MATS3002

Fundamentals of Ceramic Processing

Course Outline
Session 1, 2014
Course Objective

The Course is a core course in Year 3 of the BE in Materials Science and Engineering and is intended to teach students the fundamentals of ceramic materials and their processing and the importance of processing in determining the composition-microstructure-property relationships for ceramic products. Specific objectives include:

1. Understand the main processes and technology involved in the manufacture of each of the main classes of ceramic products from the initial raw materials through to finished products.
2. Understand the critical importance of ceramic processing in determining the composition-microstructure-property relationships for ceramic materials.
3. Understand the raw materials used to manufacture ceramic products, the chemical and physical material changes that take place when manufacturing a ceramic, and the resultant effects on microstructure and properties.
4. Ability to determine fundamental design aspects and perform calculations relevant to specific forming operations, drying operations, and firing operations used in ceramic processing.
5. Understand and design basic processing routes for ceramic materials and components, and undertake practical problem solving.
## Your Course at a Glance:

<table>
<thead>
<tr>
<th>What you will learn</th>
<th>Weeks</th>
<th>Assessment Task</th>
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<tbody>
<tr>
<td><strong>What you will learn</strong></td>
<td><strong>Weeks</strong></td>
<td><strong>Assessment Task</strong></td>
</tr>
<tr>
<td><strong>1</strong> Overview of Ceramic Materials &amp; Processing Operations (OS)</td>
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<tr>
<td><strong>2</strong> Ceramic Raw Materials and their Processing (OS)</td>
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<td><strong>3</strong> Ceramic Forming: Objectives and Powder Compaction (OS)</td>
<td>2</td>
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<td><strong>4</strong> Dry Forming Processes: Uniaxial Pressing, Cold Isostatic Pressing (OS)</td>
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<tr>
<td><strong>5</strong> Plastic Forming Processes: Mechanism of Plasticity, Stiff Extrusion, Soft Extrusion, Jiggering, Press Forming, Ram Forming (OS)</td>
<td>3,4</td>
<td>Extrusion Laboratory  Done in Week 4-6 Report due in Week 8</td>
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<tr>
<td><strong>6</strong> Wet Forming Methods: Suspension Electrokinetics and Rheology, Slip Casting, Pressure Casting, Tape Casting, Sol-Gel Deposition (OS)</td>
<td>4,5</td>
<td>Slip Casting Laboratory  Done in Week 4-6 Report due in Week 8</td>
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<tr>
<td><strong>7</strong> Drying of Ceramics: Principles, Psychrometry, Dryer Design and Operation (OS)</td>
<td>5,6</td>
<td>Psychrometry Tutorial  Done in Week 6 Due in Week 8</td>
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<tr>
<td><strong>Mid Session Exam (Week 9)</strong></td>
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<tr>
<td><strong>8</strong> Firing of Ceramics: Solid State Sintering, Liquid State Sintering &amp; Vitrification (OS)</td>
<td>7</td>
<td>Sintering Assignment  Issued in Week 8 Due in Week 11</td>
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<tr>
<td><strong>9</strong> Firing of Ceramics: Ternary Phase Diagrams (CS)</td>
<td>7-10</td>
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<tr>
<td><strong>10</strong> Statics and Kinetics of Firing, Kiln Design and Operation. Specialised Sintering Processes. (OS)</td>
<td>11</td>
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<tr>
<td><strong>11</strong> Glass Making Technology: Glass Compositions &amp; Structure; Glazes &amp; Enamels. (OS)</td>
<td>12</td>
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<tr>
<td><strong>12</strong> Cement and Concrete Processing: Cement Raw Materials, Calcination, Hydration Settings Reactions &amp; Microstructural Development (OS)</td>
<td>12</td>
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**Final Exam**
**Course staff**

<table>
<thead>
<tr>
<th>Dr Owen Standard</th>
<th>Room 216, School of Materials Science and Engineering (Building E8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course Coordinator &amp; Lecturer</td>
<td>Phone: 9385 4437 <a href="mailto:o.standard@unsw.edu.au">o.standard@unsw.edu.au</a></td>
</tr>
<tr>
<td></td>
<td>Consultation hours: by appointment (please contact by email)</td>
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<tr>
<th>Prof Chris Sorrell</th>
<th>Room 105, School of Materials Science and Engineering (Building E8)</th>
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<tr>
<td>Lecturer</td>
<td>Phone: 9385 4421 <a href="mailto:c.sorrell@unsw.edu.au">c.sorrell@unsw.edu.au</a></td>
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<td>Consultation hours: by appointment (please contact by email)</td>
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**Course Outline**

Processing of ceramics and its relationship to structure, properties and performance of ceramic materials. Starting materials, ceramic processing fundamentals, and processing technology taught in context of the main classes of ceramic materials (polycrystalline monolithic ceramics, glasses, and films/coatings) and the determination of structure, properties and performance. Ternary phase equilibria in ceramic systems.

**Timetable**

**Lectures**

<table>
<thead>
<tr>
<th>Weeks 1-12</th>
<th>13:00 – 15:00</th>
<th>Monday</th>
<th>Old Main Building 229</th>
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<td></td>
<td>09:00 – 11:00</td>
<td>Friday</td>
<td>Chemical Science M11</td>
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**Laboratory**

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<tr>
<th>Weeks 4-6</th>
<th>16:00 – 18:00</th>
<th>Thursday</th>
<th>MSE, Teaching Lab. PG05</th>
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**Laboratory Work**

Laboratory work in the course is designed to directly complement the lecture material and to provide practical understanding and experience in ceramic processing. It consists of:

- Extrusion Laboratory
- Slip Casting Laboratory

Both will also involve aspects of drying and firing/sintering. Students should note that:

- The laboratory component will be done as group-work in Weeks 4-6. Groups and timetable for the laboratory will be finalized prior to Week 4 according to the total number of students enrolled in the course. Students may change groups only if they apply in writing to the Course Coordinator and have another student who has agreed to swap with them. Students are permitted to attend only the laboratory group to which they have been assigned. Students attending other laboratory groups will be asked to leave.
- Attendance at laboratory classes is compulsory.
Prior to selected laboratories, students will receive WHS information (such as risk assessments) and will be required to sign a declaration that they have read and understood this information.

Appropriate footwear must be worn by students in laboratories at all times. Safety glasses and laboratory coats must be worn in laboratories. These items will not be provided by the School – students are expected to provide their own. Any student not wearing these items will not be permitted in the laboratory and will not be allowed to retake the laboratory at another time and will receive a mark of zero for that laboratory.

Assessment

<table>
<thead>
<tr>
<th>ASSESSMENT TASK</th>
<th>FRACTION</th>
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<tr>
<td>Extrusion Laboratory Report</td>
<td>5%</td>
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<tr>
<td>Students will work in groups using laboratory facilities to investigate the effect of selected material and extruder parameters on the rate of extrusion and the properties of the extruded/fired product. Laboratory done in Weeks 4-6, Report due in Week 7</td>
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<tr>
<td>Slip Casting Laboratory Report</td>
<td>5%</td>
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<tr>
<td>Students will work in groups using laboratory facilities to investigate the electrokinetic and rheological behavior of ceramic particulate suspensions and to analyse their effects on slip casting behavior and the resultant properties of the cast/sintered materials. Laboratory done in Weeks 4-6, Report due in Week 7</td>
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<tr>
<td>Psychrometry Tutorial Sheet</td>
<td>10%</td>
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<tr>
<td>Students will undertake psychrometric calculations involving air-water vapour systems and apply them to mass and energy balances calculations for ceramic drying processes. Issued in Week 7, due in Week 8</td>
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<tr>
<td>Sintering Assignment</td>
<td>10%</td>
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<td>Students will complete numerical problems related to sintering including application of diffusion equations to model specific sintering and grain growth mechanisms, to calculate sintering rates, and determine sintering shrinkage. Students will learn the fundamental particle size-time-temperature dependency of sintering and shrinkage. Issued in Week 8, due in Week 11</td>
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<tr>
<td>Mid-Session Examination</td>
<td>35%</td>
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<td>The mid-session exam will be 2hrs in duration and held in Week 9. It will assess the understanding and application of ceramic processing operations learnt in Weeks 1-6 up to and including Drying of Ceramics</td>
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<tr>
<td>Final Examination</td>
<td>35%</td>
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<tr>
<td>The final exam will be 2hrs in duration and held in the final exam period. It will assess the understanding and application of sintering theory and ternary phase diagrams, glass making and cement &amp; concrete technology learnt in Weeks 7-12</td>
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<td>TOTAL:</td>
<td>100%</td>
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Penalties for Late Submission of Assessment Tasks

Assignments submitted after the deadline will receive a 10% of maximum grade penalty for every day late, or part thereof.
Final Exam

This final exam will cover all aspects of the course consisting of formal lectures, nominated reading material (from course handouts), laboratory work, and assignments. It will consist of a combination of essay-style answers and calculations. Any derivations will assume knowledge of the material rather than resorting equations to memory with relevant background equations provided. The exam will held in the formal UNSW examination period following Session 2.

Students who fail to score at least 50% collectively for the mid-session exam and final exam, but achieve a final mark >50% for the course, may still be awarded a UF (Unsatisfactory Fail) for the course.

Please refer to the UNSW guide to grades:

References

There is no single textbook for the course. Below is a list of references which students may find useful.

• W.E. Brownell, Structural Clay Products. Springer - Verlag, New York, 1976

The majority of these books are in the UNSW library. Students seeking resources can also obtain assistance from the UNSW Library — a starting point for assistance is:
info.library.unsw.edu.au/web/services/services.html

**Learning and teaching philosophy underpinning the course**  
(based on UNSW Learning Guidelines)

• **Students are actively engaged in the learning process.**  
It is expected that, in addition to attending classes, students read, write, discuss, and are engaged in solving problems on the electronic properties of materials, and in analysis and evaluation of materials’ electron-related properties in the context of modern theories of physics.

• **Effective learning is supported by a climate of inquiry where students feel appropriately challenged.**  
Problems involving electron theory are challenging; students will be given assignments that will motivate deep analysis of various physical phenomena in materials science and engineering.

• **Learning is more effective when students’ prior experience and knowledge are recognised and built on.**  
This course is built on prior courses in mathematics, physics and chemistry.

• **Students become more engaged in the learning process if they can see the relevance of their studies to professional and disciplinary contexts**  
Students will be asked to analyse the role of electron theory in understanding various physical phenomena in materials science and how properties such as electrical conduction and magnetism influence the science and engineering of existing and new devices and components.
## Course Information

<table>
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<tr>
<th>Units of credit</th>
<th>6 UOC</th>
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| How the course relates to other course offerings and overall program(s) in the discipline | This course gives knowledge and understanding of ceramic and processing as part of the overall discipline of Materials Science and Engineering. It builds upon the intellectual framework of previous materials science courses such as kinetics and diffusion, phase equilibria, heat transfer, materials characterisation etc. and will enable students to:  
- Predict changes in ceramic materials/structures as a function of composition, temperature, pressure, and time;  
- Relate the structure of ceramics to processing required to make them; and,  
- Relate the ceramics of materials to the resultant properties and applications. |

| Graduate attributes which will be gained through the course | **In doing this course students should be able to:**  
- Identify and specify key features pertaining to the design and operation of powder processing equipment, forming equipment, dryers, and kilns used in industrial ceramic processing.  
- Design basic processing routes suitable for the forming of specific types of ceramic products, including selection of specific equipment and identification of potential processing problems and their prevention.  
- Explain and predict the effect of heat treatment conditions on the high temperature reactions of specific ceramic materials and resultant microstructure and properties.  
- Perform calculations related to static and kinetic aspects of drying and firing processes used in ceramic manufacturing.  
- Solve problems and to undertake design in the area of ceramic processing. |

| Teaching strategies | Core concepts, theories and approaches to numerous problems concerning materials characterisation techniques will be covered in lectures. Examples will be provided to demonstrate these principles in materials science and engineering.  
- A series of tutorial, demonstration, and laboratory exercises which demonstrate various characterisation techniques and calculations.  
- It is expected that students attending classes are prepared for discussion.  
- Teaching material, including the course outline, lecture presentations, tutorials, assignments, examples of solutions of problems, and course announcements are available on the Blackboard9 online website. |

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1 Based on the professional attributes given in Engineers Australia National Generic Competency Standards - Stage 1 Competency Standard for Professional Engineers and UNSW Graduate Attributes.
Academic honesty and plagiarism

**What is Plagiarism?**

Plagiarism is the presentation of the thoughts or work of another as one’s own.* Examples include:

- direct duplication of the thoughts or work of another, including by copying material, ideas or concepts from a book, article, report or other written document (whether published or unpublished), composition, artwork, design, drawing, circuitry, computer program or software, web site, Internet, other electronic resource, or another person’s assignment without appropriate acknowledgement;
- paraphrasing another person’s work with very minor changes keeping the meaning, form and/or progression of ideas of the original;
- piecing together sections of the work of others into a new whole;
- presenting an assessment item as independent work when it has been produced in whole or part in collusion with other people, for example, another student or a tutor; and
- claiming credit for a proportion a work contributed to a group assessment item that is greater than that actually contributed.†

For the purposes of this policy, submitting an assessment item that has already been submitted for academic credit elsewhere may be considered plagiarism.

Knowingly permitting your work to be copied by another student may also be considered to be plagiarism.

Note that an assessment item produced in oral, not written, form, or involving live presentation, may similarly contain plagiarised material.

The inclusion of the thoughts or work of another with attribution appropriate to the academic discipline does not amount to plagiarism.

The Learning Centre website is main repository for resources for staff and students on plagiarism and academic honesty. These resources can be located via:

[www.lc.unsw.edu.au/plagiarism](http://www.lc.unsw.edu.au/plagiarism)

The Learning Centre also provides substantial educational written materials, workshops, and tutorials to aid students, for example, in:

- correct referencing practices;
- paraphrasing, summarising, essay writing, and time management;
- appropriate use of, and attribution for, a range of materials including text, images, formulae and concepts.

Individual assistance is available on request from The Learning Centre.

Students are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting, and the proper referencing of sources in preparing all assessment items.

* Based on that proposed to the University of Newcastle by the St James Ethics Centre. Used with kind permission from the University of Newcastle

† Adapted with kind permission from the University of Melbourne.

Continual course improvement

- Students will be asked to provide evaluative feedback through the UNSW’s Course and Teaching Evaluation and Improvement (CATEI) process at the end of the course
• Students are encouraged to address any problems regarding teaching of this course at the annual staff-student meeting.

• Student comments on teaching during the session are welcome and will be appreciated.
  
  At times students may be asked to answer a short questionnaire for feedback on the course.

**Administrative Matters**

• Students should attend at least 80% of all classes.

• Students unable to submit assignments on time or attend the mid-session quizzes or final exams on health grounds should make a request for special consideration. Information on this process can be found here ([https://my.unsw.edu.au/student/atoz/SpecialConsideration.html](https://my.unsw.edu.au/student/atoz/SpecialConsideration.html)). Medical certificates or other appropriate documents must be included. Students should also advise the lecturer of the situation.

• Assignments/lab reports submitted after the deadline will receive a 10% of maximum grade penalty for every day late, or part thereof.

• Students who have a disability that requires some adjustment in their teaching or learning environment are encouraged to discuss their study needs with the course coordinator prior to, or at the commencement of, their course, or with the Equity Officer (Disability) in the Equity and Diversity Unit ([www.studentequity.unsw.edu.au](http://www.studentequity.unsw.edu.au)). Early notification is essential to enable any necessary adjustments to be made.

**Rules for Exams**

Rules governing conduct during exams are given at: [https://my.unsw.edu.au/student/academiclife/assessment/examinations/examinationrules.html - Rulesfortheconductofexaminations](https://my.unsw.edu.au/student/academiclife/assessment/examinations/examinationrules.html)

**Note that the use of mobile phones or music players in an exam room will constitute Academic Misconduct.**