BFF1113
Engineering Materials

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FACULTY OF MANUFACTURING ENGINEERING

ENGINEERING MATERIALS FOR MANUFACTURING ENGINEERS

Reference books:

William D.Callister, Jr.
Materials Science & Engineering: An Introduction.
John Wiley & Sons Inc.

Serope Kalpakjian, Steven R. Schmid.
Manufacturing Engineering and Technology
Pearson Prentice-Hall, Inc.

1	Course Code and Name	BFF1113 ENGINEERING MATERIALS
2	Semester / Year	Semester 1 / Year 1
3	Program Level / Category	Bachelor Degree / Materials
4	Unit	3 Credits
5	Prerequisite Course	NIL
6	Contact Hours	Lecture — 2 unit — 2 H X 14 weeks Tutorial — 0.5 unit — 1 H X 14 weeks Laboratory — 0.5 unit — 1 H X 14 weeks
7	Course Synopsis	This course introduces the fundamental concepts of engineering materials which includes the structure of materials, mechanical and physical properties of materials, binary phase diagrams, TTT diagram, heat treatment, applications and current developments of metal, polymer, ceramic, composite and advanced materials. Also, basic understanding on the environmental degradation of engineering materials.
8	Course Outcomes	By the end of semester, students should be able to: CO1: Gain fundamental concepts on the classification of various engineering materials. CO2: Perform structure-property correlations for engineering materials based on the microstructures. CO3: Analyse binary phase diagrams, TTT diagram, cooling curve, and correlate with microstructures and properties. CO4: Evaluate the criteria in the selection of materials. CO5: Recognize the importance of sustainable materials.

9	**CO-PO Mapping**	CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
		CO1	✓											
		CO2		✓										
		CO3		✓										
		CO4			✓									
		CO5							✓					

10	**Assessment Methods**	Distribution (%)		CO1	CO2	CO3	CO4	CO5
		Assignment	15%	✓	✓	✓	✓	✓
		Test 1	15%	✓	✓			
		Test 2	15%			✓	✓	
		Final Examination	40%	✓	✓	✓	✓	
		Lab Report	15%	✓	✓			
		Total	100%					

PO	1	2	3	4	5	6	7	8	9	10	11	12
	Knowledge	**Problem Analysis**	**Design/Development of Solution**	Investigation	Modern Tool Usage	Engineer & Society	**Environment and Sustainability**	Ethics	Communication	Individual & Teamwork	Life Long Learning	Project Management and Finance

Contribution of assessment

	DISTRIBUTION (%)	REMARKS
1) ASSIGNMENTS	15 %	• +- 3 assignments • submit on time. Late submission not ALLOWED. • student to solve each assignment **independently. No copy and paste.** Discussion are allowed.
2) LAB ASSIGNMENTS	15 %	• +- 2 lab assignments • perform experiment in the materials lab.
3) TEST 1	30 %	• given during semester after a sizeable of lessons are learned. • 1 hour and 30 minutes test.
4) TEST 2		
5) FINAL EXAMINATION	40 %	• 3 hours examination with 4 questions. • contributes 40% of the final grade.

Course Guidelines:

1. Introduction to Engineering Materials
2. Bonding and Properties
3. Crystal Structures & Properties
4. Imperfection in Solids
5. Mechanical Properties of Materials
6. Physical Properties of Materials
7. Failure & Fundamental of Fracture
8. Metal Alloys
9. Phase Diagram
10. Phase Transformation – Heat Treatment
11. Processing and Application of Metals
12. Ceramic Materials
13. Polymer Materials
14. Composite Materials
15. Corrosion & Degradation of Materials
16. Environment and Sustainability

Introduction to Engineering Materials

What are Materials?

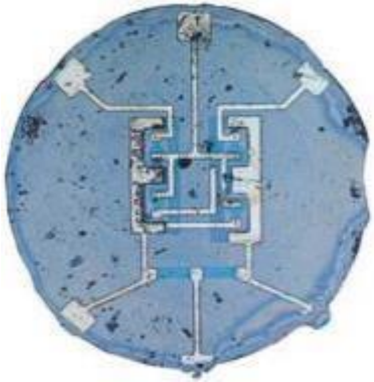
- Materials
  - Substances from which something is composed or made from.
  - Materials can be natural - like wood, or human made - like plastic
  - There are now more than 300,000 different known materials

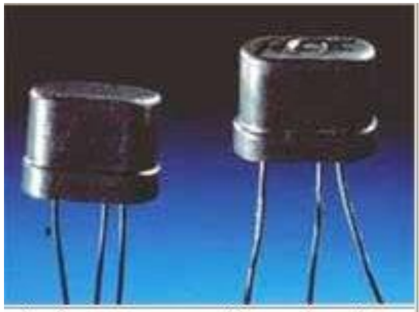
What are Engineering Materials?

- Engineering Materials
  - Materials used to produce technical products.
  - Engineered materials with desired properties.

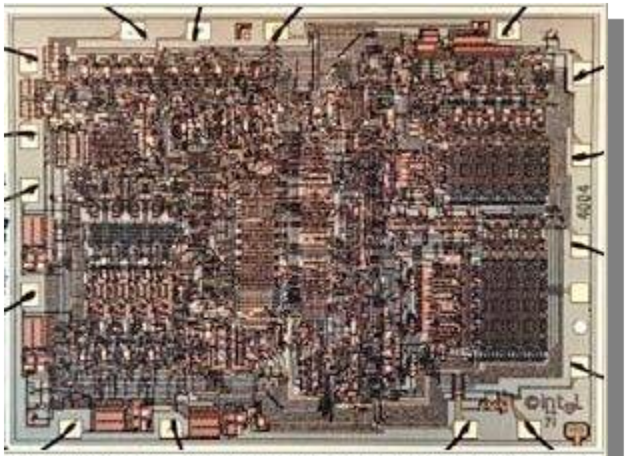
1.1 Materials in our daily life

Electrical & Electronic





The first commercially produced silicon transistor, developed by Texas Instruments in the early 1950s. Courtesy: Texas Instruments.



The Intel 4004 microprocessor, which was introduced in 1971. The 4004 contained only 2300 transistors and performed 60,000 calculations per second. Courtesy: Intel.

Civil & Structural

Aerospace

Chemical


250ml
KIMAX
Home
NO. 14000
APPROX. VOLUMES
200ml
Events
150
Executive
100
Tutoring
50
Links

Infrastructural & Transportation

1.2 Historical development of materials

Evolution of Materials

MATERIALS → ENGINEERING MATERIALS

Prehistoric → Stone Age → Bronze Age → Iron Age (Industrial Revolution) → Electric Age (Silicon Age) → Designed Materials Age → Nano Material Age

Stone Age
- Materials existing in nature.
- stone, wood, clay

Bronze Age
- Alloy of copper

Iron Age (Industrial Revolution)
- Minimum material processing.
- Produce better **material properties** to those occurring naturally
- Iron, steel, other metals.
- Steam engine

Designed Materials Age
- Advance composites
- Surface treatment
- Artificial layered structures

Prehistoric

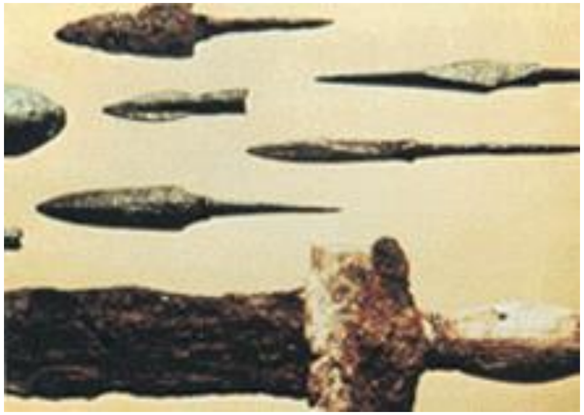
Stone, clay, wood

Stone Age

- Early in the developments of human cultures, before the use of metals
- Tools & weapons were made of stone

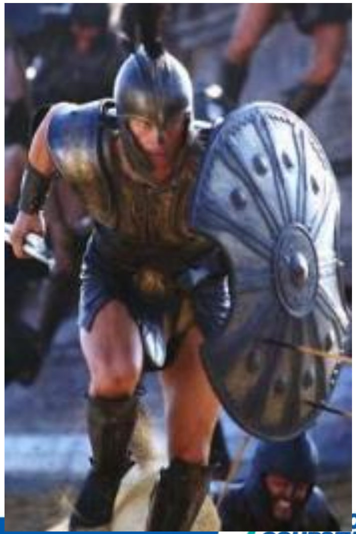

Bronze Age

- Bronze (Cooper + tin + zinc)
- The time in the development of any human culture
- Before introduction of iron, when most tools and weapons were made from bronze

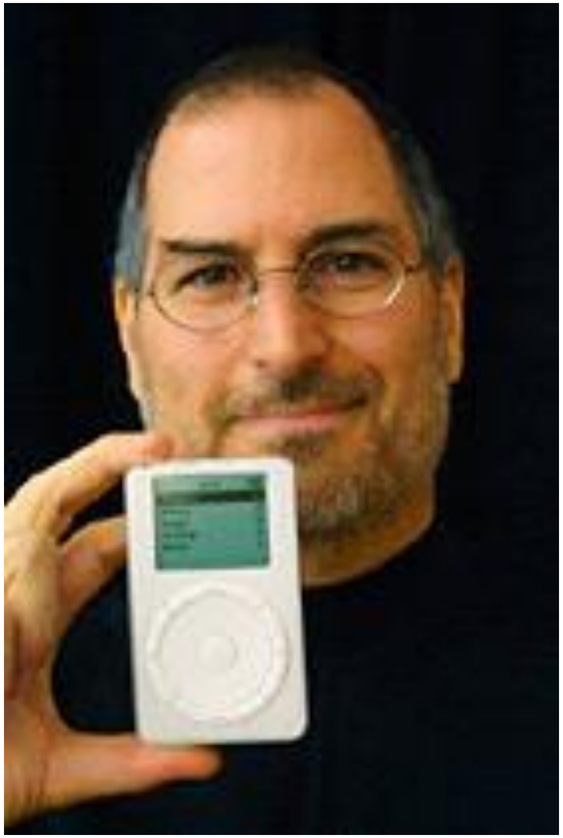


Iron Age

- Marks the period of development of technology replacing bronze as the basic material for tool implemention and weapon
- Last stage of the archaeological sequence



Electrical Age (Silicon Age) and beyond



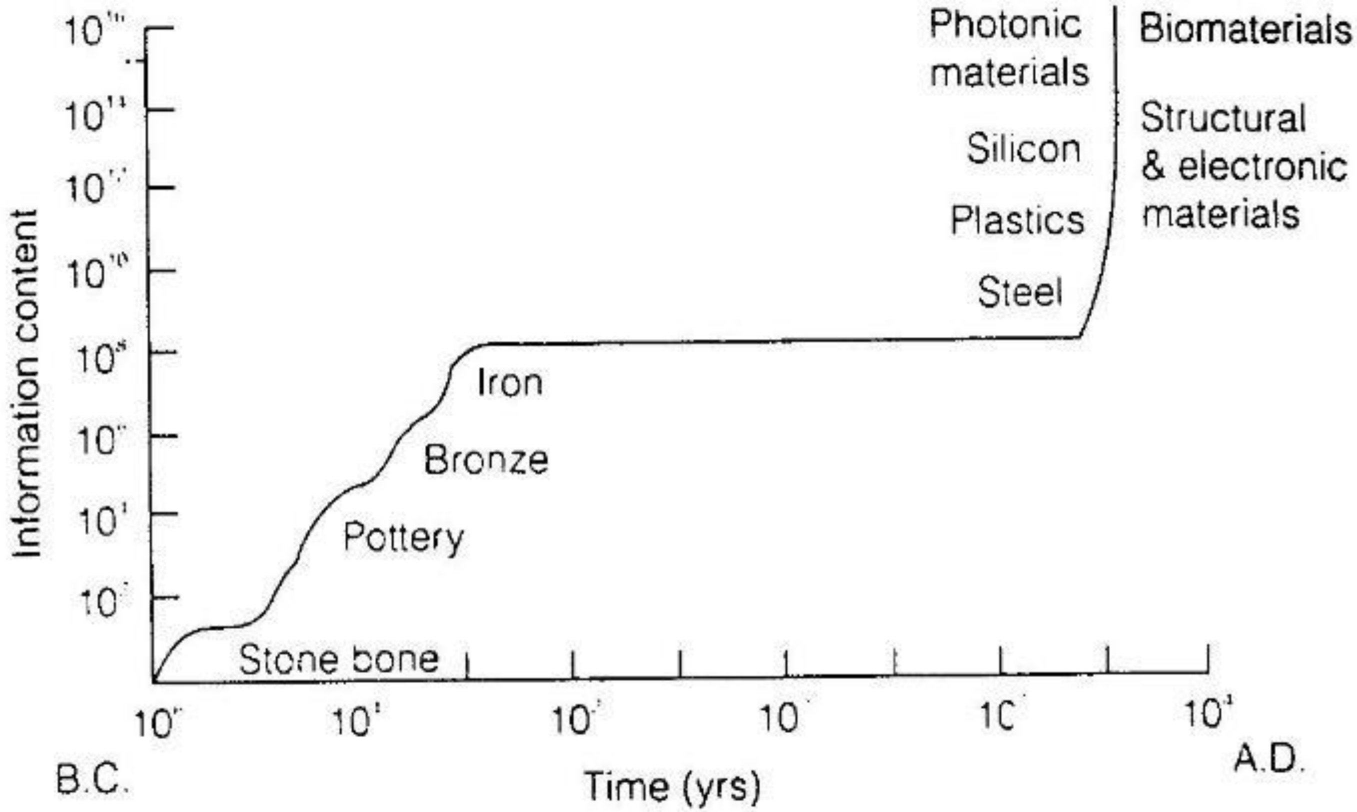


Fig. 1.4 A schematic diagram showing the growth in technology information content inherent in the use of new materials. It emphasizes the present rapidly changing circumstances before reaching another plateau when the second industrial revolution nears maturity.

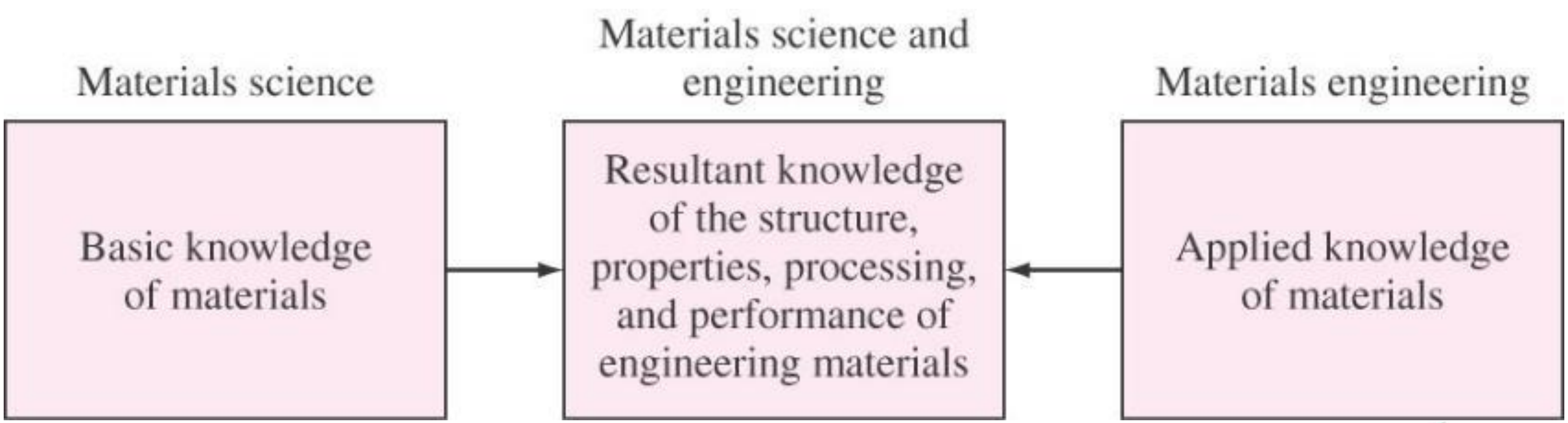
- 1.3 Materials science and engineering

Discipline of Materials Study

- Materials Science
  - Science - *scientia* (Knowledge)
  - Study of basic materials knowledge.
    - Investigation of the relationship between ***STRUCTURES*** and ***PROPERTIES*** of materials
- Materials Engineering
  - Engineer – *ingeneur*
  - ***Used*** of Materials Science knowledge (fundamental) to ***design*** and to ***produce*** materials with ***properties*** that will meet the ***requirements*** of society.
  - Structure-Property correlations, designing or engineering the structure of a material to a pre-determined set of properties.

Materials Science and Engineering (MSE)

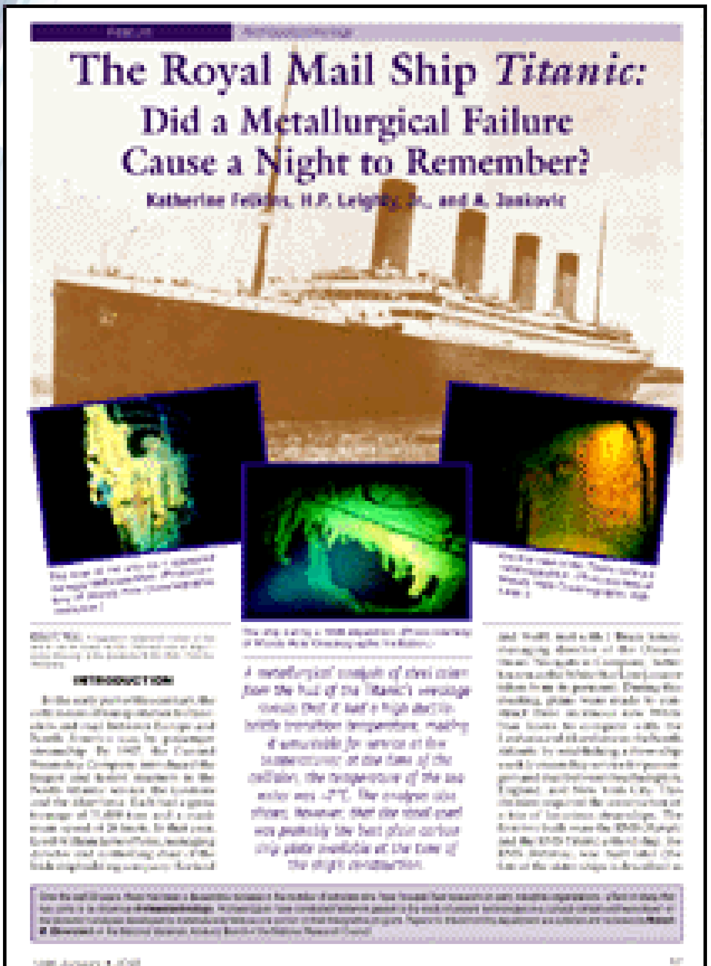
- Combines both basic knowledge and applications and forms a ***bridge*** between the basic sciences (physics, chemistry, and mathematic) and the **various** engineering disciplines (electrical, mechanical, manufacturing, chemical, civil, and aerospace engineering).
- **Interdisciplinary** nature.



Why do we need to study Materials Science & Engineering ?

- Cost? Effective?
- Fabrication?
- Safety?

Case Study: Titanic



The Royal Mail Ship *Titanic*: Did a Metallurgical Failure Cause a Night to Remember?

Katherine Felkins, H.P. Leighly, Jr., and A. Jankovic

At the time of the collision,
the temperature of
the sea water was **-2° C**.

Plain carbon steel had a high ductile-brittle transition temperature, making it unsuitable for service at low temperatures;

UMP OPEN COURSEWARE

Video:
Effect of DBTT to Materials

Materials Selection Process

1. Pick Application → Determine required Properties

   Properties: mechanical, electrical, thermal, magnetic, optical, deteriorative.

2. Properties → Identify candidate Material(s)

   Material: structure, composition.

3. Material → Identify required Processing

   Processing: changes *structure* and overall *shape*
   ex: casting, sintering, vapor deposition, doping
   forming, joining, annealing.

Selecting the RIGHT material.

- To succeed in **processing** materials with a given set of **properties**, it is necessary to understand the basis of the **properties** from the atomic and molecular level, and to understand how small differences in structure can lead to large differences in observed properties.
- 4 components that are involved in design, production, and utilization of materials.
  - Processing
  - Structure
  - Properties
  - Performance

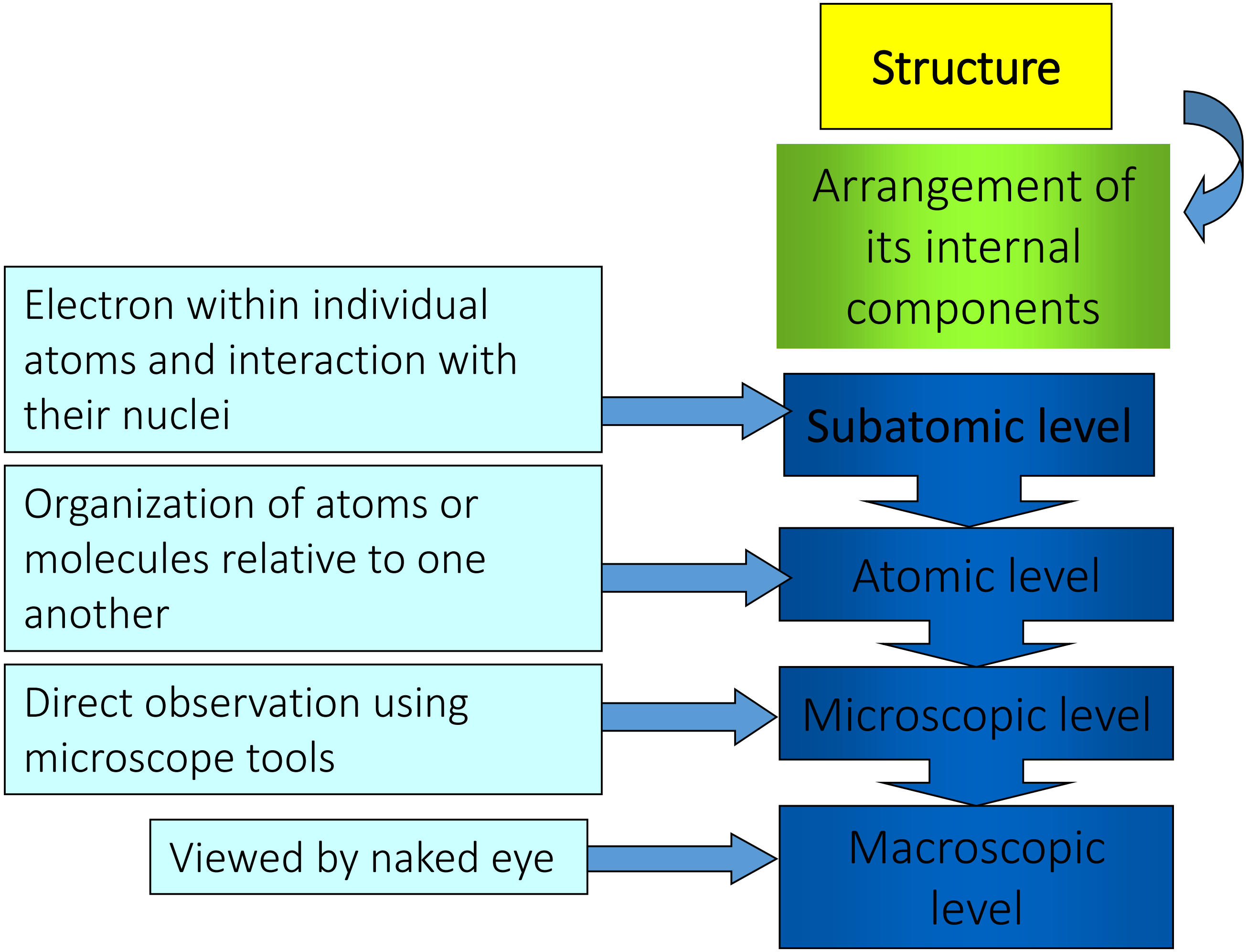
IMPORTANT

- How do these components interrelated?

1. What is Processing?

Multiple procedures to produce something pre-determined.

2. What is Structure?



3.0 What is Property?

Properties

Materials trait in term of the kind and magnitude of response to a specific imposed stimulus

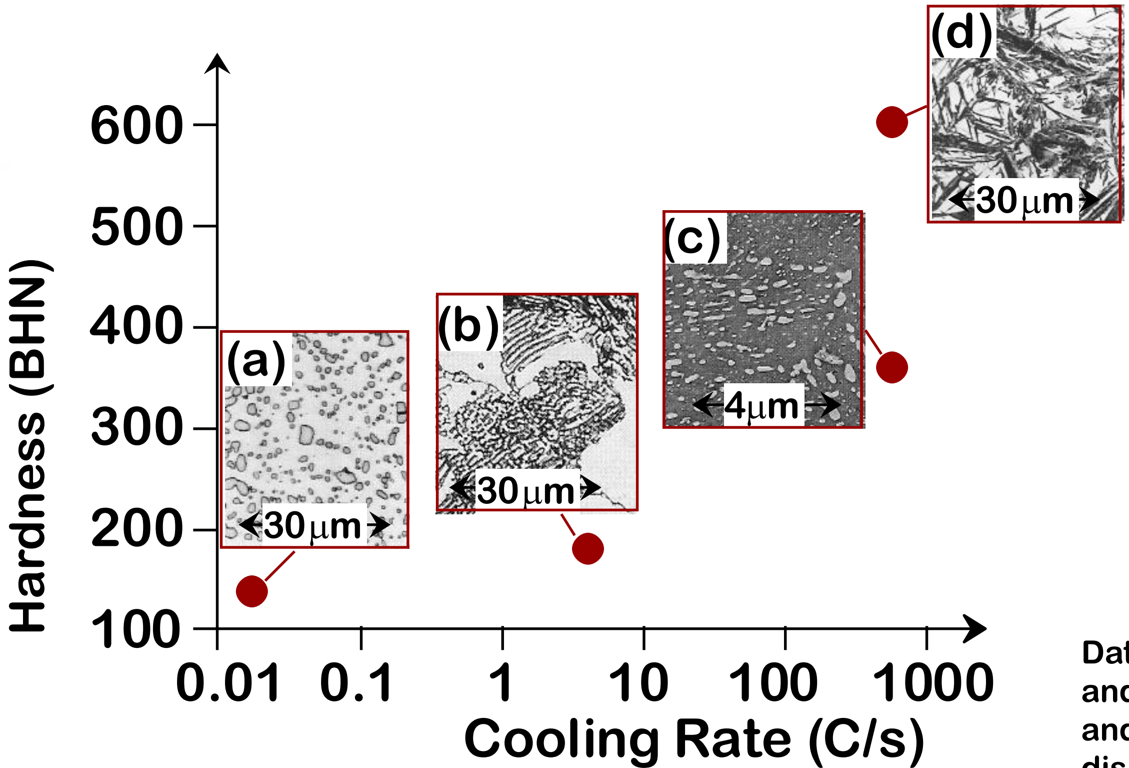
- Material: Conductor
- Stimulus: voltage
- Response: Electric Current

- PROPERTIES
  - Mechanical
  - Electrical
  - Thermal
  - Magnetic
  - Optical
  - Deteriorative

Property	Stimulus	Response
Mechanical	Applied load or force	Deformation
Electrical	Electric field	Conductivity

- Properties depend on structure

ex: hardness vs structure of steel



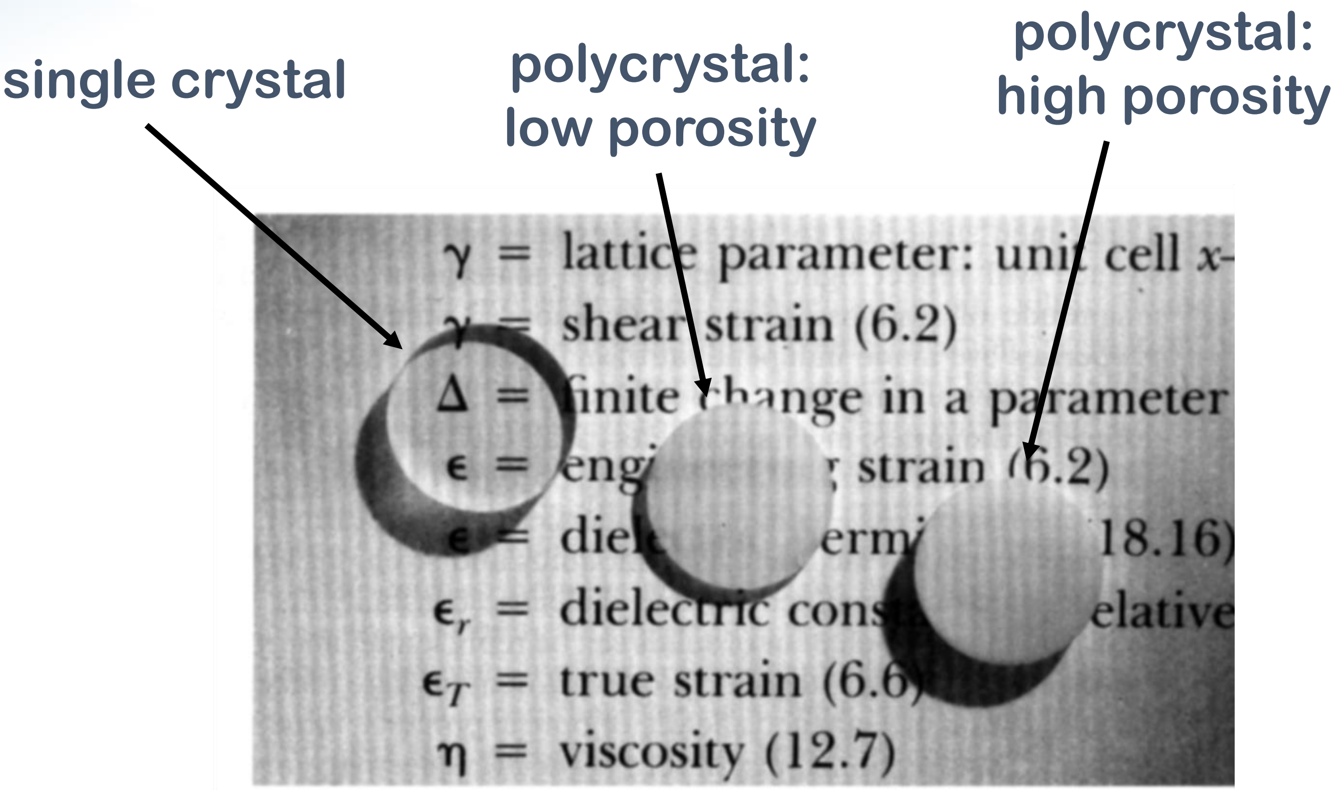
Data obtained from Figs. 10.21(a) and 10.23 with 4wt%C composition, and from Fig. 11.13 and associated discussion, *Callister 6e*. Micrographs adapted from (a) Fig. 10.10; (b) Fig. 9.27;(c) Fig. 10.24; and (d) Fig. 10.12, *Callister 6e*.

- Processing can change structure

ex: structure vs cooling rate of steel

Optical property

- Transmittance:
  --Aluminum oxide may be transparent, translucent, or opaque depending on the material structure.



Adapted from Fig. 1.2, *Callister 6e.* (Specimen preparation, P.A. Lessing; photo by J. Telford.)

Change of Properties

Heat Treatment

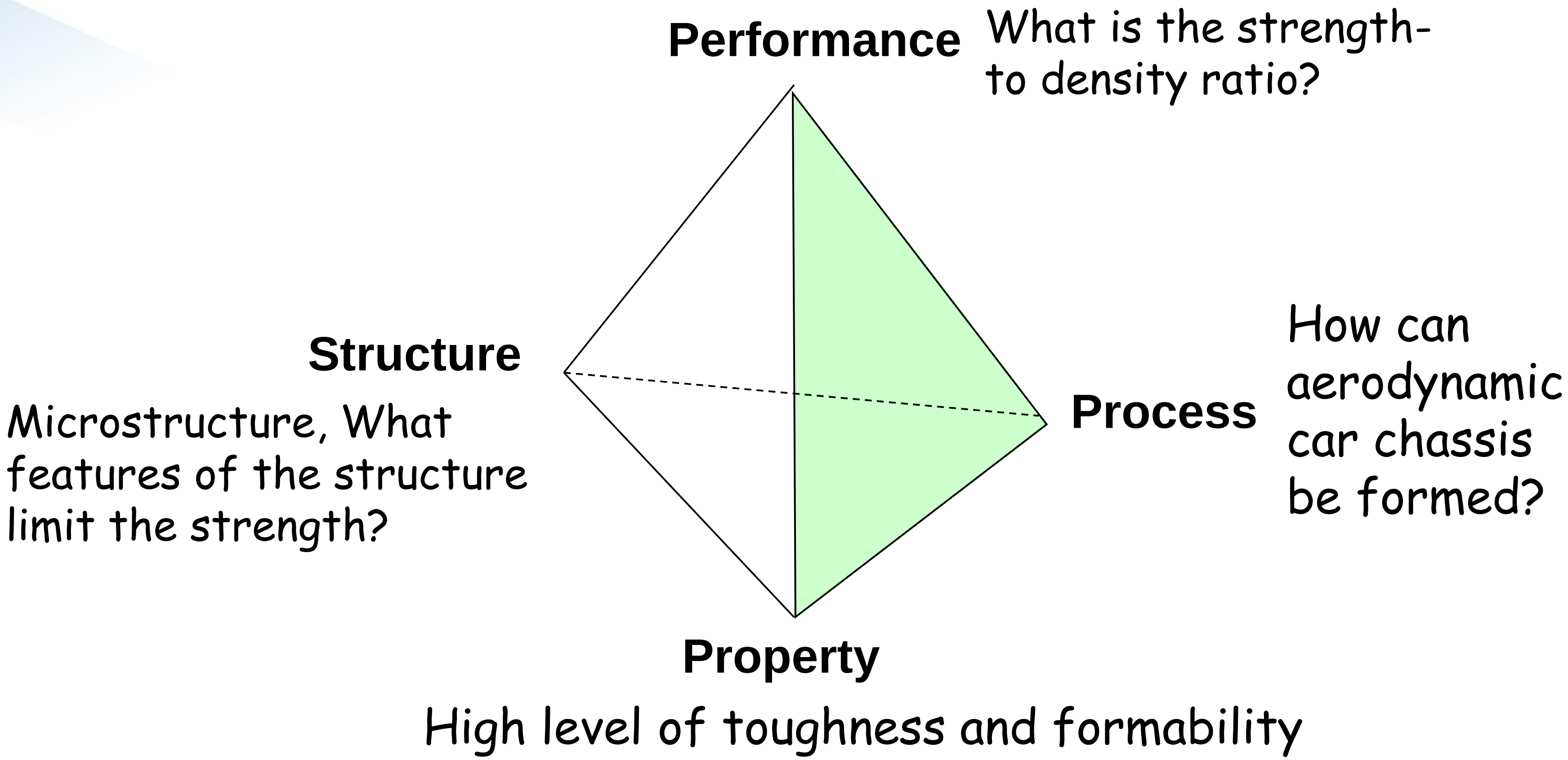
Adding other substances

Structure ⟷ Properties

4. What is Performance?

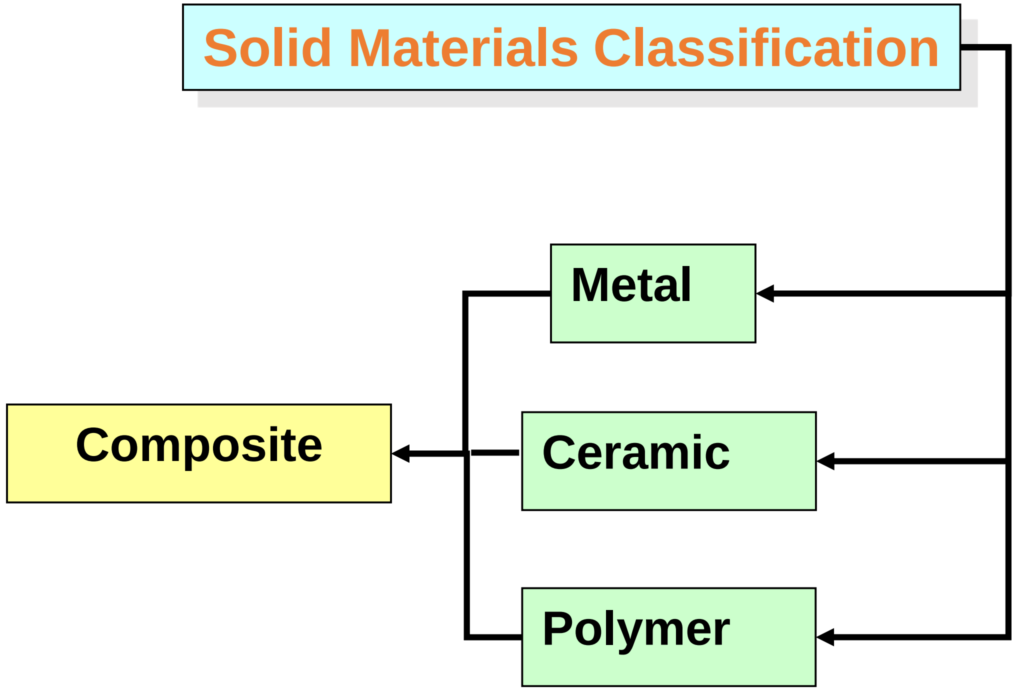
A measurement of how good a product is.

- "Tetrahedron" Interrelationship:
  - Car body ➔ What is the right material to use?



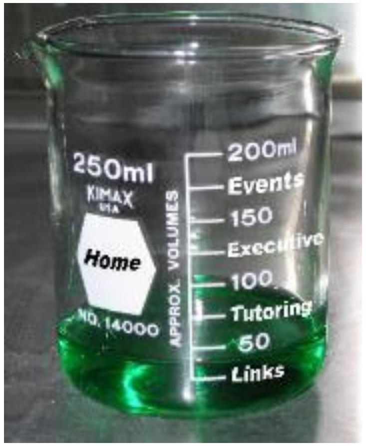
1.4 Class of Materials

Class of Materials

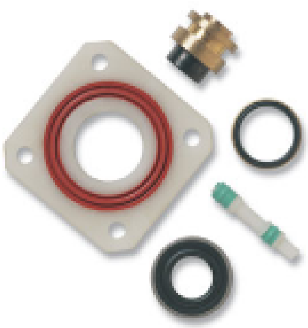


- **METALS:**
  - Inorganic materials (one or more metallic elements – alloy)
  - Crystalline structure
  - May contain a small amount of non-metallic elements
  - Good thermal & electrical conductors (large numbers of non-localized electrons = electrons are not bound to particular atoms)
  - Properties at room temperature (RT)
    - Strong and ductile (capable of large amounts of deformation without fracture)
    - Stiff
    - Good strength
    - Dense
    - Resistance to fracture

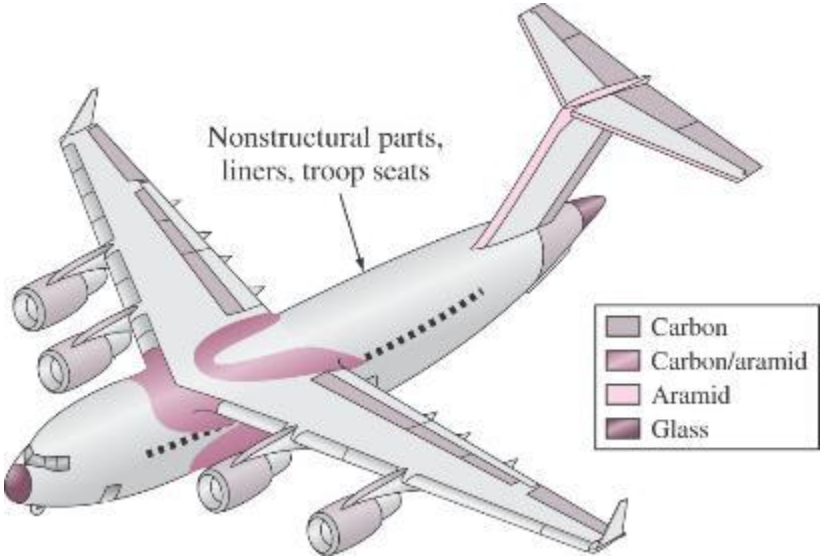
- **CERAMICS:**
  - Inorganic materials (metallic + non-metallic elements)
  - Oxides, nitrides, carbides
  - Crystalline, non-crystalline, or a mixture of both
  - Properties at RT
    - High melting point
    - High chemical stabilities
    - High hardness
    - High temperature strength
    - Brittle (lack ductility)
    - Poor electrical and thermal conductor.



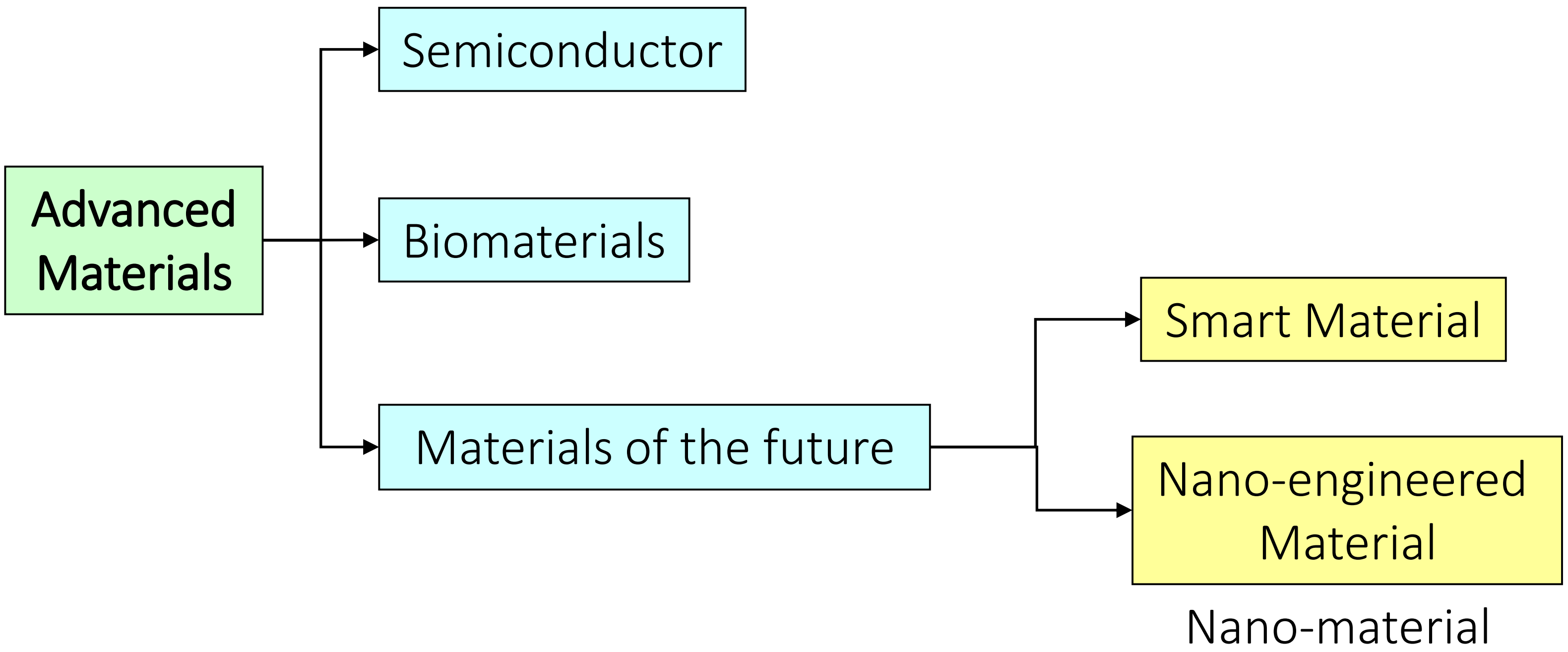
- **POLYMERS:**
  - Plastic and rubber materials
  - Organic materials
  - Long molecular chains/network containing C, H, and other nonmetallic elements (O, N, Si)
  - Non-crystalline (mostly) or a mixture of both
  - Properties at RT
    - Low density
    - Mechanically flexible
    - Poor electrical conductor



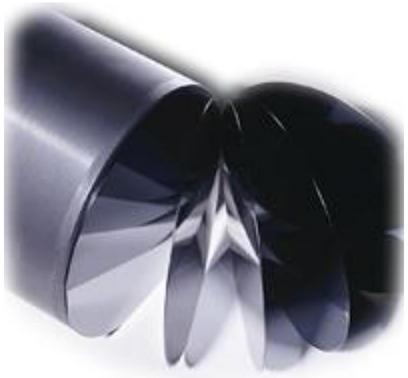

- **COMPOSITES:**
  - Mixture of two or more types of materials
  - A matrix phase + a reinforcing phase
  - Designed to ensure a combination of the best properties of each component material.

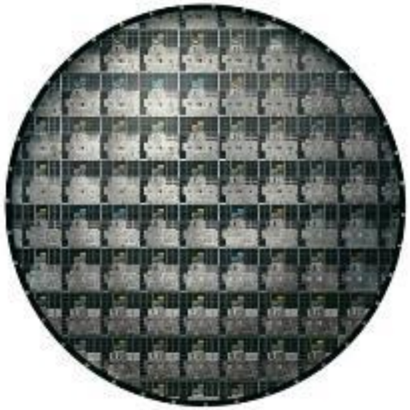


- Besides the above mentioned classification, we also have:
- **ADVANCED MATERIALS:**
  - Materials that are utilized in **high-tech application** (device/product that operates or functions using relatively intricate and sophisticated principles)
  - DVD Players, Microprocesser, Liquid Crystal Display.



- SEMICONDUCTORS:
  - Electrical properties intermediate between conductors and insulators
  - Electrical characteristics are extremely sensitive to the presence of minute concentration of impurity atoms, which concentrations may be controlled over very small spatial region
  - Conductivity increasing with temperature





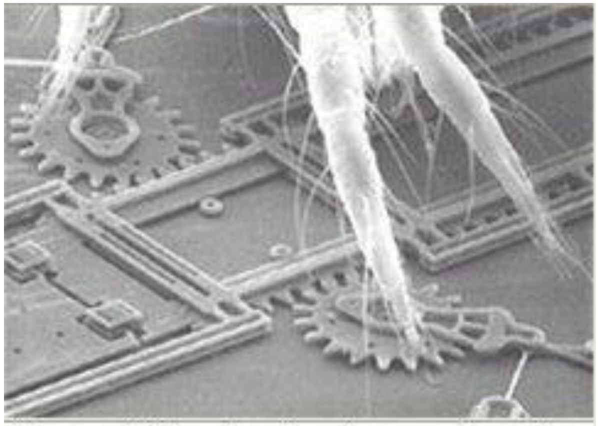
- BIOMATERIALS:
  - Components implanted into human body for replacement of diseased or damaged parts.
  - Must not produce toxic substances
  - Compatible with body tissues
  - All above materials may be used as biomaterials

- SMART MATERIALS:
  - Materials that are able to sense changes in their environments and then respond to these changes in predetermined manners

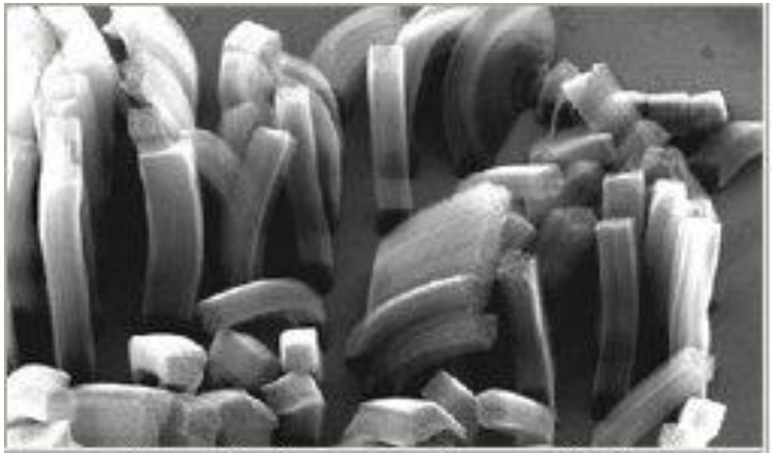
Devices made from Smart Materials

- Sensors (detects an input signal)

- NANO-ENGINEERED MATERIALS:
  - Dimension <100 nm (~500 atom diameters)
  - Bottom-up technique
  - Top-down technique
  - Materials by design
  - Exp: carbon nanotube



Micromachining involves the creation of microscopic mechanical devices, like that shown here. The legs belong to a spider mite placed to demonstrate scale. Courtesy: Sandia National Laboratories.



Nanotubes, which are made in a flask by a chemical process. Courtesy: National Center of Competence in Research (Switzerland).

End of Topic 1

QUIZ……

- What is Materials science? What is material science tetrahedron?
- What are the major properties of Nickel base superalloys that make it suitable for aircraft turbine engines?

Answer: Excellent mechanical strength, creep resistance at high temperature, good surface stability, corrosion resistance