In the name of God

Technical English Language

for MSE Bachelor students

Lesson 1: Physical Metallurgy

Taught by:

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❑ Course Syllabus

- Lesson 1: Physical Metallurgy
- Lesson 2: Thermodynamics of Materials
- Lesson 3: Mechanical Metallurgy
- Lesson 4: Extractive Metallurgy
- Lesson 5: Corrosion and Surface Engineering
- Lesson 6: Casting and Solidification
- Lesson 7: Metal Forming Processes
- Lesson 8: Welding and Inspection
- Lesson 9: Additive Manufacturing
- Lesson 10: Advanced Materials

❑ Selected References

1. Eisenbach I. English for Materials Science and Engineering: Exercises, Grammar, Case Studies. Springer-Verlag; 2011.
2. Reed-Hill RE, Abbaschian R. Physical metallurgy principles. New York: Van Nostrand; 1973.
3. Callister Jr WD, Rethwisch DG. Materials science and engineering: an introduction. Wiley; 2020.
4. Gaskell DR, Laughlin DE. Introduction to the Thermodynamics of Materials. CRC press; 2017.
5. Dieter GE, Bacon D. Mechanical metallurgy. New York: McGraw-hill; 1976.
6. Fontana MG, Greene ND. Corrosion engineering. McGraw-hill; 2018.
7. Altan T, Oh SI, Gegel HL. Metal forming: fundamentals and applications. American Society for Metals; 1983.
8. Kou S. Welding metallurgy. Wiley. 2020.
9. Mukherjee T, DebRoy T. Theory and practice of additive manufacturing. John Wiley & Sons; 2023.
10. ASM Metals Handbook series

❑ Assessment Criteria

- ✓ Mid-term Exam: 5 Scores → 25% (Date: 1404/09/16)
- ✓ Technical Presentation: 3 scores → 15%
- ✓ Teaching Assistant (TA): 2 scores → 10% (Focusing on listening skill)
- ✓ Final Exam: 10 scores → 50%
- ✓ Active presence in the class: + 1 score

1. To fix a subject and a presentation time (07/15 to 10/09, ASAP)
2. To summarize the content on the fixed subject to two pages (En(12)/Fa(14)) and share it
3. To present the subject in about 10-12 min by PowerPoint
4. To answer to 2-3 questions on the presentation by students
5. To submit your summary and presentation files (Up to the presentation day)

1. Historical background

- Fill the gaps in the text with words from the box in their correct form.

Alloy (2); characteristic; communication; clay; crystal; heat; housing; manipulate; metal; property (2); skin; specimen; substance; structure; technological; wood

Materials used in food, clothing, ……communication……, transportation, recreation and ……housing…… influence virtually every segment of our everyday lives.

Historically, materials have played a major role in the development of societies, whose advancement depended on their access to materials and on their ability to produce and ……manipulate…… them. In fact, historians named civilizations by the level of their materials development, e.g. the Stone Age (beginning around 2.5 million BC), the Bronze Age (3500 BC), and the Iron Age (1000 BC). The earliest humans had access to only a very limited number of materials, those that occur naturally, e.g. ……clay……, ……wood…… and ……skin…… . With time they discovered techniques for producing materials that had properties superior to those of the natural ones; these new materials included ……metals…… and various ……alloys…… . Furthermore, early humans discovered that the properties of a material could be altered by ……heat…… treatments, e.g. to soften metals, and by adding other ……substances…….. to produce a new material, e.g. by melting copper, then mixing it with tin to form bronze which could be regarded as the first ………alloy……… .

Until recently, selecting a material involved choosing from a number of familiar materials the one most appropriate for the intended application by virtue of its characteristics but without knowing much about its structure. Only in the 19th century did scientists begin to understand the relationships between the structural elements of materials and their ………properties………… . In 1864 the Englishman Henry Sorby first showed the microstructure of a metal when he developed a technique for etching the surface layer of a polished metal ……specimen…….. by a chemical reaction. He used a light reflecting microscope to show that the material consisted of small ……crystals…….. which reflected the light in different ways because they were oriented in different directions. The crystals were well fitted together and joined along grain boundaries.

Modern techniques such as X-ray diffraction, transmittance electron microscopy (TEM) and scanning electron microscopy (SEM) make possible to see further into the ……characteristics…….. of materials, which leads to a better understanding of their characteristics and promotes intentional alteration and improvement of their ……properties…… . By now more than 50,000 materials with specialized

structures
……………….. have been developed and are available to the engineers, who has to choose the one best suited to serve the given purpose. Since much of what can be done technologically ………………. is limited by the available materials, engineers must constantly develop new materials with improved properties.

Definitions:

To etch: to cut into a surface, e.g. glass, using an acid

Grain boundary (GB): a surface separating differently oriented crystals in a polycrystal

2. Structure

The structure of a material is usually determined by the arrangement of its internal components. On an atomic level, structure includes the organization of atoms relative to one another. Subatomic structure involves electrons within individual atoms and interactions with their nuclei. Some of the important properties of solid materials depend on geometrical atomic arrangements as well as on the interactions that exist among atoms or molecules.

Various types of primary and secondary interatomic bonds hold together the atoms composing a solid.

The next larger structural area is of nanoscopic scale which comprises molecules formed by the bonding of atoms, and particles or structures formed by atomic or molecular organization, all within 1 nm - 100 nm dimensions. Beyond nano-scale are structures called microscopic, meaning that they can directly be observed using some kind of microscope. Finally, structural elements that may be viewed with the naked eye are called macroscopic.

- Fill in table with the different structural levels and their characteristics as described in the text.

Structural level	Characteristics
Macroscopic	Structural elements that may be viewed with the naked eye
Microscopic	They can directly be observed using some kind of microscope
Nanoscopic	Comprising molecules formed by the bonding of atoms, and particles or structures formed by atomic or molecular organization, all within 1 nm - 100 nm dimensions
Atomic	Including the organization of atoms relative to one another
Subatomic	Involving electrons within individual atoms and interactions with their nuclei

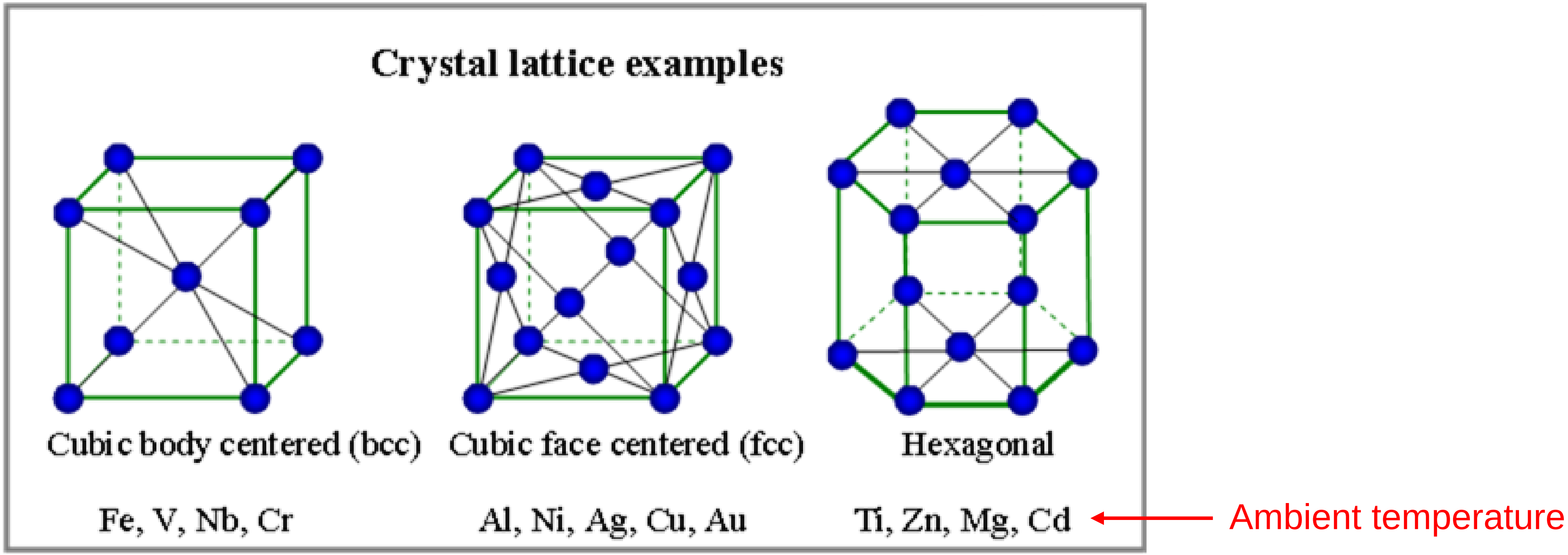
- *Choose the correct terms for the following definitions.*

- A sufficiently stable, electrically neutral group of at least two units in a definite arrangement held together by strong chemical bonds ……………………………….. Molecule
- The smallest particle characterizing an element ……………………….. Atom
- A fundamental subatomic particle, carrying a negative electric charge ………………… Electron
- It makes up almost all the mass of an atom ……………………… Nuclei
- A positively charged subatomic particle …………………………… Proton
- An electrically neutral subatomic particle ………………………….. Neutron

3. Crystallography

Crystallography is a tool that is often employed by materials scientists. In single crystals, the effects of the crystalline arrangement of atoms are often easy to see macroscopically, because the natural shapes of crystals reflect the atomic structure. In addition, physical properties are often controlled by crystalline defects. The understanding of crystal structures is an important prerequisite for understanding crystallographic defects. A number of other physical properties are linked to crystallography. For example, the minerals in clay form small, flat, plate-like structures. Clay can be easily deformed because the plate-like particles can slip along each other in the plane of the plates, yet remain strongly connected in the direction perpendicular to the plates. Such mechanisms can be studied by crystallographic texture measurements. In another example, iron transforms from a body-centered cubic (BCC) structure to a face-centered cubic (FCC) structure called austenite when it is heated. The FCC structure is a close-packed structure, but the bcc structure is not, which explains why the volume of the iron decreases when this transformation occurs.

Crystallography is useful in identification of phases. When performing any process on a material, it may be desired to find out what compounds and what phases are present in the material. Each phase has a characteristic arrangement of atoms. Techniques like X-ray diffraction (XRD) can be used to identify which patterns are present in the material, and thus which compounds are present. Crystallography covers the enumeration of the symmetry patterns which can be formed by atoms in a crystal and for this reason has a relation to group theory and geometry.



- Choose the best choice using your knowledge of metallurgy and the details in the previous reading.

1. …….. indices are a symbolic vector representation for the orientation of an atomic plane in crystal lattice.

   a) Brag b) Wulff c) Lambert ✓ d) Miller

2. The most common technique employed for …….. The crystal structures is X-ray ……

   a) performing, absorption c) occupying, diffraction
   b) b) modifying, absorption ✓ d) determining, diffraction

3. Iron transforms from a …… structure to a …….. Structure, called austenitic transformation, it is heated.

   a) FCC, BCC b) BCC, HCP c) FCC, HCP ✓ d) BCC, FCC

4. The ………. Structure is a close-packed structure, while the ………. structure is not.

   a) BCC, FCC ✓ b) FCC, BCC c) BCC, HCP d) FCC, HCP

4. Phase diagram

A phase diagram in physical chemistry, engineering, mineralogy, and materials science is a type of chart used to show conditions at which thermodynamically distinct phases can occur at equilibrium. Common components of a phase diagram are lines of equilibrium or phase boundaries, which refer to lines that mark conditions under which multiple phases can coexist at equilibrium. Phase transitions occur along lines of equilibrium. Triple points are points on phase diagrams where lines of equilibrium intersect. Triple points mark conditions at which three different phases can coexist. For example, the water phase diagram has a triple point corresponding to the single temperature and pressure at which solid, liquid, and gaseous water can coexist in a stable equilibrium. 'The solidus is the temperature below which the substance is stable in the solid state. The liquidus is the temperature above which the substance is stable in a liquid state. There may be a gap between the solidus and liquidus; within this gap, the substance consists of a mixture of solid crystals and liquid.

The simplest phase diagrams are pressure-temperature diagrams of a single simple substance, such as water. The axes correspond to the pressure and temperature.

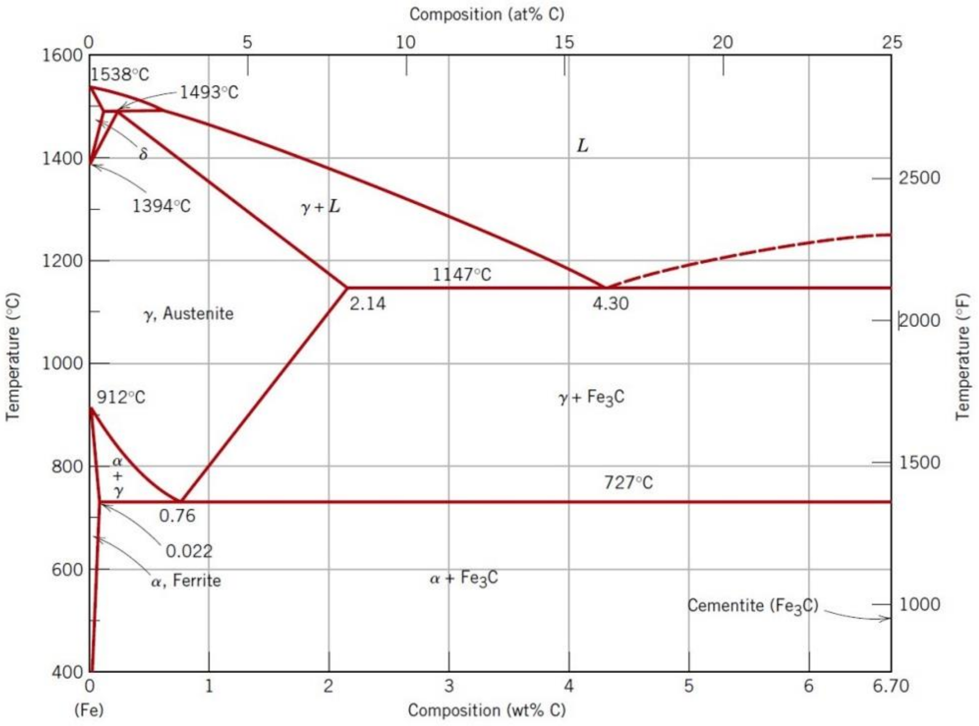
The phase diagram shows, in pressure-temperature space, the lines of equilibrium or phase boundaries between the three phases of solid, liquid, and gas. The curves on the phase diagram show the points where the free energy (and other derived properties) becomes non-analytic: their derivatives with respect to the coordinates (temperature and pressure in this example) change discontinuously (abruptly). For example, the heat capacity of a container filled with ice will change abruptly as the container is heated past the melting point. The open spaces, where the free energy is analytic, correspond to single-phase regions. Lines of non-analytical separate single-phase regions, where phase transitions occur, are called phase boundaries.

The solid-liquid phase boundary in the phase diagram of most substances has a positive slope; the greater pressure on a given substance, the molecules of the substance are brought closer together to each other, which increases the effect of the substance's intermolecular forces. Thus, the substance requires a higher temperature for its molecules to have enough energy to break out the fixed pattern of the solid phase and enter the liquid phase. A similar concept applies to liquid-gas phase changes. Water, because of its particular properties, is one of the several exceptions to this rule.

In addition to just temperature or pressure, other thermodynamic properties may be graphed in phase diagrams. Examples of such thermodynamic properties include specific volume, specific enthalpy, or specific entropy. For example, single-component graphs of Temperature vs. specific entropy (T vs. s) for water/steam or for a refrigerant are commonly used to illustrate thermodynamic cycles such as a Carnot cycle, Rankine cycle, or vapor- compression refrigeration cycle. In a two-dimensional graph, two of the thermodynamic quantities may be shown on the horizontal and vertical axes.

Other much more complex types of phase diagrams can be constructed, particularly when more than one pure component is present. In this case, concentration becomes an important variable. Phase diagrams with more than two dimensions can be constructed that show the effect of more than two variables on the phase of a substance. Phase diagrams can use other variables in addition to temperature, pressure and composition, for example the strength of an applied electrical or magnetic field.

We use as an example the cooling of a eutectoid alloy (0.76 wt% C) from the austenite (γ- phase) to pearlite, that contains ferrite (α-phase) plus cementite (Fe_3C or iron carbide). When cooling proceeds below the eutectoid temperature (727 °C) nucleation of pearlite starts. The S-shaped curves (fraction of pearlite vs. log. time) are displaced to longer times at higher temperatures showing that the transformation is dominated by nucleation (the nucleation period is longer at higher temperatures) and not by diffusion (which occurs faster at higher temperatures). The family of S-shaped curves at different temperatures can be used to construct the TTT (Time-Temperature-Transformation) diagrams.



- Choose the best choice using your knowledge of metallurgy and the details in the previous reading.

1. What is the meaning of “eutectic” in a phase diagram?

a) The presence of an equilibrium in a system with two different metals.
✓ b) A region of low melting point between the pure metals.
c) A horizontal tie line in a phase diagram.
d) A vertical tie line in a phase diagram

2. Equilibrium diagrams have been developed to ……….. and study changes ….…. during heating & cooling cycles pf pure or alloyed metallic materials.

✓ a) record, occurring b) obtain, occurred c) gain, occurring d) understand, occurred

3. Vacancies play a ……… role in the diffusion process in metals.

a) scarified b) stagnant c) volatile ✓ d) vital

4. Quenching a metal from a temperature near its melting point, produces a supersaturated structure of …………

✓ a) dislocations b) vacancies c) inclusions d) gas

5. Selected vocabulary

En	Fa	En	Fa
Absorption	جذب حجمی	Prerequisite	پیش نیاز
Adsorption	جذب سطحی	Interact	برهمکنش
Diffraction	پراش، تفرق	Enumeration	تعیین شماره
Scatter	پراکندگی، پراکندن	Concentration	غلظت، تجمع
Spectrum	طیف	Diffusion	نفوذ
Spatial	فضایی	Equilibrium	تعادل
Temporal	زمانی	Interface	فصل مشترک
Crystalline	بلورک، بلورین	Liquidus	خط ذوب
Crystal defects	عیوب بلوری	Solidus	خط انجماد
Crystal lattice	شبکه بلوری	Phase transformation	استحاله فازی
Single crystal	تک بلور	Phase diagram	دیاگرام فازی
Close-packed structure	ساختار فشرده	Meta-stable	شبه پایدار
Body-centered cubic	مکعب مرکزدار	Vacancy	جای خالی
Face-centered cubic	مکعب وجوه مرکزدار	dislocation	نابجایی