Cambridge material eyes

Autumn 2005 Issue 14

Cambridge, the moon and beyond…

NASA's vision for the next twenty years is to establish a colony on the moon from which to launch rockets to the rest of the solar system, facilitated by the lower gravitational force ($^{1}/_{6}{}^{th}$ that on the earth). This is not without its challenges as the most likely fuel is a one-to-six mixture of hydrogen and oxygen. Neither element is freely available on the moon, but would have to be shipped there – at a cost of $4m/tonne. But lunar rocks are mainly oxides, permitting our Department to come to the rescue –

Mission STS-108 lifts-off © NASA

The FFC Cambridge process, in which oxygen extraction is used to produce pure metals and alloys from their oxides, will be familiar to our readers. An oxide powder is converted electrochemically to a pure metal in a single step by applying an electric current, causing the oxygen in the oxide to ionise, dissolve in the salt, and be discharged at the anode, leaving behind the metallic components – a great improvement on complex traditional extraction often involving intermediate compounds. Derek Fray, Tom Farthing and George Chen developed the process in the mid-1990s while investigating how to remove oxide from the surface of titanium. Progress has since been made on the reduction of the oxides of titanium and other metals. High-technology alloys such as NbTi, FeNdB and Ni_2MnGa have been produced directly by the reduction of mixtures of metal oxides. An exciting new opportunity has arisen from a proposal submitted to NASA by engineers at British Titanium. Of 4,000 proposals submitted, only seventy are being funded and of those only two are from outside the US – at British Titanium and at Snecma, the French aerospace company. The project, now underway, is making excellent technical progress with laboratory cells producing oxygen. Cells have been shipped to the US for evaluation and, if successful, will be redesigned for use on the moon. Once working satisfactorily there, NASA's intention is that the technology will be exported to the rest of the solar system.

The process originally conceived to remove dissolved oxygen from titanium, has been adapted to reduce metal oxides, to prepare high-technology alloys, and now to assist in further space exploration – a fascinating evolution. Back on earth, work on the NASA project is carried out in Cambridge, in the pilot facility of British Titanium plc. and in the Department. The company's new venture with Norsk Hydro will install titanium production units in redundant Norwegian aluminium smelters – thereby preserving employment in isolated communities. More information about the process is available at http://www.britishtitanium.co.uk/. Meanwhile Metalysis Ltd, which has the rights to the exploitation of the process outside the field of titanium, recently raised £5m of venture capital, the largest amount of finance won by the metallurgical sector in recent times. The company, now in South Yorkshire, employs nearly 20 people, and is starting to participate in the regeneration of the region. For more information, see http://www.metalysis.com/.

Thus the simple FFC Cambridge process is creating employment in the Cambridge, South Yorkshire, Norway and perhaps on the moon!

Editorial

I trust that this issue of *Material Eyes* will give you a flavour of the exciting research and teaching in the Department. But together with the many successes to applaud, I have also to report the very sad news of the death of Prof. Jan Evetts on 18th August. Jan was much loved and tributes have poured in; an appreciation will appear in the next issue. Just such a mixture of joy and sadness is likely to permeate any history: our Department's story is now wonderfully accessible through Dr Jim Charles' new book, and I urge you to take advantage of the pre-publication offer on the enclosed flyer.

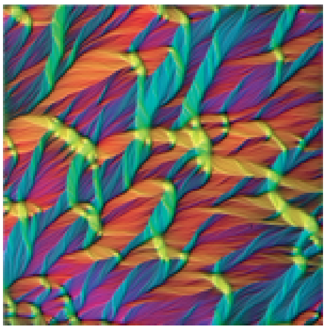
These are my parting words to you as the Head of Department: I thank you for your support over the last five years, and I wish my successor Prof. Lindsay Greer all the best in his new position.

***Professor Derek Fray*, Head of Department**

Contents

Magnetic domains in a thin cobalt film

This picture gained first prize in the "Science as Art" category in the 2004 *Daily Telegraph* Visions of Science competition for Rafal Dunin-Borkowski and his collaborators: A. Husmann (Toshiba Cambridge Res. Lab.), M. McCartney (Arizona State University), and C. Boothroyd (Inst. of Materials Res. and Eng., Singapore).



The colours in the image show the different directions of the magnetic field in a layer of polycrystalline cobalt only 20 nm thick. The direction of the magnetic field in the film changes at the domain walls. The field of view is ~ 200 µm wide. The image was acquired using the Fresnel mode of Lorentz microscopy in a field-emission-gun TEM. It was recorded out of focus to enhance the contrast of the domain walls, and then converted to a colour induction map. For further information contact rafal.db@msm.cam.ac.uk.

New Head of Department

Lindsay Greer will succeed Derek Fray as Head of Dept. from 1 January 2006. An undergraduate and graduate student in the Dept., then a Research Fellow at Churchill College, Lindsay's first teaching position was as Assistant Professor of Applied Physics at Harvard. He returned to the academic staff here in 1984, rising to a Personal Chair in 2001. A Fellow of Sidney Sussex, he is currently Vice-Master of the College. He has held visiting positions at the Institut National Polytechnique de Grenoble, the Institute for Materials Research (Sendai, Japan) and Washington Univ. (St Louis, MO). Lindsay edits *Philosophical Magazine* (founded 1798, treating the physics of condensed matter)

His research, which has attracted awards from academic and professional institutions in Japan and the USA as well as the UK, focuses on the kinetics of microstructural evolution, of interest for assessing the stability of materials, and for developing new microstructures and properties. Stemming from his PhD with John Leake and subsequent work with David Turnbull at Harvard, Lindsay has maintained interests in metallic glasses and in nucleation. But his group (website: www.msm.cam.ac.uk/mkg/) has worked on a wide range of other topics: deposition and stability of metallic multilayered thin films, sugar-based glasses for drug delivery, nanocomposites, electromigration in microelectronic devices, chalcogenide thin films for data storage, grain refinement and intermetallic phase selection in aluminium alloys.

Lindsay was awarded a Pilkington Teaching Prize by the University in 2000 for his consistently successful contributions to the Department's teaching, and currently gives lectures on biomaterials to our first-year undergraduates.

Where we came from, where we are now

A history of the Dept. with the title *Light Blue Materials* has been prepared by 'old-timer' Jim Charles, assisted by Lindsay Greer. Jim was on the academic staff from 1960 until retirement in 1990, but still frequents the place! The book follows the growth of the Dept. from its origins in the Sidney Sussex laboratory used by C.T. Heycock, later to become the first Reader in Metallurgy with his own Goldsmiths' Laboratory as a small sub-department of Chemistry. This early development owed much to the good offices of the successive Heads of Chemistry, Prof. G.D. Liveing and Prof. Sir William Pope. Then followed a new degree course in Metallurgy, growth to take over the greater part of the Chemistry building when that Department moved to Lensfield Road, and establishment within the new Arup building as the top-rated Materials department that it is now.

The account remembers the main areas of effort, some individual characters, both academics and assistants, and their unique contributions to all aspects of Dept. life. The periods of successive Heads of Department are covered, interspersed with consideration of specific areas of research. That such matters are currently of keen interest is heavily underlined by Raymond Hart's article in this issue about his time here 50 years ago, and by the imminent appearance of Robert Cahn's autobiography, of which more details are enclosed, not forgetting Jim's autobiographical book *Out of the Fiery Furnace*. A 'flyer' enabling orders for *Light Blue Materials* to be sent to Maney Publishing taking advantage of a pre-publication discount is enclosed with this issue of *Material Eyes*. All royalties from sales will go to a Dept. student assistance fund.

Master's course – Micro and nano

October 2004 saw 14 students embark on the latest degree course with which the Department is closely involved. Organised by Mark Blamire and Steffi Friedrichs, the one-year programme in Micro- and Nanotechnology Enterprise, leading to the M.Phil., unites world-leading scientists and successful entrepreneurs to deliver a programme combining scientific rigour with a practical perspective on the exploitation of rapidly developing technologies. It is intended for students with a good first degree in the physical sciences, engineering or relevant areas of biology or biochemistry, ideally with some post-graduate experience in an industrial or business environment and who are enthusiastic about enterprise and innovation. The students use of the Nanoscience Centre on the University's West Cambridge site, and are taught also in other parts of the University, particularly the Judge Business School. They have some joint video-conference sessions with MIT and visits by MIT faculty. The course modules are taught in the first two terms and followed by individual project work involving scientific-literature and business-case studies leading to a 15,000 word dissertation. The modules are drawn from strands covering Science and Technology, Business Management, and Innovation and so cover the many complexities involved in discovery and exploitation.

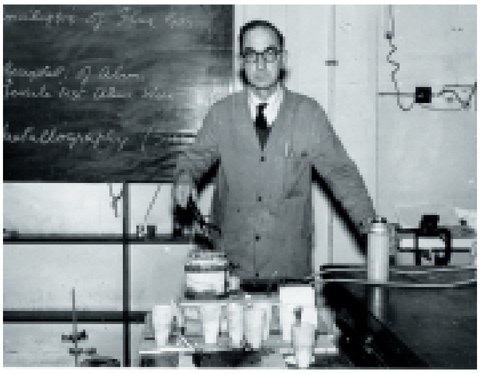
The Department in the 1950s

Dr Raymond K. Hart, IOM, winner of the 1995 Morton D. Maser Distinguished Service Award of the Microscopy Society of America, sent us his reflections on his time in the Department fifty years ago. What follows is a slightly condensed version.

Upon reading the recent issue of *Material Eyes* it grieved me to read the obituary of Gerry Smith. Although I was a graduate student of U.R. Evans, Gerry and I talked on many occasions, since we had mutual interests in aluminum alloys and hydrogen in metals. I was drawn again to the Department's 1954 group photograph, which still hangs in my library. At that time the Department had a complement of four lecturers under Professor G. Wesley Austin. With the passing of Gerry Smith, all five of the then academic staff are now deceased.

The first eight to ten years following World War II was truly a most fascinating period of time to enter the field of Materials Science. Many new materials and processes had been developed under wartime urgency and security, but those materials required additional research/development/refinement in order to be acceptable for use in everyday commerce. Also, those early post-war years saw the mandatory retirement at age 65 of many materials scientists of great stature. Fortunately, only a few of those persons withdrew from their professional activities.

During my time in Cambridge one was able to attend lectures by Sir Lawrence Bragg on his bubble model dislocation theory, followed by Sir Nevill Mott on dislocations in metals. Those lectures were often followed by discussion meetings at the Cambridge Philosophical Society, which nearly always concluded with a lively discussion between Sir George Thomson and Sir Charles Galton Darwin, and on occasion even Professor Paul Dirac would enter into the fray.



Arthur Tabor assisting in the teaching laboratory of the 1950s

Also, during my time at Cambridge, Professor G. I. Taylor was working on a more satisfactory solution to his plastic deformation theory, which he originally put forward in the early 1930s.

By 1950, fundamental metals research was either aimed at elucidating the physical nature of the system, such as behavior of dislocations and defect structure, or determining a material's environmental compatibility. In particular, metals for the nuclear industry, on which my research was focused, had to accommodate extremes in temperature and pressure, as well as be corrosion-resistant and not suffer degradation while under intense radiation.

A somewhat similar situation also existed with aircraft gas-turbine engines, but without the added complication of irradiation and fission-fragment damage. However, the service life of many turbine engines was severely shortened as a result of vanadium compounds in the fuel and later by sulfur. I investigated the nature of the fused vanadium compounds (vanadates) in the surface of turbine blades by electron diffraction in the mid 1950s. Sulfidation problems are still real even today in the hot-sections of turbine engines when inferior grade fuel is used, and unfortunately that practice still occurs in many locations around the world.

By the early 1950s there was an urgent need for new methodologies to explore the surfaces of metals as well as their bulk properties. During the previous 15 years, excluding the World War II years, X-ray diffraction, electron diffraction and optical spectroscopy had played an important role in metals research. Transmission electron microscopy (TEM) became a research tool in 1939, and following the war TEM became an important biological research tool, a role in which it is still very prominent today.

As a research tool in metals research the early series of post-war electron microscopes were highly inadequate for the task which was assigned to them. All operated under very poor vacuum, at relatively low accelerating voltage, with poor stigmator control and rudimentary electron beam control. It was not until 1957-1958 when Siemens introduced its Elmiskop 1, and which incorporated a double condenser lens system, that serious transmission electron metallography was realized.

A major commitment of Professor Wesley Austin was to build up the research standing of the Department and to obtain new instruments which were to be commensurate with the aims of the Department. To that end, a 75 kV Siemens electron microscope and an Edwards (Finch-Type) electron diffraction camera were installed in the Goldsmiths' Laboratory by the end of 1952.

During the winter of 1952-1953 an intense interest for what I will call electron metallography was generated within university departments that were lucky enough to have electron-optical equipment. The enthusiasm shown by both faculty and graduate students alike was so intense that a summer school in The Use of Electrons in the Examination of Metals was organized for 20-31 July, 1953. By courtesy of Professor Bragg, Professor Austin and Dr F.P. Bowden, the course was held in the Cavendish and Goldsmiths'

Laboratories as well as in the Laboratory for the Physics and Chemistry of Surfaces (PCS). Important work at that time was being carried out by Dr J.W. Menter, in studying surface morphology by reflection electron microscopy in a modified "Metro-Vic" instrument.

As a demonstrator during that course, I was able to apply my skills in preparing oxide replicas as well as in electro-polishing/electro-thinning metal surfaces and foils.

Of historical note, the Tuesday afternoon session of the 1953 Summer School was devoted to scanning electron microscopy with a practical demonstration by Dr K.C.A. Smith, using the Engineering Department's SEM-1. The inclusion of SEM as a specific topic in that summer school's schedule was the first occasion, to my knowledge, in which SEM was included in an academic course.

I received my Ph.D. in Metallurgy in early 1955, and until 1970 I set up and managed an electron microscope facility at the Argonne National Laboratory, near Chicago, USA. My main research interests were corrosion/oxidation of nuclear reactor materials and environmental damage from fission fragments and fusion by-products. For the past 35 years I have been involved in forensic engineering science as President of Raymond K. Hart, Ltd., Consultant Metallurgists.

Many of my investigations have involved hot-section failures in aircraft gas-turbine engines, which I first became interested in during my Cambridge years.

Dr R K Hart, Atlanta GA

Vacation Placements in Europe

Although it is open to our undergraduates to participate in the exchange with MIT that started under the auspices of the Cambridge-MIT Institute, it is not possible for them to spend a year in Europe under the ERASMUS scheme.

EPFL Lausanne ***Photo: James Chivall***

Instead, largely through the initiative of Professor Bill Clyne, a series of summer vacation placements in Europe was initiated nearly ten years ago and to-date upwards of 100 undergraduates have each spent about eight weeks in laboratories in one of a number of universities or research establishments in Germany, Switzerland, France, Austria or Belgium. The list of placements available evolves from year to year and currently includes institutions such as the Max Planck Institut für Metallforschung in Stuttgart, the Ecole Polytechnique Fédérale de Lausanne and the Technische Universität in Vienna. Apart from providing valuable experience in the application of their subject, the participants have an excellent opportunity to improve their language skills, which can help them with the language options available in the third and fourth years of our four-year Materials Science course. Of the 20 or so placements on offer in a typical year, roughly one quarter are in French-speaking regions and the rest are almost all in German-speaking areas. For each placement, the host institution provides financial support in some form, possibly as free accommodation, and a bursary is also available via the Department from Alcan and the Worshipful Company of Armourers & Brasiers, for whose generous support we are most grateful. To provide gentle encouragement to complete it in a timely manner, the second part of the bursary is paid only after receipt of the (short) final report! Some undergraduates are also eligible for additional support from other sources and so, in practice, the placements impose little or no net financial burden on participants and, for many, provide an opportunity for further European exploration. As can easily be imagined, all this involves a substantial administrative burden, ably carried out over several years by Mary MacGinley and now by Lianne Sallows.

The students selected are those judged most likely to benefit from the experience and to prove most satisfactory from the viewpoint of the host institution – both in terms of successfully completing a research project and from the point of view of interacting well with personnel there at various levels. Projects carried out cover an enormous range of topics and give experience of many important techniques. For example, in summer 2004 sample projects ranged from investigating carbon nanotubes for future industrial composites, through measuring the effect of temperature on fracture mechanism in particle-reinforced metal-matrix composites, to determining the TTT diagram for crystallization of some bulk metallic glasses, and carrying out a structural and mechanical characterisation of insect cuticle. The great majority of the projects involve the student in producing a written report for the host institution or giving an oral presentation, or both, thus providing further valuable experience in these important skills. Happily, but not surprisingly, the great majority of students rate the interest of their projects and the general experience gained very highly indeed. Further details can be found at:
www.msm.cam.ac.uk/Teaching/placement/euro

For any comments about this newsletter or alterations to your address, please contact Carol Ann Monteith by e-mail: cm259@msm.cam.ac.uk

Armourers & Brasiers' Cambridge Forum 16 June 2005

This year saw the second in this annual series of events, hosted by our Department with the aim of raising the profile of materials science in the UK academic and industrial communities, while being international in scope. The Forum attracts high-level involvement from industry, research councils and other influential bodies. It is generously supported by the Armourers & Brasiers' Livery Company and other sponsors (Corus, IOM^3, Innoval Technology, Institute of Physics, NAMTEC, Novelis UK, Rolls-Royce, Royal Academy of Engineering, Royal Society of Chemistry).

The speakers were: Dr Bill Jones (Associate Director, Pfizer Institute, and Dept. of Chemistry, Cambridge) on "Relating structure and properties in pharmaceutical solids"; Prof. Tony West (Head, Dept. of Engineering Materials, Univ. of Sheffield) on "Electroceramics: The role of solid state chemistry"; Prof. John Kilner (Head, Dept. of Materials, Imperial Coll.) on "Powering the future: Materials selection for solid oxide fuel cells"; Dr Graham Cooley (CEO, Metalysis plc) on "Introducing a new technology to a traditional industry"; and Prof. Peter Edwards FRS (Inorganic Chemistry Lab., Oxford) on "Materials for hydrogen storage: The grand challenge". There followed the main event of the day, the 7th Kelly Lecture, given by Prof. Daniel Morse (Director, UCSB-MIT-Caltech Institute for Collaborative Biotechnologies, Univ. of California Santa Barbara). His talk, "Biologically inspired routes for materials synthesis and nanofabrication: High performance with low environmental impact" provided a masterly overview showing (among other things) how an in-depth understanding of biomineralization can lead to new environmentally friendly routes for the synthesis of electronic ceramics.

We hope to see you at the 2006 Forum, to be held on 13th June; for further information please contact the authors of this item Lindsay Greer, alg13@cam.ac.uk and Rachel Hobson, rjh24@msm.cam.ac.uk.

Materials Modelling – now read the book

Our M.Phil. course in Materials Modelling has led to publication by Maney of a book entitled *Introduction to Materials Modelling* edited by Dr Zoe Barber and incorporating contributions from several members of the academic staff of the Department. In nine chapters it covers a wide range of modelling techniques in computer simulation of the structure and properties of materials (quantum and continuum) with examples of applications on length scales from atomic upwards. In addition to being the "course book", it is undoubtedly useful to anyone seeking an introduction to the increasingly significant area of modelling.

Attracting the next generation

This July young science enthusiasts have been getting first-hand experience of what studying at Cambridge is really like by taking part in the *Headstart* physical sciences summer school. The course gives Year 12 (or equivalent) students a taste of the Natural Sciences courses at Cambridge – lectures, practicals and taking part in seminars. The week was organised by Dr Rob Wallach and Lianne Sallows from the Department as part of the Royal Academy of Engineering's national *Headstart* programme for young people interested in pursuing scientific careers. The 36 participants stayed in King's College and learnt about astronomy, materials science, chemistry and physics, as well as experiencing mock admissions interviews, working on team projects and getting careers advice.

Participants in the *Headstart* programme investigating fracture toughness

A practical session in the *Science for Society* course

Another way of attracting the next generation is by informing and enthusing their science teachers. With this aim, the Goldsmiths' Company funds free residential *Science for Society* courses for science teachers, broadening their perspective on subjects allied to A-levels. So, in parallel with the *Headstart* summer school, the Department has been host to the inaugural *Science for Society* course in Materials Science, a happy reminder of the long-standing connections between the Department and the Company. The course provided an insight into the broad field of modern materials, spanning the physical sciences, engineering and biomedical applications, through lectures, practical demonstrations and industrial visits covering topics as diverse as aerospace, superconductivity, and biomedical materials. Highlights of the course included talks by Goldsmiths' Professor Colin Humphreys on "How materials science can reduce global warming" and Head of Department Derek Fray on "Electrochemical processing – from metal extraction, through high technology, to space exploration".

Nanostructures and Excellence
- profile of Dr Judith Driscoll

Dr Judith Driscoll returned to the Department in Sept. 2003, twelve years after completing her PhD in Derek Fray's group. She brought with her a research group and many interesting bits of equipment, which have been dispersed in different labs across the department. In her career so far, she has worked at some of the world's leading research establishments including the Max Planck Institute Stuttgart, IBM Almaden, Stanford University, Los Alamos National Laboratory, and Imperial College, London.

Judith is a Reader in Materials Science, her speciality being materials chemistry and processing of functional materials. She is also a Marie Curie Excellence Fellow where she leads an Excellence Team called "NanoFen" in the area of nanostructuring of functional oxides. The materials systems she works on include high-temperature superconductors for power applications, medium-temperature superconductors (MgB_2) mainly targeted towards MRI applications, oxides for spintronic and magnetoresistive applications (e.g. highly spin-polarised oxides and dilute magnetic semiconductors) and nano-composites for enhanced and novel functionalities. Some of her work is undertaken in partnership with Los Alamos National Laboratory, where she is a long-term visiting staff member.

Dr Driscoll lectures a Part IA course on Device Materials. She recently became a Fellow of Trinity College, where she supervises and directs studies of undergraduates. She and husband Kelly have two daughters, who are the usual passengers of the bright yellow cycle trailer that is often seen parked outside the department. When not working, enjoying the children, or renovating their home in Cambridge, they are avid outdoors people, and are fortunate to spend a number of weeks each year hiking and ski-ing in both the Northern and Southern Rocky mountains (namely Montana, where Kelly is from, and New Mexico where Los Alamos is located).

http://www.msm.cam.ac.uk/dmg/GroupInfo/homepages/Judith.html

Congratulations to:

Dr Serena Best and **Dr Ruth Cameron:** Personal Readerships from October 2003.

Professor Mark Blamire: Personal Chair from Oct. 2004.

Professor Bill Bonfield: the Prince Philip Gold Medal of the Royal Academy of Engineering (the Academy's Premier Medal) for his exceptional contribution to Engineering.

Professor Tim Burstein: the 2004 Pilkington Teaching Prize, in recognition of excellence in teaching at the University; Fellow of the Electrochemical Society; a Personal Chair from October 2005.

Professor Robert Cahn: Membership of the Johns Hopkins Society of Scholars.

Dr Bill Clegg: Department Teaching Prize for 2003-2004.

Professor Bill Clyne: IOM^3 Griffith Medal and Prize.

Dr Judith Driscoll, Personal Readership from October 2004.

Dr Caterina Ducati: Royal Society Dorothy Hodgkin Research Fellowship, 2004.

Mr Dave Duke: two score years with the Department.

Dr John Durrell, Dr Athina Markaki, and **Dr Charlie Wu:** EPSRC Advanced Fellowships, 2005.

Professor Derek Fray: 2003 Royal Society Armourers and Brasiers' Award; TMS 2005 LMD Light Metals: Reactive Metals Technology Award.

Dr Ian Kinloch: Royal Academy of Engineering / EPSRC Research Fellowship, 2004.

Saurabh Kundu: Indian Institute of Metals "Young Metallurgist of the Year Award", 2004.

Dr John Leake: President of St John's College from 2003.

Dr Neil Mathur: University Lecturer from Oct 2005.

Dr Paul Midgley: Personal Readership from Oct 2003; the IOM^3 Rosenhain Medal and Prize 2004.

Alex Mischenko: Churchill College Peter Roth Prize.

Dr Tom Quested: *Mater. Sci. Technol.* Literature Review Prize for 2004 for his article "Understanding the mechanisms of grain refinement of aluminium alloys by inoculation".

Dr Cathie Rae: the 2003 Rolls-Royce Mark Shipton Award for the best Rolls-Royce patent, with Ken Grubb, Neil Jones, and Bob Broomfield from Rolls-Royce, for their patent "A Single Crystal Alloy for Maximum Creep Strength".

Dr Karl Sandeman: College Lectureship in Physics and Fellow, Churchill College; Royal Society University Research Fellowship from Oct 2005.

Dr Sammy Tin and Robbie Hobbs: the 2004 Rolls-Royce Mark Shipton Award for the best Rolls-Royce patent, with Bob Broomfield and Neil Jones from Rolls-Royce, for "Single Crystal Superalloy with Improved Castability".

Professor Sir John Meurig Thomas: Gold Medal from The Honourable Society of Cymmrodorion for distinguished services to Welsh culture and British public life; Honorary Doctorate from the University of Turin during the 600th Anniversary celebrations of the founding of the University; Honorary Doctorate from Clarkson University, at the 79th Colloid and Surface Chemistry Symposium of the American Chemical Society; Honorary Fellow of Accademia Nazionale Dei Lincei, Rome, the oldest scientific academy in the world, founded 1603; the RSC Sir George Stokes Gold Medal for "pioneering and innovative electron-based nanochemical analyses".

Yokota Tomoyuki: Tawara Medal of the Iron and Steel Institute of Japan for his work on the Spontaneous Reverse Transformation in Steel.