MS2016 Introduction to Metallurgy

Academic Year	2023-2024	Semester	1
Course Coordinator	A/P Aravind Dasari		
Course Type	Core		
Pre-requisites	MS1016 Thermodynamics of Materials (pre-requisite)		
	MS1017 Introduction to Materials Science (co-requisite)		
	MS1018 Properties of Materials (co-requisite)		
AU	2		
Grading	Letter Grading		
Contact Hours	24 (Lecture 16 h, Tutorial 8 h)		
Proposal Date	22 January 2024		

Course Aims

The fundamental understanding of phase transformations in materials is the key for tuning their structure and properties. This course will provide the necessary basic knowledge to relate bonding, diffusion, and temperature (heat treatment) in solids to their evolution of structure (covering aspects of interphase movement and solidification). Emphasis will also be on the thermodynamic concepts behind these different phenomena.

Intended Learning Outcomes (ILO)

By the end of this course, you (as a student) would be able to:

1. Predict the properties and interactions of different materials by understanding their composition, making connections to structure and bonding.
2. Explain the different types of imperfections in solids (metallic and ionic) and their influence on properties.
3. Identify carbon sites (interstitial positions – octahedral and tetrahedral) in both $\alpha-$ and $\gamma-$ iron lattices; illustrate the importance of strain energy in choosing the correct interstitial site; explain the symmetric and asymmetric distortion
4. Calculate the effect of temperature on vacancy formation and the rate at which they move in a lattice.
5. Explain and analyse Hume-Rothery rules that govern the formation of solid solutions.
6. Apply Fick's first and second laws for solid state diffusion in binary systems; to solve fundamental and industry-oriented problems and recognize the significance of diffusion coefficient D.
7. Explain the importance of interfacial energy and its influence on grain shape as well as grain boundary migration and pinning force concepts.
8. Describe the driving forces for growth of a pure solid or alloy after nucleation.
9. Explain the concepts of constitutional undercooling, solute pile-up at the solid-liquid interfaces, differences between columnar and equiaxed solidification, formation of dendrites, and eutectic solidification.
10. Analyse the implication of nucleation and nucleation rate in relation to Gibbs free energy requirements.

Course Content

No	Topic	Hours	
		Lecture	Tutorial
1	L1: Imperfections in Solids I	2	1
2	L2: Imperfections in Solids II	2	1
3	L3: Diffusion I	2	1
4	L4: Diffusion II + CA1	2	1
	CA1: Physical Exam		
5	L5: Thermodynamics of Interface I	2	1
6	L6: Thermodynamics of Interface II	2	1
7	L7: Solidification I	2	1
8	L8: Solidification II + CA2	2	1
	CA2: physical test		
		16	8
	Total	**24**	

Assessment (Includes both continuous and summative assessment)

Component	Course LO Tested	Related EAB's Graduate Attributes	Weightage	Team/ Individual	Assessment rubrics
1. Final Examination (1. 5 hr)	1 to 10	(a), (b), (c)	50%	Individual	N.A.
2. Continuous Assessment 1 (CA1): Test	1 to 6	(a), (b), (j), (c)	20%	Individual	Appendix 1
3. Continuous Assessment 2 (CA2): Test	7 to 10	Same as above (a, b, c, j)	20%	Individual	Appendix 1
4. Class Participation	1 to 10	(a), (b)	10%	Individual	N.A.
Total			100%		

EAB Graduate Attributes[1]	
a)	**Engineering Knowledge** Apply the knowledge of mathematics, natural science, engineering fundamentals, and an engineering specialisation as specified in WK1 to WK4 respectively to the solution of complex engineering problems.
b)	**Problem Analysis** Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
c)	**Design/Development of Solutions**

[1] *Reference: EAB Accreditation Manual*

	Design solutions for complex engineering problems and design systems, components or processes that meet the specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
d)	**Investigation** Conduct investigations of complex problems using research-based knowledge (WK8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
e)	**Modern Tool Usage** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering problems, with an understanding of the limitations.
f)	**The Engineer and Society** Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems.
g)	**Environment and Sustainability** Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts.
h)	**Ethics** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
i)	**Individual and Team Work** Function effectively as an individual, and as a member or leader in diverse teams and in multidisciplinary settings.
j)	**Communication** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
k)	**Project Management and Finance** Demonstrate knowledge and understanding of engineering management principles and economic decision-making, and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
l)	**Life-long Learning** Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Formative Feedback

- CA questions are thoroughly discussed in the class;
- Feedback will be provided to the students on their approaches, common mistakes, and other general issues;
- Class average marks will be posted. Each student will also be informed of his/her CA marks;
- Students are encouraged to use the consultation hours to discuss and clarify questions related to the content taught in this course.

Learning & Teaching Approach

Approach	**How does this approach support students in achieving the learning outcomes?**
Conceptual understanding	As this course is a key course that relates the structure of metallic solids, in particular, to properties, there will be a lot of emphasis on fundamental understanding of the concepts and self-directed learning. Though lecture notes are provided to students, they are encouraged to refer different books and the self-assessment questionnaires are designed to test the students' critical understanding of the subject. Also, the systematic approach of starting at the basics of imperfections / solid state diffusion and relating to solidification will help students in achieving a comprehensive understanding of the evolution of the structure and effect on properties. Other approaches like Class Participation, and discussion sessions are in place to achieve the said learning outcomes.
Showing real-world applications	Most of the concepts that are dealt in the course have real-world implications and applications. Therefore, they are used as examples while discussing the related concepts.
Use of Multimedia tools to teach abstract concepts and complex processes	➢ Multimedia tools such as videos and animations have been prepared exclusively for this course to help students better understand the contents. ➢ E-books with interactive images and videos are available for the students to download. ➢ Even a software package was developed for the students that can help them with the distortion of the lattices when diffusing foreign species.
Face-to-face discussion sessions	For most part of the course, tutorials are replaced with discussion sessions that are designed to check and reinforce the students' understanding of various concepts. The questions posed during the discussion sessions will further clarify important concepts/principles covered in lectures, and cultivate critical thinking.

Readings & References

Suggested reading:

- Phase Transformations in Metals and Alloys, 3rd edition, David A Porter, Kenneth E Easterling, Mohamed Sherif, PUB Feb 2009, CRC Press.
- Fundamentals of solidification, W. Kurz and D.J. Fisher, Trans Tech Publications, 4th Edition, 1998.

Additional reading:

- Materials science and engineering: an introduction, Willian D Callister, Wiley.
- Introduction to the thermodynamics of materials, 5th edition by David Gaskell, Yaylor and Francis, 2008.

- Foundations of Materials Science and Engineering, 5th edition by William Smith and Javed Hashemi, McGraw Hill, 2009.
- Defects in Solids, Richard J.D. Tilley, Wiley InterScience, 2008.

Course Policy & Student Responsibility

(1) CA: Absentees must be supported by a medical certificate or other valid official documents.
(2) Class Participation: Students have to register for Wooclap accounts using their NTU email address. These questions will be posed in every lecture or tutorial and the active participation is accounted.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office	Phone	Email
A/P Aravind Dasari	ABN-B2c-14/15	67906402	aravind@ntu.edu.sg
Prof Ali Miserez	N4.1-01-16	63168979	ali.miserez@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course ILO	Readings/Activities
1	Imperfections in solids - fundamentals	1 to 2	Lectures, tutorials, and Class Participation
2	Imperfections in solids – solid solution strengthening	2 to 5	Lectures, tutorials, and Class Participation
3	Diffusion in solids – relation with imperfections, mechanisms, temperature and pathways	5 and 6	Lectures, tutorials, and Class Participation
4	Diffusion in solids – Fick's laws and their implications	6	Lectures, tutorials, Class Participation and CA1

5	Nucleation and importance of surface energy	7, 8	Lectures, face-to-face discussion sessions on Topic 3, and Class Participation
6	Interface movement and pinning force concepts	7, 8	Lectures, tutorials on Topic 4, and Class Participation
7	Solidification – concepts of interfacial stability, solute pile up and constitutional undercooling	9	Lectures, tutorials on Topic 5, and Class Participation
8	Solidification – equiaxed versus columnar growth of grains, dendritic solidification; eutectic solidification	9, 10	Lectures, tutorials on Topic 6, Class Participation, and CA2