



Postgraduate Lecture and Training Course Synopses
and Research Colloquia Details

2016 - 2017



Department of Materials



Postgraduate Lecture & Training Course Synopses
2016-17

and Research Colloquia Details

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This booklet contains the synopses of postgraduate courses in the department for 2016-17. **'Postgraduate training'** courses provide essential training for using some of our research facilities and a selection of transferable career skills training (which is a requirement of many sponsors of research degrees). If you are a probationer research student, in addition to the compulsory safety lecture you are required to attend the workshops and lectures listed under **mandatory skills training**. **'Postgraduate teaching'** courses are intended to broaden and deepen your education by offering you more advanced material bot

h in areas within and outside your own research. This booklet also contains synopses of the undergraduate **third year materials options** from our MEng degree programme. Synopses of lecture courses offered to first and second year undergraduates are contained in separate booklets.

The wide range of some 400 **postgraduate lecture and training courses available within the Mathematical and Physical Sciences Division** can be viewed and searched at the MPLS Researcher Training Information site on WebLearn at:

<https://weblearn.ox.ac.uk/portal/site/:grad>. (You will need to log in using Single Sign On)

If you are a probationer research student you will be required to offer two subjects at the end of the first year for assessment. One of these subjects must be in an area outside your research topic. You should first consult your supervisor and, if necessary, the Director of Graduate Studies (Dr Adrian Taylor) about the selection of your two topics for assessment. Your selection may be made from any of the courses listed under **Postgraduate teaching**, or the **third year options** (provided you have not already taken the option as an undergraduate), or other **postgraduate lecture courses available within the Mathematical and Physical Sciences Division**.

It is essential that your performances on the two courses you select are assessed. To pass an assessed course you must (i) normally have attended a significant proportion of the complete course of lectures (some lecturers will define this more specifically in the synopsis for the course) and (ii) obtain a grade of at least 50% on the written work set by

the lecturer (this is equivalent to a 'pass' at MSc level and is regarded as satisfactory for the purpose of transfer of status.)

- SOME OF THE LECTURE COURSES COMMENCE IN WEEK 1 OF MICHAELMAS TERM, SO PLEASE CONSULT YOUR SUPERVISOR PRIOR TO THIS.
- IF YOU ARE UNDERTAKING AN ELECTRON MICROSCOPY TRAINING MODULE YOU MAY NEED TO TAKE A PARTICULAR POSTGRADUATE LECTURE COURSE. IN SUCH CASES YOUR SUPERVISOR SHOULD HAVE LIAISED WITH THE EM SUPPORT STAFF BEFORE YOUR PROJECT COMMENCED AND WILL BE ABLE TO ADVISE YOU ON THIS. THE EM SUPPORT STAFF WILL PROVIDE YOU WITH A SCHEDULE FOR YOUR EM TRAINING. PLEASE SEE P33 FOR INFORMATION ON ARRANGING EM MODULAR TRAINING.

The Department's formal research colloquium series is normally held on select Thursdays throughout term at 4.00 pm in the Hume-Rothery lecture theatre. If you are a probationer research student you will be required to attend a minimum of seven colloquia during Michaelmas and Hilary terms of your first year, to include at least three of these Departmental Colloquia. Evidence of this attendance will be required, as described in the Graduate Student Handbook. See section 9 of the Graduate Course Handbook for guidance if you wish to offer towards this course requirement colloquia you have attended in another Department or Materials colloquia other than our Thursday afternoon series. You should check www.materials.ox.ac.uk for the final version of the list of colloquia. Information about colloquia in Hilary and Trinity terms will be distributed later in the academic year, and posted on the web site. Everyone in the Department with an interest in research is encouraged to attend the colloquia and hear of cutting-edge research across a broad range of the science and engineering of materials. The colloquia also provide a means to interact with other members of the Department and the speaker during tea before or after the talk.

Dr Adrian Taylor
Director of Graduate Studies

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Postgraduate Training Mandatory

Postgraduate Training: Mandatory

Michaelmas Term

Organised by Dr A O Taylor

1 session of 3 hours led by Dr Paul Warren, NSG (Pilkington Glass), assisted by Dr A O Taylor

Project Management

This four-hour course is directed towards the application of project management to the research undertaken for a research degree. It will cover topics such as defining a DPhil project, structuring the research and managing its progress. The aim is to teach new research students techniques which will help them to complete successfully their degree within the funded period for the degree. Experience of project management is also a useful generic skill and one that is valued by graduate recruiters

The Department's graduate course structure includes six-monthly project management reviews. This allows and encourages you as the student to take responsibility for the successful outcome of your research by assessing expectations and progress throughout the duration of your course. It will enable you to flag up any concerns you might have that your research is not keeping to schedule, so that your supervisor and, if necessary, the Graduate Studies Committee can consider whether remedial action is required.

You are expected to bring a draft of your Project Management Form 1 (excluding the Gantt Chart and WBS) to the afternoon seminar of the workshop.

Postgraduate Training: Mandatory

Michaelmas Term

Dr Claire Conway (OU Careers Service)

Dr Andy Norton (Rolls Royce)

Dr Mohinder Saran (ex-Royal Bank of Scotland)

Dr Adrian Taylor

1 session of 2 hours

Looking to the Future – What do employers seek?

A guide to the qualities and skills sought by employers; given in year one to enable you to deliberately develop these qualities, thus maximising your chance of winning your 'dream job' in due course. Careers in industry and academia are covered.

Postgraduate Training: Mandatory

Michaelmas Term

Prof A A R Watt

1 hour

Safety Lecture

A guide to the Departmental Safety Policy as described in the Safety Organisation and Laboratory Safety documents. Provides an outline from the Departmental Safety Officer about how risks are formally assessed, what to do in an emergency, how to access help and report incidents, training and first aid. Also identifies sources of relevant information.

Compulsory for all new research workers

Postgraduate Training

Postgraduate Training

Michaelmas Term

S Boad (Institute of Materials, Minerals & Mining)

1 session of 1 hour

The Institute of Materials, Minerals & Mining (IoM³)

An introduction to the professional body for Materials Scientists. For those first year research students who attend this talk the Department will pay for your student membership of the IoM³ for one year.

Optical Microscopy

1. Introduction – equipment, location, key system, support.
2. Parts of the microscope:
 - (i) objectives, resolution, depth of field, colour correction, flatness of field, etc.;
 - (ii) eyepieces, compensated, widefield;
 - (iii) illumination systems, lamps, field stop, aperture stop, Bertrand lens, filters.
3. Specialized imaging modes: polarizing and interferometry.

X-Ray Diffractometry

- Physical basis of X-ray diffraction.
- Powder X-ray diffraction as an everyday analytical tool.
- Learning to use the powder diffractometer, software and database.
- More complex applications of X-ray diffraction – quantitative phase fractions, grain size analysis.
- Typical problems encountered in practical X-ray diffraction and how to overcome them.
- Texture analysis – pole figures.

Information Skills

This session aims to introduce you to the electronic sources of scientific information used by Materials Scientists and how to access and search them, focussing on:

- Use of SOLO for searching Oxford Library Collections
- Electronic resources for Materials Science research
- General principles for a comprehensive literature search
- Effective use of electronic databases Materials Research Database, Web of Science and SciFinder (chemistry) as examples
- Finding e-journals and conference proceedings
- Citation searching using the Web of Science
- Copyright and plagiarism (introduction)

There will be hands-on practice and an opportunity for students to discuss their projects.

(Use of the standard search engines for the World Wide Web will not be covered in any detail, as these will be familiar to most people. However there are additional lectures organised by the University Computing Service if you feel you need some help in this area.)

Managing your References (Bibliographic Software)

This 2-hour session will introduce you to software tools used to organise your references. Reference Management software such as EndNote and RefWorks will be demonstrated to help you export references as you search databases, library catalogues and the Internet, and create bibliographies when you require them.

Further options of using 'Write as you cite' software to add in-text citations and create a Reference List using appropriate referencing style will also be shown. Practical part of the session includes exploring 'RefWorks' software for collecting, organising and managing your references.

Additional session on managing your references is organised as part of the WISER Program. This session provides a comparison of five software tools to help you choose the software that suit your needs.

Postgraduate Training

Michaelmas Term

L Ristic (Radcliffe Science Library)

1 session of 2 hours

Patent Literature

This session provides an introduction to patent literature, where patents can be found and how to search patent databases and obtain full-text patent information.

Searching for patent information will also be demonstrated in materials science and chemistry research databases using the Proquest platform and SciFinder database.

Further examples include tracking patent application, or finding a specific patent in databases. The session will include hands-on searching of patent databases.

This session does not cover any legal issues related to use of patents.

Dr A O Taylor

1 workshop of 1 hour (MT), plus Poster Session itself (2 hours, HT)

Poster Presentation Skills

A workshop to discuss the use of the poster for scientific communication.

Posters are widely used at scientific conferences and in this workshop guidance will be given on how to make effective use of this medium.

During Hilary term a Departmental DPhil Poster session will be held to give practical experience (Year 3 students will present posters). Two prizes, each of £200, are sponsored:

1. Best "Scientific Conference" entry (sponsored by Rolls-Royce).
2. Best "Public Understanding" entry (sponsored by the Ironmongers Company).

Postgraduate Training

Michaelmas Term

Dr Abby Evans (OUCaS)

1 session of 1 hour

The OU Careers Service – Active Job Hunting

An introduction to the support available from OUCaS to students and post-docs reaching the end of their research and who are seeking jobs.

Postgraduate Training

Michaelmas Term

Dr A O Taylor and others, including several alumni

1 session of approximately 2 hours

Careers and Networking Evening with Alumni

An opportunity for informal discussion of careers available to Materials graduates, with several alumni of the Department representing a broad range of employment sectors. Informal one-to-one chats are held over a glass of wine or soft drink in the Holder Café.

Biographies of those alumni who are participating will be provided in advance.

This event will be useful both (i) if you already know in which sector you would like to work, in which case you can seek “insider” knowledge from specific alumni or (ii) if you are simply seeking inspiration for the direction in which your Materials degree might now take you.

Postgraduate Training
D Baker (ITS) & Dr A O Taylor
4 sessions totalling 6 hours

Hilary Term

Presentation Skills

What is it that makes a good talk? As scientists, we constantly need to convey information about our work and explain new results, so it is as important for us to have good presentational skills as it is for those within the business world. Most scientific and other presentations are given using electronic media, especially using software such as PowerPoint. This is just a method of presentation, and while it allows a wider range of techniques, computer presentation is no more a guarantee of a good talk than the use of a blackboard is proof of a bad one. These sessions will aim to give some insight into how you should prepare, structure and present your talks in order to get your message across. Hints will also be given as to how to use computer presentation methods effectively, based on PowerPoint, which is available through a University site license. The course will comprise four sessions:

- PowerPoint for scientific presentations, including hands-on practice (ITS Level 3 course; basic knowledge of PowerPoint is assumed).
- An introduction to advanced audio-visual technology (including 'Smart Boards', Visualisers and 'Sympodia').
- Production of posters using PowerPoint.
- Practical tips on delivering a research talk.

It is permissible to attend just those sessions in which you are interested.

Only one of the two options below will run.

EITHER

Dr Lewys Jones & Dr Andrew Watt

2 sessions each of 3 hours.

An Introduction to LabVIEW & MatLab – Data acquisition, data analysis and computer control of experiments.

A hands-on workshop to introduce the use of MatLab and LabVIEW.

OR

A scientist from National Instruments UK & Ireland

1 session of approximately 3 hours

LabVIEW – Data Acquisition & Computer Control of Experiments

A hands-on workshop to introduce the National Instruments (NI) LabVIEW graphical programming and NI data acquisition tools for automated / programmable control of experiments and data collection, data analysis and data sharing.

If you are currently involved (or think you might be) in tedious data collection, or in experiments that need watching for hours because you need to tweak a knob occasionally, or want to develop a sophisticated experiment under precise computer control, then come along and see how it could be done using NI software and/or equipment.

Writing Skills and Keeping Laboratory Notebooks

Part 1 – Creative Writing

Why is it that some pieces of writing grab your attention from the opening sentence, and lead you through almost effortlessly from one concept to the next, while others leave you wondering what the message is even if you read them more than once? The lecture will cover aspects of writing such as sentence and paragraph construction to encourage high quality scientific writing.

During the course of your scientific career you will be engaged in a number of different writing tasks and some of these are explored in more detail including:

- Literature review.
- Presentations.
- Journal articles.
- Thesis.

The issue of plagiarism will be discussed.

Part 2 – Technical Aspects

This section of the session gives practical and technical advice for writing documents such as reports, papers or theses. The main focus will be the best use of Microsoft Word, as the most common tool for preparing documents, but other software will also be considered.

Part 3 – Intellectual Property & Patents, Keeping Laboratory Notebooks

The importance and nature of IP will be explained, along with discussion of what is required to secure a patent. Key to this is proper recording of your work. Various motivations for and issues to be faced in the keeping of appropriate lab notes are outlined.

Reading list:

On Writing, Stephen King, Hodder Stoughton 2000 (paperback 2001)

Science & Medical Style Guide, Vol 1, Reza Arshandy, Kentus 2006.

The Craft of Scientific Writing, 3rd Edn, Michael Allay, 1996, Springer

Intellectual Property in Academia, a practical guide for scientists and engineers, Ed.

Nadya Reingand, 2012, CRC Press

Postgraduate Training

Hilary Term

Dr Maggie Charles (OU Language Centre)

5 sessions of 2 hours

10 places only

Academic Writing (for overseas students)

This intensive course runs over five consecutive afternoons and is aimed at students for whom English is a second language, with priority given to those who are finding it difficult to write reports in English. If you have already attended one of the Language Centre's courses on Academic Writing please contact Marion Beckett to determine if the present course will be of any value to you.

Knowledge & Technology Transfer

A member of staff from ISIS Innovation will run a workshop to introduce the various means of knowledge and technology transfer. Patents and IPR licensing form part of this topic, but we will also talk about spin-out companies, joint venture, consultancy, movement of trained graduates and other means of K&T transfer such as Knowledge Transfer Partnerships and Knowledge Transfer Secondments, illustrating these various processes with real examples.

During the coffee break the ISIS staff member will be available to talk about how ISIS can help you if you think you have some intellectual property that is ripe for 'exploitation' or if you have been approached by a company who wish you to act as a consultant.

Isis Innovation Ltd is Oxford University's technology transfer company; it manages the licensing of intellectual property and creation of the University's spin-out companies. Oxford University Consulting is the group within Isis that manages consultancy contract negotiation for Oxford's academics. For more information and contact details please see: www.isis-innovation.com

The University's Policy on Intellectual Property Rights is reproduced in our Graduate Course Handbook, <http://www.materials.ox.ac.uk/uploads/file/handbooks/2016GRADHBK.pdf> (section 21, pp 60-64).

Postgraduate Training

All Terms

Dr L.B. Jones

Each visit requires approx 4 hours (including travel time)

Industrial Visits

If places are available, research students may join one or more of the several visits that are arranged each year to industrial sites to illustrate some of the applications of Materials Science.

Industrial Tour

Some places may be available on the Industrial Tour. A visit of 5-10 days, usually during the Easter Vacation, is made to a region overseas in order to visit several companies that make use of Materials Science. Recent visits were to Japan, Italy, China, the Netherlands, California, Poland and Sweden.

Postgraduate Training

All Terms

Several talks, each typically 40-60 minutes

Industrial Talks

Each year, scientists from Rolls Royce, Tata Steel and Johnson Matthey visit the Department to give short talks on the applications of Materials Science in industry. Often these talks are followed by a buffet lunch during which you can network with the industrialists and learn of career opportunities.

Owning a Successful DPhil

This is a 1 hour workshop organised and run by the student members of the JCCG. It is very much by students for students, and covers some inside advice about the following topics:

Motivation;

Working Hours;

Deadlines & Finishing On-time;

Expectations –

“What does my supervisor expect from me?”

“What do you want from your supervisor?”

The truth about doing a DPhil;

Organising a long project;

Internal & External Resources.

The workshop is followed by lunch over which you will have the opportunity to talk with older DPhil students (3rd/4th years) and some post-docs about their experiences.

Teaching Skills

A series of workshops to introduce the topic to those new to teaching and to enable existing teachers to share experiences & best practice.

- **Tutoring Maths Classes** Michaelmas Term
Prof M L Galano
3 hours
- **Tutoring Materials Science** Michaelmas Term
Prof S C Speller
3 hours
- **Materials Options Classes** Hilary Term
Prof M L Galano
3 hours
[Please note: This workshop is run only if required]
Newcomers to class teaching at Oxford should also attend the first part of the workshop on class teaching organised in Michaelmas Term by the Department of Engineering Science, details to be announced.
- **Junior Demonstrating in the Materials Teaching Lab** Michaelmas Term
Prof K A Q O'Reilly & Dr L B Jones
3 hours
In addition to the workshop, one-to-one mentoring is provided by the Senior Demonstrator(s) for the experiment(s) you are "demonstrating", and you are required to practise the full experiment in advance of the actual lab classes.
- **Senior Demonstrating**
One-to-one mentoring is provided by the Practical Class Organiser (Prof K A Q O'Reilly) and normally a Senior Demonstrators' forum is arranged once or twice each year for the sharing of best practice, etc.

- **Lecturing a Taught Course**

Dr A O Taylor

3 hours

[Please note: This workshop is run only if the equivalent MPLSD workshop is oversubscribed or offered at an unsuitable time.]

This workshop is aimed particularly at those who might have to deliver all or part of an **existing** lecture course to undergraduates or taught MSc students, for example if covering for a member of staff on sabbatical leave. It is also open to others who are interested and keen to develop this area of their CV.

The workshop will include:

- The expectations of colleagues and students.
- The lecture in its context as one part of an integrated 'unit of study' (e.g. an Oxford 'Paper' or, elsewhere, a 'Module').
- A digest of the relevant educational research on student learning by means of lectures.
- Practical tips on delivering a lecture course.
- Open discussion to share opinions on 'best' practice.

[Note: the workshop will **not** cover topics such as writing a **new** lecture course, syllabus design or delivering a research talk; these topics either are or will be covered in other workshops].

See also Teaching Skills workshops run by the MPLS Division, advertised at <http://www.mpls.ox.ac.uk/training>.

Postgraduate Teaching

- **Graduate student teaching and training in electron microscopy**

User training takes place throughout the year in response to EM access requests to support research projects. EM training is split into lectures on the theory behind techniques (see pages 33- 37 of this document) and also practical training on the operation of instrumentation and collection of data.

Practical training builds upon the concepts covered in EM postgraduate lectures and is tailored to the applicants specific research project. It is usually conducted in small groups or 1:1 and led by one of the EM Facility Research Support Scientists. Because training is tailored to match individual researchers needs then there is no set syllabus. Topics include an introduction to practical operation of the scanning electron microscope, and similarly an introduction to the transmission electron microscope. EM facility staff may also offer practical training in further techniques such as energy dispersive X-ray analysis, electron energy loss spectroscopy, high-resolution EM, scanning transmission electron microscopy and specimen preparation as necessary for the progress of researchers projects. All of these practical skills link in with the material covered in the EM-specific graduate lecture courses. Additionally support scientists provide instrument-specific practical training to teach users to safely and effectively operate instruments within the EM facility.

Some of our EM training is delivered through stand-alone modules covering advanced or specialist techniques dealing with aspects beyond the scope of the postgraduate lectures. These include topics such as focussed ion-beam milling, electron backscatter diffraction and advanced microanalysis. Full details are given in the 'Modular Courses in Electron Microscopy' section of the present synopses.

All EM related training can only be accessed through the EM access request process of the David Cockayne Centre for Electron Microscopy. Users are given a timetable for lectures/practical classes that they should attend at the start of their training. Equally, any researcher is welcome to enquire about lectures/courses that may be useful to them. Further details are available in the departmental graduate handbook or at www-em.materials.ox.ac.uk/

Foundation Topics for Electron Microscopy

The course covers foundation level topics necessary for progress in both theoretical and practical understanding of electron microscopy (SEM, TEM & FIB). The syllabus concentrates on the basic physics of optical systems, waves, diffraction, the relation of these to the electron, plus properties of charged particles in E and B fields. Sample preparation and FIB are discussed in detail. Mathematical methods important to researchers using EM are also included and will be drawn upon in later postgraduate courses and training. All who wish to use SEM, TEM & FIB instrumentation within the department must attend the course and will be advised by EM support staff on the lectures most relevant to them. The course may also be taken for credit, see below.

Lecture 1: Optics: Basics, refractive index, Snell's law, dispersion, properties of thin lenses, magnification. The optical microscope, comparison to electron microscopy.

Lecture 2: Quantum physics of electrons and practical EM: Wave interference, diffraction. Quantum nature of the electron and relation to EM. Magnetic fields, simple magnetic lenses, electric field, actions on charged particles.

Lecture 3: The vacuum: Concept, gases, gas-laws, measurement, chambers, pumps, outgassing, partial pressures, vapour pressure, contamination.

Lecture 4: Specimen preparation for EM: Scientific considerations for SEM and TEM. Overview of preparation techniques and suitability to various materials and applications.

Lecture 5: Focused ion beams: Introduction to FIB and LMIS, milling and imaging with ions, deposition, applications

Lecture 6: FIB-SEM Instruments: The FIB-SEM concept, field emission SEM, imaging and contrast, example applications. Pros and cons of FIB-SEM

Lecture 7: Mathematical topics for EM I: Discrete sampling, aliasing, Poisson distribution. Nyquist Frequency. Waves, Fourier Transforms, Spatial frequencies, application in EM.

Lecture 8: Mathematical topics for EM III: Convolutions, cross correlations, links to EM, image processing, image filtering.

Pre-requisites: None

Postgraduate Assessment:

Students will be assessed at the end of the course on their written answers to several questions. In addition, students can only be assessed if they have attended a minimum of six lectures.

Suggested texts:

Transmission Electron Microscopy, D B Williams and C B Carter, Plenum, New York and London, 1996.

Transmission Electron Microscopy, 2nd edition, L Reimer, Springer-Verlag, Berlin, 1989.

Scanning Transmission Electron Microscopy: Imaging and Analysis, S.J. Pennycook, P.D. Nellist, Springer, 2011 ISBN 1441971998

The Fourier Transform & Its Applications R. Bracewell, McGraw-Hill 3rd edition (1999)
ISBN-13: 978-0073039381

Microscopy and Analysis of Surfaces

This lecture course covers the main experimental techniques that are used to investigate the structure and composition of surfaces and the near surface region. In particular scanning electron microscopy, scanning probe microscopy, and surface chemical analysis techniques are discussed. The principles of operation are illustrated through numerous practical examples. Those wishing to use SEM instrumentation in their research must attend at least the three lectures on SEM.

Scanning Electron Microscopy (SEM) 1

Layout of the SEM, electron sources, electromagnetic lenses, secondary electron and back scattered electron detectors, image formation.

SEM 2

Electron - sample interactions in the SEM, elastic and inelastic scattering processes, interaction volumes, convolution of probe size and interaction volume, the signal to noise ratio and visibility criteria.

SEM 3

Advanced SEM imaging techniques, low voltage SEM, EBIC, EBSD, environmental SEM, voltage contrast, magnetic contrast, cathodoluminescence.

Scanning Tunnelling Microscopy (STM)

Principle of operation of the STM, atomic resolution imaging, atomic manipulation, electronic structure measurements with the STM.

Atomic Force Microscopy (AFM)

Principle of operation of the AFM, nanoscale imaging, related scanning probe microscopes (SPM).

Micro and nanomechanical techniques

Micro and nano-indentation, modifications to the AFM, force modulation microscopy and phase mapping.

Chemical analysis 1

Atom probe, secondary ion mass spectroscopy (SIMS). Raman spectroscopy, Photoluminescence.

Chemical analysis 2

Auger electron spectroscopy, X-ray photoelectron spectroscopy, EDX.

Postgraduate Assessment:

To obtain a pass credit for this course it is necessary to attend all the lectures (unless there are exceptional circumstances), and to provide satisfactory answers to the questions on the problem sheet.

Suggested Texts:

Scanning Electron Microscopy: Physics of image formation & microanalysis, L Reimer, Springer, 1998, RSL-Eng Vt66.

The Scanning Electron Microscope, C W Oatley, CUP, 1972, RSL Eng Vt12.

Scanning Electron Microscopy: Applications to materials and device science, P R Thornton, 1968, 32THO.

Electron Microscopy and Analysis, P J Goodhew and F J Humphreys, Taylor & Francis, 1988, 32GOO.

Atom probe field-ion microscopy, T T Tsong, CUP, 1990.

Introduction to Surface Analysis by Electron Spectroscopy, F Watts.

Scanning Probe Microscopy and Spectroscopy, D A Bonnell, second edition.

Introduction to Scanning Tunneling Microscopy, C J Chen, OUP, New York, 1991.

Scanning Force Microscopy, D Sand, OUP, New York, 1991.

Scanning Tunnelling Microscopy II Further Applications and Related Scanning Techniques, R Wiesendanger and H-J Guntherodt, eds, Springer-Verlag, NY, Berlin, Heidelberg, 1992.

Modern techniques of surface science, Woodruff and Delchar, CUP.

Spectroscopy with the (S)TEM

The lecture course describes spectroscopic modes which allow chemical analysis in the electron microscope. The content builds on that from the '[Foundation topics for electron microscopy](#)' course and centres on the two most widely employed techniques of Energy Dispersive X-ray (EDX) analysis and Electron Energy-Loss Spectroscopy (EELS). The course must be taken by those wishing to use EDX and/or EELS in their research. EM support staff will advise researchers on the lectures most relevant to them. The course may also be taken for credit, see below.

Lecture 1: X-rays: Generation, properties, production, structure of atom, selection rules, allowed and forbidden transitions, mean free path, ionisation cross-section.

Lecture 2: Detection of X-rays: Absorption coefficient, detector setup, charge pulse amplification, pulse processing, MCA, dead time, resolution, (instrument) artefacts.

Lecture 3: X-ray Spectrum Processing: Background removal, filtering, binary and multi-element specimens, standard vs standard-less analysis, detection efficiency, self absorption, detection limits.

Lecture 4: Other applications of X-rays: Real examples, Monte-Carlo modelling, ALCHEMI, Coherent Bremsstrahlung, STEM-EDX mapping, data cube.

Lecture 5: X-ray spectroscopy in SEM : Applications, differences from the transmission case, Wavelength dispersive spectroscopy (WDS), cathodoluminescence.

Lecture 6: EELS: Basics, inelastic scattering, phonons, ionisation process and notation. The EEL spectrum: zero loss, plasmons, core-loss, ELNES, EXELFS. Spectrometers. Example spectra.

Lecture 7: EELS II: Edge shapes, Quantification, simulation

Lecture 8: Advanced Analytical Techniques: Energy filtered TEM (EFTEM), chemical mapping, spectrum imaging, examples from research.

Pre-requisites: [Foundation topics for electron microscopy](#) lecture course.

Postgraduate Assessment:

Students will be assessed at the end of the course on their written answers to several questions. In addition, students can only be assessed if they have attended a minimum of six lectures.

Useful texts:

Diffraction Physics, J M Cowley, North Holland, Amsterdam, 1975.

Transmission Electron Microscopy, 2nd edition, L Reimer, Springer-Verlag, Berlin, 1989.

Quantitative Microbeam Analysis, eds A G Fitzgerald et al, SUSSP and IOP Publishing, Bristol, 1993.

Introduction to Analytical Electron Microscopy, eds J J Hren et al, Plenum, New York, 1979.

Electron Energy-Loss Spectroscopy in the Electron Microscope, R F Egerton, Plenum, New York, 1986.

Fundamentals of Energy Dispersive X-Ray Analysis, J C Russ, Butterworths, London, 1984.

Electron Microprobe Analysis, S J B Reed, CUP, Cambridge, 1975.

Physical Methods for Materials Characterisation, P J Flewitt and R K Wild, IOP Publishing, Bristol, 1994.

Transmission Electron Microscopy, D B Williams and C B Carter, Plenum, New York and London, 1996.

Imaging and Diffraction in (S)TEM

The lecture course covers the theory behind imaging and diffraction in TEM, explaining the origin of this data and how it may be interpreted. High-resolution phase contrast TEM (HRTEM) is discussed, in addition to Scanning Transmission Electron Microscopy (STEM) imaging. A brief overview of electron-optical aberration-correction is included with reference to the topics of HRTEM and STEM. The course builds upon the material covered in the '[Foundation topics for electron microscopy](#)' lectures and must be taken by those wishing to use TEM/HRTEM/STEM instrumentation in their research. EM support staff will advise researchers on the lectures relevant to them. The course may also be taken for credit, see below.

Lecture 1: Electron diffraction: Ewald sphere, reciprocal space, indexing of crystals, Bragg law.

Lecture 2: Kinematical theory: Diffraction contrast, extinction distance, limitations of kinematical theory

Lecture 3: Dynamical theory of ED: Two beam equations, image contrast in the two-beam approximation, wave-mechanical approach, anomalous absorption.

Lecture 4: Phase contrast HRTEM: Overview, imaging theory, PCTF

Lecture 5: HRTEM II: Factors limiting resolution, Temporal and spatial coherence, simulation, Multislice approach.

Lecture 6: Scanning Transmission Electron Microscopy: Reciprocity, practical setup, imaging modes, coherent/incoherent imaging

Lecture 7: STEM II: Probe formation, Brightness, high-resolution imaging, the Ronchigram

Lecture 8: Aberration correction in (S)TEM: Lens aberrations, nomenclature, wave aberration-function, aberration-measurement, methods of correction, exit-waves. Implications for HRTEM and STEM.

Pre-requisites: [Foundation topics for electron microscopy](#) lecture course.

Postgraduate Assessment

Students seeking credit for the course should attend a minimum of 6 of the 8 lectures, and answer a set of problems and questions based on the topics covered in the lectures.

Reading list and References

Transmission Electron Microscopy, chapters 6 (electron lens), 11-19 (diffraction), 22-25 (imaging), 27-28 (HREM), 29 (image simulation), D B Williams and C B Carter, Plenum Press 1996, ISBN 3 306 45324 X (softback).

Transmission Electron Microscopy, (Springer Series in Optical Sciences vol 36), chapters 2, 3 (electron optics), 6 (image contrast), 7 (kinematic and dynamical theory of ED), 8 (diffraction contrast), L Reimer, Springer Verlag, 1989 ISBN 3 540 50499 0 or 0 387 50499 0.

Electron Microscopy of Thin Crystals, P B Hirsch, A Howie, R B Nicholson, D W Pashley and M J Whelan (1970) R E Krieger Publishing (US) 1993 ISBN 0 88 275376 2.

High-Resolution Electron Microscopy, 3rd edition, chapters 2, 3 (electron optics), 5 (HREM theory), 10 (HREM parameter measurement), J C H Spence, Oxford Science Publications 2003, ISBN 0 19 850915 4.

Early Metallurgy

This course presents the development of metallurgy from its inception to the beginning of the industrial era. It focuses on the understanding of metallurgical principles acquired at each stage.

1. Prehistory of materials: mechanical and thermal treatment of materials from palaeolithic onwards - stone tools, minerals, pigments; requirements for metallurgy - temperature and containment; lime plaster technology and ceramics; fuels; native metals and the first metallurgy; the beginning of smelting, melting and mining; spread of metallurgy in the old world.
2. Alloys: possible modes for the discovery of alloying; initial use restricted to prestige/cult material; relationships between technology and composition; change from alloying as a specialised technology to a universal technology; early alloy systems : As-Cu; As-Cu-Sb; As-Cu-Ni; Cu-Sb-Ni etc.; microstructures; use of alloys; introduction of tin bronze and possible means of discovery; how bronze superseded previous alloys; technical advantages of bronze; developments of bronze - leaded bronze for castings, high tin bronzes and martensites; a new alloy - brass; calamine process and zinc smelting; brass and the Romans in Britain.
3. The workshop: casting: mould materials and techniques: single-valve and piece moulds, investment casting, slush casting, casting on; cores and chaplets; gating and venting; pouring of copper alloys; casting defects. Working and finishing: cold work or hot work; annealing; mass production; prestige production; sheet metal; time and resources, complexity and specialisation; different types of metalworking site; the metal trade.
4. Precious metals and decoration: the earliest gold; vein and placer gold; spread of goldworking; uses of gold; evolution of goldsmithing in Europe in Europe; precious metal alloys; silver alloys and uses of silver; gold-smithing/silver smithing techniques; gilding and silvering; plating with other metals; embossing chasing and engraving; coinage.

5. Iron: possible routes to the discovery of iron; location of early iron-working; spread of iron; first uses of iron; properties of iron and iron alloys and why iron gradually came to supersede copper alloys as the basic metal; iron ores and iron smelting; direct and indirect processes; the problem of melting iron; discovery and use of iron alloys.
6. Developments of iron technology; variety of iron smelting techniques and relation to ores; function of slags - non-tapping and tapping furnaces; stages of extraction process; development towards blast furnace; requirements of the blast furnace; refining cast iron; changes in steel making processes; effects on iron production and diversity of products; artillery.
7. Ironworking and iron and steel products; forging and welding; anvils and tools; pattern-welding; carburising, nitriding; alloy selection; production of particular types, e.g. swords, armour, hammers, chisels; assembly of large wrought iron fabrications; iron founding.
8. World metallurgy: China and Far East - was metallurgy a separate invention; problems of earliest Chinese metallurgy; development of casting technology; Shang bronzes; later developments in bronze-casting; mirrors; cast iron. Sub-Saharan Africa: chronology of copper and iron smelting; use of local resources; later contacts. Pre-Columbian America: native copper in N. America; metalworking regions in Latin America; chronology and technology; differences from Old world technology - slush casting; depletion gilding; Au-Pt alloys.

Postgraduate Assessment:

This course will be assessed through set written work which will be marked on a satisfactory/unsatisfactory basis although students may ask for more detailed feedback. Students will normally be expected to attend at least six of the eight lectures.

Background reading :

L'Or dans l'antiquité: de la mine à l'objet, Aquitania, Supplément 9, B Cauuet, ed., 1999.

Early metal mining and production, P T Craddock, Edinburgh University Press, Edinburgh, 1995.

L'or des Celtes, C Eluère, Office du Livre, Paris, 1987.

Old World Archaeometallurgy, A Hauptmann, E Pernicka & G A Wagner, eds., Deutsches Bergbau-Museums, Bochum, 1989 (Der Anschnitt, Beiheft 7).

The beginnings of metallurgy, A Hauptmann, E Pernicka, Th Rehren and Ü Yalçin, eds, (Bochum: Deutsches Bergbau-Museum: Der Anschnitt, Beiheft 9), 1999.

The beginning of the use of metals and alloys, R Maddin, ed., MIT Press, Cambridge, Mass., 1988.

Celtic Art, R Megaw and V Megaw, Thames and Hudson, London, 1989

Métallurgie Préhistorique, J-P Mohen, Masson, Paris, 1990.

L'Atelier du bronzier en Europe du XX^e au VIII^e siècle avant Notre Ère, 3 volumes, C Mordant, M Pernot et V Rychner, eds., Paris: Éditions du CTHS, 1998.

The exploration of the long-distance movement of bronze in Bronze and early Iron Age Europe, J P Northover, Bulletin of the Institute of Archaeology, University of London, 19, 45-72, 1982/3.

Decorative metallurgy of the Celts, J P Northover and C J Salter, Materials Characterisation, 25(1), 47-62, 1990.

Metallography and microstructure of ancient and historic metals, D A Scott, The Getty Conservation Institute, Marina del Rey, 1991.

Ancient and historic metals: Conservation and research, D A Scott, J Podany and B Considine, eds., The Getty Conservation Institute, Marina del Rey, 1994.

The prehistory of metallurgy in the British Isles, R F Tylecote, The Institute of Metals, London, 1986.

The early history of metallurgy in Europe, R F Tylecote, Longman, London, 1987.

Also: various issues of Historical Metallurgy (Journal of the Historical Metallurgy Society), Archaeomaterials, Bulletin of the Metals Museum, and Gold Bulletin.

All these are either in the Department Library or Ashmolean Library.

Modular Courses in Electron Microscopy

1 WDS and Quantitative X-ray Analysis

Module Co-ordinator: Dr C J Salter

Pre-requisites: Course open to provisional or approved users of SEMs who require to use EPMA techniques in the Department. Participants will be expected to be current users of EDX hardware. Attendance of the following postgraduate lecture courses (or relevant parts of, to be advised by EM support staff): [‘Foundation topics in electron microscopy’](#) and [‘Spectroscopy with the \(S\)TEM’](#).

Given by: C Salter

Description: Two one-hour lectures plus about 9 hours of practical instruction and practice

Aim: To give potential microprobe users basic knowledge of practical qualitative and quantitative WDS analysis so that that can understand how data produced by the machine was obtained and the limitation of such data. As such anyone wanting to have work carried out on the JXA8800 should attend this course. The course also covers the methodology required to carry out quantitative X-ray analysis using Energy Dispersive Spectrometers.

Course Structure:

Lectures: Understanding of X-ray generation . K, L, M lines shape and intensity (in comparison to EDX), relationship between accelerating voltage, critical X-ray excitation energy, X-ray intensity and X-ray generation volume.

X-ray detection using WDS: Rowland’s Circle, Bragg’s Law, pulse height detector, dead-time, counter types, n-th order lines, the limited range of specific crystals, detector geometry.

Matrix effects: Atomic number, absorption and fluorescence effects, geometry.

Data acquisition: Qualitative - spectral, line and area techniques, nature and sources of errors, counting and sampling statistics, detection limits; semi-quantitative - appropriate use and limits of quantification; Quantitative - the nature use of primary and secondary standards, peak and background overlap corrections and deconvolution. Correction methods ZAF, PhiRhoZ, calibration curve, thin film, and Monte Carlo Methods.

Presentation of results.

Simple image processing and analysis. Common practical problems: sample preparation, sample charging, carbon coating. Analysis of thin films on solid substrates.

Practicals: Demonstration of:- Loading specimens. Selection of appropriate conditions for analysis. Acquisition of a full WD spectrum: elemental identification, identification of nature and scale of interference and overlap problems. The acquisition line and area data. Processing of linear and area data, including plotting phase analysis from images, and limited image processing and analysis. Demonstration of acquisition of standard data. The setting up of analysis points using beam and stage movement methods.

Outcome: It is necessary for anybody intended to use JXA8800 to attend this course so that they understand how any microprobe results were obtained, the statistical, chemical and spatial limitations of those results. However, the course is not intended to train the participant to approved user status; that will require further one to one training.

Assessment: Simple tests using various samples will be set for each technique.

Frequency: Trinity Term (possibly repeated if sufficient demand)

Primary Reference Texts:

Quantitative Electron-Probe Microanalysis, V.D. Scott and G. Love, Ellis Horwood, 1983

Further Modules: Required for approved user status (by arrangement):

- Qualitative analysis – line and area
- Quantitative analysis – acquisition
- Data processing
- Acquiring standards

2. Electron Back Scattered Diffraction (EBSD)

Module Coordinator: G Chapman

Pre-requisites: Course open to provisional or approved users of the Zeiss EVO or JSM6500F who require to use EBSD facilities in the department.

Given by: A Wilkinson, G Chapman

Description: Two one-hour lectures covering the basic principles of EBSD and analysis of EBSD data, plus approximately six hours of practical instruction and practice.

Aim: To give inexperienced users a basic knowledge of practical EBSD.

Course Structure: (Features in brackets are described but not taught as part of this course.)

Lectures: Formation of EBSD patterns: backscattering of electrons by solids, structure factors, (intensity profiles across Kikuchi band requires dynamical diffraction theory). Indexing EBSD Patterns: Pattern centre, Gnomonic projection, angles between diffracting planes, orientation measurement, the Hough transform, automated analysis. Data Analysis: pole figures, inverse pole figures, (Euler angles and Orientation Distribution Functions), misorientations, disorientations, matrices, axis/angle pairs (RF vectors, quaternions), coincident site lattice. Orientation mapping, enhancing/filtering maps. Spatial and angular resolution.

Practicals: TSLOIM EBSD mapping software. Specimen loading and geometry. Input of sample details - crystal phases present, macroscopic reference axes. Appropriate microscope settings - beam energy, beam current, magnification. Appropriate EBSD camera settings - binning, exposure time, video gain, 'flat fielding'. Appropriate Index Algorithm settings - number of bands to index, angular tolerance. Verifying automated analysis results. Setting up and running an orientation map. Data Analysis.

Outcome: Course participants will learn the basics of EBSD, and its limitations. They will be trained: how to obtain EBSD patterns, how to perform automated crystal orientation mapping and when to seek help with more difficult analysis problems.

Assessment: Individual practical assessment.

Frequency: Michaelmas Term (possibly repeated if sufficient demand).

Further Courses: Training on TSL EBSD system at Begbroke (by arrangement)

3 Focussed Ion Beam milling

Module co-ordinator: Dr G M Hughes

Given by: G Hughes

Description: Two one-hour lectures and two to three three-hour practical training sessions.

Lecture 1:

Background to FIB. Liquid metal ion sources. Optical design. Ion-sample interaction and sputtering. Imaging and contrast mechanisms – secondary electron and ion imaging. Ion milling and implantation. Ion beam resolution and profile.

Lecture 2:

Applications of FIB. Gas injection system for enhanced milling and deposition. Sample preparation. Ion beam damage. General applications overview, followed by general discussion/workshop about the attendees' projects – how to approach their problem.

Practical Sessions:

1. Introduction to the instrument. Mounting and loading samples. Turning on and off the Ga ion source. Basic imaging, setting sample to the eucentric height. Focusing and correction of astigmatism. Basic milling operations.
2. Application based session, dependent on attendees – e.g. cantilever fabrication, TEM sample prep.
3. Individual sessions where the user will practice sample exchange, setting up and working on the instrument toward their application.

Outcome: Trainees should become competent users of the FIB system and capable of carrying out basic milling / deposition specific to their application.

Assessment: During the first session trainees are demonstrated loading and unloading specimens, turning on and off the system and using the gas injector needles. Upon reaching a standard whereby the machine can be used safely, the user will be granted approved status.

Frequency: Termly

Pre-requisites: Those attending the module will be required to take part in basic SEM training prior to the start date if they do not already have SEM experience.

Primary Reference Texts:

Introduction to Focused Ion Beams: instrumentation, theory, techniques and practice, L.A. Giannuzzi, FA Stevie, Springer, 2005, ISBN: 0387231161 or 038723313X

4 Advanced Microanalysis

Module Co-ordinator: Dr N P Young

Given by: S Lozano-Perez

Pre-requisites: Experienced (S)TEM users with existing knowledge of EELS and EDX (e.g. EDX module, EELS module, STEM module). Approved users of Jeol 3000F or Jeol 2200FS or VG HB501. Attendance of the following postgraduate lecture courses (or relevant parts of, to be advised by EM RSG): [‘Spectroscopy with the \(S\)TEM’](#).

Description: A one-hour lecture plus about six hours of practical instruction and practice.

Aim: To ensure that (S)TEM users in this department use the different microanalysis techniques efficiently and are up to date with the latest trends.

Course Structure:

Review of all microanalysis techniques available in the department

Quick review of EDX, EELS and HAADF: advantages and disadvantages

Approaches to elemental mapping:

EDX Spectrum Imaging

EELS Spectrum Imaging

EELS Image Spectroscopy

How to improve spatial resolution

How to improve SNR

Microscope’s suitability with advantages and disadvantages

Optimizing acquisition and processing: Using Digital micrograph scripting language

Benefits of simultaneous acquisition of different signals

Practicals: Hands-on sessions in the Jeol ARM or on the dedicated computers in the EM lab to demonstrate the concepts covering in the lectures, including:

- Optimization of EFTEM acquisition
- STEM alignment for EDX and EDX/EELS/HAADF simultaneous acquisition
- Demonstration of related Digital Micrograph scripts

Outcome: Course participants will be aware of the potentiality of the facilities in the department and they will use them efficiently. This course will enable some researchers to become advanced users who will further develop these techniques.

Assessment: Some standard samples will be used to demonstrate the potential of the various techniques and their associated artefacts. Course attendants will be asked about the quality/suitability of different results and to explain the origin of the artefacts.

Frequency: Annually, Trinity Term

5 Analysis of HREM Images

Module Co-ordinator: Dr N P Young

Given by: N Young

Pre-requisites: Course open to HREM users. Participants will already have significant experience in HRTEM and/or obtained focal-series data with Dr Young or others.

Attendance of the following postgraduate lecture courses (or relevant parts of): ['Imaging & Diffraction in \(S\)TEM'](#).

Description: Two one-hour lectures plus about 4 hours of practicals.

Aim: To allow FEGTEM and HREM users in this department to interpret properly their HREM images and to calculate the exit-wavefunction.

Course Structure:

Lectures: on Image Simulation and Exit-wave restoration

Practicals: Hands-on sessions using JEMS multislice image simulation and FTSR exit-wave restoration software

Outcome: Course participants will be aware of the need to interpret HREM images correctly, and know how to use the basic software to do this.

Assessment: Individual.

Frequency: Hilary (possibly repeated if sufficient demand)

Primary Reference Texts:

High-Resolution Electron Microscopy, 3rd edition, J C H Spence, Oxford Science Publications 2003, ISBN 0 19 850915 4.

Third Year Undergraduate Options

Prediction of Materials' Properties

The objective of this option course is to introduce the students to the current state-of-the-art in first-principles materials modelling. This course develops the basic theoretical concepts underlying current computational research in materials using quantum-mechanical atomic-scale simulations. This course responds to the questions “Which materials properties can we predict using atomic-scale first principles computer simulations? How reliable are the results? How complex is the underlying methodology? What is the computational power required to perform such calculations?” This course will provide an essential background to any student willing to engage in the study of materials by combining quantum theory and high-performance computing. In addition, this course will constitute a necessary complement to the curriculum of those students oriented towards experimental materials research, as it will enable them to understand the current literature on atomistic modelling and to interact meaningfully with computational researchers throughout their future career in materials.

Introduction to first-principles materials modelling: Density-functional theory (DFT) and prediction of materials properties from first principles. Examples: optical absorption in silicon, superconductivity in magnesium diboride. Historical development of electronic structure calculations. Why DFT is universally adopted in quantum-mechanical atomistic modelling of materials.

Density-functional theory I: Many-body Schroedinger equation. Independent electron approximation. Self-consistent field method. Hartree-Fock method. Density-functional theory.

Density-functional theory II: Kohn-Sham representation. Exchange and correlation functionals. Electronic ground state and excited states. Limitations of density functional theory.

Ground-state structure: Born-Oppenheimer approximation. Atomic forces. Bulk and surface structures at zero temperature. Comparison with X-ray crystallography and Scanning Tunneling Microscopy.

Elasticity: Elastic constants. Predicted vs measured elastic properties. Predictions for materials under extreme conditions.

Introduction to phonons: Force constants and dynamical matrix. Phonons. General properties of phonon dispersion relations.

Inelastic Neutron and X-ray scattering: Comparison of predicted phonon dispersions to Inelastic Neutron Scattering and Inelastic X-ray Scattering measurements. Calculation of the heat capacity.

Phonon-mediated superconductivity: Basics of Bardeen-Cooper-Schrieffer theory. Electron-phonon coupling. Predicted critical temperatures vs experiment.

Photoemission spectra: Band structures. Measurement of band structures using Photoemission spectroscopy. Predicted vs measured band structures.

Optical spectra I: Electron-photon coupling. Direct absorption and phonon-assisted absorption.

Optical spectra II: Excitons. Predicted vs measured optical absorption spectra.

Dielectric permittivity: Lattice contribution to the dielectric screening. Predicted vs measured dielectric permittivities.

Reading list

F. Giustino, **Materials modelling using density functional theory: property and predictions**, Oxford University Press, 2014

Other recommended texts:

E. Kaxiras, **Atomic and electronic structure of solids**, Cambridge University Press, 2003 (RSL QC 176 KAX).

N. W. Ashcroft and N. D. Mermin, **Solid state physics**, Harcourt College Publishers, 1976 (22ASH).

P. Y. Yu and M. Cardona, **Fundamental of semiconductors**, Springer, Heidelberg, 2003 (RSL QC 611 YU).

Engineering Ceramics: Synthesis & Properties

1. Introduction: Engineering Ceramics

2. Ceramic processing

- Overview of ceramic processing from starting powder to final product.
- Production of powders
- Powder characterisation
- Forces between particles
- Powder processing before firing.
 - Dry forming routes.
 - Wet forming routes
- Sintering
- Reaction processing
- Sol-Gel: powderless processing of ceramics.

3. Mechanical properties of ceramics

- Weibull statistics and strength of ceramics
- Time-dependent strength
- Thermal shock
- Mechanical properties and applications of:
 - a. traditional triaxial porcelains,
 - b. alumina,
 - c. zirconia,
 - d. silicon nitride,
 - e. silicon carbide.
- R-curve behaviour

Books:

Introduction to Ceramics 2nd Ed., W.D. Kingery, H.K. Bowen and D.R. Uhlmann. Wiley Interscience.

Physical ceramics : principles for ceramic science and engineering, Yet-Ming Chiang et al., Wiley

Sintering : densification, grain growth, and microstructure, Suk-Joong L. Kang, Elsevier Butterworth-Heinemann (44KAN)

Principles of Ceramic Processing 2nd Ed., J. S. Reed. Wiley Interscience.

Ceramic Microstructures: Property Control by Processing W.E. Lee and W.M. Rainforth. Chapman and Hall.

Ceramic processing and sintering M.N. Rahaman. 2nd edition, New York : M. Dekker, c2003 (44RAH)

Processing of ceramics / volume editor: Richard J. Brook, Materials science and technology (VCH) ; v. 17A & v. 17B Materials Library 44 BRO/a and b

Engineering Materials 2, M F Ashby and D R H Jones, Chapters 15-20.

Mechanical Properties of Ceramics, R W Davidge.

Fracture of Brittle Materials, B R Lawn.

An Introduction to the Mechanical Properties of Ceramics, D J Green.

Ceramic Science for Materials Technologists, I J McColm.

Ceramic Microstructures, W E Lee and W M Rainforth.

Ceramic Matrix Composites, I M Low (ed.).

Toughness of Ceramics: Resistance Curves, R I Todd, in **The Encyclopedia of Advanced Materials**, (D Bloor et al, eds.) pp. 2887-2890, Pergamon, Oxford, UK, (1994).

Transformation Toughening, R I Todd and M P S Saran, in **Materials Processing Handbook**, CRC Press/Taylor & Francis, Boca Raton, Florida, USA, 2007, Chapter 20.

Strength & Failure of Materials

- **Design of strong alloys (EL):**
 - Principles of alloy design for high yield strength.
 - Examples from aluminium, titanium, nickel and iron-based alloys.
- **Fracture (EL):**
 - Plasticity and fracture.
 - Ductile - brittle transitions.
 - Principles of alloy design for high fracture strength.
 - Examples from aluminium, titanium, nickel and iron-based alloys.
- **Wear and surface treatments (EL):**
 - Wear mechanisms.
 - Wear – resistant materials.
 - Surface treatments.
- **Fatigue (AJW):**
 - Cyclic deformation of fcc, bcc & hcp metals (mostly fcc).
 - Cyclic stress strain curves.
 - Persistent slip bands, dislocation structures, strain localisation.
 - Crack initiation.
 - Crack growth.
- **Non-destructive testing (AJW):**
 - Need for NDT.
 - X-rays, ultrasonics, eddy currents, dye penetrant, magnetic particles.

Reading list:

Design of strong alloys (EL):

Physical metallurgy, R W Cahn & P Haasen, 1996.

Steels: microstructure and properties, H K D H Bhadeshia, 2006.

Fracture (EL):

Fundamentals of fracture mechanics, J F Knott, 1973.

Fracture & ductile vs. brittle behavior, G E Beltz (ed.), MRS Proceedings, **539**, 1999.

Wear and surface treatments (EL):

Tribology, I M Hutchings, 1992.

Fatigue (AJW):

Fatigue of Materials, S Suresh, CUP, 1991.

Fracture - 2nd year lecture notes

Deformation & Fracture Mechanics of Engineering Materials, R. W. Hertzberg, Wiley, 1989.

Fatigue as a Design Criterion, T. V. Duggan & J. Byrne, Macmillan, 1977

Fatigue and Fracture ASM Handbook, Vol 19

Fundamentals of Fracture Mechanics, J.F. Knott, Butterworths, 1975

Fracture Mechanics—Worked Examples, J.F. Knott & P.A. Withey, Institute of Materials, 1993

Materials & Devices for Optics & Optoelectronics

1. Classical theory of light, Maxwell's equations and the wave equation. Interaction of light and matter. Snell's law. Diffraction. Refraction and reflection at interfaces. Total internal reflection. Polarization dependence.
2. Waveguides. Discrete modes of propagation. Optical fibres for telecoms. Attenuation and dispersion. Single vs multi mode fibres.
3. Birefringence and optical nonlinearity. Relevant materials. Optical switches and modulators. Wavelength conversion.
4. Novel optical materials. Photonic crystals, metamaterials
5. Semi-classical theory of light. Absorption and emission. Black body radiation and Planck's law. Einstein A and B coefficients. Electromagnetic harmonic oscillator.
6. Light emitting diodes. Inorganic and organic semiconductor devices. Wannier and Frenkel excitons. Quantum efficiency.
7. Optical amplifiers. Population inversion. Atom-like vs band engineered gain media. Semiconductor devices. Erbium doped fibres.
8. Lasers I. Optical cavities. Threshold condition for lasing. Lasing materials. Heterostructure lasers. Device designs. Quantum wells, wires, and dots.
9. Photodetection. P-i-ns, APDs, and single photon detectors.
10. Solar cells I, principles of operation
11. Solar cells II, inorganic cells. Polycrystalline silicon, single crystal heterojunction cells, and thin film semiconductor cells
12. Solar Cells III, Dye sensitized solar cells, organic solar cells and perovskites.

Nanomaterials

1) Basics of nanomaterials (NG)

Nanoscale; Nanotechnology; Surface area bulk; 0-D, 1-D, 2-D materials

2) Synthesis of nanomaterials I (NG)

Particle synthesis chemistry, solgel; metallic nanoparticles; core-shell nanoparticles; composites, hybrid coatings, thin films

3) Synthesis of nanomaterials II (NG)

CVD, Arc discharge; other methods (exfoliation etc.); bulk synthesis; up-scaling; safety of nanomaterials, ethics & regulations

4) Carbon nanomaterials, Chalcogenides - I (NG)

Fullerenes, carbon nanotubes, graphene; sample preparation; Characterization-I methods

5) Carbon nanomaterials, Chalcogenides – II (KP)

Modification of carbon nanomaterials I; non-covalent; supramolecular

6) Modification of carbon nanomaterials II (KP)

Covalent

7) Characterization - II (KP)

Raman, HPLC, MS, ...

8) Applications of Carbon Nanomaterials (KP)

Medical; Energy

9) Properties at the Nanoscale (HB)

Physical properties & how they manifest at the nanoscale; challenges

10) Nanofabrication-I (HB)

How devices are made (optical); next steps (etching, deposition etc..)

11) Nanofabrication-II (HB)

AFM and E-beam-based lithography; problems with lithography

12) Emerging Device Concepts (HB)

Devices using nanomaterials

Reading list:

There is no comprehensive textbook on nanomaterials. Students are encouraged to browse through the following books, as well as using the internet and reading journals, such as Nature Materials, MRS Bulletin and Nanotechnology.

General Reading:

- **Nanostructures and Nanomaterials**, G. Cao, Imperial College Press 2004 (**in RSL**)
- **Nanomaterials: Synthesis, Properties and Applications**, A S Edelstein & R C Cammarata (Eds.), Taylor & Francis 1996, (**DOM library: 58EDE**).
- **Introduction to Nanotechnology**, C P Poole & F J Owens, Wiley, 2003, (**DOM library: 58POO**).
- **The Physics and Chemistry of Nanosolids**, F J Owens, C P Poole, Jr. , Wiley 2008, (**DOM library: 58 OWE**).
- **Introduction to Nanoscale Science and Technology**, Massimiliano Di Ventra, Kluwer, 2004 (**DOM library**).
- **Nanochemistry**- A chemical approach to nanomaterials, G A Ozin, A C Arsenault, L Cademartiri, RSC Publishing 2009 (**DOM library: 40 OZI**).
- **Introduction to Nanoscience**, G L Hornyak et al., CRC Press, Taylor & Francis 2008, (**DOM library: 58 HOR/2**).
- **Fundamentals of Nanotechnology**, G L Hornyak et al., CRC Press, Taylor & Francis 2008, (**DOM library: 58 HOR/1**).
- **Clusters and nanomaterials: theory and experiment**, Y Kawazoe, T Kondow, K Ohno (eds.) Berlin, New York: Springer, 2002 (**DOM library**).
- **Quantum properties of atomic-sized conductors**, N Agrait, A L Yeyati, J M van Ruitenbeek, Preprint (**DOM library**).
- **Nanoscale Physics for Materials Science**, T. Tsurumi, H. Hirayama, M. Vacha, T. Taniyama, CRC Press, Taylor & Francis 2010.
- **Nanophysics and Nanotechnology**. An introduction to modern concepts in nanoscience, E. L. Wolf, Wiley-VCH, 2005 (**DOM library: 58 WOL/1**)

Fabrication of Nanomaterials for Materials Science Applications:

- **Nanostructured Materials: Processing, Properties and Applications**, Carl C. Koch (ed.), IOP 2002, (**DOM library: 40KOC**).
- **Nanostructured Materials and Nanotechnology**, Concise Edition, H.S. Nalwa (ed.), Academic Press, 2002, (**DOM library: 58NAL & RSL**.)

Carbon Nanotubes:

- **Carbon Nanotubes and Related Structures**, P J F Harris, CUP, 1999, (**DOM library: 40HAR**.)
- **Carbon nanotubes and related structures** : synthesis, characterization, functionalization, and applications, D M Guldi and N Martin, Wiley 2010, (**DOM library: 40 GUL**)
- **Science of Fullerenes and Carbon Nanotubes**, M S Dresselhaus, G Dresselhaus, and P C Eklund, Academic Press, 1996 (**in RSL**).

Q-dots and Q-wires:

- **Low-dimensional Semiconductor Structures**, K Barnham & D Vvedensky (Eds.), CUP, 2001, (**DOM library: 21BAR**.)
- **Quantum Dot Heterostructures**, D. Bimberg, Wiley 1999, (**DOM Library: 22BIM**).
- **Optical Properties of Semiconductor Quantum Dots**, U Woggon, Springer, 1997.

Light Scattering:

- **Absorption and Scattering of Light by Small Crystals**, C E Bohren and D R Huffman, John Wiley, 1983.
- For surface plasmons there are two reviews that are worth reading, along with references quoted in them:
“Plasmonics: localization and guiding of electromagnetic energy in metal/dielectric structures”, S Maier and H A Atwater, J. Appl. Physics, 98, 011101 (2005).
“Exploitation of localized surface plasmon resonance”, E Hutter and J H Fendler, Adv. Mater., 16, 1685 (2004).

Environmental and safety aspects:

- **Nanotechnology and the Environment**, editors B Karn et al, ACS Symposium Series vol 890, 2005.
- **Nanotoxicology; an emerging discipline evolving from studies of ultrafine particles**, G Oberdorster et al, Environmental Health Perspectives, 113, p823, 2005.
- **Safe Handling of nanotechnology**, A D Maynard et al, Nature, 444, p267 2006.
- **Toxicology of nanoparticles: A historical perspective**, G Oberdorster et al. Nanotoxicology, 1, p2, 2007.
- **Nanomaterials and nanoparticles: Sources and toxicity**, C Buzea et al., Biointerphases, 2, p.MR17, 2007.

Devices

1. Prof P R Wilshaw

- Semiconductor crystal growth. Purification of precursors. Czochralski and Bridgman growth. CVD, MBE.
- Fabrication of integrated circuits. Oxidation, diffusion, implantation, lithography, etching, metallization.
- Bipolar, passive, and MOS devices.
- Assembly and packaging.

Suggested reading:

VLSI Technology, Sze, McGraw-Hill.

Microelectronic Materials, Grovenor, Hilger.

Materials for Semiconductor Devices, Grovenor, IOM.

Electronic Materials, Murarka and Peckerar, Academic Press.

Crystal Growth, Vere, Plenum.

VLSI Fabrication Principles, Ghandhi, Wiley.

Electronic Materials and Devices, Navon, Houghton/Mifflin

2. Prof C R M Grovenor

- Electroceramics: how to control the electrical properties of ceramics.
- Ceramic conductors: Resistors and varistors, temperature sensitive resistors, sensors and fuel cells.
- Dielectrics and capacitors: Control of permittivity, capacitor types and materials selection, dielectric memory devices.
- Piezoelectric and pyroelectric materials and devices

Reading list:

Electroceramics, A J Moulson and J M Herbert, Chapman & Hall, 1990.

Electrical Properties of Materials, 6th edition, Solymar and Walsh, OUP, 1998.

Gas Sensing Materials, MRS Bulletin, **24**, No. 6, June 1999.

3. Prof S C Speller

- Fundamentals of superconductivity.
- Influence of microstructure on superconducting properties: flux pinning, Josephson effect.
- Superconductors for magnet applications: wires and tapes, bulks.
- Superconducting thin films for device applications: digital electronics, passive microwave devices, Superconducting Quantum Interference Devices (SQUIDS).
- Novel superconducting materials: Fe-based compounds.

Reading list:

Recommended books which are available in the Materials Library:

Electrical Properties of Materials, 6th edition, Solymar and Walsh, OUP, 1998, chapter 14

- Concise introduction to the fundamentals of superconductivity
- Required reading with the exception of section 14.6, which is useful as background reading.

Superconductivity, 2nd edition, Buckel and Kleiner, Wiley-VCH, 2004

- Chapters 1-2 provide useful background information on fundamental properties and superconducting materials.
- Chapters 3-6 are useful background, but the detailed mathematical treatments are beyond the scope of this course
- Chapter 7 is required reading on applications of superconductors

High Temperature Superconductors (HTS) for Energy Applications, Woodhead publishing, ed, Melhem, 2012

- Chapters 1-4 provide background reading on applications of HTS materials

Concise Encyclopedia of Magnetic and Superconducting Materials, Pergamon Press, ed Evetts, 1997

- Good reference book on a wide range of superconducting materials and applications

Other books on fundamentals of superconductivity that may be useful include:

Superconductivity, superfluids and condensates, Oxford Master Series in Condensed Matter Physics, Annett, 2004

- Excellent book but more advanced than needed for this course.

Introduction to Superconductivity, International Series in Solid State Physics, Vol 6, 2nd ed, Rose-Innes and Rhoderick

- Undergraduate level physics book on superconductivity – not written in a very accessible style.

Advanced Engineering Alloys & Composites: Design & Applications

1. Stability of Microstructure:

A comparison between classical nucleation and the spinodal reaction. The Cahn-Hilliard model of spinodal decomposition. Particle coarsening. Order-disorder reactions: the Bragg-Williams model. Martensitic reactions and related phenomena: e.g. bainite and shape memory effects. Crystallographic theory of martensite formation.

2. Design for Lightness:

Alloys for transportation and aerospace; magnesium alloys and their applications. Advanced aluminium alloys including aluminium-lithium, aluminium-scandium, aluminium-transition metal and aluminium-transition metal-rare earth alloys. Advanced titanium alloys: near-alpha alloys, beta alloys, casting alloys. Laminates and carbon fibre composites for aerospace applications.

Case Study: Planes, trains and automobiles.

3. Design for Maximum Strength and Toughness:

High strength steels; dual phase (ferrite-martensite) steels. High-alloy tempered martensites: bearing steels and tool steels; drawn pearlitic steels; maraging steels; austempering and martempering; thermomechanical treatments: ausforming, isoforming; transformation induced plasticity (TRIP) steels.

Case Study: aircraft undercarriages, gearboxes.

4. Design for High Temperatures: Superalloys and Beyond

Creep-resistant steels; nickel and cobalt based superalloys; Single crystal turbine blade alloys; high temperature intermetallics; refractory metals: niobium, molybdenum, tantalum, tungsten, rhenium.

Case Study: power generating turbines and jet engines.

Reading list:

Physical Metallurgy, 3rd edition, P Haasen, CUP, 1996, 50HAA.

Transformations in Metals, P G Shewmon, McGraw Hill, 1969, 53SHE.

Fundamentals of Physical Metallurgy, J D Verhoeven, Wiley, 1975, 50VER.

The Theory of Transformations in Metals and Alloys, 3rd edition, J W Christian, Pergamon, 2002, 53CHR.

Light Alloys: From Traditional Alloys to Nanocrystals, 4th edition, I J Polmear, Butterworth Heinemann, 2006, 52POL.

Steels, Microstructure and Properties, 3rd edition, H K D H Bhadeshia and R W K Honeycombe, 2005, Butterworth Heinemann, 51BHA.

Steels : metallurgy and applications, 2nd Edition, D.T. Llewellyn, Butterworth-Heinemann, 51LLE

The Superalloys: Fundamentals and Applications, R C Reed, CUP, 2006, 52REE.

Titanium, Gerd Lütjering, James C. Williams, Springer, 52LUT

Selection and Use of Engineering Materials, 3rd edition, (chapters 6-1, 15, 17, 18), J A Charles, F A A Crane & J A G Furness, Butterworth Heinemann, 1997. 56CHA.

Structure-property relations in nonferrous metals, Alan M. Russell, Kok Loong Lee , Wiley-Interscience, 52Rus

Advanced Manufacture with Metals & Alloys: Processing, Joining & Shaping

Melt Processing - Casting & Other Melt-based Processes

Cast iron: Grey iron, ductile iron, white iron, malleable iron.

Steel, Al alloys, metal matrix composites, Ni alloys, Ti alloys.

Grain structure, competitive growth, dendrite fragmentation, grain refiners.

Microsegregation, macrosegregation, local segregates.

Defects: porosity/pore formation, inclusions/oxide, cracks and hot tears, shrinkage, cold shuts, misruns.

Melt conditioning.

Heat flow, modelling.

Shaped casting: die casting and others.

Continuous casting: DC casting, twin roll casting, spray forming and others.

Rapid Solidification.

Reading list:

Casting ASM Handbook Vol 15, 9th edition, section "Principles of Solidification" and "Molding and casting processes".

Castings, chapters 6, 7, 8, 9 and 10, J Campbell

Fundamentals of solidification, chapters 2, 3, 4, 5 and 6, W Kurz and D J Fisher.

Solidification processing, M C Flemings.

Advanced Manufacture with Metals & Alloys

1. Joining:

Mechanical joining.

Soldering.

Brazing.

Welding.

Adhesive bonding.

2. Surface finishing

Cleaning.
Plating.
Coating.
Surface hardening.

Reading list:

Joining of Materials and Structures: From Pragmatic Process to Enabling Technology, R W Messler Jr, Elsevier Butterworth-Heinemann, 2010.

A key text covering all aspects of joining including joining a wide range of material types. (A copy has been requested for the Materials Library.)

Manufacturing with Materials, L Edwards and M Endean (eds.), Butterworths / Open University Press, 1990, 50MAS/4A.

The “process datacards” were taken from here. Chapter 5 covers aspects of joining.

Process Selection: from Design to Manufacture, 2nd edition, K G Swift and J D Booker, Butterworth-Heinemann, 2005, 56SWI.

Chapter 7 covers joining processes.

Introduction to the Physical Metallurgy of Welding, 2nd edition, K E Easterling, Butterworth–Heinemann, 1992, 56EAS.

A key text for understanding the materials/microstructural aspects of welding.

Metallurgy of Welding, 6th edition, J F Lancaster, Abington Publishing, 1999, 56LAN/B.

Covers a wide range of welding processes.

Metals Handbook, Desk edition, chapters 24, 26 to 30, 1985 04-1ASM (for reference only).

Engineering Materials: Properties and Selection 4th edition, K G Budinski, 1992, 50BUD.

Chapter 6 contains sections on polymer coatings and adhesives. Chapter 10 covers surface hardening. Chapter 19 covers inorganic coatings, including plating. (A copy of the 9th edition (2010) has been requested for the Materials Library. In this edition, the relevant chapters are Chapter 13, covering surface hardening and Chapter 21 on surface engineering.)

Principles of Metal Manufacturing Processes, J Beddoes and M J Bibby, 1999, Arnold, 56BED.

Chapter 9 covers surface hardening, plating and thin film coatings.

The Superalloys, R C Reed, 2006, Cambridge University Press, 52REE
Chapter 5 covers coatings for Ni turbine blades.

Biomaterials & Natural Materials

1. Introduction to biomaterials. Definitions and history.
2. The structure and properties of natural materials.
 - a) basic building blocks - proteins, polysaccharides.
 - b) mammalian soft tissue - skin, tendon, muscle.
 - c) hard tissue -.
3. Biofunctionality.
4. Materials response to in vivo environment.
the three classes of biomedical material:
bioinert, bioactive and bioresorbable - the bioreactivity spectrum.
5. Tissue response to implants.
 - a) wound healing - inflammation and repair.
 - b) cellular response to implants.
6. Bioceramics, Biopolymers and Biometals and Biocomposites.
7. Tissue Engineering.
 - (a) Scaffolds.
 - (b) Scaffold - cell interactions.
8. Biomechanics.
 - (a) the joint reaction force.
 - (b) device design.
9. Drug delivery devices – liposomes, natural polymers and artificial polymer based systems.
10. Tissue expanders. Use in plastic and reconstructive surgery.
11. Osteoporosis. Trends and treatments.

Recommended reading

Biomaterials Science and Engineering, 3rd edition, Park, Plenum, NY.

Biological Performance of Materials, J Black, Marcel Dekker, NY.

Physiology of Bone, 3rd edition, J Vaughan, OUP.

An introduction to bioceramics, L L Hench & I Wilson, eds., World Scientific.

Materials Science and Technology vol.14, D F Williams (ed.), VCH, Germany.
Biomaterials Science, An Introduction to Materials in Medicine, B D Rattner,
A S Hoffman, F J Schoen and J E Lemons, Academic Press, San Diego, CA.

Advanced Polymers

This course addresses how critical microstructural phenomena dominate the macroscopic properties of polymers, and how these are exploited in some of the more advanced polymers and 'soft materials'. This will be discussed in the context of technological and industrial applications. The course will cover:

Prof Assender (4 lectures):

- Radius of gyration and other molecular dimensions, molecules in solution and gelation
- Critical phase behavior and phase separation
- Blend and block copolymer morphology
 - Micro and nano-patterning
- Interface phenomena
 - Polymer miscibility
 - Reflectivity techniques
 - Capillary waves

Dr Telling (4 lectures):

Neutron scattering as a tool for the study of polymeric materials

1. Fundamentals of the neutron scattering technique
 - Neutron vs. X-ray vs. Light Scattering
 - Pros and cons of the two techniques
 - The neutron as a probe
 - Scattering concepts
 - Elastic and Inelastic Scattering
 - Momentum Transfer, Q
 - The Scattering Process

- Differential Cross Sections
 - Scattering Cross Sections
 - Length scales
2. QENS – Quasi-Elastic Neutron Scattering: The study of dynamics
- The materials scientist and polymer dynamics
 - QENS : why and what
 - Coherent and Incoherent Scattering
 - Experimental Setup
 - Transmission
 - What we measure
 - Line width analysis and geometry
 - Example : putting it all together
3. SANS – Small Angle Neutron Scattering: The study of structure
- The materials scientist and polymeric structure
 - SANS : why and what
 - geometry of a SANS experiment
 - contributions to $d\sigma/d\Omega$
 - contrast matching
 - the single particle (shape) factor, $P(Q)$
 - the inter-particle structure factor, $S(Q)$
 - analysis via standard plots
 - Example
4. Recycling
- Setting the scene
 - Plastic: fantastic or cheap and nasty?
 - The materials life cycle: a PET bottle
 - Recycling
 - Recovery infrastructure

Prof Assender (4 lectures):

- Novel molecular topologies and molecular materials
 - Molecular self-assembly
 - Drug delivery
- Understanding T_g
 - Surface/interface T_g
- Chain entanglement and reptation
- Diffusion
- Adhesion and bonding
 - Mechanical failure of polymers
- Thin film applications

Reading list:

Required reading: (Those books core to the course material):

Soft Condensed Matter, especially chapters 2, 3 and 6, RAL Jones, OUP, 2002.
22JON/1

Polymers at Surfaces and Interfaces, R A L Jones and R W Richards, CUP, 1999.
Chapters 4, 5, 6 & 7. 45JON/1

Introduction to Physical Polymer Science, 2nd edition, L H Sperling, John Wiley and Sons, 1992. Chapters 3, 5 & 8 & 12. 45SPE/1.

Background reading:

Fundamentals of Polymer Engineering, A Kumar and R K Gupta, McGraw-Hill, 1998.
Chapters 9 & 13. 45KUM/1.

Polymer-Polymer Miscibility, O Olabisi, L M Robeson and M T Shaw, Academic Press Inc, 1979. RSL QD 381.8 OLA

Introduction to Polymer Physics, M Doi, OUP, 1997. Chapters 2 & 5. 45DOI/1

The Physics of Glassy Polymers, 2nd edition, R N Haward and R J Young (eds), Chapman and Hall, 1997. Chapters 9 & 10. RSL TA 455.P58 PHY
Chapters 5, 8 & 9.

For lectures 5 to 8 on Neutron Methods and Recycling issues you may want to refer to the following:

- 1 **Neutron scattering: A primer**, R. Pynn, Lansce <http://library.lanl.gov/cgi-bin/getfile?00326651.pdf>
 - 2 **Small angle neutron scattering**, S.M. King, ISIS Modern Techniques For Polymer Characterisation, Chapter 7, Wiley, 1999
 - 3 **Quasi-Elastic Neutron Scattering**, M. Bée, Taylor & Francis, 1988, ISBN-10: 0852743718
 - 4 **Materials and the environment**, M.F. Ashby Elsevier 2009, ISBN 978-1-85617-608-8
- Introduction to plastics recycling**, 2nd edition, V Goodship, Smithers Rapra, 2007

Materials for Energy Production, Distribution & Storage

1. Introduction.

Energy usage: domestic, transportation, industry and commerce.

Key drivers for energy supply strategy: climate change; security of resources; continuity of supply; efficiency and economy.

2. Electricity Production

Fossil generation: Boilers, heat exchangers, turbines, combined cycle systems

Carbon capture and storage technology

*Nuclear fission: reactor design, fuels, cladding, moderators, cooling systems, pressure vessels, radiation damage and embrittlement, thermal ageing, stress corrosion cracking, safety systems, waste handling, treatment and storage.

*Nuclear fusion: principles, reactor design, plasma containment, first wall materials, divertors, tritium production, latest developments.

Renewables: wind, wave, tidal, geothermal and solar thermal generation.

Biomass Technologies

*Fuel cells: principles and practice

Hydrogen production.

3. Electricity Distribution

Grid design

High voltage transmission: transformers and cables

*Superconducting transmission

4. Electrical Energy Storage

Pumped / pressurised energy storage systems

Superconducting storage

Supercapacitors

*Battery technology

*Hydrogen storage

Thermal storage systems

The course is designed to give a general overview of materials requirements for energy systems, and recent developments in this area, with more in-depth coverage of a limited number of selected topics (indicated by asterisks in the above synopsis).

NOTES:

1. Photovoltaic materials are covered in the course on semiconductor materials.
2. Fossil fuel power plant materials are covered in more depth in the Advanced Engineering Alloys and Composites course.
3. Composite materials for wind and wave/tidal applications can also be covered in the Advanced Engineering Alloys and Composites course if necessary.

Reading list:

Sustainable Energy – Without the Hot Air, David JC MacKay (available free at www.withouthotair.com). Part 1 is a gentle introduction to some of the issues in energy supply in the 21st Century, recommended as background reading.

Energy Science: Principles, Technologies, and Impacts, John Andrews & Nick Jelley (available at Departmental Library, shelf mark: 60 AND). A general overview of energy generation storage and transmission.

MRS Bulletin April 2008, Vol 33, No 4, “Harnessing Materials for Energy” (available on line at: www.mrs.org/s_mrs/sec_subscribe.asp?CID=10867&DID=200925 and at Departmental Library, shelf mark: PER). A series of articles recommended as background reading.

Colloquia and Lecture Lists in Materials and Other Physical Science Departments

Research Colloquia in Michaelmas Term 2016

The first Departmental Colloquium will be held on Thursday 13 October 2016 at 3.30 pm in the Hume-Rothery Lecture Theatre. Thereafter, normally they will be held at 3.30pm on Thursday afternoons in weeks to be advised on our website – typically four in each of Michaelmas & Hilary Terms and two in Trinity Term.

A complete list of colloquia will be available on the Departmental website

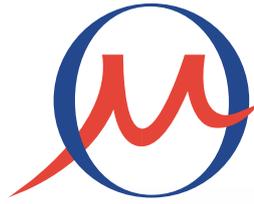
<http://www.materials.ox.ac.uk/news/colloquia.html>

Subject	Lecturer	Hours per term		
		M	H	T
Research colloquia				
Materials Colloquia	Various	4	4	4
MML Seminars	Various	8	8	8
QIP Seminars	Various	4	4	4
Begbroke Science Forum ^a	Various	4		4

^a <http://www-grobert.materials.ox.ac.uk/Main/BegbrokeScienceForum>

Lectures in Other Physical Science Departments

For up to date information on the lectures offered in Michaelmas Term by other Departments such as Mathematical Sciences, Physics or Chemistry, please see the following website: <http://www.ox.ac.uk/students/academic/lectures/> and, for further information about the Graduate Academic Programme, please see <https://weblearn.ox.ac.uk/portal/site/:grad>



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