Module Title: 5B2 Advanced Materials
Code: ME5B2
Level: Year 5 (MAI)
Credits: 5

Lecturer(s): Associate Prof. Kevin O’Kelly (okellyk@tcd.ie)
Dr. Robin Mooney (mooneyrp@tcd.ie)

Module Organisation
The module runs for 12 weeks of the academic year and comprises lectures, tutorial and laboratories. Total contact time is 44 hours.

<table>
<thead>
<tr>
<th>Semester</th>
<th>Start Week</th>
<th>End Week</th>
<th>Lectures/Tutorials hrs/week</th>
<th>Lectures total</th>
<th>Practicals hrs/peri week</th>
<th>Tutorials total hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>18</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>12</td>
<td>2</td>
<td>10</td>
<td>2</td>
<td>10</td>
</tr>
</tbody>
</table>

Module Description
The course covers the development of microstructures in materials and the characterisation of the physical and mechanical properties that arise. In particular, it will explore the solidification process in metals and powder pressing of ceramics and the associated compositions and microstructures, focussing on modelling techniques. It will cover various techniques for quanitatively evaluating the composition and properties such as x-ray diffraction (XRD), scanning electron microscopy (SEM), back-scattered electron microscopy (BSEM), nano-indentation, atomic force microscopy (AFM).

Learning Outcomes
On successful completion of this module, students will (be able to):
1. Discuss microstructures and draw conclusions about the relationship between the microstructure and the properties of the material.
2. Describe the different manufacturing processes that inherently involve solidification, such as, casting and welding.
3. Describe the typical defects that may occur in materials during the solidification process.
4. Explain fundamental theories of solidification in metals.
5. Apply solidification theory in order to understand the origins of microstructures and defects in metals.
6. Demonstrate how computer models of solidification are applied in material science.
7. Develop their own computer model of a solidification process.
8. Understand the relationship between initial powder composition and particle size on properties.
9. Understand the effect of different sintering regimes on the properties.
10. Be able to use analytical equipment to characterise the composition, structure and mechanical properties of metals and ceramics.
Module Syllabus

- **Part 1 – Solidification theory with computer modelling**
  1. An overview of casting and welding processes.
  2. Phase Diagrams for alloys
  3. Heat and Mass transfer basics for solidification theory
  4. Nucleation of solid and grain refinement
  5. Crystal Growth theory in metals
  6. Microsegregation in metals leading to macrosegregation
  7. Columnar to Equiaxed Transition in the grain structure of metals
  8. Microstructure, defects and material properties
  9. Solidification computer modelling

- **Part 2 – Ceramic powder pressing**
  1. Overview of powder pressing: solid-state diffusion
  2. Iso-static pressing: pressures and particle size
  3. Effect of binders and defloculants
  4. Sintering regimes

- **Part 3 – Characterisation techniques**
  1. Compositional analyses – XRD, BSEM, EDX
  2. Imaging – SEM, AFM, MicroCT
  3. Mechanical properties – Nanoindentation, AFM

Laboratories/Assignments

The laboratory assignments will comprise sample preparation and characterisation. There will be 5 laboratories:
  1. Sample preparation
  2. Compositional Analysis (BSEM, XRD, EDX)
  3. Imaging 1 (SEM)
  4. Imaging 2 (AFM)
  5. Mechanical Properties (Nanoindentation)

Teaching Strategies

Part one of this course is taught with a view to developing a detailed understanding of various solidification phenomenon that occur and the governing theory behind the phase-change process. This material will be learned during lectures and dedicated tutorial sessions (3 class hours per week for 6 weeks). Computer models will be developed based on the mathematical models of solidification presented in the lectures. Students will develop computer models in supervised computer programming classes (1 computer laboratory session per week for 6 weeks) and in their own time. The computer laboratory session will run in parallel to the lecture/tutorial sessions.

Parts 2 & 3 will be delivered through some lectures (2 hrs/week) and a significant amount of laboratory based learning (2 hrs per week).
**Assessment Modes**

Learning outcomes 1-5 will be assessed by in-class formative assessment during the first five weeks and by an in-class summative assessment at the sixth week of the course, accounting for **20%** of the overall module grade.

Students are required to maintain a logbook throughout the course of the supervised computer sessions. These logbooks are to be returned to the lecturer at the end of the final supervised computer session. Learning outcome 6 will be assessed by examining the log book entries. The logbook assessment will account for **10%** of the overall module grade.

In order to demonstrate learning outcome 7, students will complete a computer modelling assignment that must be completed during the course of the module. Students will be required to submit a final report on the modelling assignment. The quality and content of this report will account for **20%** of the overall module grade.

Learning outcomes 8 – 10 will be assessed entirely by laboratory practicals that will account for **50%** of the overall module grade. It will comprise a report comprising the results and analysis of an unknown material based on the 5 techniques used in the labs.

**Recommended Texts**

- Solidification, J.A. Dantzig and M. Rappaz, EPFL Press, 2009