BIOGRAPHICAL MEMOIRS

Raymond Edward Smallman CBE FREng. 4 August 1929 — 25 February 2015

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Elected FRS 1986

BY P. J. GOODHEW* FREng

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Raymond Edward Smallman was one of Britain’s leading physical metallurgists. His books influenced many generations of undergraduates, and his research group spawned more than a dozen professors of metallurgy and materials science, a university vice-chancellor and at least two directors of major metal companies. Smallman’s range was immense and during an active research and teaching life of more than 60 years he made important contributions, often using electron microscopy, to our understanding of crystal defects and deformation behaviour in metals, alloys, intermetallic compounds and ceramics. His professional career was based at the University of Birmingham for more than 50 years and he contributed hugely to the success of one of the country’s leading schools of metallurgy and materials.

FAMILY BACKGROUND AND EARLY YEARS

Raymond Edward Smallman† was born in a public house in Wolverhampton in the West Midlands on 4 August 1929. He attended Brownhills infant school for a year before the family moved to take over a fish and chip shop in Bridgtown near Cannock—now dominated by the M6 toll motorway. Here Ray stayed until he went to university. He passed the ‘11-plus’ examination at the precocious age of nine and went to Rugeley Grammar School, where he started on 4 September 1939, the day after war broke out. The end of the war and the return of his father enabled him to enter the sixth form and take his Higher School Certificate, which opened up the possibility of going to university.

Ray’s father, David, and his mother, Edith (née French), were both born in Wolverhampton and for most of his schooldays they ran the shop and kept pigs and chickens. Ray was the third of their five children and during the whole of his time at school had to help with the chores associated with the family shop. These included delivering orders and peeling potatoes, both

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† He was actually christened Edward Raymond Smallman but never used this sequence of names.

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of which had to take precedence over school homework. When he entered secondary school, the potatoes for the day had to be peeled before Ray caught the 8.30 a.m. train to Rugeley. Despite this load, Ray did well in his Higher School Certificate in mathematics, higher mathematics, physics and chemistry and was awarded a County Scholarship.

**Education and PhD studies, 1947–53**

Although he initially preferred physics, Ray was accepted into the University of Birmingham in 1947 to study for a BSc in metallurgy. In this period after the war, returning ex-servicemen were given priority for university entrance and there were fewer than 10% ‘grammar-school boys’ on most courses. Ray had been told that the metallurgy course led to a physics-based specialism in theoretical and structural metallurgy designed by Alan (later Sir Alan) Cottrell (FRS 1955). Fifty-five years later, Ray would be the co-author of the Royal Society’s biographical memoir of Sir Alan (48)*.

The Department of Metallurgy was led by Professor Daniel Hanson and during his undergraduate course Ray was fortunate to be taught by a range of outstanding staff, many of whom were already Fellows of the Royal Society. He remembered Professors P. B. Moon and Mark (later Sir Marcus) Oliphant in Physics, George Watson (a Fellow who had then just received the Sylvester Medal) in Mathematics, Walter Haworth (Nobel laureate in 1937) in Chemistry, and Cottrell, G. V. Raynor, B. A. Bilby and F. R. N. Nabarro (all Fellows) in Metallurgy and Physics. Ray did indeed take, in his final year, the theoretical and structural metallurgy option, whereas most students took the industrial metallurgy route. His chosen option involved two research projects, supervised by Bruce Bilby (on carbon-induced damping in iron) and W. H. Hall (using X-rays to examine the defect structure of aluminium). In 1950 he graduated with first-class honours and was awarded a university research scholarship to study for a PhD.

Ray had by now developed an interest in X-ray diffraction and chose to embark on his PhD studies under the supervision of Dr Hall. However, Hall left after a few months and Ray carried on with a project entitled ‘The structure of cold worked metals’ under the guidance of Alan Cottrell but supervised on a day-to-day basis by Kingsley (Dr G. K.) Williamson. He thus found himself a member of two research teams, doubling the benefit that a research student gets from seminars, discussions and visitors.

Dislocations in metals were first made directly visible by transmission electron microscopy in the mid 1950s. In 1950, when Ray started his PhD work, the usual way to determine dislocation densities was with X-ray spectrometry. In his PhD work, Ray improved a Geiger-counter X-ray spectrometer to measure diffraction line shapes and intensities from deformed metals—effectively turning it into an X-ray diffractometer. He was thus able to determine the interstitial position of carbon in α-iron, the effect of cold work on dislocation locking and—retrospectively most satisfying to him—to determine dislocation densities in some cold-worked and annealed metals just before they were observed by electron microscopy in 1956.

Ray was awarded his PhD in 1953, and his first two papers (1, 2) were published in the first volume of the new journal *Acta Metallurgica.*

* Numbers in this form refer to the bibliography at the end of the text.
In 1953, with his PhD completed, Ray was offered a post as Scientific Officer in the Metallurgy Division at the Atomic Energy Research Establishment, Harwell. He worked for a short time under Bill Mott using X-ray diffraction to study the structure of liquid metals, specifically mercury and mercury–thallium alloys, eventually using radial distribution functions to show the strong association of atoms in the liquid state that was a precursor to compound formation in the solid.

The Head of Division, Monty (later Sir Monty) Finniston (FRS 1969), took an interest in Ray and suggested that he look at textures that had become of interest in nuclear technology in both canning materials and fuel. He built a texture goniometer and produced results on the influence of alloying on textures in face-centred cubic (fcc) metals, explaining the results in terms of stacking fault energy—which was to become a theme in his work for a couple of decades. Finniston was impressed enough to put Ray up for promotion to Senior Scientific Officer at the early age of 25 years.

Alan Cottrell left Birmingham at this time to lead the Irradiation Studies Group at Harwell, and Ray joined his group as a section leader looking into the structure of irradiation damage. It proved difficult to discover much with conventional X-ray diffraction techniques so Ray decided to apply small-angle X-ray scattering to irradiated samples. Together with Ken Westmacott (then one of Harwell’s carpentry technicians!) he built a small-angle spectrometer and made the crucial decision to study quenched aluminium and copper because he expected the defect structures to be simpler, with interstitial concentrations being very low and thus only vacancies involved. They soon found evidence that small defects (later clarified as voids and dislocation loops) were present. Cottrell suggested that their estimated size of 100–1000 Å (10–100 nm) should make them visible in a transmission electron microscope (TEM). P. B. (now Sir Peter) Hirsch (FRS 1963), Bob Horne and Mike Whelan (FRS 1976) had just published the first images of dislocations in aluminium (Hirsch et al. 1956), so Ray used one of the early EM6 microscopes at AEI’s nearby laboratories and was able to produce (rather low-quality) images of prismatic dislocation loops. Collaboration with the Cambridge group soon produced much better images of Frank loops containing stacking faults.

Despite this early success of the TEM, senior staff at Harwell were not persuaded to invest in a high-quality instrument at that time, and some momentum was lost. Ray had always been attracted to teaching and in 1958 accepted a lectureship in the Department of Physical Metallurgy at Birmingham (now the School of Metallurgy and Materials), where he was to spend the rest of his career.

Ray started as a lecturer in 1958, was promoted to senior lecturer in 1963, and thence to a personal chair in 1964 at the age of 34 years, becoming the youngest professor in the university. In 1969 he was appointed Feeney Professor of Metallurgy and Materials Science and Head of the Department of Physical Metallurgy and Science of Materials. In the 1980s he was successively Deputy Dean and Dean of the Faculty of Science and Engineering and then Dean of the newly created Faculty of Engineering, while remaining Head of Department until 1988. From 1987 to 1992 he was Vice-Principal of the university. After
his retirement in 1993 Ray became an emeritus professor and was an active member of the school until his death.

In addition to his considerable research achievements, detailed below, Ray made a substantial impact on his school, faculty and university. He was successful in integrating the separate (and sometimes warring) departments of Industrial Metallurgy and Physical Metallurgy into a single Department of Metallurgy and Materials and stimulating his colleagues to high-quality research, which was in due course recognized by a 5* rating in the 1992 Research Assessment Exercise (RAE), the best score in Birmingham’s Faculties of Science, Engineering and Medicine. In 1985 he argued successfully for the formation of a Faculty of Engineering, seeking to establish parity of esteem with Science. He became its first Dean and restructured it to reduce the number of small departments. At about this time (1986) he was elected FRS.

In the same year Michael Thompson (a former colleague at Harwell in the 1950s) was appointed Vice-Chancellor and he soon asked Ray to become his Vice-Principal. The major achievement of these years was the development of a new financial model for the university, which involved a very successful new relationship between administrative departments and academic budget centres.

Ray’s increasingly successful scientific career was conducted, between 1963 and 1975, against the background of a bizarre professional harassment case. The details are not relevant to this account, but it should be recorded that for a dozen years Ray’s research and teaching were conducted in an environment in which he, his colleagues and his superiors were bombarded with abusive correspondence and outrageous claims of malpractice, all of which were eventually found to be unsubstantiated. I was a student under Ray’s supervision during this period and such was Ray’s dignity and calm under this duress that his students were unaware of the case. Despite the time it must have consumed, the affair was not allowed to interfere with research, supervision or teaching, although it must have caused considerable distress to Ray himself.

**RESEARCH AND ELECTRON MICROSCOPY**

Ray Smallman’s research career lasted for 65 years, during which time the technology available to pursue an understanding of the physical world changed dramatically. Transmission electron microscopy, with the added facility of obtaining diffraction information from small volumes, was developed over the same period. In 1959 Ray won a grant from the Department of Scientific and Industrial Research (DSIR) that enabled Birmingham to buy its first metallurgical TEM—an AEI EM6G—for £11 000. Computing arrived in the mid 1960s, and its usefulness developed rapidly. Ray was always keen to apply each newly developed technique but had little interest in instrument development or computing per se. The principal theme running through his work is the understanding of microstructures associated with deformation and damage in metals and ceramics. He worked on a very wide range of metals, alloys and ceramics, with a wide range of structures—among them fcc, body-centred cubic, hexagonal close-packed (hcp) and ordered intermetallic compounds.

A second theme is texture, which started with thorium in 1954 (3), emerged in a review paper with I. L. Dillamore in 1974 (35), flourished again in the 1980s when 1 MeV microscopy became available, and finally in the 1990s led to a major series of papers with C. S. Lee and B. J. Duggan (for example (41)).
Throughout his career Ray showed a supreme talent for enthusing and working with a series of brilliant practitioners—principally but not solely microscopists—on significant problems in physical metallurgy. He was not himself a brilliant technical microscopist but could always see the potential of a new technique and had the persuasive arts to find the money to fund the equipment, the researchers and the travel to disseminate the results. In the (long) days before the Internet his students would haunt the journals section of the library waiting for the latest issues to check that they had not been scooped by research teams in Japan or the USA, while Ray would be out visiting the rival groups. Early research students included Ken Ashbee, Trevor Lindley, John Terry and Jeff Edington; they were followed by about 100 more.

Eminent among Ray’s long-term collaborators were M. H. Loretto, I. P. Jones, K. H. Westmacott and B. J. Duggan. He published more than 60 papers with Loretto and more than 50 with Jones, both of whom remained at Birmingham with Ray for more than 30 years. Other significant collaborators who joined Ray on the academic staff were P. S. Dobson, I. R. Harris and I. L. Dillamore, the last of whom left in 1969 to follow a career in industry.

The period from 1953 to 1968 was incredibly productive for Ray, with several of his papers from this time becoming citation classics. It is noteworthy that his four most cited papers were on four quite different topics: dislocation densities measured using X-rays in cold-worked and annealed metals with Kingsley Williamson in 1956 (4), stacking faults in fcc metals and alloys with Ken Westmacott in 1957 (5), dislocation loops in quenched aluminium with Westmacott and Hirsch and J. Silcox at Cambridge in 1958 (8), and the plasticity of NiAl with Tony Ball in 1966 (22). X-ray techniques took a back seat after the 1950s, but the other three classic papers initiated major lines of work that Ray pursued for the next three decades.

Early dislocation theory implied that dislocation densities in metals should increase during cold work. Ray’s work with Kingsley Williamson from 1953 to 1956 demonstrated, using Debye–Scherrer X-ray analysis, that this was indeed the case (4). They measured the line broadening in several annealed and cold-worked metals and alloys and rather ingeniously deduced the dislocation density by comparing measurements of ‘particle size’ and ‘strain’ in aluminium, tungsten, molybdenum and α-brass which had been filed or annealed. Using this somewhat crude methodology they were able to determine dislocation densities across the range 10^7–10^11 cm^-2. This was a great achievement at the time.

A second major strand of work arose from the seminal 1958 paper (8) with Hirsch’s group on dislocation loops in quenched aluminium. Clustered vacancy defects are of course not only important in themselves but have a big role in irradiation damage in both fission and fusion reactor technology. The original work on aluminium was essentially a proof of principle and was exploited to study both point-defect aggregation and dislocation source behaviour in a series of papers with Westmacott (9, 10), Edington (14), Dobson (19), Goodhew (23) and Kritzinger (24) on aluminium, and with Eikum (16), Hales (25), Johnston (26), Fraser (31) and Hollox (20) on a range of other metals and ceramics. Later studies revealed that there can be many configurations of vacancy clusters and, as well as faulted (Frank) loops and prismatic loops, both voids and tetrahedral arrangements of stacking faults (‘stacking fault tetrahedra’) can form under specific vacancy supersaturation conditions.

The observation that condensed vacancy loops in many materials are initially sessile and faulted (containing a stacking fault) before ‘unzipping’ to become mobile prismatic loops led to some ingenious experiments to determine the stacking fault energy in materials in which its value is high and therefore measurement by determining the separation of partial dislocations...
is impracticable. This work formed a significant part of a third strand of Smallman’s work centred on stacking faults and their role in controlling deformation. As early as 1957 Ray had published observations of stacking faults with Ken Westmacott (5), and this led to a series of papers on stacking faults in titanium dioxide with Ashbee and Williamson (12) and in a wide range of metals with Dillamore (15), I. R. (Rex) Harris (13) and Beeston (18). Ray was quick to connect the behaviour of crystal defects (in this instance stacking faults) to macroscopic phenomena (such as rolling texture) that have a significant effect on mechanical properties.

The Birmingham group was one of the first to exploit the possibility of heating metallic specimens in the TEM. Hot-stage annealing, with temperatures up to 200 °C, proved useful in studying dislocation loop behaviour in low-melting-point metals such as aluminium, and oxidation-driven behaviour in other metals such as zinc and magnesium. In combination with a simple movie camera this became quantitative microscopy, not just interesting snapshot observations. Ray’s suggestion, implemented initially by Dobson and Goodhew (23), was to measure stacking fault energy by the rate of shrinkage of faulted dislocation loops.

The third strand of work, which sprang from early work on ordered NiAl with Tony Ball (21), involved the plasticity of NiAl, then a rather new material. They identified the operative slip systems as well as the nature of the vacancy defects. Ray’s increasing interest in the often complex relationships between defect structure and mechanical behaviour led to work on such diverse problems as creep in dispersion-strengthened Ni–Co (with Hancock and Dillamore (32)), deviation from stoichiometry in titanium oxides (with Vere (28)), yielding in ordered alloys (with Besag (29)), cracking in irons and steels (with Webster and Dillamore (30)), further studies of the plastic deformation of NiAl (with Fraser and Loretto (33)), yielding in Cu3Au (with Morris and Besag (34)), ordering in Ni3Fe (with Morris, Brown and Piller (37)), martensite formation in steels (with Brooks and Loretto (38)) and the strength and hardness of Ti alloys (with Woodfield, Postans and Loretto (40)). This is not by any means a complete list but it gives a flavour of the huge range of metallurgical topics in which Ray became involved and to which he contributed key data and understanding.

One of Ray’s early competitive successes was the award to Birmingham of one of the UK’s half-dozen high-voltage electron microscopes (HVEMs). These operated with electron energies up to 1 MeV and enabled thicker specimens to be penetrated. Additionally (and inevitably) the displacement of atoms by these high-energy electrons became frequent enough to be a problem (by modifying the structure of the specimen before it could be recorded) or an opportunity (by allowing radiation damage to be studied directly). The Birmingham microscope was installed in 1972 and enabled Ray to return to the issue of radiation damage, among other things. He had been active in the topic in the 1950s at Harwell (with Willis (6), Churchman, Makin and Harries (7) and Westmacott (9)) but the HVEM allowed him to exploit electron damage in a series of papers with Loretto in the 1970s and 1980s, largely in hcp metals such as zinc, titanium and zirconium (39). The HVEM operated until 1989, when its building was used to house a plasma melter that formed part of the Interdisciplinary Research Centre (IRC) in Materials for High Performance Applications.

Ray’s contribution across a vast range of materials was partly made possible by the strength and range of the Department of Metallurgy and Materials, which he himself had built. He always had plenty of colleagues working on interesting problems right across the field. In the 1980s and 1990s, when Ray was in his fifties and sixties, he was still publishing leading papers on intermetallic compounds, aluminium and copper alloys, cast iron, and high-temperature superconductors. To give a flavour of this range, in one 12-month period in 1997–98 Ray
published papers on superdislocation dissociation in twist boundaries (with Rong and Jones (43)), on the effect of silicon content on the transformation kinetics of austempered ductile iron (ADI; with Mallia and Grech (44)) and on the orientation dependence of creep in Ni$_3$Al (with Zhu, Fort and Jones (45)).

To summarize Ray’s research impact is almost impossible. He contributed to work on the microstructure of many metals, alloys, compounds and ceramics; he always tried to relate microstructure to its effect on properties and behaviour; he collaborated with, and inspired, hundreds of co-workers and he continued to do this long after conventional retirement.

**Books**

For undergraduate students of metallurgy in the 1950s and early 1960s, the most influential book on physical metallurgy was Alan Cottrell’s *Theoretical structural metallurgy*, first published in 1948, and revised in 1955, just after Cottrell left Birmingham for Harwell (Cottrell 1948). This was too late for Ray to benefit from it as a student but he soon followed Cottrell’s example in writing an undergraduate text covering all of physical metallurgy as it was then understood. The first edition of *Modern physical metallurgy* appeared in 1962 (11), when Ray was still a lecturer of only four years’ standing. It was a *tour de force* by such a young man and has been a standard text around the world for 50 years. *Modern physical metallurgy* went through four editions by 1985; subsequently—with collaborators R. J. Bishop and A. H. W. Ngan—four further editions and variants have appeared (42, 46).

Ray also found time to co-author *Modern metallography* with K. H. G. Ashbee—his first PhD student—in 1966 (17) and *Defect analysis in electron microscopy* with M. H. Loretto in 1975 (36) and in 1969 to revise and update W. Hume-Rothery and C. W. Haworth’s *The structure of metals and alloys* (27).

**Academic leadership**

Ray Smallman was never content to work within a system when he thought that he could change it for the better. His loyalty to the University of Birmingham was unwavering but he frequently found himself discontented with aspects of its organization. His initial reaction on taking over as Head of the Department of Physical Metallurgy in 1969 was to negotiate its merger with the Department of Industrial Metallurgy, correctly perceiving that metallurgy (and subsequently materials science) was not just a science to be pursued for academic interest but a key enabling technology for much of engineering. The same reasoning led him to argue for a distinct Faculty of Engineering at Birmingham, and almost inevitably to become its first Dean in 1985. The standards set by Ray were largely responsible for the department’s excellent performance in the first—and all subsequent—national research assessment exercises. He quickly saw the need to do more than just good research: to publish and publicize it, to collaborate with industry to exploit it, to win funding for dedicated national and regional centres (first the HVEM, then—led by Mike Loretto—the IRC in Materials for High Performance Applications, then—led by Paul Bowen—the Rolls-Royce University Technology Centre), and also (dear to his heart) to devise and implement budgetary funding models within the university to ensure that funds clearly came to those whose excellent research earned them.
In 1987, under new Vice-Chancellor Michael Thompson, Ray became Vice-Principal of the university and eventually had to give up the headship of his beloved department in 1988. He continued lecturing, against his Vice-Chancellor’s advice, throughout his stint as Vice-Principal and indeed afterwards in nominal retirement. His approach to fitting his teaching commitments into the busy life of a Vice-Principal was characteristically pragmatic. He asked for all his classes to be scheduled at 12 noon. He then had a perfect excuse to draw morning meetings to a close in good time, or to escape from a long meeting if he was not in the chair.

It was during his period as Vice-Principal that Ray devised and pushed through a new resource allocation model for the university and ensured that the university library was computerized, rather against the inclination of the administration. Personal charm must have played a significant part in getting these reforms accepted, particularly as (he subsequently boasted) the new models happened to benefit the Department of Metallurgy and Materials.

Beyond the university Ray played a leading role both locally (for example in the Birmingham Metallurgical Association) and nationally, in the Institute of Metals, the Metals Society and the Institute of Materials, in which he served as Vice-President. For more than 20 years he was chair of the Editorial Committee of Metal Science Journal and he served on the Science and Engineering Research Council (SERC).

**Later years: impact on other institutions, 1993–2015**

Although remaining devoted to Birmingham, Ray hugely enjoyed travel both for its own sake and for the opportunities for involvement with overseas scientists and their laboratories. At various times he held visiting professor positions at the universities of Pennsylvania and Stanford, California, Berkeley (with Gareth Thomas), Case Western Reserve, Cape Town (with Tony Ball), Hong Kong (with Brian Duggan), New South Wales and Novi Sad in (then) Yugoslavia (with Professor L. Sidjanin). He also acted as an advisor to the University of Queensland, the University of Topi in Pakistan and the University of Dhaka in Bangladesh. He was an Honorary Foreign Member of the China Ordnance Society and of the Czech Society for Metal Science.

An anecdote arising from Ray’s visits to Novi Sad illustrates the serendipitous effect of travel on one’s home institution. Professor Sidjanin introduced Ray to ADI and together they studied its microstructure by electron microscopy. On returning to Birmingham Ray discovered that his colleague Voya Kondic and his students had in fact been studying this system for several years but had declined to use electron microscopy to elucidate its microstructure, principally because of the friction (at the time) between the departments of Physical and Industrial Metallurgy.

Ray also played a significant part in the early success of the Federation of European Materials Societies (FEMS), becoming Vice-President in 1992 and President in 1994, just after he retired from his position as Vice-Principal and a full-time academic. After this demanding role in FEMS, rather than cutting back on his professional activities Ray undertook still more. In addition to continuing to lecture at Birmingham he went to Australia to review the Department of Mining and Metallurgical Engineering at the University of Queensland, prepared yet another revised edition of Modern physical metallurgy, accepted a position as academic advisor to the Vice-Chancellor of Hong Kong University, where he
Raymond Edward Smallman attempted to introduce an RAE-like system for research assessment, and became a Warden of the Birmingham Assay Office and a non-executive director of the University Hospital Birmingham National Health Service Trust.

Throughout his retirement Ray remained active in research, and his last technical publication was with Sidjanin on ADI in 2010 (47), 20 years after he had been introduced to the topic in Novi Sad.

**Family life**

On 6 September 1952 Ray married Doreen Faulkner in St Luke’s Church, Cannock. Their marriage lasted until Ray’s death and they had two children, Lesley-Ann (a pathologist) and Robert (a GP), and seven grandchildren.

The above account of Ray’s professional life might give the impression of a man wholly dedicated to science in our universities. This would be to ignore an important aspect of this family man, who found the time and energy to write not one but two family memoirs. *Base metal to gold* is subtitled ‘Memoirs of an academic metallurgist’ and devotes about half of its 150 pages to Ray’s activities with his family and friends. *Family heritage and social history*, which was completed in 2011, describes the background of the Smallman and Faulkner families, starting with Ray and Doreen’s great-great-grandfathers at the beginning of the nineteenth century. Almost its only defect as a source is its lack of page numbers—an uncharacteristic detail of omission! Figure 1 shows Ray and Doreen among many of their extended family at one of their regular gatherings.
In addition to describing the development of Ray’s extended family, both memoirs reveal Ray’s love of travel, almost always with Doreen, and his knack of making lifelong friendships. One friend revealed at a recent event that he and Ray would have a regularly weekly phone call (between Hong Kong and the UK) ‘just to keep in touch’. Ray was also proud of the recognition represented by the award of a CBE in 1992. Figure 2 shows Ray and Doreen at Buckingham Palace with their daughter Lesley-Ann and son Robert.

**Honours**

- **1986**  Fellow of the Royal Society
- **1990**  Honorary DSc, University of Wales
- **1991**  Fellow of the Royal Academy of Engineering
- **1990**  Honorary DSc, University of Novi Sad, Yugoslavia
- **1992**  Companion of the British Empire (CBE)  
- **1993**  Foreign Member of the China Ordnance Society, China
- **2000**  Honorary DSc, Cranfield University
- **2005**  Foreign Associate of the US National Academy of Engineering
Raymond Edward Smallman

AWARDS

1969 Sir George Beilby Gold Medal, Institute of Metals and Society of Chemical Industry
1972 Rosenhain Medal, Institute of Metals
1978 Elegant Work Prize, Metals Society
      Van Horn Distinguished Lecture Award
1989 Platinum Medal, Institute of Materials
2004 Acta Materialia Gold Medal

ACKNOWLEDGEMENTS

The author gratefully acknowledges advice and support in writing this memoir from Professor Ian Jones and Professor Rex Harris FREng, longstanding colleagues of Ray Smallman at the University of Birmingham and from Ray's children, Lesley-Ann and Robert. He also wishes it to be known that it was Ray's wish that Professor John Knott FRS FREng should be a co-author but that Professor Knott's illness prevented him from being able to make a major contribution to the memoir.

The frontispiece photograph was taken in 1986 by Godfrey Argent and is reproduced with permission.

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