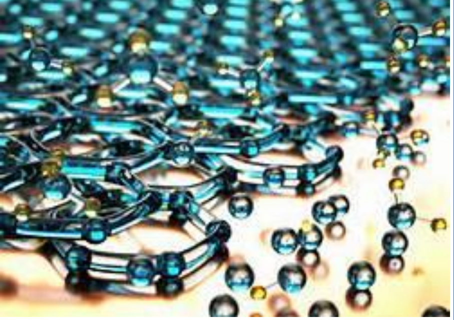



Materials Science

Lecture 1

Lebanese University - Faculty of Engineering – Branch 3

Fall 2022

Dr. Ali HARKOUS

Contents

Lecture 1:

Syllabus overview

- Grade distribution
- Course outline and Goals
- Topics

Chap1: Introduction to Materials Science and Engineering

1.1. Historical Perspective

1.2. Materials Science and Engineering

1.3.Why to study Materials Science and Engineering?

1.4.Classification of Materials

1.5.Advanced Materials

1.6.Modern Materials' Needs

Syllabus overview

See the attached PDF file

Syllabus overview

- Lectures' documents
- Homework file
- Deposit of Homework, Project ...
- Any announcement
- Any contact

Google Classroom

"Materials Science" class code

jubjgci

Office hours

M 11:30-12:30

Contents

Lecture 2:

Syllabus overview

- Grade distribution
- Course outline and Goals
- Topics

Chap1: Introduction to Materials Science and Engineering

1.1. Historical Perspective

1.2. Materials Science and Engineering

1.3.Why to study Materials Science and Engineering?

1.4.Classification of Materials

1.5.Advanced Materials

1.6.Modern Materials' Needs

1.1. Historical Perspective

- Materials are probably **deeper seated in our culture than most of us realize**.

- Transportation, housing, clothing, communication, recreation, and food production—virtually **every segment of our everyday lives is influenced to one degree or another by materials.**

- Historically, the development and advancement of societies have been intimately tied to the members' ability to produce and manipulate materials to fill their needs. In fact, early civilizations have been designated by the level of their materials development (**Stone Age, Bronze Age, Iron Age**). The approximate dates for the beginnings of the Stone, Bronze, and Iron ages are 2.5 million BC, 3500 BC, and 1000 BC, respectively.

- **The earliest humans** had access to only a **very limited number of materials, those that occur naturally: stone, wood, clay, skins, and so on.**

- With time, they discovered techniques **for producing materials that had properties superior to those of the natural ones**; these new materials included **pottery and various metals**.

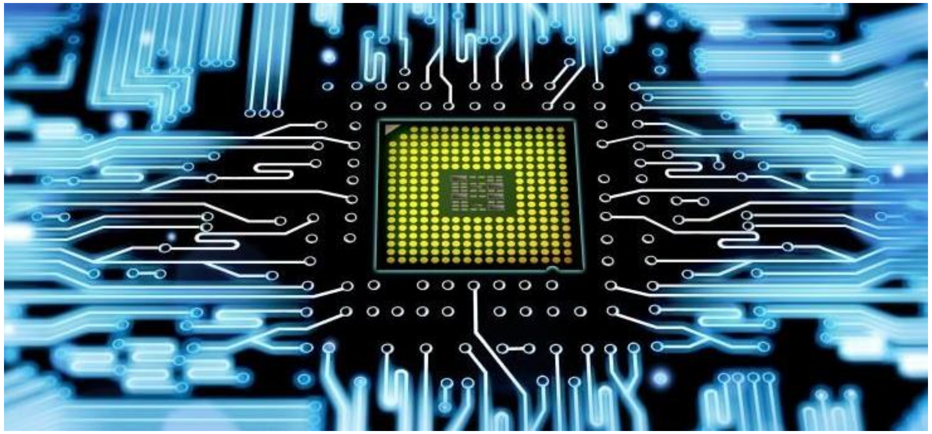
1.1. Historical Perspective

- Furthermore, it was discovered that the **properties of a material could be altered by heat treatments and by the addition of other substances.**

- At this point, materials **utilization was totally a selection process that involved deciding from a given, rather limited set of materials**, the one best suited for an application by virtue of its **characteristics**.
- It was not until relatively **recent times that scientists came to understand the relationships between the structural elements of materials and their properties.**
- This knowledge, acquired over approximately **the past 100 years, has empowered them to fashion, to a large degree, the characteristics of materials.**

1.1. Historical Perspective

- Thus, **tens of thousands of different materials have evolved with rather specialized characteristics** that meet the needs of our modern and complex society, including **metals, plastics, glasses, and fibers.**
- The **development of many technologies that make our existence so comfortable** **has been intimately associated with the accessibility of suitable materials**.
- An **advancement in the understanding of a material** type is often the forerunner to the **stepwise progression of a technology**. **For example**, automobiles would not have been possible without the availability of inexpensive steel or some other comparable substitute.
- In the contemporary era, **sophisticated electronic device**s rely on components that are made from what are called **semiconducting materials**.



1.1. Historical Perspective

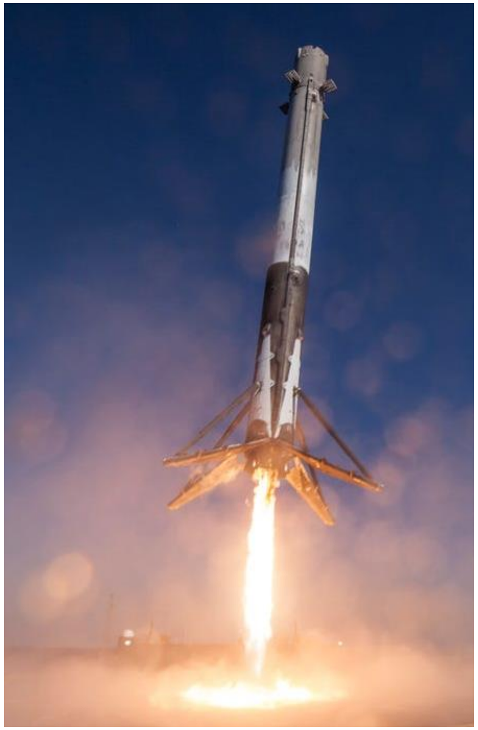
Stone age

Bronze age

1.1. Historical Perspective

Iron age

1.1. Historical Perspective



Scientific age

1.1. Historical Perspective

Scientific age

Contents

Lecture 2:

Syllabus overview

- Grade distribution
- Course outline and Goals
- Topics

Chap1: Introduction to Materials Science and Engineering

1.1. Historical Perspective

1.2. Materials Science and Engineering

1.3.Why to study Materials Science and Engineering?

1.4.Classification of Materials

1.5.Advanced Materials

1.6.Modern Materials' Needs

1.2. Materials Science and Engineering

- Sometimes it is useful to subdivide the discipline of materials science and engineering into **materials science** and **materials engineering** subdisciplines.

- Strictly speaking, **materials science** involves investigating the **relationships that exist between the structures and properties of materials.**

- In contrast, **materials engineering** involves **designing or engineering the structure of a material to produce a predetermined set of properties**.

- From a functional perspective, the role of a **materials scientist** is to **develop or synthesize new materials**, whereas a materials engineer is called upon **to create new products or systems using existing materials** and/or to **develop techniques for processing materials.**

1.2. Materials Science and Engineering

What is Structure?

- The structure of a material usually relates to **the arrangement of its internal components.**
- **Subatomic** structure involves **electrons within the individual atoms and interactions with their nuclei**.
- On an **atomic level**, structure encompasses the **organization of atoms or molecules relative to one another.**
- The next larger structural realm, which contains **large groups of atoms that are normally agglomerated together**, is termed **microscopic**, meaning that which is subject to direct observation using some type of microscope.
- Finally, structural elements that can be viewed with the **naked eye** are termed **macroscopic**.

1.2. Materials Science and Engineering

What is Property?

- While in service use, all materials are exposed to external **stimuli that evoke some type of response.**
- **For example:** a specimen subjected to forces experiences deformation, or a polished metal surface reflects light.
- **A property is a material trait in terms of the kind and magnitude of response to a specific imposed stimulus.**
- Generally, definitions of properties are made **independent of material shape and size.**
- Virtually all important properties of solid materials may be grouped into six different categories: **mechanical, electrical, thermal, magnetic, optical, and deteriorative.**
- For each, there is a characteristic type of stimulus capable of provoking different responses.

1.2. Materials Science and Engineering

What is Property?

- **Mechanical properties relate deformation to an applied load or force**. Examples include elastic modulus (stiffness), strength, and toughness.

- For **electrical** **properties, such as electrical conductivity and dielectric constant**, the stimulus is an electric field.

- The **thermal behavior** of solids can be represented in terms of heat capacity and thermal conductivity.

- **Magnetic properties** demonstrate the response of a material to the application of a magnetic field.

- For **optical properties**, the stimulus is **electromagnetic or light radiation**; index of **refraction** and **reflectivity** are representative optical properties.

- Finally, **deteriorative characteristics** relate to the **chemical reactivity of materials**.

1.2. Materials Science and Engineering

- **In addition to structure and properties**, two other important components are involved in the science and engineering of materials—namely, **processing and performance.**

- Regarding the **relationships of these four components**, the structure of a material depends on how it is processed. Furthermore, a material's performance is a function of its properties.

- We draw attention to the relationships among these **four components** in terms of the **design, production, and utilization of materials**.

Processing → Structure → Properties → Performance

The four components of the discipline of materials science and engineering and their interrelationship.

1.2. Materials Science and Engineering

- **Example:** the photo shows three thin **disk specimens** placed over some printed matter. It is obvious that the **optical properties** (i.e., the light **transmittance**) of each of the three materials are different.
- The one on the **left is transparent** (i.e., virtually all of the reflected light passes through it), whereas the disk in the **center is translucent** (meaning that some of this reflected light is transmitted through the disk).
- And the disk on the **right is opaque** (none of the light passes through it).
- All of these specimens are of the **same material, aluminum oxide**, but the leftmost one is what we call a single crystal—that is, has a **high degree of perfection**—which gives rise to its transparency.

1.2. Materials Science and Engineering

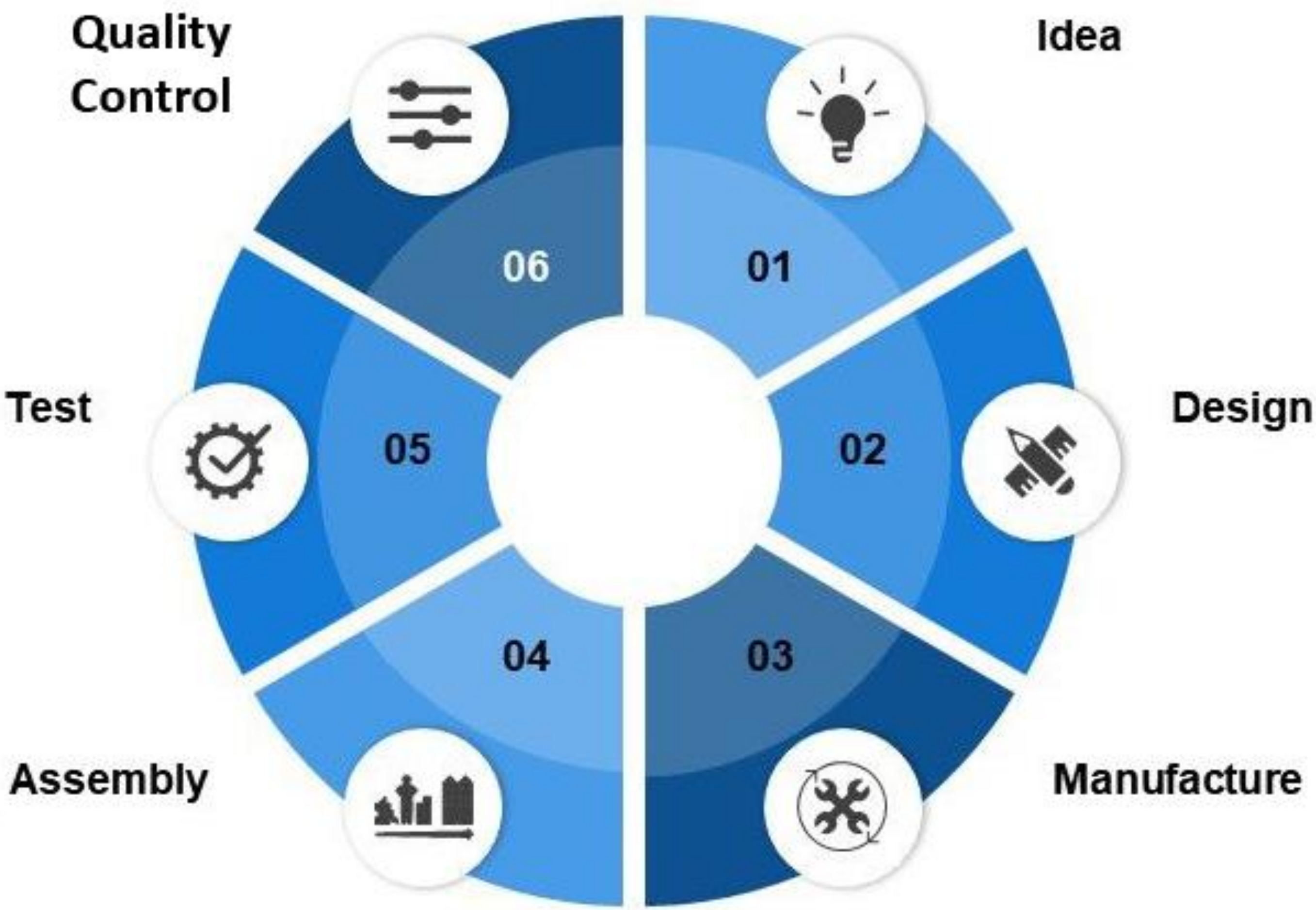
- The **center one is composed of numerous and very small single crystals that are all connected;** the **boundaries between these small crystals scatter a portion of the light reflected from the printed page**, which makes this material optically translucent.

- Finally, the specimen on the **right is composed not only of many small, interconnected crystals, but also of a large number of very small pores or void spaces**. These pores also effectively scatter the reflected light and render this material opaque.

- Furthermore, **each material was produced using a different processing technique.**

1.2. Materials Science and Engineering

Production Process



Contents

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Chap1: Introduction to Materials Science and Engineering

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1.3.Why to study Materials Science and Engineering?

- An **applied scientist or engineer, whether mechanical, civil, chemical, or electrical,** is at one time or another **exposed to a design problem involving materials, such as a transmission gear, the superstructure for a building, an oil refinery component, or an integrated circuit chip.**

- **Many times, a materials problem is one of selecting the right material** from the thousands available. The final decision is normally based on several criteria.

- **First, the in-service conditions must be characterized**, for these dictate the properties required of the material.

- On only **rare cases, a material possess the maximum or ideal combination of properties**. Thus, **it may be necessary to trade one characteristic for another**.

- **The classic example** involves **strength and ductility**; normally, a material having a high strength has only a limited ductility. In such cases, a reasonable compromise between two or more properties may be necessary.

1.3.Why to study Materials Science and Engineering?

- **A second selection consideration is any deterioration of material properties that may occur during service operation.**

- **For example:** significant reductions in mechanical strength may result from exposure to elevated temperatures or corrosive environments.

- **Finally**, probably the **overriding consideration is that of economics**: What will the finished product **cost**?

- A material may be found that has the **ideal set of properties but is prohibitively expensive**. Here again, **some compromise is inevitable**.

- The **cost of a finished piece also includes any expense incurred during fabrication to produce the desired shape**.

- Therefore, an engineer has to consider the various characteristics and structure–property relationships, as well as the processing techniques of materials and the cost.