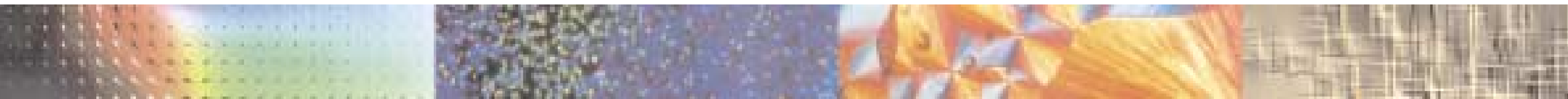
OxfordMaterials

Postgraduate Lecture and Training Course Synopses and Research Colloquia Details

2019-20



Department of Materials

Postgraduate Lecture & Training Course Synopses 2019-20

and Research Colloquia Details

Postgraduate Lecture & Training Course Synopses and Research Colloquia Details 2019-20

This booklet contains the synopses of postgraduate courses in the department for 2019-20. '**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 both 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 during 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 P34 FOR INFORMATION ON ARRANGING EM MODULAR TRAINING.

The Department's formal research colloquium series is normally held on selected 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 2-3 hours led by Dr Paul Warren, NSG (Pilkington Glass), assisted by Dr Adrian Taylor

Project Management

This two to three 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 associated activities and managing their 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 Panel can consider whether remedial action is required.

You are expected to bring a first 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 Rachel Bray (OU Careers Service)

Dr Mohinder Saran (HSBC) tbc

Dr Andy Norton (Rolls Royce) tbc

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

Dr P.A.J. Bagot

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

Dr S. Boad (Institute of Materials, Minerals & Mining)

1 session of 1 hour

The Institute of Materials, Minerals & Mining (IoM^3)

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 IoM^3 for your first year.

Postgraduate Training Michaelmas Term

Prof P.D. Nellist

3-hour lecture and demonstration

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.

Postgraduate Training Michaelmas Term

Prof C.R.M. Grovenor

2 lectures

Practical Aspects of 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

Postgraduate Training Michaelmas Term

Radcliffe Science Library

1 session of 1h 30mins

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.)

Postgraduate Training Hilary Term

Radcliffe Science Library

1 session of 2 hours

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

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.

Postgraduate Training Michaelmas & Hilary Terms

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 (OU Careers Service)

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 Hilary Term

D. Baker (ITS) & Dr A.O. Taylor

4 sessions totalling 6 hours

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 presentation 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 Touch Screens and Visualisers).
- 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.

Postgraduate Training Trinity Term

Prof R.I. Todd

1 session of 1 hour

Preparing an article for submission to a materials journal

Need some tips on how to write a scientific journal paper for acceptance?

This workshop is complementary to the workshop offered by MPLS (see https://www.mpls.ox.ac.uk/training/course-programme-for-graduate-students/scientific-writing-getting-your-paper-published for details) but is more focussed on the Materials side of publishing, looking at the most important factors you need to consider in writing the paper and getting it accepted, drawing on the convenor's experience as an author, supervisor and editor (Journal of the European Ceramic Society).

This workshop is suitable for PGR students looking to prepare their first paper.

Dr G. Matthews
Dr F. Vigneau
Dr Z. Cheng

LabVIEW Introduction & MATLAB Introduction

LabVIEW Introduction (Dr G. Matthews)
MATLAB Introduction (Dr F. Vigneau & Dr Z. Cheng)

2 sessions each of 3 hours.

Hands-on workshops to introduce the use of MATLAB and LabVIEW.

Postgraduate Training Hilary Term

Prof H.E. Assender and Dr P.J. Warren

1 session of 3 hours

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.

Background Reading

King, S., **On Writing**, Hodder Stoughton

Arshandy, R., **Science & Medical Style Guide**, Vol 1, Kentus

Allay, M., **The Craft of Scientific Writing**, Springer

Reingand, N. ed., **Intellectual Property in Academia, a practical guide for scientists and engineers**, CRC Press

Postgraduate Training | Hilary Term

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.

Postgraduate Training | Trinity Term

ISIS Innovation

1 session of 2 hours (tbc)

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 E. Liotti

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 Italy, California, Poland, Sweden, China, the south of France and Singapore.

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.

Postgraduate Training | Michaelmas Term

JCCG Members

1 session of 2 hours

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 J.R. Yates
  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]

- **Junior Demonstrating in the Materials Teaching Lab** Michaelmas Term
  Prof S. Lozano-Perez
  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 Courses Organiser (Prof S Lozano-Perez) 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 needed.

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 35-38 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/

Postgraduate Teaching Michaelmas Term

Dr N.P. Young, Dr G.M. Hughes & Prof P.D. Nellist

8 lectures

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.

Background Reading

Williams, D. B., & Carter, C. B., **Transmission Electron Microscopy**, Plenum

Reimer, L., **Transmission Electron Microscopy**, Springer-Verlag

Pennycook, S.J. &, Nellist, P.D., **Scanning Transmission Electron Microscopy: Imaging and Analysis**, Springer

Bracewell, R., **The Fourier Transform & Its Applications**, McGraw-Hill

Postgraduate Teaching Michaelmas Term

Dr C.S. Allen

8 lectures

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.

Background Reading

Reimer, L., **Scanning Electron Microscopy: Physics of image formation & microanalysis**, Springer

Oatley, C. W., **The Scanning Electron Microscope**, Cambridge University Press

Thornton, P. R., **Scanning Electron Microscopy: Applications to materials and device science**, Chapman and Hall

Goodhew, P. J., & Humphreys, F. J., **Electron Microscopy and Analysis**, Taylor & Francis

Tsong, T. T., **Atom probe field-ion microscopy**, Cambridge University Press

Watts., F., **Introduction to Surface Analysis by Electron Spectroscopy**, Oxford Science Publications

Bonnell, D. A., **Scanning Probe Microscopy and Spectroscopy**, Wiley

Chen, C. J., **Introduction to Scanning Tunneling Microscopy**, Oxford University Press

Sarid, D., **Scanning Force Microscopy**, Oxford University Press

Wiesendanger, R., & Guntherodt, H-J., eds., **Scanning Tunnelling Microscopy II Further Applications and Related Scanning Techniques**, Springer-Verlag

Woodruff & Delchar, **Modern techniques of surface science**, Cambridge University Press

Postgraduate Teaching Hilary Term

Prof J.M. Titchmarsh, Prof S. Lozano-Perez & Dr R.J. Nicholls

8 lectures

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.

Background Reading

Cowley, J. M., **Diffraction Physics**, North Holland

Reimer, L., **Transmission Electron Microscopy**, Springer-Verlag

Fitzgerald, A. G., et al., **Quantitative Microbeam Analysis**, SUSSP and IOP Publishing

Hren, J. J., et al., eds., **Introduction to Analytical Electron Microscopy**, Plenum

Egerton, R. F., **Electron Energy-Loss Spectroscopy in the Electron Microscope**, Plenum

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

Reed, S. J. B., **Electron Microprobe Analysis**, Cambridge University Press

Flewitt, P. J., & Wild, R. K., **Physical Methods for Materials Characterisation**, IOP Publishing

Williams, D. B., & Carter, C. B., **Transmission Electron Microscopy**, Plenum

Postgraduate Teaching | Hilary Term

Dr J.S. Kim & Dr N.P. Young

8 lectures

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: Kinemactical 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.

Background Reading

Williams, D. B. & Carter, C. B., **Transmission Electron Microscopy**, Plenum, chapters 6 (electron lens), 11-19 (diffraction), 22-25 (imaging), 27-28 (HREM), 29 (image simulation)

Reimer, L., **Transmission Electron Microscopy**, Springer-Verlag, chapters 2, 3 (electron optics), 6 (image contrast), 7 (kinematic and dunamical theory of ED), 8 (diffraction contrast)

Hirsch, P. B., Howie, A., Nicholson, R. B., Pashley, D. W., & Whelan, M. J., Electron **Microscopy of Thin Crystals**, R E Krieger Publishing

Spence, J. C. H., **High-Resolution Electron Microscopy**, Oxford Science Publications chapters 2, 3 (electron optics), 5 (HREM theory), 10 (HREM parameter measurement)

Postgraduate Teaching Hilary Term

Dr C.J. Salter

8 lectures

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

Cauuet, ed., **L'Or dans l'antiquité: de la mine à l'objet**, Aquitania,

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

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

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

Hauptmann, A., Pernicka, E., Rehren, T. H., & Yalçin, Ü., eds., **The beginnings of metallurgy**, (Bochum: Deoutsches Bergbau-Museum: Der Anschnitt, Beiheft 9)

Maddin, R., ed., **The beginning of the use of metals and alloys**, MIT Press

Megaw, R., & Megaw, V., Celtic Art, Thames & Hudson

Mohen, J. P., **Métallurgie Préhistorique**, Masson

Mordant, C., Pernot, M., & Rychner, V., eds., **L'Atelier du bronzier en Europe du XXe au VIIIe siècle avant Notre Ère**, 3 volumes, Èditions du CTHS

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

Northover, J. P., & Salter, C. J., **'Decorative metallurgy of the Celts'**, in Materials Characterisation, pp. 47-62

Scott, D. A., **Metallography and microstructure of ancient and historic metals**, The Getty Conservation Institute

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

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

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

Historical Metallurgy (Journal of the Historical Metallurgy Society),

Archaeomaterials, various

Bulletin of the Metals Museum, various

Gold Bulletin, various

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.J. 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)

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

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

Background Reading

Scott, V.D. & Love, G., **Quantitative Electron-Probe Microanalysis**, Ellis Horwood
Giannuzzi, L.A., & Stevie, F. A., **Introduction to Focused Ion Beams: instrumentation, theory, techniques and practice**, Springer

2. Electron Back Scattered Diffraction (EBSD)

Module Coordinator: J. Holter

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: J. Holter, G.M. Hughes, P. Karamched

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, quarternions), 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.M. 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.

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 ARM 200F. Attendance of the following postgraduate lecture courses (or relevant parts of, to be advised by EM Facility): '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.P. 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)

Third Year
Undergraduate Options

Third Year Undergraduate Options Michaelmas Term

Dr C.E. Patrick

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.

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.

Optical spectra II: Direct absorption and phonon-assisted absorption.

Excitons: Predicted vs measured optical absorption spectra.

Background Reading

Recommended course textbook:

Materials Modelling using Density Functional Theory: Properties and Predictions, F. Giustino, Oxford University Press, 2014

Additional references, especially for information on superconductivity and photoemission:

Solid state physics, N. W. Ashcroft and N. D. Mermin, Harcourt College Publishers, 1976 chapter 34

Solid state physics: An Introduction to Principles of Materials Science, H Ibach and H Luth, Springer, 2009, chaps 7 and 10

Other electronic structure references:

Introduction to Solid State Physics, C. Kittel, Wiley 22KIT, chaps 6, 7, 8

Atomic and electronic structure of solids, E. Kaxiras, Cambridge University Press, 2003

Fundamentals of semiconductors, P. Y. Yu and M. Cardona, Springer, 2003

Third Year Undergraduate Options Michaelmas Term

Prof R.I. Todd

12 lectures

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

Background Reading

Riley, F.L., **Structural Ceramics: Fundamentals and Case Studies**, CUP

Kingery, W.D., Bowen, H.K., & Uhlmann, D.R., **Introduction to Ceramics**, Wiley Interscience

Chiang, Y. M., et al., **Physical ceramics: principles for ceramic science and engineering**, Wiley

Kang, S. L., Sintering: **densification, grain growth, and microstructure**, Elsevier Butterworth-Heinemann

Reed, J.S., **Principles of Ceramic Processing**, Wiley Interscience

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

Rahaman, M.N., **Ceramic processing and sintering**, M. Dekker

Brook, R.J., **Processing of ceramics**, VCH

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

Davidge, R.W., **Mechanical Properties of Ceramics**

Lawn, B. R., **Fracture of Brittle Materials**

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

McColm, I. J., **Ceramic Science for Materials Technologists**

Lee, W.E., & Rainforth, W.M., **Ceramic Microstructures**

Low, I. M., ed., **Ceramic Matrix Composites**

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

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

Third Year Undergraduate Options Michaelmas Term

Prof J.M. Smith

12 lectures

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 nolinearity. 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.

Required Reading

Fox, M., **Optical properties of solids**, Oxford University Press, An excellent overview of the materials properties and some basic devices

Background Reading

Hecht, E., **Optics**, Addison Wesley. A standard undergraduate text in optics

Wilson, J. & Hawkes, J., **Optoelectronics: and introduction**, Prentice Hall. A good introduction to some of the devices featured

Singh J, **Optoelectronics**, McGraw Hill. A good introduction to some of the devices featured

Senior, **Optical Fiber Communications**, Prentice Hall. A standard text on fibre communications

Rogers, A., **Essentials of Optoelectronics**, Chapman and Hall. A good introduction to some of the devices featured

Nelson, J., **The physics of solar cells**, Imperial College Press. A good introduction to solar cells

Third Year Undergraduate Options | Michaelmas Term

Prof K.A.Q. O'Reilly & Dr E. Liotti

12 lectures

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.

Background reading

Casting ASM Handbook Vol 15, Melt Processing - Casting & Other Melt-based Processes: section "Principles of Solidification" and "Molding and casting processes"

Campbell, J., **Castings**, Melt Processing - Casting & Other Melt-based Processes: chapters 6, 7, 8, 9 and 10

Kurz, W., & Fisher, D. J., **Fundamentals of solidification**, Melt Processing - Casting & Other Melt-based Processes: chapters 2, 3, 4, 5 and 6

Flemings, M. C., **Solidification processing**, Melt Processing - Casting & Other Melt-based Processes

Advanced Manufacture with Metals & Alloys

1. **Joining:**
    - Mechanical joining.
    - Soldering.
    - Brazing.
    - Welding.
    - Adhesive bonding.
2. **Surface finishing**
    - Cleaning.
    - Plating.
    - Coating.
    - Surface hardening.

Background Reading

N.B. There is no single book that is required reading. There is no need to read ALL of these books – they are largely alternatives for each other – see which ones you can get hold of, or which ones suit you, but do do some reading around.

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

Edwards, L., & Endean, M., eds., **Manufacturing with Materials**, Butterworths / Open University Press. 50MAS/4A. The "process datacards" were taken from here. Chapter 5 covers aspects of joining.

Swift, K. G. & Booker, J. D., **Process Selection: from Design to Manufacture**, Butterworth Heinemann. 56SWI. Chapter 7 covers joining processes.

Easterling, K. E., **Introduction to the Physical Metallurgy of Welding**, Butterworth Heinemann. 56EAS. A key text for understanding the materials/microstructural aspects of welding.

Lancaster, J. F., **Metallurgy of Welding**, and Abington Publishing, 56LAN/B. Covers a wide range of welding processes.

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

Budinski, K. G., **Engineering Materials: Properties and Selection**, 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.)

Beddoes, J., & Bibby, M. J., **Principles of Metal Manufacturing Processes**, Arnold, 56BED. Chapter 9 covers surface hardening, plating and thin film coatings.

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

Third Year Undergraduate Options Michaelmas Term

Prof N. Grobert, Prof K. Porfyrakis & Prof H. Bhaskaran

12 lectures

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.

Background Reading

Cao, G., **Nanostructures and Nanomaterials**, Imperial College Press

Edelstein, A. S. & Cammarata, R. C., eds., **Nanomaterials: Synthesis, Properties and Applications**, Taylor & Francis, DOM library: 58EDE

Poole, C. P., & Owens, F. J., **Introduction to Nanotechnology**, Wiley, DOM library: 58POO

Owens, F. J., & Poole, C. P., **The Physics and Chemistry of Nanosolids**, Wiley, DOM library: 58 OWE

Di Ventra, M., **Introduction to Nanoscale Science and Technology**, Kluwer, DOM library

Ozin, G.A., Arsenault, A. C., & Cademartiri, L., **Nanochemistry- A chemical approach to nanomaterials**, RSC Publishing, DOM library: 40 OZI

Hornyak, G.L., et al., **Introduction to Nanoscience**, CRC Press, Taylor & Francis, DOM library: 58 HOR/2

Kawazoe, Y., Kondow, T., & Ohno, K., eds., **Clusters and nanomaterials: theory and experiment**, Springer, DOM library

Agrait, N., Yeyati, A. L., & van Ruitenbeek, J. M., **Quantum properties of atomic-sized conductors**, Preprint, DOM library

Tsurumi, T., Hirayama, H., Vacha, M., & Taniyama, T., **Nanoscale Physics for Materials Science**, CRC Press, Taylor & Francis

Wolf, E. L., **Nanophysics and Nanotechnology. An introduction to modern concepts in nanoscience**, Wiley-VCH, DOM library: 58 WOL/1

Madou, M. J., **Fundamentals of Microfabrication and Nanotechnology**, 3 volumes, CRC Press

Fabrication of Nanomaterials for Materials Science Applications

Koch, K. C., ed., **Nanostructured Materials: Processing, Properties and Applications**, IOP, DOM library: 40KOC

Nalwa, H. S., ed**., Nanostructured Materials and Nanotechnology**, Concise Edition, Academic Press, DOM library: 58NAL & RSL

Carbon Nanotubes

Harris, P. J. F., **Carbon Nanotubes and Related Structures**, Cambridge University Press, DOM library: 40HAR

Guldi, D.M., & Martin, N., **Carbon nanotubes and related structures: synthesis, characterization, functionalization, and applications**, Wiley, DOM library: 40 GUL

Dresselhaus, M.S., Dresselhaus, G. & Eklund, P.C., **Science of Fullerenes and Carbon Nanotubes**, Academic Press

Q-dots and Q-wires

Barnham, K., & Vvedensky, D., eds., **Low-dimensional Semiconductor Structures**, Cambridge Univeristy Press, DOM library: 21BAR

Bimberg, D., **Quantum Dot Heterostructures**, Wiley, DOM Library: 22BIM

Woggon, U., **Optical Properties of Semiconductor Quantum Dots**, Springer

Light Scattering

Bohren, C.E., & Huffman, D. R., **Absorption and Scattering of Light by Small Crystals**, Wiley

For surface plasmons there are two reviews that are worth reading, along with references quoted in them:

> Maier, S., & Atwater, H. A., **"Plasmonics: localization and guiding of electromagnetic energy in metal/dielectric structures**" in J. Appl. Physics, 98, 011101.
>
> Hutter, E. & Fendler, J. H., **"Exploitation of localized surface plasmon resonance"**, in Adv. Mater., 16, 1685

Environmental and safety aspects

Karn, B., et al. eds., **Nanotechnology and the Environment**, Vol. 890, ACS Symposium Series

Oberdorster, G., et al., **Nanotoxicology; an emerging discipline evolving from studies of ultrafine particles**, in Environmental Health Perspectives, 113, p823

Maynard, A. D., et al., **Safe Handling of nanotechnology**, in Nature, 444, p267,

Oberdorster, G., et al., **Toxicology of nanoparticles: A historical perspective, in Nanotoxicology**, 1, p. 2.

C Buzea et al., **Nanomaterials and nanoparticles: Sources and toxicity**, in Biointerphases, 2, p.MR17

Third Year Undergraduate Options Hilary Term

Prof C.R.M. Grovenor, Prof S.C. Speller & Prof P.R. Wilshaw

12 lectures

Devices

1. 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

Background Reading

Moulson, A. J., & Herbert, J. M., **Electroceramics**, Chapman & Hall

Solymar, & Walsh, **Electrical Properties of Materials**, Oxford University Press, Gas Sensing Materials, in MRS Bulletin,

Solymar, & Walsh, **Electrical Properties of Materials**, Oxford University Press chapter 14. Concise introduction to the fundamentals of superconductivity. Required reading with the exception of section 14.6, which is useful as background reading

2. 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.

Recommended books which are available in the Materials Library:

Solymar, & Walsh, **Electrical Properties of Materials**, Oxford University Press, chapter 14. Concise introduction to the fundamentals of superconductivity. **Required reading** with the exception of section 14.6, which is useful as background reading

Buckel, & Kleiner, **Superconductivity**, Wiley-VCH. Chapter 7 is **required reading** on applications of superconductors

Buckel, & Kleiner, **Superconductivity**, Wiley-VCH. 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.

Melhem, ed., **High Temperature Superconductors (HTS) for Energy Applications**, Woodhead Publishing

Evetts, ed., **Concise Encyclopedia of Magnetic and Superconducting Materials**, Pergamon. Good reference book on a wide range of superconducting materials and applications

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

Annett, **Superconductivity, superfluids and condensates**, Oxford Master Series in Condensed Matter Physics. Excellent book but more advanced than needed for this course.

Rose-Innes, & Rhoderick, **Introduction to Superconductivity**, International Series in Solid State Physics, Vol 6, Undergraduate level physics book on superconductivity – not written in a very accessible style.

3. 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.

Background reading

Sze, S. M., **VLSI Technology**, McGraw-Hill

Grovenor, **Microelectronic Materials**, Hilger

Grovenor, **Materials for Semiconductor Devices**, IOM

Murarka, & Peckerar, **Electronic Materials**, Academic Press

Vere, **Crystal Growth**, Plenum Press

Ghandhi, **VLSI Fabrication Principles**, Wiley

Navon, **Electronic Materials and Devices**, Houghton/Mifflin

Third Year Undergraduate Options | Hilary Term

Prof M.L. Galano & Prof D.E.J. Armstrong

12 lectures

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 decompostion. 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. Titanium matrix composites.
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. Precipitation hardened stainless steels.
Case Study: aircraft undercarriages, gearboxes.

4. Design for High Temperatures: Superalloys and Beyond

Creep-resistant steels; high temperature intermetallics; refractory metals: niobium, molybdenum, tantalum, tungsten, rhenium.
Case Study: power generating turbines and jet engines.

Background Reading

Hassan, P., **Physical Metallurgy**, Cambridge University Press, 50HAA

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

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

Christian, J. W., **The Theory of Transformations in Metals and Alloys**, Pergamon, 53CHR

Polmear, I. J., **Light Alloys: From Traditional Alloys to Nanocrystals**, Butterworth Heinemann, 52POL

Bhadeshia, H. K. D. H., & Honeycombe, R. W. K., Steels, **Microstructure and Properties**, Butterworth Heinemann, 51BHA

Llewellyn, D.T., **Steels: metallurgy and applications**, Butterworth Heinemann, 51LLE

Lütjering, G., & Williams, J. C., Titanium, Springer, 52LUT

Charles, J. A., Crane, F. A. A., & Furness, J. A. G., **Selection and Use of Engineering Materials**, Butterworth Heinemann, 56CHA. Chapters 6-1, 15, 17, 18

Russell, A. M., & Lee, K. L., **Structure-property relations in nonferrous metals**, Wiley-Interscience, 52Rus

Sha, W., & Guo, Z., **Maraging steels: Modelling of microstructure, properties and applications**,

Abe, F., **Creep Resistant Steels**

Prof J.T. Czernuszka

12 lectures

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.

Background Reading

Park, **Biomaterials Science and Engineering**, Plenum Press

Black, J., **Biological Performance of Materials**, Marcel Decker

Vaughan, J., **Physiology of Bone**, Oxford University Press

Hench, L. L., & Wilson, I., eds., **An introduction to bioceramics**, World Scientific
Williams, D. F., ed., **Materials Science and Technology** vol.14, VCH
Rattner, B. D., Hoffman, A. S., Schoen, F. J., & Lemons, J. E., **Biomaterials Science, An Introduction to Materials in Medicine**, Academic Press

Options Paper 2 Hilary Term

Prof H.E. Assender & Dr M. Lefferts

12 Lectures

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 (8 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
- 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

Dr Lefferts (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

Required Reading

Jones, R. A. L., **Soft Condensed Matter**, Oxford University Press especially chapters 2, 3 and 6

Jones, R. A. L., & Richards, R. W., **Polymers at Surfaces and Interfaces**, Cambridge University Press, Chapters 4, 5, 6 & 7

Sperling, L. H., Introduction to Physical Polymer Science, Wiley, Chapters 3, 5, 8 & 12

Background Reading

Kumar, A., & Gupta, R. K., **Fundamentals of Polymer Engineering**, Marcel Dekker Chapter 13

Olabisi, O., Robeson, L. M., & Shaw, M. T., **Polymer-Polymer Miscibility**, Academic Press

Doi, M., **Introduction to Polymer Physics**, Oxford University Press, Chapters 2 & 5

Haward, R. N., & Young, R. J., eds., **The Physics of Glassy Polymers**, Chapman and Hall, Chapters 9 & 10

For lectures on Neutron Methods and Recycling issues:

Pynn, R., **Neutron scattering: A primer**, Lansce http://library.lanl.gov/cgi-bin/getfile?00326651.pdf.

King, S. M., **Small angle neutron scattering**, Wiley, Chapter 7 ISIS Modern Techniques For Polymer Characterisation

Bée, M., **Quasi-Elastic Neutron Scattering**, Taylor & Francis

Ashby, M. F., **Materials and the environment**, Elsevier

Goodshire, V., **Introduction to plastics recycling**, Smithers Rapra, Chapters 5, 8 & 9

Third Year Undergraduate Options Hilary Term

Prof T.J. Marrow & Dr P. Adamson

12 lectures

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.

Required Reading

Martin, J. W., ed., **Concise Encyclopedia of Materials for Energy Systems**, Elsevier, http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=oxfaleph017062013&context=L&vid=SOLO&search_scope=LSCOP_ALL&tab=local&lang=en_US

Chetal, S. C., Nuclear Reactors: Coolant Materials

Sharma, B. P., Nuclear Reactors: Moderator and Reflector Materials

Odette, G. R., Nuclear Reactors: Pressure Vessel Steels

Simnad, M. T., Nuclear Reactors: Shielding Materials

Ishino, S., Fusion Reactors (Magnetically Confined) –Tokamaks: Materials

Smith, D.L., et al., **Performance limits for fusion first-wall structural materials'**, in Journal of Nuclear Materials, pp. 716-720, http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=TN_sciversesciencedirect_elsevierS0022-3115(00)00315-9&context=PC&vid=SOLO&search_scope=LSCOP_ALL&tab=local&lang=en_US

Hayman, B et al, **Materials Challenges in Present and Future Wind Energy**, in MRS Bulletin, pp. 343-354, http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=TN_crossref10.1557/mrs2008.70&context=PC&vid=SOLO&search_scope=LSCOP_ALL&tab=local&lang=en_US

Mehos, M, **Another Pathway to Large-Scale Power Generation: Concentrating Solar Power in MRS Bulletin**, pp. 364-365, http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=TN_crossref10.1557/mrs2008.72&context=PC&vid=SOLO&search_scope=LSCOP_ALL&tab=local&lang=en_US

Martin, J. W. ed., **Concise Encyclopedia of Materials for Energy Systems**, pp. 136-152, 597-599

Arunachalam, V. S. & Fleischer, Elizabeth L., MRS Bulletin, **Harnessing Materials for Energy**, MRS, pp. 303-305, 309-315, 399-407, 411-420, 421-428

Ghosh, T.K., & Prelas, M.A. , **Energy Resources and Systems Volume 1: Fundamentals and Non-Renewable Resources**, Springer, pp. 77-87, 89-122, 141-203, http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=oxfaleph017561997&context=L&vid=SOLO&search_scope=LSCOP_ALL&tab=local&lang=en_US

Burmeister, L.C., **Elements of Thermal-Fluid System Design**, Prentice Hall, pp. 74-108

Barbir, F., PEM Fuel Cells: Theory and Practice, Elsevier, pp. 1-31 Electronic Resource, http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=oxfaleph000496097&context=L&vid=SOLO&search_scope=LSCOP_ALL&isFrbr=true&tab=local&lang=en_US

Huggins, R. A., **Energy Storage**, Springer pp. 69-92, http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=oxfaleph021338336&context=L&vid=SOLO&search_scope=LSCOP_ALL&isFrbr=true&tab=local&lang=en_US

Dincer, I., Rosens, M., **Thermal Energy Storage: Systems and Applications**, Wliey pp. 83-290, http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=oxfaleph000532433&context=L&vid=SOLO&search_scope=LSCOP_ALL&isFrbr=true&tab=local&lang=en_US

Miller, J.R., & Simon, P., **Fundamentals of electrochemical capacitor design and operation, The Interface**, ECS Publications, pp. 31-32, https://www.electrochem.org/dl/interface/spr/spr08/spr08_p31-32.pdf

Garcia-Martinez, J., **Nanotechnology for the Energy Challenge**, Wiley-VCH. pp. 139-153, http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=oxfaleph017209467&context=L&vid=SOLO&search_scope=LSCOP_ALL&isFrbr=true&tab=local&lang=en_US

Kiehne, A., **Battery Technology Handbook**, Verlag, pp. 1-111, http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=oxfaleph019468882&context=L&vid=SOLO&search_scope=LSCOP_ALL&tab=local&lang=en_US

Grigsby, L. L., **Electric Power Generation, Transmission, And Distribution**, CRC Press Chapters 8, 9, 11, 13,14,19, http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=oxfaleph016571831&context=L&vid=SOLO&search_scope=LSCOP_ALL&isFrbr=true&tab=local&lang=en_US

Gellings, C. W., **The Smart Grid: Enabling Energy Efficiency and Demand Response**, The Farmont Press, pp. 1-14, electronic resource, http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=oxfaleph000623896&context=L&vid=SOLO&search_scope=LSCOP_ALL&tab=local&lang=en_US

Background Reading

MacKay, D. J. C., **Sustainable Energy – Without the Hot Air**, 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, http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=TN_dspace1810/217849&context=PC&vid=SOLO&search_scope=LSCOP_ALL&tab=local&lang=en_US

Andrews, J., & Jelley, N., **Energy Science: Principles, Technologies, and Impacts**, OUP, A general overview of energy generation storage and transmission. http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=oxfaleph019489577&context=L&vid=SOLO&search_scope=LSCOP_ALL&isFrbr=true&tab=local&lang=en_US

Arunachalam, V. S. & Fleischer, Elizabeth L., **'Harnessing Materials for Energy'** in MRS Bulletin, MRS, available on line at: http://solo.bodleian.ox.ac.uk/primo-explore/fulldisplay?docid=TN_untlark/67531/metadc894448&context=PC&vid=SOLO&search_scope=LSCOP_ALL&tab=local&lang=en_US 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 2019

The first Departmental Colloquium will be held on Thursday 17 October 2019 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.

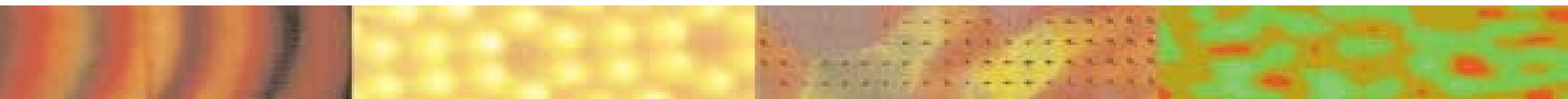
A complete list of colloquia, including links to colloquia lists from other MPLS departments, will be available on the Departmental website
http://www.materials.ox.ac.uk/news/colloquia.html

Subject	Lecturer	Hours per term		
		M	**H**	**T**
Research colloquia				
Materials Colloquia	Various	4	4	2
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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