Introduction to Materials Science and Engineering

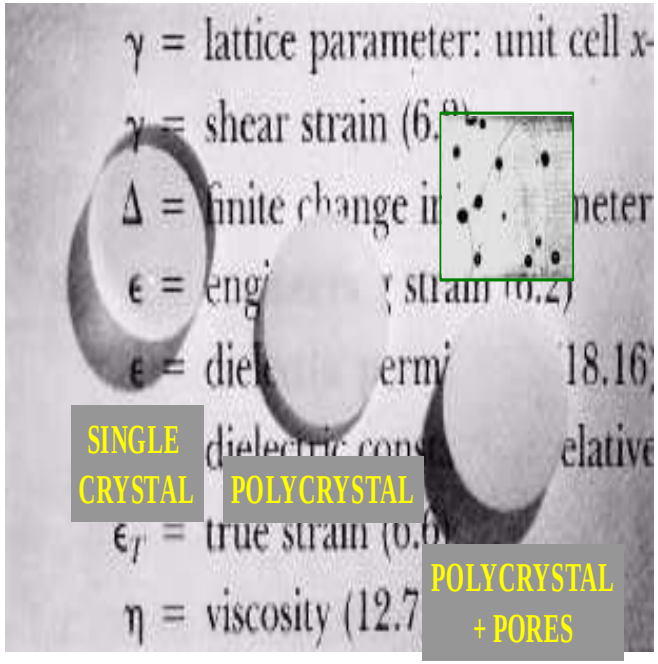


Figure 1.2 – Alumina (Al_2O_3) – single crystal and polycrystal

Course content and Learning Objectives

This course aims to provide students with the basic knowledge in materials sciences which are connected to subjects that will study further.

- ✓ To know why studying materials sciences is important
.
- ✓ Know classification of materials and structure property relations.
- ✓ To learn about the different classes of materials such as metals, ceramics, glass, polymers and composites.
- ✓ To learn about their mechanical properties.
- ✓ Corrosion and degradation

Total number of lectures are 12

Textbook: Fundamentals of Materials Science and Engineering, 3nd Ed. 2008. D. Callister, Jr. J. Wiley & Sons, NY

Introduction: Definitions

- **Materials Science**
  - The discipline of investigating the relationships that exist between the structures and properties of materials.
- **Materials Engineering**
  - The discipline of designing or engineering the structure of a material to produce a predetermined set of properties based on established structure-property correlation.
- **Four Major Components of Material Science and Engineering:**
  - **Structure of Materials**
  - **Properties of Materials**
  - **Processing of Materials**
  - **Performance of Materials**

Introduction

Materials are probably more deep-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.

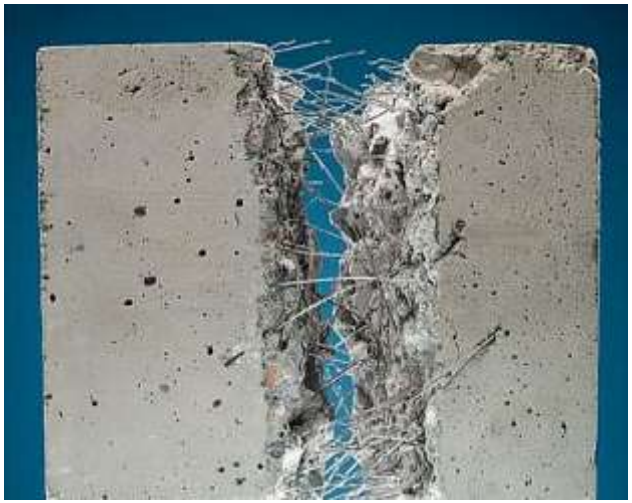
Aluminum (metal) cans

glass (ceramic)

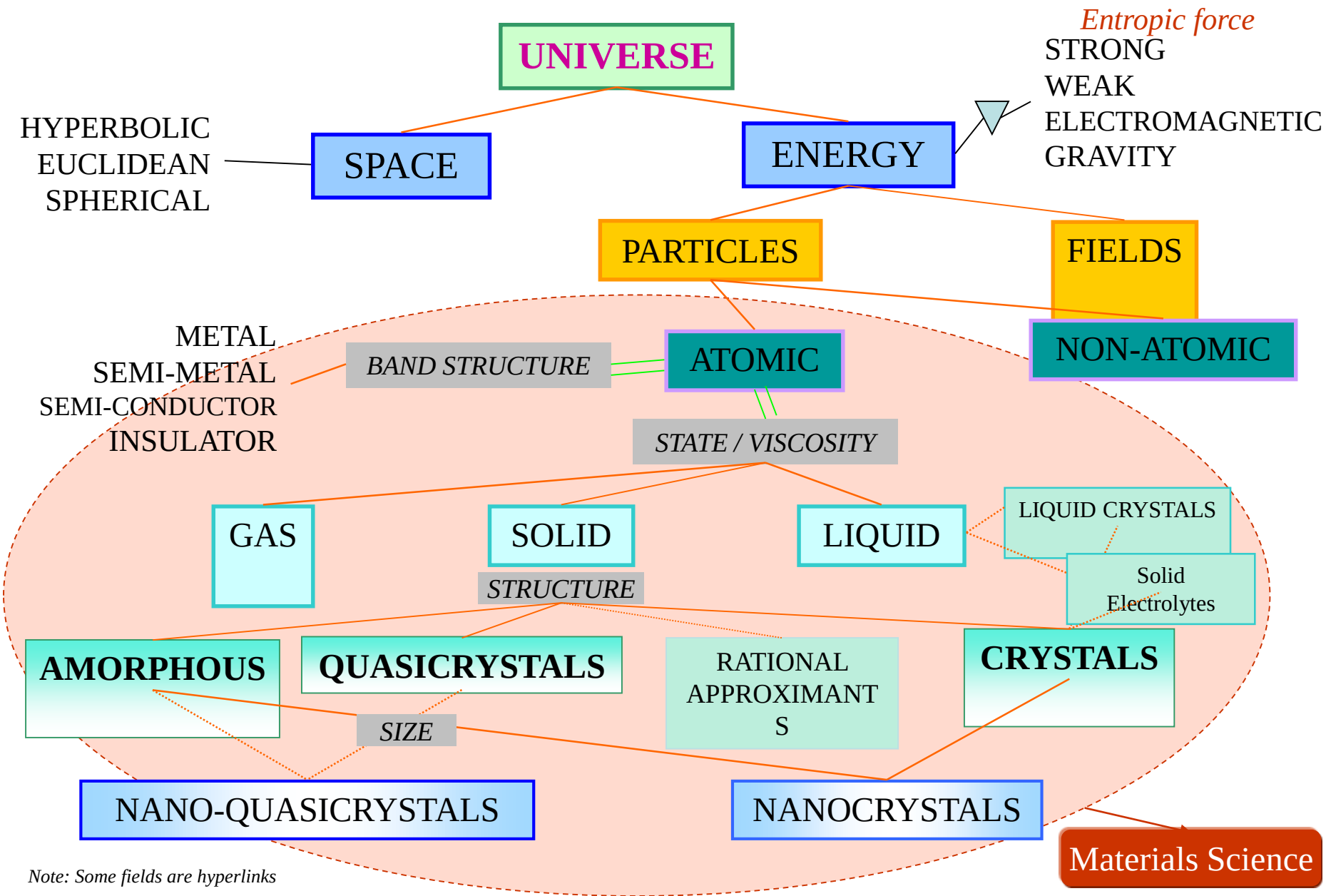
plastic (polymer) bottles

Why study materials?

- Applied scientists or engineers must make **material choices**
- Materials selection
  - in-service performance
  - deterioration
  - Economics



Where does Materials Science lie in the broad scheme of things



Note: Some fields are hyperlinks

History of Materials Science & Engineering

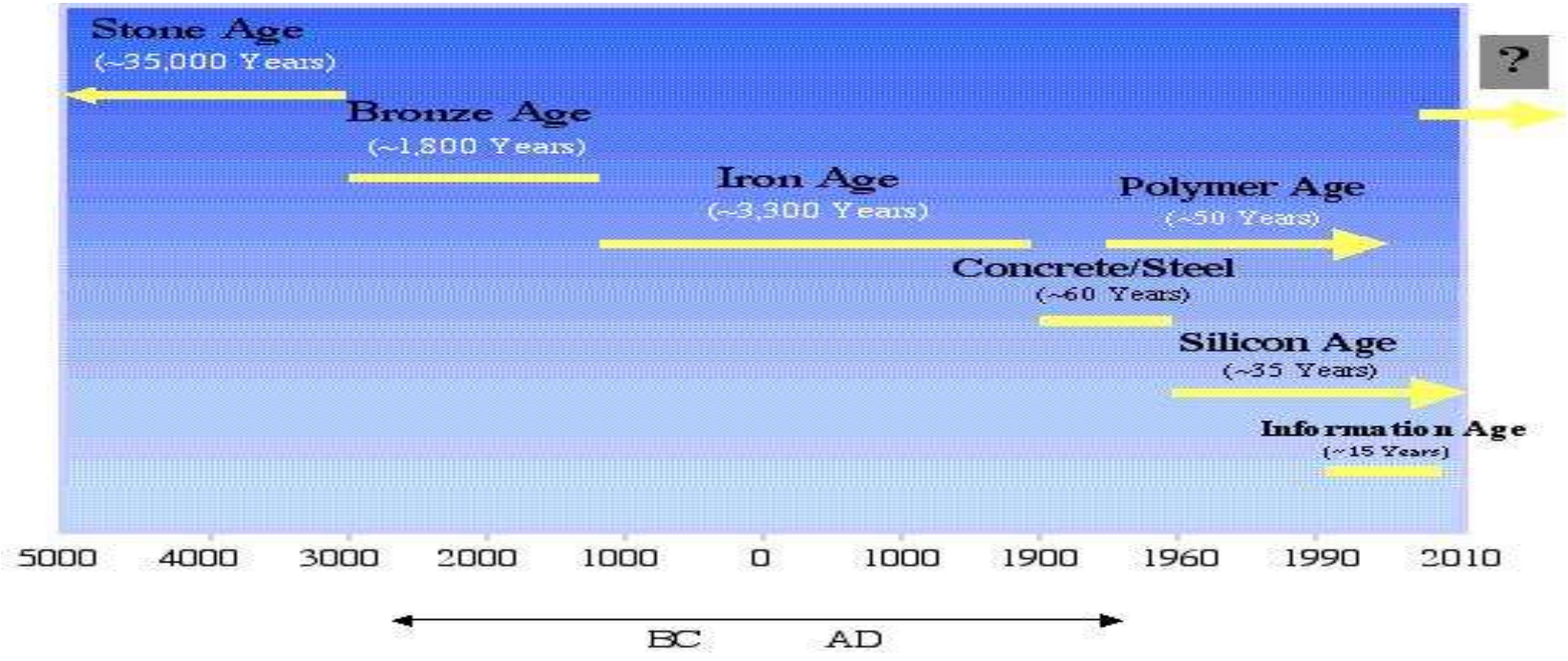
•Materials closely connected our culture

•The development and advancement of societies are dependent on the available materials and their use.

•**early civilizations designated by level of materials development**.

•initially natural materials

•develop techniques to produce materials with superior qualities (heat treatments and addition of other substances)



- Ages of “Man” we survive based on the materials we control
  - **Stone Age** – naturally occurring materials
    - Special rocks, skins, wood
  - **Bronze Age**
    - Casting and forging
  - **Iron Age**
    - High Temperature furnaces
  - **Steel Age**
    - High Strength Alloys
  - **Non-Ferrous and Polymer Age**
    - Aluminum, Titanium and Nickel (superalloys) – aerospace
    - Silicon – Information
    - Plastics and Composites – food preservation, housing, aerospace and higher speeds
  - **Exotic Materials Age?**
    - Nano-Material and bio-Materials – they are coming and then …

Stone age

Bronze age

Iron age

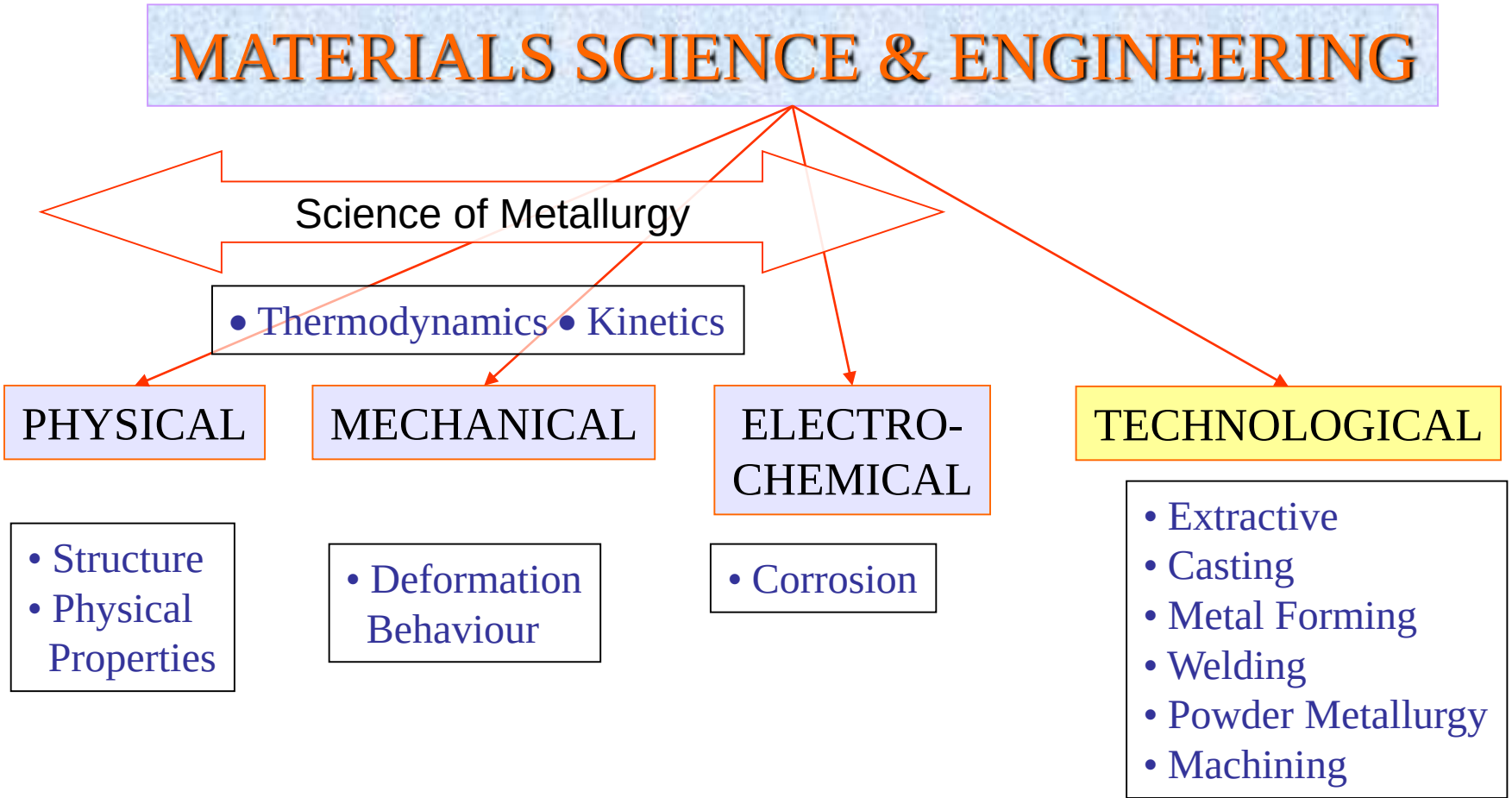
Silicon age

Doing Materials!

- Engineered Materials are a function of:
  - Raw Materials Elemental Control
  - Processing History
- **Your Role** in Engineering Materials then is to understand the **application** and specify the appropriate material to **do the job** as a function of:
  - Strength: yield and ultimate
  - Ductility, flexibility
  - Weight/density
  - Working Environment
  - Cost: Lifecycle expenses, Environmental impact*

* Economic and Environmental Factors often are the most important when making the final decision!

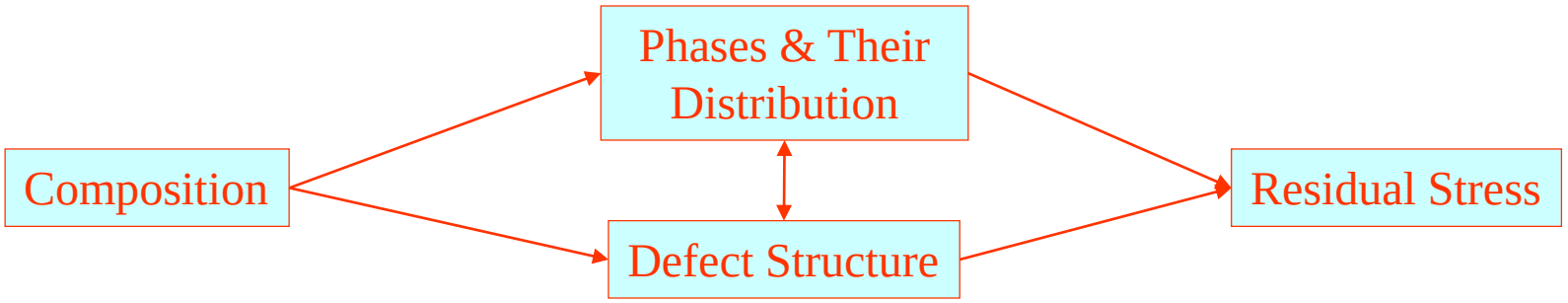
- The broad scientific and technological segments of Materials Science are shown in the diagram below.
- To gain a **comprehensive understanding** of materials science, all these aspects have to be studied.



What determines the properties of materials?

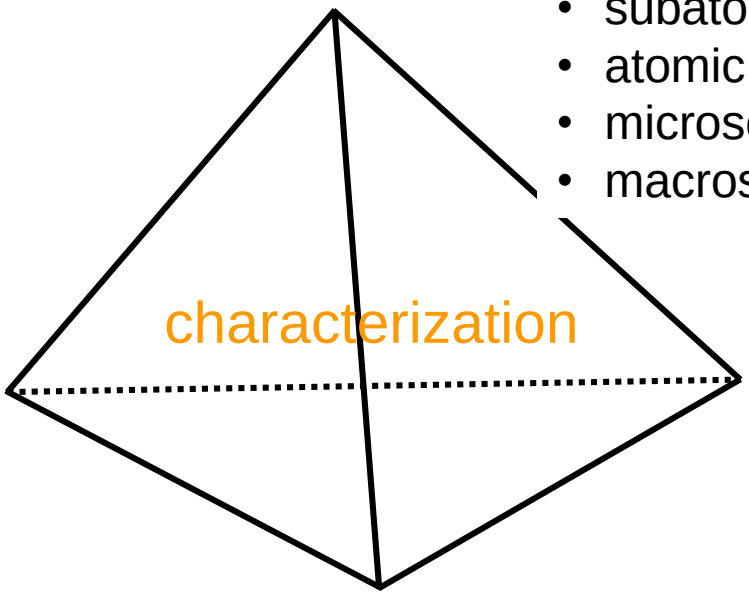
- The following factors put together determines the properties of a material:
  - **Composition**
  - **Phases present and their distribution**
  - **Defect Structure *(in the phases and between the phases)***
  - **Residual Stress; the stress present in an object in the absence of any external load or force.** *(can have multiple origins and one may have to travel across lengthscales)*
- These factors do NOT act independent of one another *(there is an interdependency)*

Hence, one has to *traverse across lengthscales* and look at various aspects to understand the properties of materials



Structure-property relations

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



- arrangement of internal components
- subatomic
- atomic
- microscopic
- macroscopic (bulk)

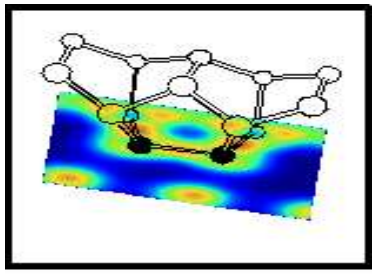
- method of preparing material

- material characteristic
- response to external stimulus
- mechanical, electrical, thermal, magnetic, optical, deteriorative

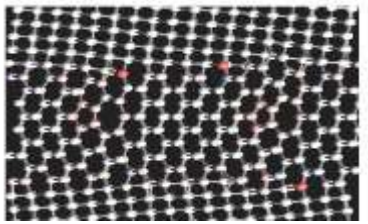
- behavior in a particular application

Level of Structure

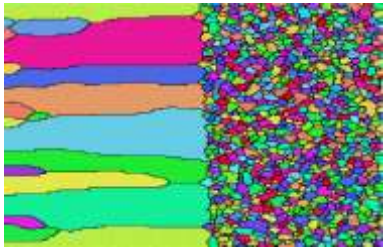
- **Subatomic level :** Electronic structure of individual atoms that defines interaction among atoms (interatomic bonding).



Atomic level: Arrangement of atoms in materials (for the same atoms can have different properties, e.g. two forms of carbon: graphite and diamond)



Microscopic structure: Arrangement of small grains of material that can be identified by microscopy. (to see present or absent of defects)



Macroscopic structure: Structural elements that may be viewed with the naked eye.

Summary

- The goal of Materials Science and Engineering is to design materials with a certain set of properties, which gives a certain desired performance. Using suitable processing techniques the material can be synthesized and processed. The processing also determines the microstructure of the material.
- To understand the microstructure the material scientist has to traverse across lengthscales and has to comprehend the defect structure in the material along with the phases and their distribution. The residual stress state in the material is also very important.
- The four components (pillars) of the discipline of materials science and engineering are the; Structure, properties, performance and processing.
- Structure has four level, subatomic, atomic, Microscopic and macroscopic level