A Century, and more, of Cambridge Materials Science & Metallurgy

(the centre-page spread in the Centenary Supplement to *Material Eyes* issue 37 (Winter 2021)

Additional Material and a Guide to Original Sources

General reference works

many issues of the *Cambridge University Reporter.*

RS Hutton, *Recollections of a Technologist*, Pitman, London (1964).

AL Greer, The Sidney College Laboratory, pp 195–221, in *Sidney Sussex College Cambridge: Historical Essays in Commemoration of the Quatercentenary*, eds DED Beales & HB Nisbet, The Boydell Press, Woodbridge (1996).

JA Charles & AL Greer, *Light Blue Materials*, Maney/IoM^3, London (2005).

The starting point

From their research spanning 20 years in the laboratory at Sidney Sussex College, CT Heycock and FH Neville produce a series of seminal papers. Their first metallurgical work (**1889**) is *The lowering of the freezing point of tin caused by the addition of other metals*. Neville recognizes intermetallic compounds; his 1900 review lists the 37 then known (>20,000 today).

CT Heycock & FH Neville, On the lowering of the freezing point of tin caused by the addition of other metals, *Proceedings of the Cambridge Philosophical Society* **6**, 366–368 (1889).

FH Neville. Report on the chemical compounds contained in alloys. *Brit. Assoc. for the Advancement of Science* (1900) 1–20 (1900).

Francis Henry Neville FRS (1847–1915)
— in charge of the Sidney College Laboratory from 1980; Bursar of the College 1890–1896.

The Bakerian Lecture (1903)

The Royal Society's premier lecture in the physical sciences is given by Heycock and Neville, in distinguished company: the 1902 lecture was by Rayleigh, the 1904 by Rutherford. Heycock & Neville's paper *On the Constitution of the Copper-Tin Series of Alloys*, with 101 photomicrographs, is the foundation of modern studies of phase equilibria and microstructure in alloys. Later Bakerian lecturers from the Dept are AH Cottrell (1963) and A Kelly (1995).

CT Heycock & FH Neville, On the constitution of the copper-tin series of alloys, *Philosophical Transactions of the Royal Society of London Series A* **202**, 1–70 (1904).

Bakerian Lecture 1963: https://royalsocietypublishing.org/doi/pdf/10.1098/rspa.1963.0188

Bakerian Lecture 1995: https://royalsocietypublishing.org/doi/pdf/10.1098/rsta.1996.0081

Readership in Metallurgy

The Goldsmiths' Company endows a Readership for Heycock in the University Chemical Laboratory (**1908**), and in **1910** donates £700 to equip four rooms in the basement of the Chemistry building on Pembroke St. In Michaelmas Term 1909, Heycock offers a course on *Metallurgy of gold, silver, lead, platinum, copper, tin and other metals* (the fee is one guinea).

Charles Thomas Heycock FRS (1858–1931)
first Goldsmiths' Reader in Metallurgy, 1908

The endowment of the Readership, and the appointment of Heycock, are covered in vol. 38 of the *Cambridge University Reporter* (1908), pp. 702, 880, 983, 1124, 1154, 1350.

The date we celebrate: 5th October 1920

The Goldsmiths' Metallurgical Laboratory is opened by RM Tabor, Prime Warden of the Company. The Laboratory extends existing rooms and is the first purpose-built accommodation for metallurgy in Cambridge.

The Cambridge Review, 15 October 1920

An undergraduate identity (1938)

Graduation of the first Part II Class in Metallurgy (cohort of 4 students).

Light Blue Materials, p. 133.

Summer School (1953): *The use of electrons in the examination of metals*

The Dept acquires its first transmission electron microscope (Siemens 75 kV) in 1952, and plays a key role in this Cambridge Summer School. A world-leading series of papers on TEM of the interaction of dislocations and precipitates culminates in Kelly & Nicholson's 1963 review *Precipitation Hardening*. From then, the pathway of distinction (in technique development and materials understanding) is clear all the way to the Wolfson Electron Microscopy Suite, the world-class facility in our present building.

RB Nicholson, G Thomas, J Nutting, A technique for obtaining thin foils of aluminium and aluminium alloys for transmission electron metallography (1958)

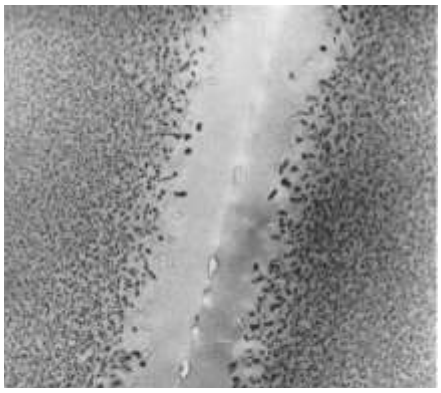
RB Nicholson, J Nutting, Direct observation of the strain field produced by coherent precipitated particles (1958)

RB Nicholson, G Thomas, J Nutting, The interaction of dislocations and precipitates (1960)

EJ Freise, A Kelly, RB Nicholson, Guinier-Preston zone in an aluminum-silver alloy (1961)

JD Embury, RB Nicholson, Dislocation sources in an aluminium alloy (1963)

A Kelly, RB Nicholson, Precipitation hardening, *Progress in Materials Science* **10**, 151–391 (1963).



A grain-boundary precipitate-free zone
[Unwin, Lorimer & Nicholson (1969)]

PNT Unwin, GW Lorimer & RB Nicholson, The origin of the grain boundary precipitate free zone, *Acta Metallurgica* **17**, 1363–1377 (1969).

Crystalline State

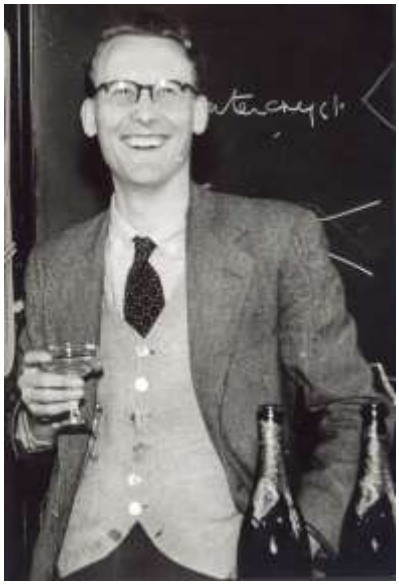
This NST Pt IA course, shared with the Dept of Mineralogy & Petrology, begins in the Michaelmas Term **1965**, lectured in parallel by Tony Kelly and Christine Kelsey to a class too numerous to fit in one theatre. The course evolves through *Crystalline Materials* and *Materials & Mineral Sciences* to (in 2010) *Materials Science* (taught by us alone).

All lecture timetables are available in the *Cambridge University Reporter*.

Strong Solids (1966)

This influential book builds Tony Kelly's reputation. He goes on to be known as 'the father of composite materials', a research theme that further flourishes under D Hull, TW Clyne and WJ Clegg.

A Kelly, *Strong Solids*, Clarendon Press, Oxford (1966).



Anthony Kelly KSG CBE DL ScD FREng FRS (1929 2014) (based in the Cambridge Dept. of Metallurgy, 1959–1967)

worked on particle and fibre-reinforced metals, hybrid composites and laminates, fibre-reinforced cements and concretes, ceramic composites, polymer composites and carbon-carbon composites, analysis of composite strength, plastic flow, fracture mechanics, and fatigue.

Birth of the Device Materials Group

Cottrell established the Dept's research on superconducting materials. In **1972** AM Campbell & JE Evetts publish their seminal (229 pp) *Flux Vortices and Transport Currents in Type II Superconductors*. Jan Evetts goes on to found the DMG, now the Dept's largest grouping of academic staff, working on a wide range of physical properties of materials.

AM Campbell & JE Evetts, Flux vortices and transport currents in type II superconductors, *Advances in Physics* **21**, 199–428 (1972).

At last!

1978: Jane Weston is the first female member of academic staff. Now women are 46% of our academic staff, and of our professors. From the start, of course, women made key contributions: in their Bakerian Lecture paper, Heycock & Neville acknowledge their indebtedness to Miss D Marshall, BSc, Lecturer at Girton, for 'help in the experiments'. Later, Dr Constance Tipper (one of Cambridge's most distinguished metallurgists and ultimately a Reader in Mechanical Engineering) lectures to our early cohorts of Metallurgy undergraduates.

Progressive crushing of fibre-reinforced composite tubes [D Hull (1991)]

D Hull, A unified approach to progressive crushing of fibre-reinforced composite tubes, *Composites Science and Technology* **40**, 377–421 (1991).

University Technology Centre

Of the Dept's industrial partnerships, the Rolls-Royce UTC is the longest lasting and by far the most successful. Established in **1994**, the UTC has inspired many other companies to support research in the Dept.

***Material Eyes* (1996)**

Our newsletter starts to spread the word to our alumni, partners and friends.

https://www.msm.cam.ac.uk/news-and-events/material-eyes-newsletter

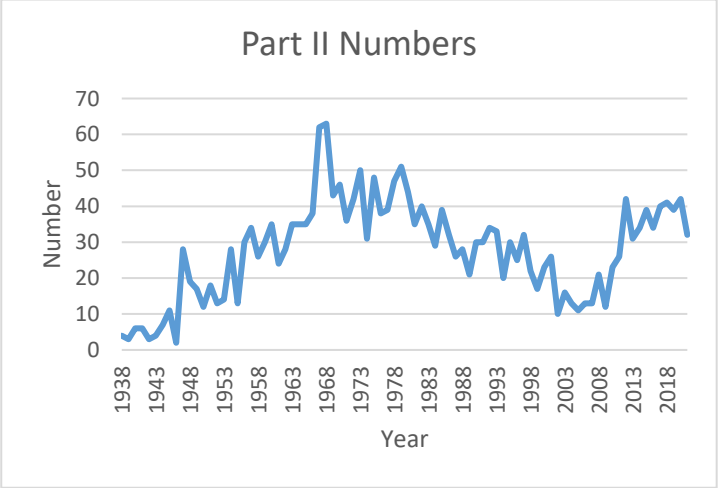
Highs and Lows

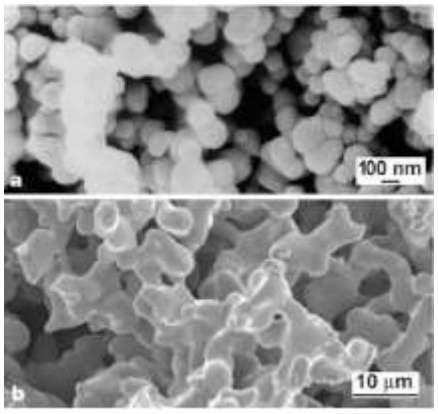
Our graduating classes reached a high of 62 in 1967 and 1968. A steady decline followed to just 11 graduates in 2002. Our student numbers have since risen sharply. From **1998**, our Part II Class may graduate with a BA or (as most choose) stay on for a further Part III year and gain an MSci degree.

From:

JA Leake,
Teaching —100 not out

available on the DMSM website in the section:
"100 years of …"



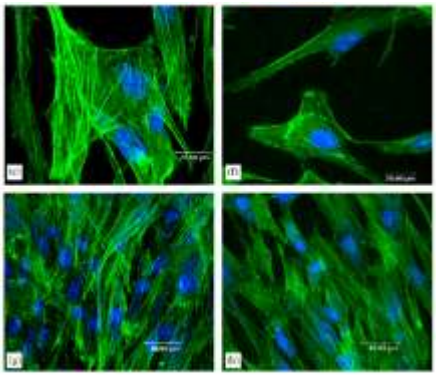


Direct electrochemical reduction of TiO_2 to titanium in molten $CaCl_2$ [Chen, Fray & Farthing (2000)]. A worthy successor to the electrochemistry of UR Evans & the extractive metallurgy of JA Charles, Fray's work has also led to oxygen generation for wound healing and for survival in space missions.

GZ Chen, DJ Fray & TW Farthing, Direct electrochemical reduction of titanium dioxide to titanium in molten calcium chloride, *Nature* **407**, 361–364 (2000).

Medical Materials (1999)

The appointment of Prof W Bonfield nucleates our thriving *Cambridge Centre for Medical Materials*, now directed by Ruth Cameron and Serena Best. Biomaterials is now an essential component of our undergraduate teaching.



Response of osteoblasts to silicon-substituted hydroxyapatite thin films [Thian et al (2006)]

ES Thian, J Huang, SM Best, ZH Barber, RA Brooks, N Rushton & W Bonfield, The response of osteoblasts to nanocrystalline silicon-substituted hydroxyapatite thin films, *Biomaterials* **27**, 2692–2698 (2006).

Modelling of Materials (2000)

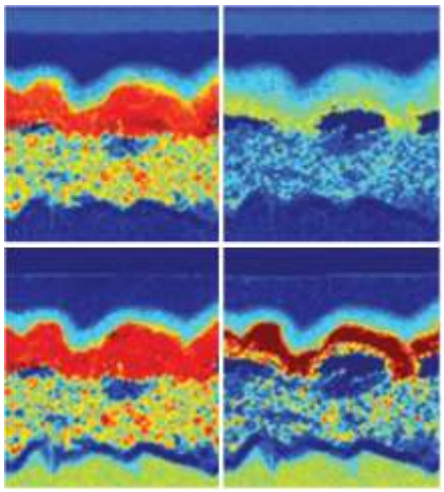
Recognizing the rapidly growing importance of computer modelling, the Dept launches the UK's first masters' course in this subject.

This leads to the publication of:
ZH Barber (ed.) *Introduction to Materials Modelling*, Maney/IoM^3, London (2005).

DoITPoMS

Launched in **2000**, our on-line resource to assist undergraduate-level learning and teaching of materials science now has a library of nearly 900 micrographs in 12 categories, some 70 teaching and learning packages produced by and for students, and lecture demonstration packages. Over the last year, from across the world, there were 498,100 users and 2,134,434 page views.

https://www.doitpoms.ac.uk/index.php



In-situ observation of thermal degradation of perovskite solar cells [Divitini, Cacovich, Matteocci, Cinà, Di Carlo & Ducati (2016])

G Divitini, S Cacovich, F Matteocci, L Cinà, A Di Carlo & C Ducati, *In situ* observation of heat-induced degradation of perovskite solar cells, *Nature Energy* **1**, 15012 (2016).

Armourers & Brasiers' Cambridge Forum

Inaugurated in **2004**, incorporating the Kelly Lecture (1999). The Forum, supported by the A&B Company and other sponsors, highlights global developments in Materials Science. Each Kelly lecturer, whether Nobel laureate or captain of industry, provides insight on how Materials Science can transform, even save, our world. In **2007**, for example, our graduate **Mike Ashby** educated us on the environmental audit of materials choices.

https://www.msm.cam.ac.uk/forum

Iron, cold iron, is master of them all

Kipling's words capture the importance of Harry Bhadeshia's work, recognized in his election (**2008**) as inaugural *Tata Steel Professor* (our second endowed chair), and in his knighthood (**2015**). Harry's work on nanoscale bainite is the culmination of the Dept's research on steels, first energized by his PhD supervisor RWK Honeycombe.

Sir Robert Honeycombe FRS FREng (1921–2007)
— our longest serving Goldsmiths' Professor (1966–1984)

A greener light

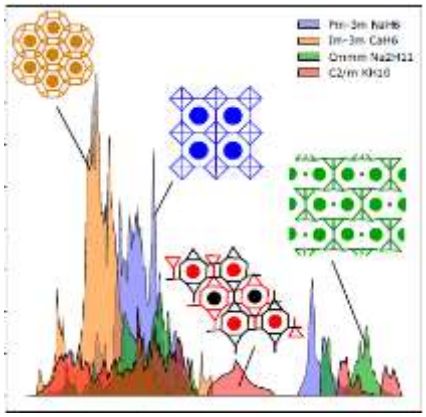
Colin Humphreys' knighthood (**2010**) recognizes his services to science. We note in particular his work on gallium-nitride-based, energy-efficient, and now ubiquitous, light-emitting diodes. Spin-out companies have followed, and work on nitride semiconductors and quantum dots currently flourishes under the direction of Rachel Oliver.

Sir Colin Humphreys CBE FRS FREng FIMMM FInstP FCGI HonFRMS

Head of Department (1991–1995)
Goldsmiths' Professor (1993–2008)

Sir Alan Cottrell Professorship (2015)

Christopher Pickard is the inaugural electee to our third named chair. His work realises Sir Alan's ambition, some six decades earlier, to predict materials properties from electron fundamentals.



High-throughput discovery: the highest-T_c conventional superconductors at 100 GPa. [Shipley, Hutcheon, Needs & Pickard (2021)]

AM Shipley, MJ Hutcheon, RJ Needs & CJ Pickard, High-throughput discovery of high-temperature conventional superconductors, *Physical Review B* **104**, 054501 (2021).

The main room of the Sidney College Laboratory c. 1908. [AL Greer, The Sidney College Laboratory, in *Sidney Sussex College Cambridge: Historical Essays in Commemoration of the Quatercentenary*]

The elusive PhD

The first paper from the 'Metallurgy Laboratory, Cambridge' (**1914**) is *The System Silver–Silver Sulphide* by CC Bissett who, already a Sheffield graduate, is pursuing a BA by research. Cambridge awards its first PhD only in 1921. Cambridge's first Metallurgy PhD is TP Hoar's *The Mechanism of Metallic Corrosion* in **1932**, supervised by UR Evans.

CC Bissett, The system silver–silver sulphide, *Transactions of the Chemical Society* **105**, 1223–1228 (1914).

100 years of the Cambridge PhD: https://specialcollections-blog.lib.cam.ac.uk/?p=17052

Light Blue Materials, p. 177.

Crellyn Colgrave Bissett had an exceptionally good academic record. He served in the Aeronautical Inspection Department of the War Office from 1914, and became Technical Manager of Fry's Metal Foundries in 1919 [*Grace's Guide to British Industrial History*].

Corrosion of Metals (1924)

A student in Heycock's first course, UR Evans in this book promotes his 'new electrochemical theory'. He dominates this field for >50 years; in 1976, aged 87, he publishes his final, 421-page work. His 47 research students go on to distinction at Cambridge and far beyond.

Ulick R Evans CBE, FRS (1889–1980)
Author of >200 papers
BOOKS:
Metals and Metallic Compounds (4 vols), 1923
Corrosion of Metals, 1924
Metallic Corrosion Passivity and Protection, 1937
An Introduction to Metal Corrosion, 1948
Corrosion and Oxidation of Metals, 1960
— First Supplementary Volume, 1968
— Second Supplementary Volume, 1976

UR Evans (right) with Marcel Pourbaix (left) 1969

New Museums cites

From 1972 to 2013 our postcode in the city centre was CB2 3QZ, from which we have more than 5800 papers. Two of these each have more than 7000 citations: *First Principles Methods using CASTEP* (2005) (co-author CJ Pickard, then at the Cavendish Laboratory); *Electron-Energy-Loss Spectra and…* (1998) (co-author CJ Humphreys).

SJ Clark, MD Segall, CJ Pickard, PJ Hasnip, MIJ Probert, K Refson, & MC Payne, First principles methods using CASTEP, *Zeitschrift für Kristallographie* **220**, 567–570 (2005).

SL Dudarev, GA Botton, SY Savrasov, CJ Humphreys & AP Sutton, Electron-energy-loss spectra and the structural stability of nickel oxide: An LSDA+U study, *Physical Review B* **57**, 1505–1509 (1998).

Citation numbers from *Web of Science* in November 2021.

Research Excellence

In REF2014, 69% of the Dept's activities are rated 'world-leading' and our grade point average is 3.65, the highest for any STEM unit of assessment across the UK's universities. This goes far beyond our lead in materials science in all previous RAE/REF assessments.

https://results.ref.ac.uk/(S(bgfziptqdgy4ttlubdtk3afy))/Results/ByUoa/13

South side of the new building at West Cambridge, October 2013

ALG, December 2021