ENGINEERING MATERIALS (ME 281)

Course Introduction

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Course outline

- Introduction to Material Science and Engineering
- Atomic Structure and Interatomic Bonding
- Structure of Crystalline Solids
- Imperfections and Diffusion in Solids
- Mechanical Properties of Metals
- Dislocations and Strengthening Mechanisms
- Phase Diagrams and Transformations
- Thermal Properties of Materials
- Introduction to Ferrous and Non Ferrous Materials
- Introduction to Ceramics and Polymer Materials

Course Objectives

At the end of the course, students should be able to:

- Explain the various material classifications with examples.
- Understand the concept of atomic structure and bonding in atoms
- Explain crystal structure and identify specific directions and planes in crystals using Miller indices.
- Explain the various imperfections and diffusion in solids.
- Describe elastic deformation using stress-strain diagram.
- Explain the tensile properties of materials under plastic deformation.
- Explain the mechanics of dislocation motion in relation to plastic deformation.
- Describe and illustrate the phase transformations that occur in an iron-carbon alloy using transformation diagrams.

Assessment

➢ Continuous Assessment (30%)

- Mid-Semester Exams.
- Quizzes.
- Attendance

➢ End of Semester Exams (70%)

- Multiple Choice/Fill-in Spaces
- Theory

➢ Class Regulation

- No lateness
- No unwarranted use of mobile phone in class.
- You will NOT be allowed to write the End of Semester Exams if you miss at least three (3) lectures without permission.

Reading/Reference Materials

- W. D. Callister, Jr and D. G. Rethwisch, Materials Science and Engineering – An introduction, 8th edition, John Wiley & Sons, Inc. 2010.

- Donald R. Askeland, Pradeep P. Fulay, Wendelin J. Wright. The Science and Engineering of Materials, 6th Edition, 2011.

- K. O. Amoabeng, Engineering Materials I, Lecture notes, 2020.

Introduction to Engineering Materials

Lecture outline

- Historical perspective of materials
- Material Science and Engineering
- Importance of Engineering Materials
- Classification of Materials
- Advanced, Future and Modern Materials

Learning Objectives

After this chapter, you should be able to do the following:

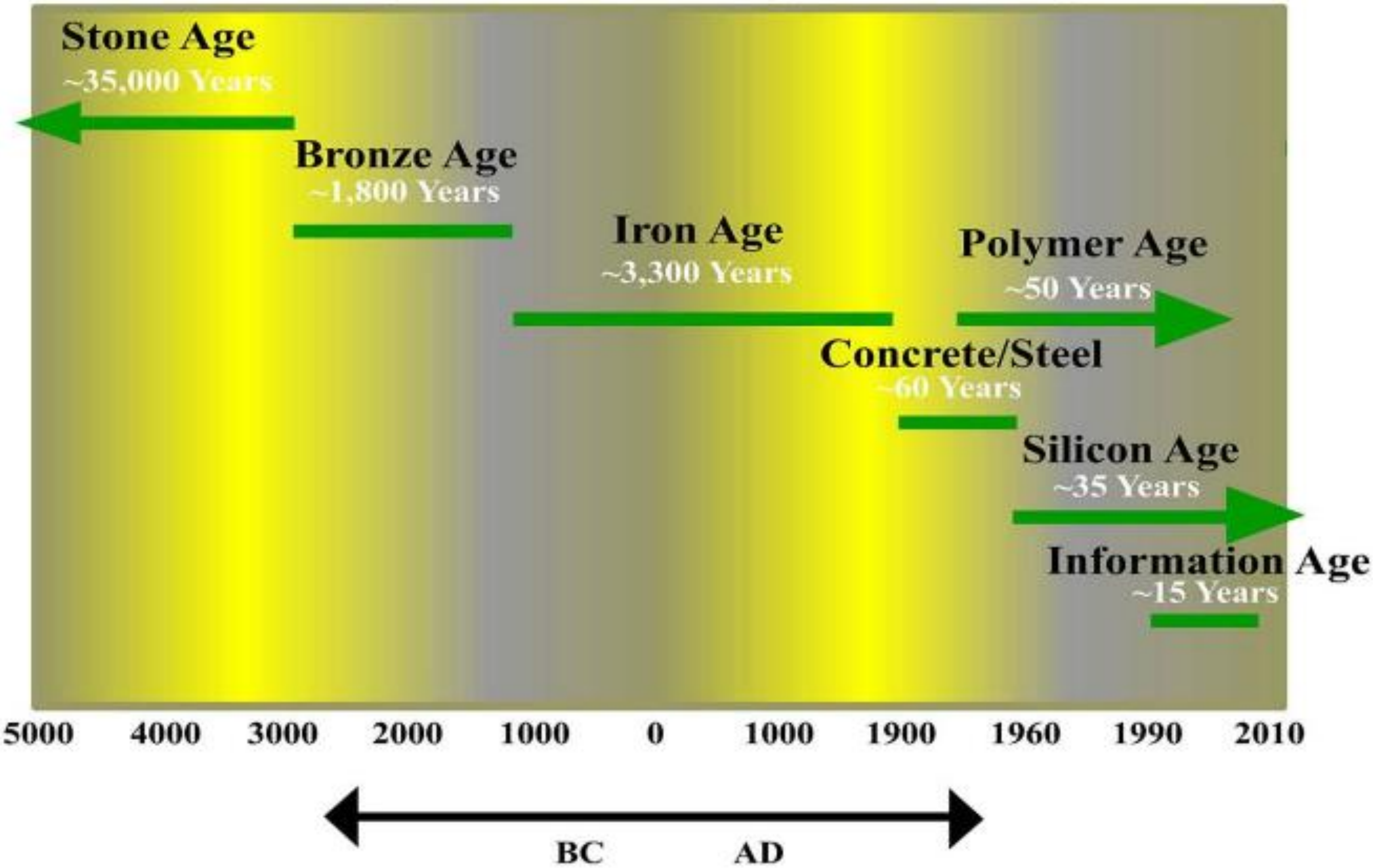
- Describe the concept of engineering materials from historical viewpoint.
- State the importance of studying engineering materials.
- Identify the four main components of material science and their interrelation.
- Explain the various material classifications with examples.

Historical Perspective

Early Civilizations

- Stone age: Materials occurred naturally (stone, wood, clay, etc.) for the purposes of making weapons, instruments, shelter, etc.
- The increasing need for better quality tools led to Bronze Age (started about 3000 BC), followed by Iron Age (began about 1200 BC).
- The history of human civilization evolved from;
- Stone Age →Bronze Age →Iron Age →Steel Age →Space Age.

Historical Perspective



Historical Perspective Contd.

Early Civilizations

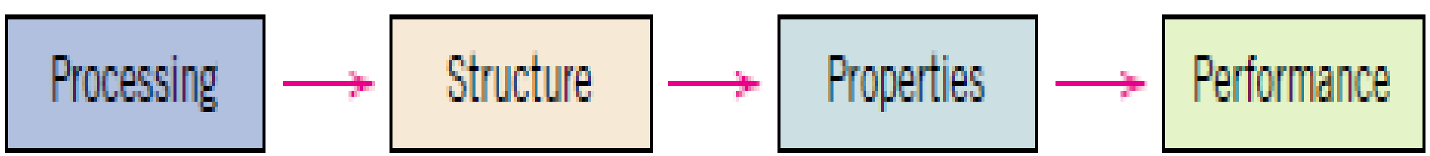
- Each age is marked by the advent of certain materials.
- Bronze Age → Copper materials and their alloys
- Iron Age → Tools and utensils
- Steel Age → Railroads, instruments and industrial revolution
- Space Age → Materials for stronger and lighter structures (composite and electronic materials)

- ***In Summary, the foundation of technology rest on materials.***

Material Science and Engineering

Material Science

- ➢ It involves the investigation of the relationships between the structures of materials and their properties.
- ➢ Components of material science are : structure, properties, processing and performance.
- The **structure** of a material usually relates to the arrangement of its internal components (atoms and molecules).
- **Property** refers to the material kind and magnitude of response to a specific imposed stimulus.
- The structure of a material will depend on how it is **processed**.
- Also, a material's **performance** will be a function of its properties.



Material Science and Engineering

Engineering of Materials

- It involves designing the structure of a material to produce a predetermined set of properties using the structure-property correlations derived from material science.

- Innovation in engineering often means the clever use of a new material for a specific application. For example: plastic containers in place of age-old metallic containers.

- It is well learnt lesson that engineering disasters are frequently caused by the misuse of materials.

- The professional engineer should know how to select materials which best fit the demands of the design as well as demands of strength and durability.

Importance of Engineering Materials

It is very important that every engineer study and understand the concepts of materials science and engineering. This enables the engineer;

- To select a material for a given use based on considerations of cost and performance.
- To understand the limits of materials and the change of their properties with use.
- To create a new material that will have some desirable properties.
- To be able to use the material for different application.

Classification of Materials

Classifications are based on:

- Composition (chemical makeup of the material)
- Structure (arrangement of atoms and bonds between them)
- Properties (mechanical, thermal, electrical, magnetic, chemical, etc.)

Three Basic Classification:

- Metals, Ceramics and Polymers

Other Classifications:

- Semiconductors
- Composite
- Biomaterials

metals

ceramics

polymers

semiconductors

Metals

- The atoms are bound together by metallic bonds (valence electrons are detached from atoms, and spread in an electron sea that glues the ions together).
- They are characterized by high thermal and electrical conductivity; strong yet deformable under applied mechanical loads.
- Pure metals are not good enough for many applications, especially structural applications.
- They are opaque to light (shiny if polished).
- They are used in alloy form i.e. a metal mixed with another metal to impr ove the desired qualities. E.g.: aluminium, steel, brass, gold.



Ceramics

- They are usually combinations of metals with oxygen, nitrogen or carbon (oxides, nitrides, and carbides).
- Atoms (ions often) in ceramic materials behave mostly like either positive or negative ions, and are bound by very strong Coulomb forces between them.
- These materials are characterized by very high strength under compression, low ductility; usually insulators to heat and electricity. Examples: glass, porcelain, many minerals.



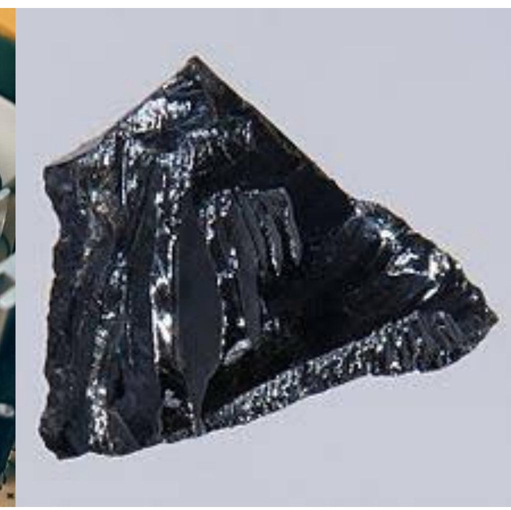
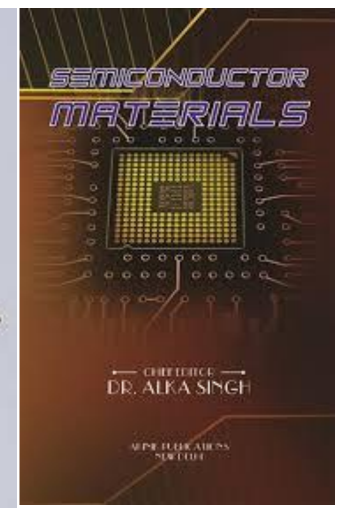
Polymers

- Commercially called plastics; noted for their low density, flexibility and use as insulators.
- Mostly are organic compounds and other non-metallic elements
- Consist large molecular structures bonded by covalent and Van der Waal's forces.
- They decompose at relatively moderate temperatures (100 to 400 °C).
- Application: Packaging, textiles, biomedical devices, optical devices, etc.
- Examples: Nylon, Teflon, Rubber, Polyester, etc.



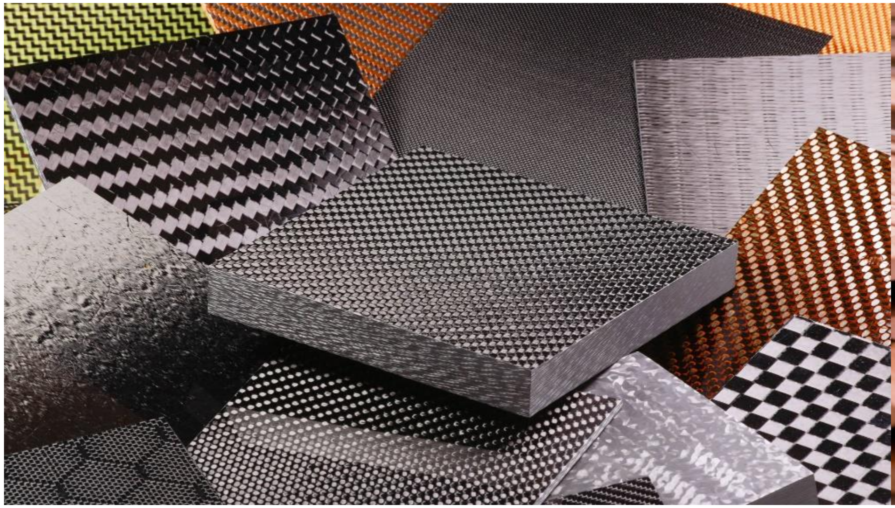
Semiconductors

- They are covalent in nature.
- Their atomic structure is characterized by the highest occupied energy band (the valence band, where the valence electrons reside energetically).
- Their electrical properties depend extremely strongly on minute proportions of contaminants.
- They are usually doped in order to enhance electrical conductivity.
- They are opaque to visible light but transparent to the infrared. Examples: silicon (Si), and germanium (Ge).

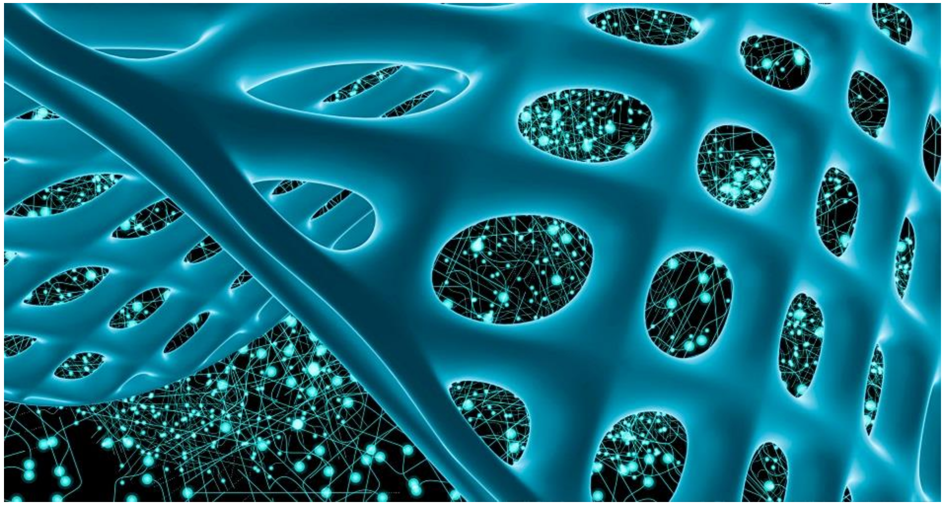
Composite Materials

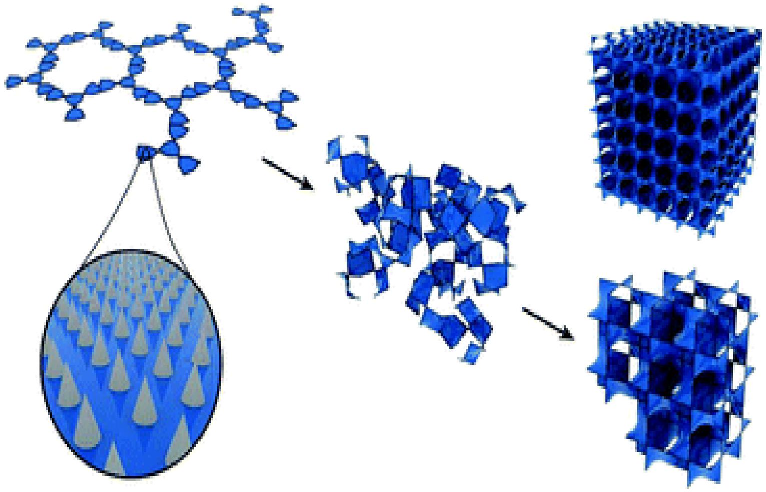
- They are multiphase materials obtained by artificial combination of different materials to attain properties that the individual components cannot attain.
- In general, composites are classified according to their matrix materials. The main classes of composites are metal-matrix, polymer-matrix, and ceramic-matrix.
- An example is a lightweight brake disc obtained by embedding SiC particles in Al-alloy matrix.



Biomaterials

- Used for replacement of damaged or diseased human body parts.
- Primary requirement: they must be biocompatible with body tissues, and must not produce toxic substances.
- Material factors: ability to support forces; low friction, wear, density, cost; reproducibility.
- Typical applications: heart valves, hip joints, dental implants, etc. Examples: Stainless steel, ultra-high molecular weight poly-ethylene, etc.





Advanced, Modern and Future Materials

Advanced Materials

- They are used in High-Tech devices those operate based on relatively intricate and sophisticated principles (e.g. computers, air/space-crafts, electronic gadgets, etc.).

- They are either traditional materials with enhanced properties or newly developed materials with high-performance capabilities. Hence they are relatively expensive.

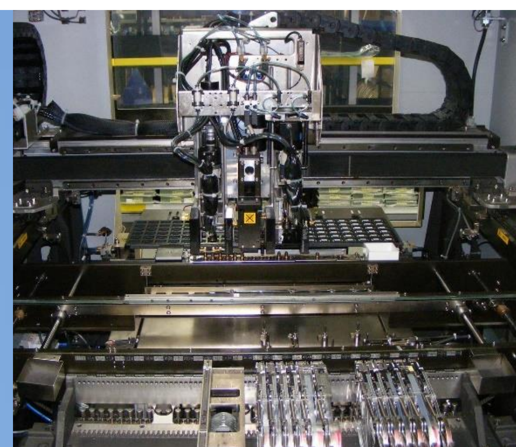
- Typical applications: integrated circuits, lasers, fibre optics, thermal prote ction for space shuttle, etc.

- Examples: Metallic foams, inter-metallic compounds, magnetic alloys, special ceramics and high temperature materials, etc.

Advanced, Modern and Future Materials

Future Materials

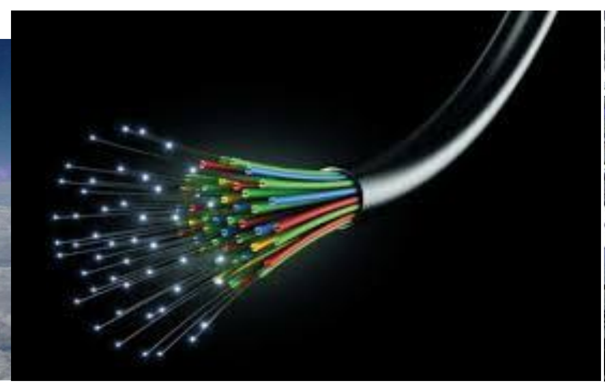
- State-of-the-art materials being developed, and expected to have significant influence on present-day technologies, especially in the fields of medicine and manufacturing.
- Smart/Intelligent material system have sensors (detects an input) and an actuator (performs responsive and adaptive function).
- Typical applications: High speed helicopter rotor blades; Small micro-electronic circuits in machines ranging from computers to photolithograph prints; Health monitoring detecting the success or failure of a product.



Advanced, Future and Modern Materials

Modern Materials

- Innovation of new technologies, and need for better performances of existing technologies demands much more from the materials field.
- New materials/technologies are needed to be environmental friendly.
- Hypersonic flight requires materials that are light, strong and resist high temperatures.
- Optical communications require optical fibers that absorb light negligibly.
- Civil construction – materials for unbreakable windows.
- Structures: materials that are strong like metals and resist corrosion like plastics.


Lecture Ends