Transitional course for PhD students

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BCAST

Why do we need a transitional course?

Who is a PhD student?

aspirant
əˈspʌɪər(ə)nt,ˈasp(ɪ)r-/
adjective
adjective: **aspirant**
1.
having ambitions to achieve something, typically to follow a particular career.
noun
noun: **aspirant**; plural noun: **aspirants**
2.
a person who has ambitions to achieve something.

What is the problem?

- PhD (postgraduate) studies as separate from BSc and MSc
- PhD studies are in fact, mostly, research projects linked to specific grants
- PhD students in many countries are not really students but researchers

- Specifics of a PhD research may require skills not available in the university
- PhD applicants maybe have different educational or research background
- PhD application maybe from different country where the contents/focus of education is different

Who is a solution?

Introduce a PhD student to a new field/subject and supply practical and useful information that can be absorbed using only basic knowledge and will allow a PhD student to learn deeper and wider by him/herself

Aims of the module

The main emphasis is on supplying PhD students from various BSc/MSc backgrounds with essential knowledge on materials science and processing that is required for successful pursuing of PhD project in the areas of materials science, metallurgy and materials processing.
The module creates the background that allows PhD students to further develop and deepen their knowledge and enhance the quality of analysis of their research outcome.
Other than materials science transitional modules maybe developed based on the same approach

Learning outcomes

The module provides opportunities for PhD students to develop and demonstrate knowledge and understanding, qualities, skills and other attributes in the following areas:

- Main relationships governing phase transformations in condensed systems.
- Principles and types of phase diagrams and learn to apply phase diagrams to the analysis of metallic alloy processing.
- Phenomena of nucleation and growth and controlling parameters.
- Controlling parameters of structure formation in metallic alloys.
- Metal processing routes, from solidification to deformation and heat treatment.
- Basics of data analysis and scientific writing.

Learning outcomes

At the end of the course, participants are expected:

- **To understand the laws of thermodynamics**, descriptions of thermodynamic systems and the basic thermodynamics and kinetics of nucleation and growth in solidification;
- **To understand principles and mechanisms** governing **the formation of** characteristic solidification **microstructures** and the importance of grain refinement;
- **To be familiar with various casting technologies** and appreciate both strong and weak points of individual casting processes;
- **To apply the above knowledge to the analysis** of the solidification process of a given alloy, predict solidification structure, and identify and solve practical problems, particularly in the context of microstructural control in their own research.
- **To become familiar with the current solidification science and practices** within the archival literature.

Contents

1. Basics of thermodynamics and kinetics in solidification. (2 hrs)

- Introduction to phase transformation and solidification.
- Basics of thermodynamics and kinetics in solidification.
- Driving force for solidification.
- Brief review of classical nucleation theory (homogeneous and heterogeneous nucleation).
- Free growth model.

Contents

2. Phase diagrams. (2 hrs)

- Free energy and Gibbs phase rule.
- Binary phase diagrams: principles.
- Typical mistakes on phase diagrams
- Types of solidification and solid-state reactions.
- Cooling curves and phase transformations.
- Examples of practically important phase diagrams and their analysis.

Contents

3. Equilibrium and non-equilibrium solidification. (2 hrs)

- Lever rule and Scheil approximation.
- Solute segregation and microsegregation. Constitutional undercooling.
- Effects of nonequilibrium solidification.
- Metastable and nonequilibrium phases.

Contents

4. Microstructure evolution during solidification. (2 hrs)

- Crystal growth mechanisms.
- Main growth morphologies: faceted and nonfaceted.
- Main growth types: equiaxed and columnar, columnar-equiaxed transition.
- Stability of Interfaces and dendritic growth.
- Eutectic and peritectic structures.
- Controlling factors of microstructure evolution: cooling rate, thermal gradient.

Contents

5. Nucleation and grain refinement. (2 hrs)

- Classical nucleation theory.
- Homogeneous and heterogeneous nucleation.
- Nucleation criteria for good substrate.
- Grain refining practice.
- Current views on the nature of grain refinement in metallic alloys.
- Eutectic modification.
- Importance of grain refining and eutectic modification in alloy performance.
- Application of the same principles to solid-state precipitation.

Contents

6. Structure formation in castings and its control. (2 hrs)

- Grain size, dendrite arm spacing, eutectic colony.
- Grain refinement
- Thermal and solutal convection.
- Dendrite fragmentation and coarsening.
- Special morphologies.
- Transition region in solidification, slurry and mushy zones, permeability.
- Structure zones and control in castings.

Contents

7. Casting defects. (2hrs)

- Processes during solidification.
- Shrinkage, gas, porosity.
- Control of porosity: modern technology.
- Macrosegregation: mechanisms.
- Control of macrosegregation: from structure to process parameters.
- Hot tears: mechanisms and challenges.
- Control of hot cracking: from structure to process parameters.
- Cold cracks: mechanisms and challenges.
- Control of hot cracking: from structure to process parameters.

Contents

8. Modern casting technologies. (2 hrs)

- Types of casting products: final and semi-finished items.
- Continuous processes: direct-chill and continuous casting; twin-roll casting.
- Shape casting: investment and die casting, low- and high-pressure die casting.
- Post-casting treatment: stress relief, homogenisation, cleaning.

Contents

9. Strengthening mechanisms and thermo-mechanical treatment. (2 hrs)

- Hardening mechanisms: precipitation, phase re-crystallization, martensite.
- Deformation and recrystallization.
- Heat treatment of light alloys.
- Heat treatment of steels.

Contents

10. Data analysis. (1 hr)

- Sample preparation and microscopic analysis.
- Mechanical testing: hardness, tensile testing.
- Statistical analysis of results.

Contents

11. Scientific writing. (1 hr)

- Journal choice (citation metrics)
- Basics of a good scientific paper.
- Review process.

Literature/course material

1 ESSENTIAL READING [* Purchase advised] (subject specific)
•*I.I. Novikov et al., Metals Science, vol. 1 and 2, Moscow, MISiS, 2009 (in Russian).
or
•*I.I. Novikov, Theory of Heat Treatment of Metals, Moscow, Metallurgiya, 1986 (or other edns.) (in Russian).
•*W. Kurz, D.K. Fisher, Fundamentals of Solidification, 4th Edn, Transtec Publ., 2005.
•J. Campbell, Complete Casting Handbook. Metal Castings Processes, Techniques and Design, Oxford, Butterworth-Heinemann, 2011.

2 RECOMMENDED READING (subject specific)
•*N.A. Belov, D.G. Eskin, A.A. Aksenov. Multicomponent Phase Diagrams. Applications for Aluminum Alloys, Amsterdam, Elsevier, 2005.
•*D.G. Eskin. Physical Metallurgy of Direct Chill Casting of Aluminum Alloys, Boca Raton, CRC Press, 2008.

3. OTHER (advanced reading; subject specific)
•*J.A. Dantzig, M. Rappaz. Solidification, Lausanne, EPFL/CRC Press, 2009
•K.F. Kelton, A.L. Greer. Nucleation in Condensed Matter. Applications in Materials and Biology, Oxford, Pergamon, 2010.