matan (1995-1998) defended his thesis on 'Rationalisation of the Creep Performance of Single Crystal Superalloys' (now a Professor at Walailak University, Thailand). Howard Stone (1995-1999) defended his thesis on 'Modelling of the Residual Stresses and Distortion Induced by the Electron Beam Welding of Superalloys' (now a Assistant Director of Research at the University of Cambridge). Mudith Karunaratne (1996-2000) defended his thesis on the 'Modelling of Diffusional Phenomena in Superalloys' (research fellow at the University of Loughborough). David Dye (1997-2000) worked on the 'Numerical Analysis of the Welding of Superalloys' (now a Lecturer at Imperial College, London). David Cox (1997-2000) defended his thesis on 'Characterisation of Microstructural Evolution in Single Crystal Superalloys' (research fellow at University of Surrey, UK). Nettem Sekhar (1996-2002) defended his thesis on 'The Welding Metallurgy of the Superalloys' (at the Welding Institute, Cambridge). Ray Cho (1999-2002) wrote his thesis on 'Power Beam Welding of Titanium Alloys' and is now working for a major steel company in Korea. Matthew Hook (2000-2003) has completed his thesis on the 'Oxidation of Coated Single Crystal Superalloys' (Financier at Deutsche Bank). Rob Guest (2001 to 2004) completed his PhD on 'Modelling of Microstructure Evolution in IN718' (now an engineer at Firth-Rixson, Sheffield). Jacky Cheng (2002-2005) completed his thesis on 'Modelling of Transient Liquid Phase Bonding' (now an Research Engineer at Acro Aerospace, Vancouver). Subray Hegde completed

his thesis on 'Modelling of Oxidation in Nickel-Based Superalloys' (now a Research Fellow at Carleton University, Ottawa, Canada). Anand Thirmulai (2002-2005) completed his thesis on 'Role of Back-Diffusion during Solidification of Advanced Nickel-Based Superalloys'. Steven Wang (2002-2006) completed his thesis on 'Dysprosia-Yttria-Zirconia Thermal Barrier Coatings' (now an Engineering at Highland Foundry International Inc, Vancouver). Mr Rudder Wu (2005-2008) completed his PhD thesis on 'Mechanisms of High Temperature Degradation of Thermal Barrier Coatings' (now a Research Fellow at National Institute for Materials Science, Tsukuba, Japan). At present, I have a further 8 PhD students whom I am supervising. Furthermore, I have extensive experience working with post-doctoral research associates employed on short-term contracts, using funding secured from successful grant applications: Dr Jonathan Robinson (1992-1996) worked on the 'Welding of Superalloys' (founded a very successful e-business, now Managing Director of NetBenefit plc). Dr Taner Akbay (1994-1996) worked on 'Reaustenisation in Steel' (see above). Dr Henri Winand (1995-1996) worked on the 'Computational Phase Transformations in Superalloys' (now an Engineer at Rolls-Royce). Dr Mark Roberts (1995-2001) worked on the 'Process Modelling of Thermal-Mechanical Working of Superalloys' (still working at Cambridge). Dr Martin Rist (1996-2002) worked on 'Constitutive Equations for the Mechanical Behaviour of Superalloys' (Lecturer at the Open University, UK). Dr Cathie Rae (1996-2002) worked on the 'Design of Novel Single Crystal Superalloys' (Lecturer at Cambridge University). Dr Phil Carter (1996-1999) worked on the 'Process Modelling of the Investment Casting of Superalloys' (consultant for Scientific Generics Limited). Dr Christian Dandre (1996-1999) worked on 'Modelling of the Thermal-Mechanical Processing of Superalloys' (Lecturer at University of Wales, Swansea). Dr Olivier Hunziker (1997-2000) worked on the 'Numerical Analysis of the Welding of Superalloys' (a technologist at Cartier, Switzerland). Dr Marco Starink (1997) worked on 'Differential Scanning Calorimetry for the Study of Phase Transformations in Superalloys' (Professor at the University of Southampton). Dr Howard Stone (1998-1999) worked on the 'Electron Beam Welding of Waspaloy' (now Assistant Director of Research at the University of Cambridge). Dr David Dye (2000-2001) worked on 'Modelling of the Welding of Superalloys' (now a Lecturer at Imperial College, London). Dr Slim Ben-Elechi (2006-2008) worked on 'Modelling of Sheet Metal Forming' (now an Engineer at Usinor, France). Currently, three research fellows are working in my group: Dr Jean-C Gebelin 'Modelling of Solidification and Casting', Dr Nils Warnken 'Phase Field Modelling of Microstructure Evolution', and Dr Yu-Pei Lin 'Modelling of Deformation Processing for High Performance Applications'.

SEMINARS AND SABBATICAL PERIODS

I have given invited seminars at many of the leading materials institutions around the world, including: Massachusetts Institute of Technology; Penn State University; Ohio State University; Lehigh University; University of Michigan, Ann Arbor; University of California, Berkeley; The University of British Columbia, Vancouver, Canada; Carleton University, Ottawa, Canada; McMaster University, Hamilton, Canada; University of Alberta, Edmonton, Canada; EPFL Lausanne, Switzerland; Tokyo Institute of Technology; University of Tokyo; Kyoto University; Nippon Steel Research Laboratories, Chiba, Japan; Kobe Steel Research Laboratories, Osaka, Japan; Indian Institute of Science, Bangalore; Monash University, Australia; ONERA, Paris, France, University of Sao Paolo, Brazil.

I spent 6 weeks during August/September 1991 and 4 weeks during August 1993 working with Professor John Goldak of the Department of Mechanical and Aeronautical Engineering, Carleton University, Canada. This work was sponsored by the Royal Society, SERC and NSERC (Canada).

I spent the period April–September 1992 on a Royal Society/JRDC fellowship, working with Dr Hiroshi Harada, of the National Research Institute for Metals, Tokyo.

I spent the period January–April 1999 on sabbatical in the Department des Materiaux, EPFL Lausanne, Switzerland in the laboratory of Professor Wilfred Kurz and Professor Michel Rappaz.

OTHER EVIDENCE OF IMPACT AND CONTRIBUTIONS

- awarded a Tier I Canada Research Chair at the University of British Columbia, Vancouver, March 2002.
- twice awarded the Marcus Grossmann Award by the American Society for Materials (in 2001 and again in 2004) for best papers published in Metallurgical & Materials Transactions, by authors

under 40 years of age, see [J46] and [J57].

- member of the TMS's High Temperature Committee, and one of the organisers of the International Symposium on Superalloys (The Seven Springs Conference) – the most prestigious conference in my field; Programme Chair for 2008 meeting, voted General Chair for 2012 meeting.
- acts as a consultant to a number of companies in the gas turbine industry, and registered as Chartered Engineer in the UK.
- member of the editorial boards of the journals Materials Science & Technology, and Metallurgical & Materials Transactions.
- elected Fellow of Institute of Materials (IoM3), London in 2005.

PUBLICATIONS – TEXTBOOK

'The Superalloys: Fundamentals and Applications', Cambridge University Press, 2006. The publishers, upon consultation with reviewers, have described this book in the following way:

Superalloys are unique high temperature materials used in gas turbine engines, which display excellent resistance to mechanical and chemical degradation. This book presents the underlying metallurgical principles which have guided their development and also the practical aspects of component design and fabrication from an engineering standpoint. The topics of alloy design, process development, component engineering, lifetime estimation and materials behaviour are covered, with emphasis on critical components such as turbine blading and discs. A chapter on engineering coatings and a final one on future projections are included. This is the first single-authored comprehensive textbook on this class of material; it provides a strong grounding for those studying physical metallurgy at the advanced level, as well as practising engineers. Included at the end of each chapter are exercises designed to test the reader's understanding of the concepts presented.

Following good sales of the original hardback version, a paperback edition was printed in 2008.

PUBLICATIONS – JOURNALS

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MAJOR RESEARCH GRANTS WON

(1) 'Modelling of the Evolution of Steel Microstructures', SERC, 36 months, 1992/1995, £17,661.

(2) 'Modelling of High Temperature Deformation in Materials subject to Phase Transformations', with Prof Malcolm McLean, SERC, 36 months, 1992/1995, £95,158.

(3) 'Laser Surface Alloying of Steam Turbine Blades for Enhanced Erosion Resistance', with Prof David West, SERC, 36 months, 1992/1995, £121,704.

(4) 'Theory for Reaustenitisation in Low-Alloy Steels', with Prof Colin Atkinson, SERC, 36 months, 1994/1997, £118,964

(5) 'Modelling of Phase Transitions in Nickel-Based Superalloys', EPSRC/ROPA, 1994/1996, £90,000.

(6) 'Modelling of the Electron Beam Welding of Compressor Drums', Defence Research Agency, 1995 - 1998, £202,000.

(7) 'The Use of a Field-Emission Gun SEM for the Validation of Modelling Studies', with Prof Colin Humphreys, EPSRC/IMI Initiative, 1996/1999, £162,000.

(8) 'Modelling of Aerospace and Power Generation Materials', with Prof Colin Humphreys, Dr D M

Knowles, Dr T W Clyne and Dr H K D H Bhadeshia, EPSRC/OST/Technology Foresight, 1997/2000, £1,400,000.

(9) 'Construction and Validation of a Process Model for the Weldability of Superalloys for Gas Turbine Applications', EPSRC, 1997/2000, £163,654.

(10) 'Microstructural Evolution in Ni-base Superalloy Forgings: Process Modelling & Validation', with Prof Russell Evans, EPSRC, 1997/2000, £219,637.

(11) 'Inverse Modelling for Constitutive Relationships using the Finite Element Method', Brite-Euram Framework 5, 1998/2001, £148,000.

(12) 'Cost-Effective Manufacture: Welding of Aerospace Materials', EPSRC, 1999/2002, £185,000.

(13) 'Cost of University Technology Centre at the University of Cambridge', Rolls-Royce plc, 2000/2004, £1,287,000, with Prof Colin Humphreys and Dr David Knowles.

(14) 'Integrated Process Modelling for Gas Turbine Manufacture', EPSRC, 2000/2003, £297,000.

(15) 'Laser Forming of Aerospace Alloys – A Direct Fabrication Technique', EPSRC, 2000/2003, £61,192.

(16) 'Design and Manufacturing of Materials and Coatings for High Temperature Applications', Canada Research Chair Programme, 2002/2005, $600,000.

(17) 'Plasma Spraying Equipment for Smart Coatings', Canadian Fund for Innovation, 2002/2005, $450,000.

(18) 'Microstructural Phenomena in Materials Processing: Characterisation and Modelling', NSERC (Canada), 2002/2005, $220,000.

(19) 'Partnership for Research In Simulation of Manufacturing and Materials (PRISM2)' Rolls-Royce plc, 2006–, £220,000 per annum, ongoing.

(20) 'Modelling of Sheet Metal Processes for Gas Turbine Combustor Applications', Rolls-Royce plc, 2006/2009, £210,000.

(21) 'Alloys by Design: A Materials Modelling Approach', with Prof David Pettifor (Oxford) and Dr Cathie Rae (Cambridge), EPSRC, 2006/2010, £1,200,000 total; £450,000 to Birmingham.

(22) 'Corrosion Resistant Superalloys for Industrial Gas Turbines', Siemens Industrial Turbomachinery, 2007/2011, £250,000.

(23) 'Structural Control of Titanium Alloys for High Strength, High Toughness', with Prof Mike Loretto and Prof Xinhua Wu, EPSRC, 2007/2010, £450,000.

(24) 'SAMULET: Strategic, Affordable Manufacturing With Leading Environmental Technologies', EPSRC, 2009/2013, £980,000.

(25) 'Structural Metallic Systems for Advanced Gas Turbine Applications', EPSRC Grant Number EP/H500367/1, 2009/2014, £3,147,908, with Professor Paul Bowen.

INTERESTS/ACTIVITIES

I pursue a number of sports, notably running; recently I completed my fastest ever 10 km race in 42:20, my best for half-marathon (1 hour 38 minutes) was in 2007. I am interested in foreign cultures and have travelled extensively in Europe, North America, Southern Africa, India, Egypt & South-East Asia, notably the four main islands of Japan. Other interests include cooking, food and wine; I hold the Wine and Spirit Education Trust's Advanced Diploma, passed with distinction.

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