UNIVERSITY OF ARKANSAS

AM^3 Lab
Advanced Manufacturing | Modeling | Materials

Additive Manufacturing

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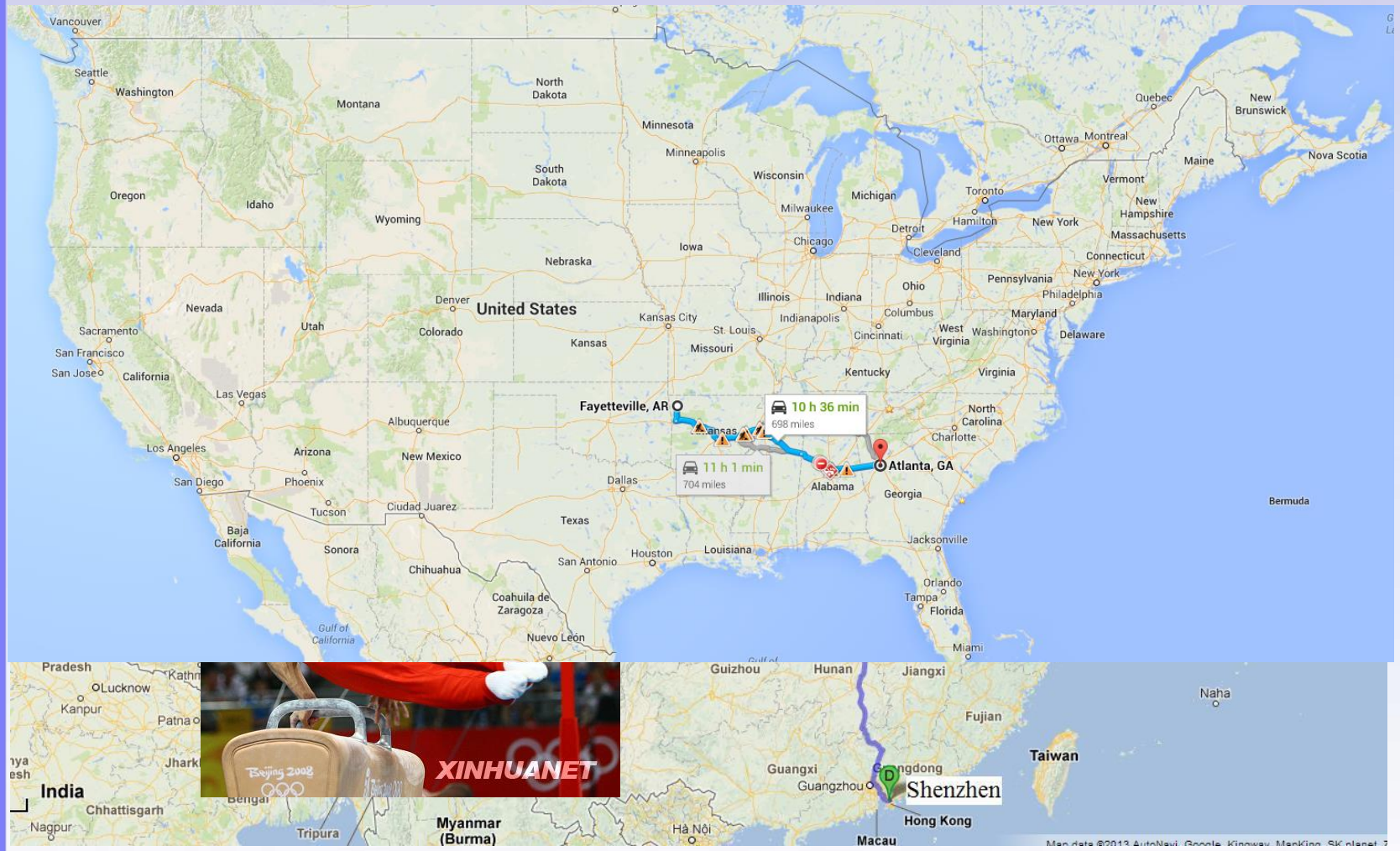
University of Arkansas, Fayetteville

Who am I

- Introduction
- What
- Why
- How
- Objectives
- Manufacturing



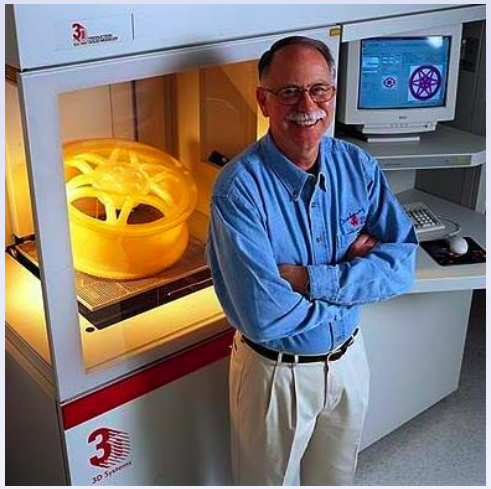
Middle China (balanced culture)→ Northwestern China (Conservative) →Southeast China (Open/Liberal)

Who are you (1 min)

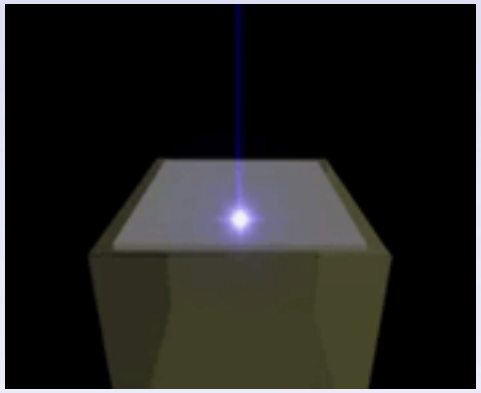
- Who are you
- Where were you from
- Why are you here (why are you interested in additive manufacturing & what do you hope to accomplish in the class)
- Where are you going (what are you planning to do after school)

What is Additive Manufacturing

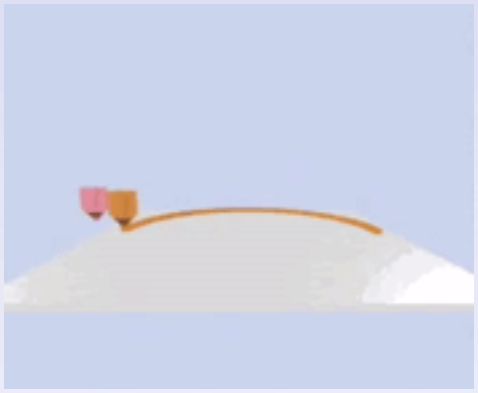
Definition: The ASTM International Committee F42 on Additive Manufacturing (AM) Technologies defines AM as the "process of joining materials to make objects from three-dimensional (3D) model data, usually layer by layer, as opposed to subtractive manufacturing methodologies."



1984 Charles Hull



Stereolithography



Fused Deposition Modeling
Extrusion based processes

A revolutionizing digital fabrication method/philosophy that renders COMPLEXITY FREE

Why AM

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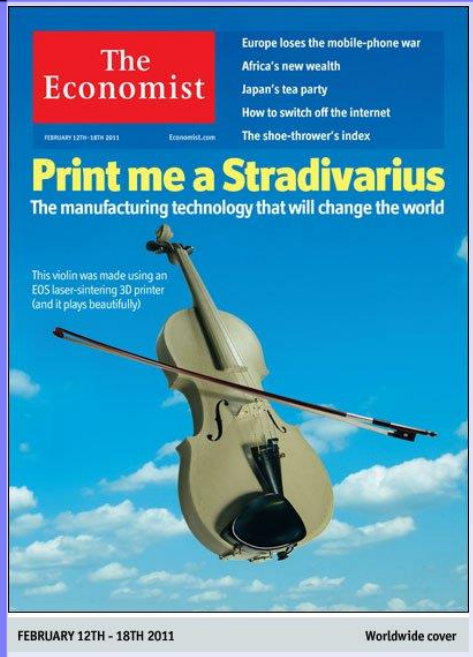


Why AM

Printed Car By Local Motors in 2014

Made in Space in 2014 by NASA

Why AM

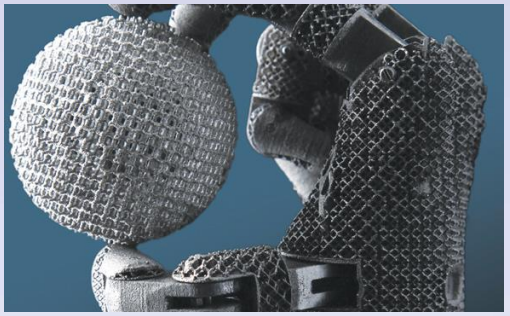
Mass Customization

Invisalign: Customized dental braces

Performance improvement

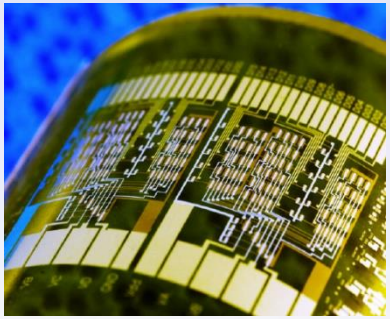
GE LEAP nozzle using AM
Original 18 parts to 1 part
5 times more durable

Weight reduction



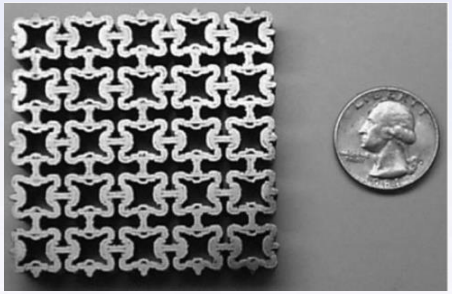
Lattice structure
Reduce weight by 10 times

Integration&Shrinking



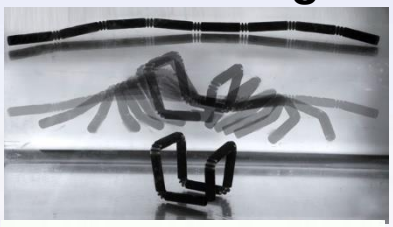
Flexible electronics, smart structures for more compact solutions with more functionalities

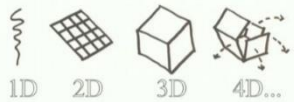
Hybrid material design



Design microstructures with multiple materials e.g., with negative thermal expansion

4D Printing



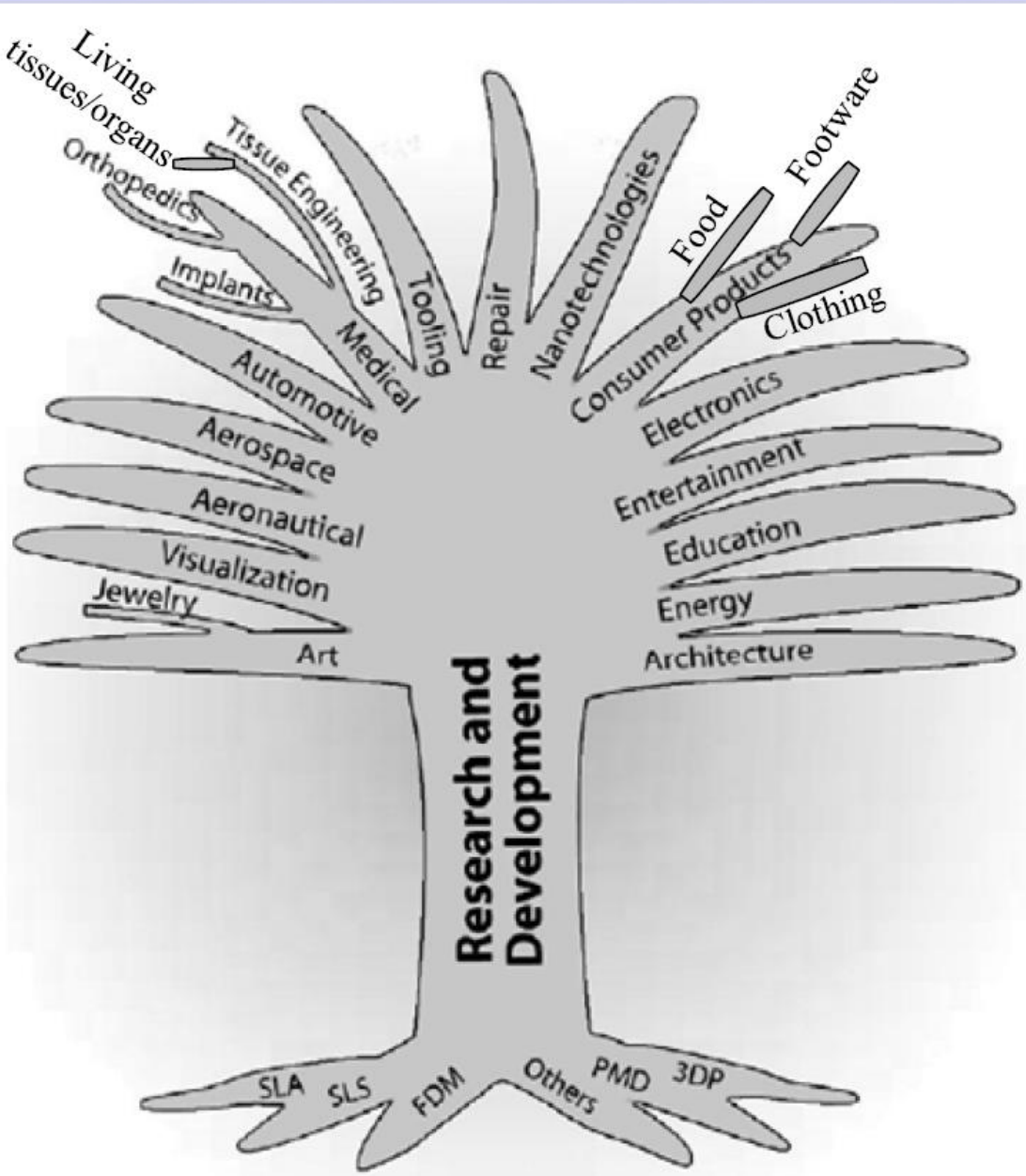


Changeable product

Better solutions

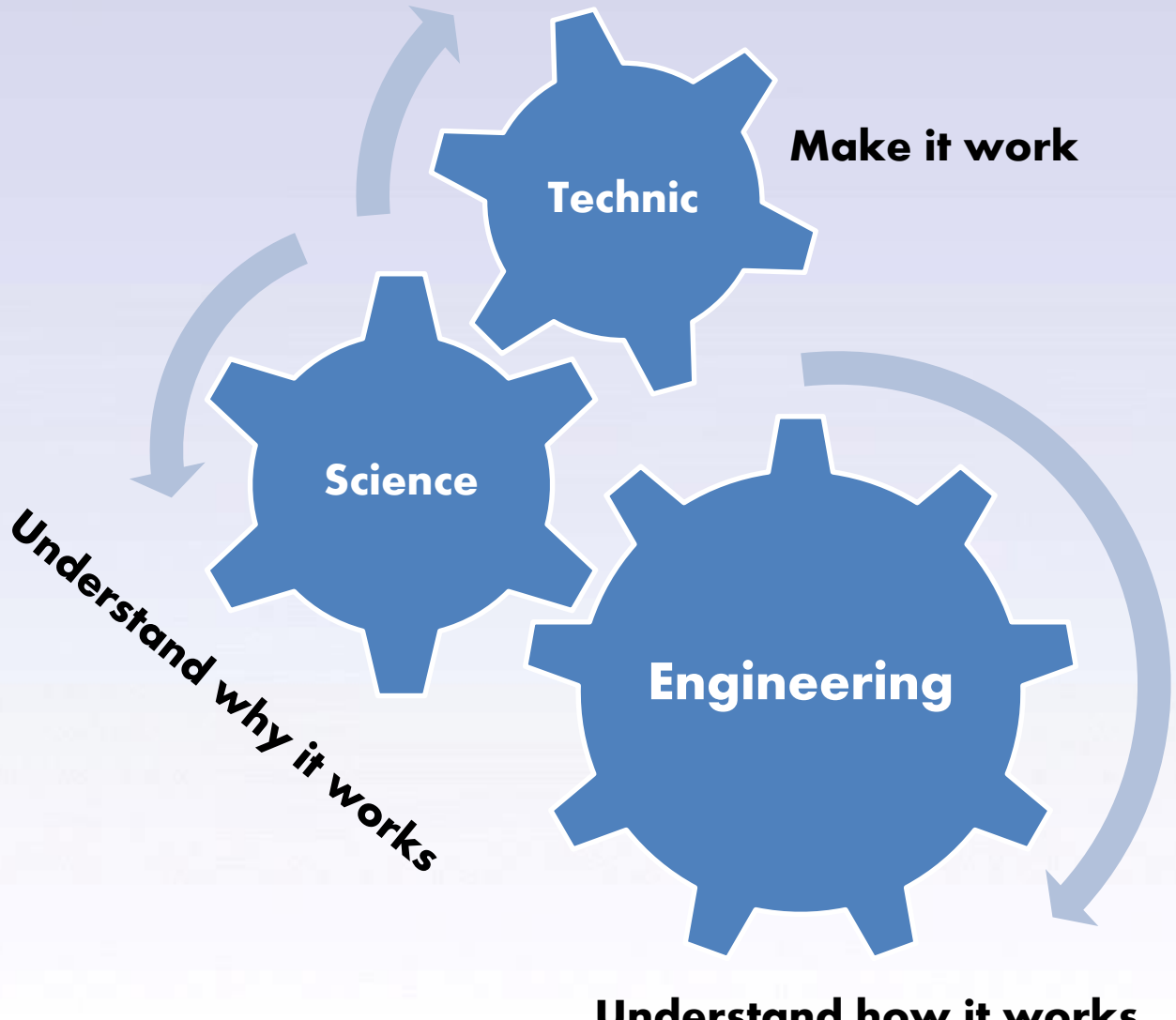
Use your imagination

Why AM


Living tissues/organs
Orthopedics
Tissue Engineering
Implants
Medical
Tooling
Repair
Nanotechnologies
Food
Footware
Consumer Products
Clothing
Automotive
Aerospace
Aeronautical
Visualization
Jewelry
Art
Electronics
Entertainment
Education
Energy
Architecture
Research and Development
SLA
SLS
FDM
Others
PMD
3DP

How to study

Manufacturing is a practical science



Topics

- Introduction
  - Traditional manufacturing
  - Overview of additive manufacturing
- How to build a 3D printer
  - Mechanical system
  - Electronics
  - Software
- How to use
  - Design and validation/optimization
  - Processes and Materials
  - Applications
- Economics and future directions

Objectives

- Fundamental concepts: Material-Process-Structure-Property—Design & Manufacturing—Machine
- Understand the underlying physical principles
- Understand how the machine works and how to build a machine
- Understand its advantages and limitations, opportunities and challenges
- Collaborative&Project learning: P2P and active learning



Activities & Grading

Grading: the grading for the class will be determined using the following weights:

○ **Assignments:**	**15%**
○ **Literature review project (individual):**	**20%**
➢ Report	15%
➢ Presentation	5%
○ **Technology survey project (individual):**	**15%**
➢ Report	10%
➢ Presentation	5%
○ **Design project (Team):**	**45%**
➢ Proposal	5%
➢ Demo	5%
➢ Final report	30%
➢ Presentation	5%
○ **Participation:**	**5%**
○ **Total Score:**	**100%**

In all team project reports, please describe the contribution of each individual team member. Team projects will be graded on both individual and team basis. Your score for the team projects will be the average of your individual score and the team project score.

What is Manufacturing

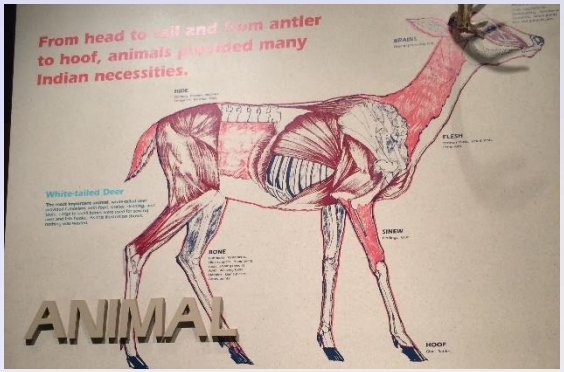
Make **Functional** **Stuff**

Out of **Raw Materials**

Raw Materials

Ancient civilization (Raw Materials – Stone age)

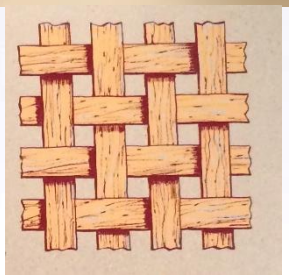
Stone: product and tooling material
Wood: most used material – buildings, tools, weapons, fuel, etc.



Animals: more than food
– bone for fishhooks, needles, arrows, etc.
– Sinew for bindings, glue, etc.
– Skin and fur for clothing, shelter, etc.

Processes:
Cutting
Molding
Weaving
Glue

Pottery: soil and earth
– container for food storage, cooking, ceremonial vessels, etc.



Shell: ornaments, tools (spoon), money
Natural Fiber: plants, tree, animal hair for house roofs, weaving materials

Raw Materials

Bronze Age (use of fire)

Weapon and tool

Container

Ornaments

Processes:

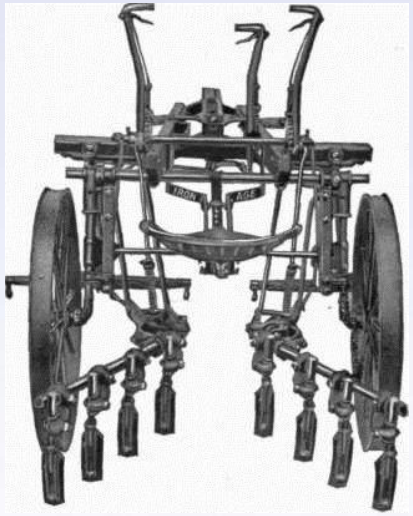
- ❑Cutting
- ❑Molding
- ❑Weaving
- ❑Casting
- ❑Forging
- ❑Welding

Raw Materials

Iron Age (use of fire – higher temperature)

Houses

Tool



Machinery

Weapon

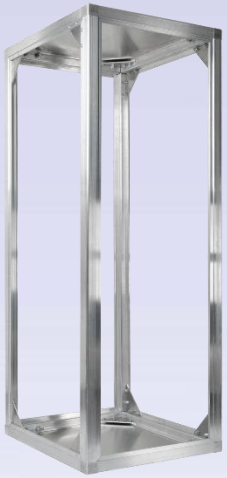
Processes:

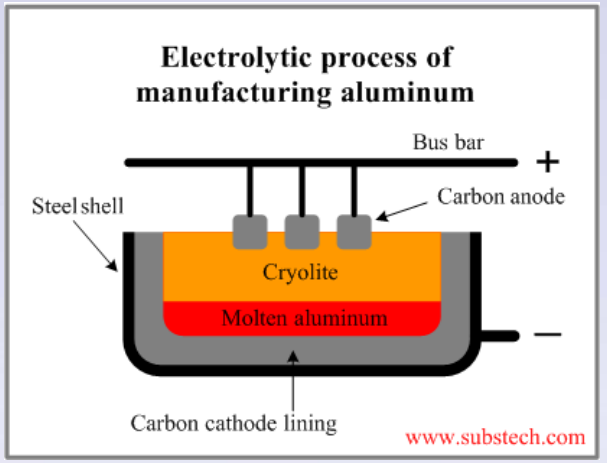
- ❑Cutting
- ❑Molding
- ❑Weaving
- ❑Casting
- ❑Forging
- ❑Welding

Raw Materials

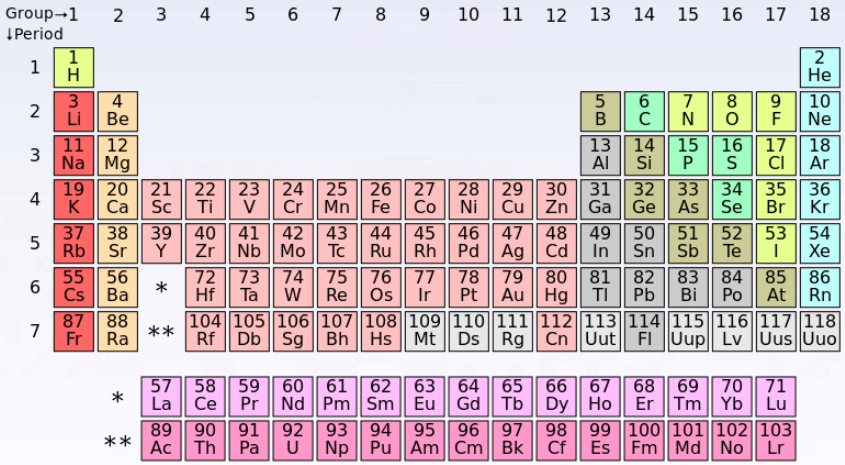
Other Natural Materials

Gold and Silver (Nobel metals)

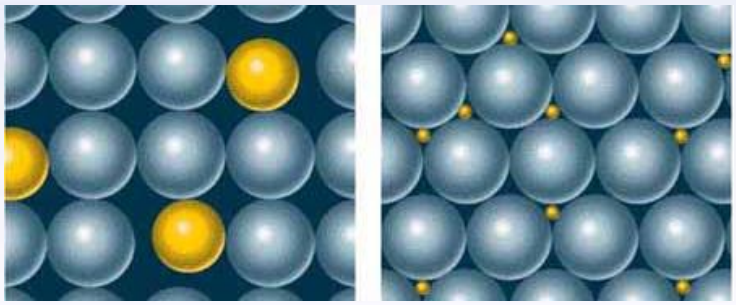




Aluminum: Hall-Heroult Process



Periodic table: Mendeleev (1869)



Alloys (mixing elements together)

Raw Materials

- Introduction
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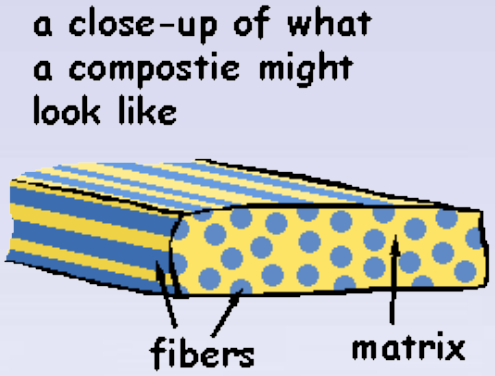
- **"New Materials Age" (More New/Synthetic/Meta Materials)**

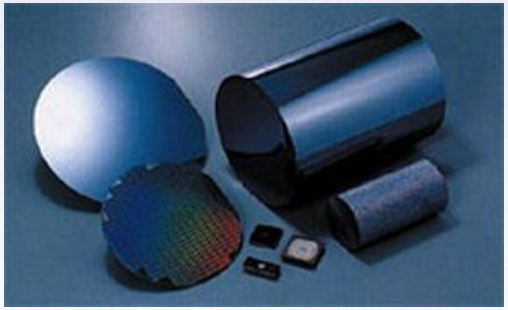
Charles Goodyear 1846 Vulcanized rubber (mixing sulfur in natural rubber)

Polymers (ubiquitous, plastic bags, DNA, etc.)

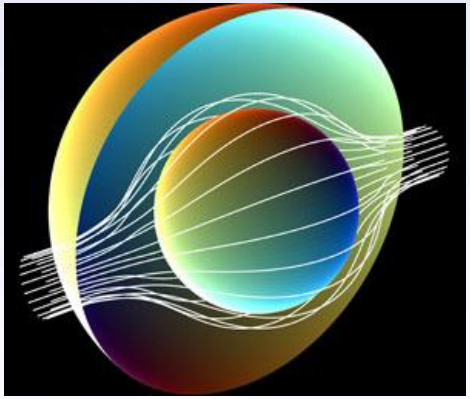


Composites

Synthetic materials (e.g. Nylon from Du Pont in 1930s)



Semiconductor materials



Metamaterials (David Smith 2000s: cloak)

What is Manufacturing

Make **Functional** **Stuff**

Out of **Raw Materials**

Functionality

What Constitutes Functionality of a product?

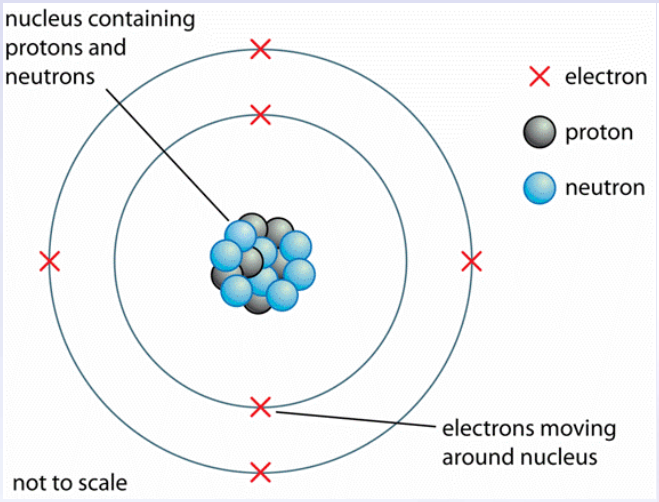
Geometry (structure)

Material Properties

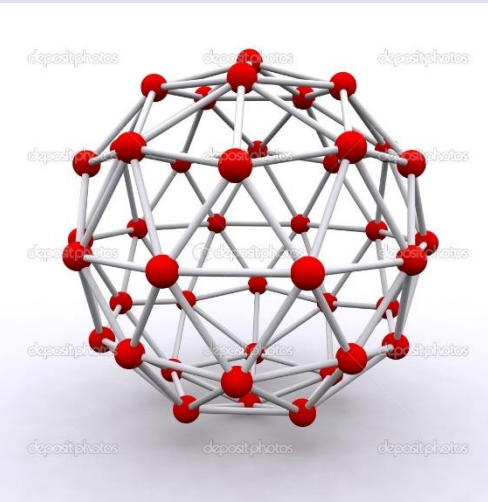
Functionality

Geometry (Multiscale)

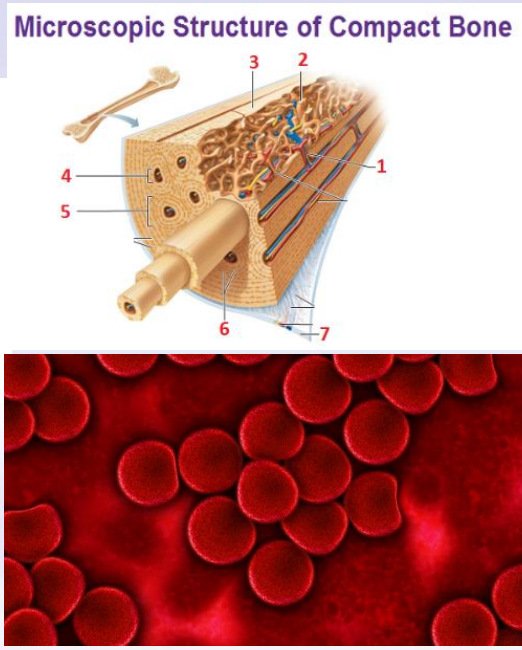
- How materials are organized in space
- On different scale



Atomic structure



Molecular structure

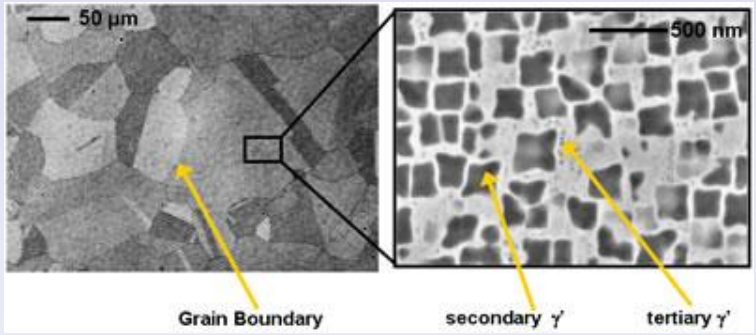


Microscopic structure

Functionality

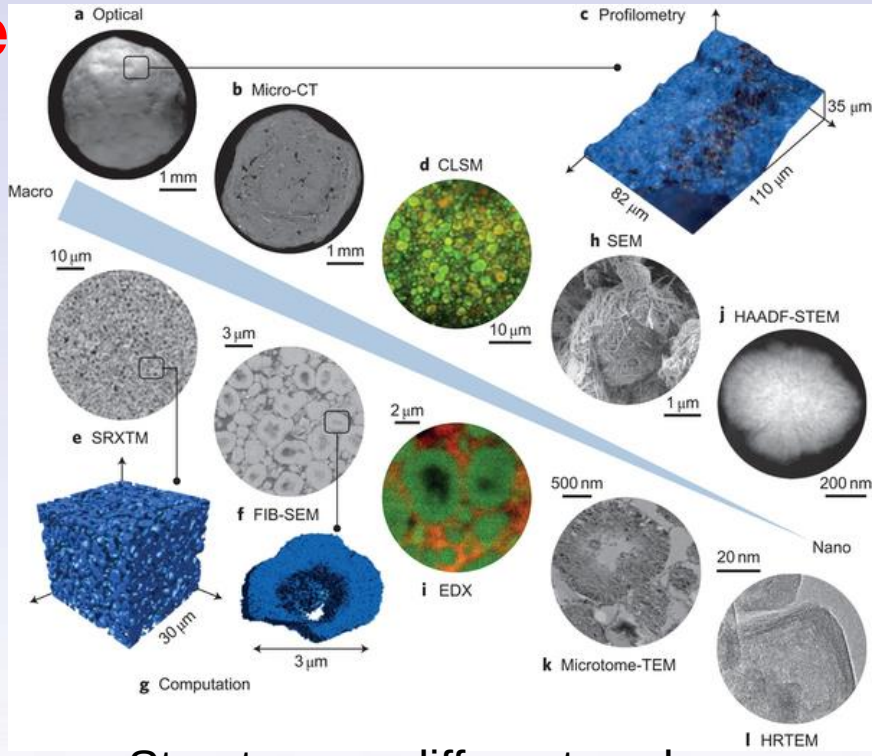
Geometry (Multiscale)

- How materials are organized in space
- On different scale



Microscopic/Mesoscopic structure

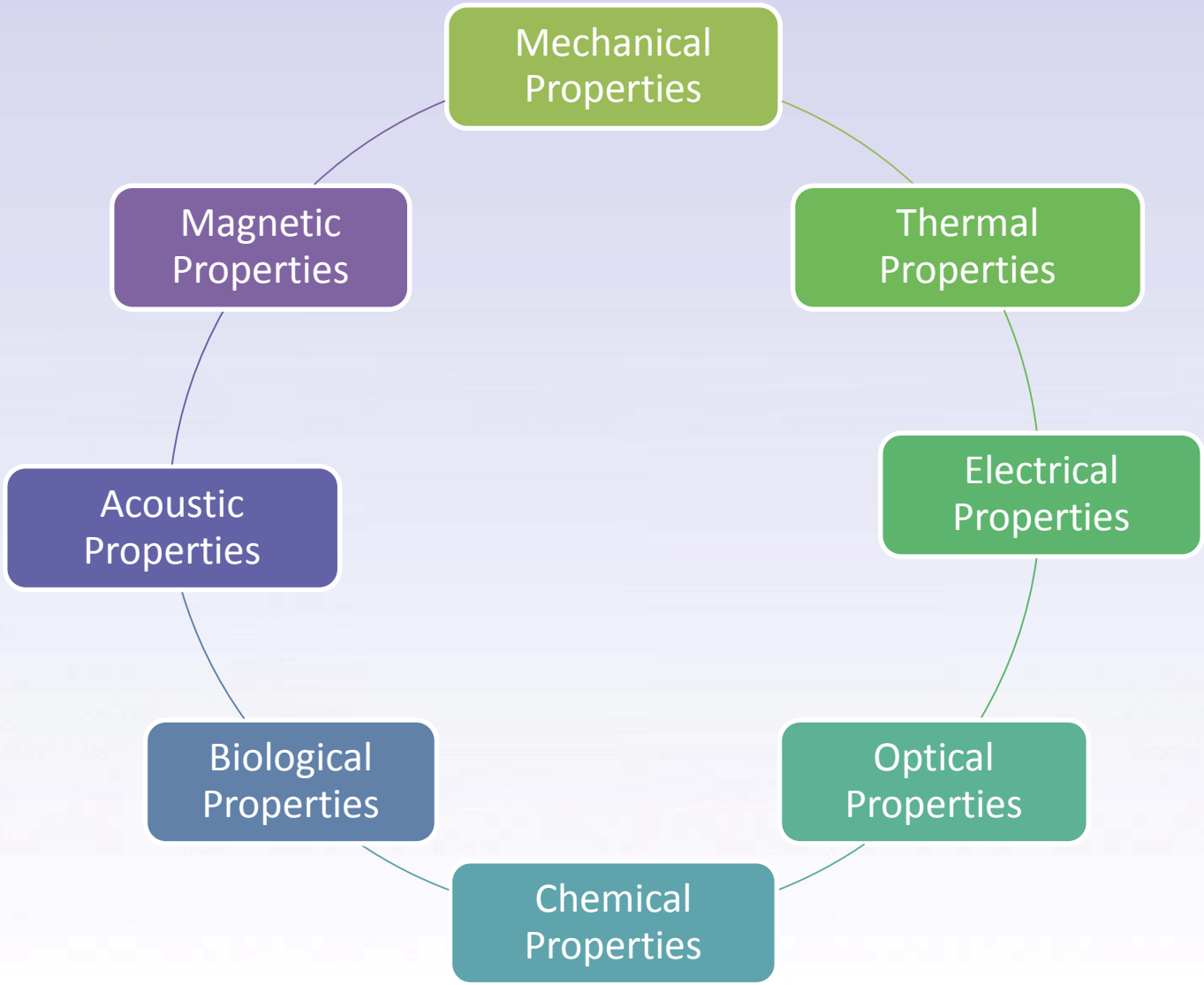
Macroscopic structures



Structure on different scale

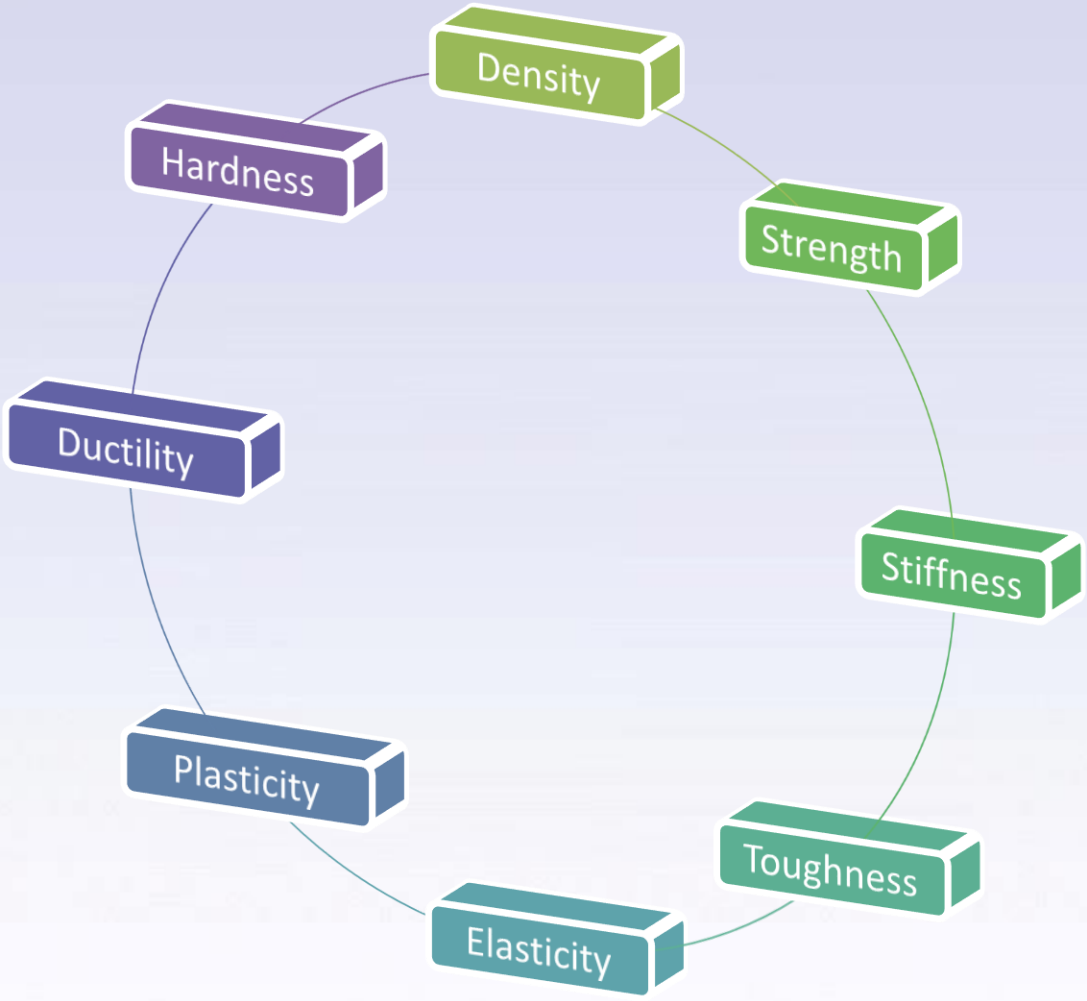
Functionality

Properties of Materials



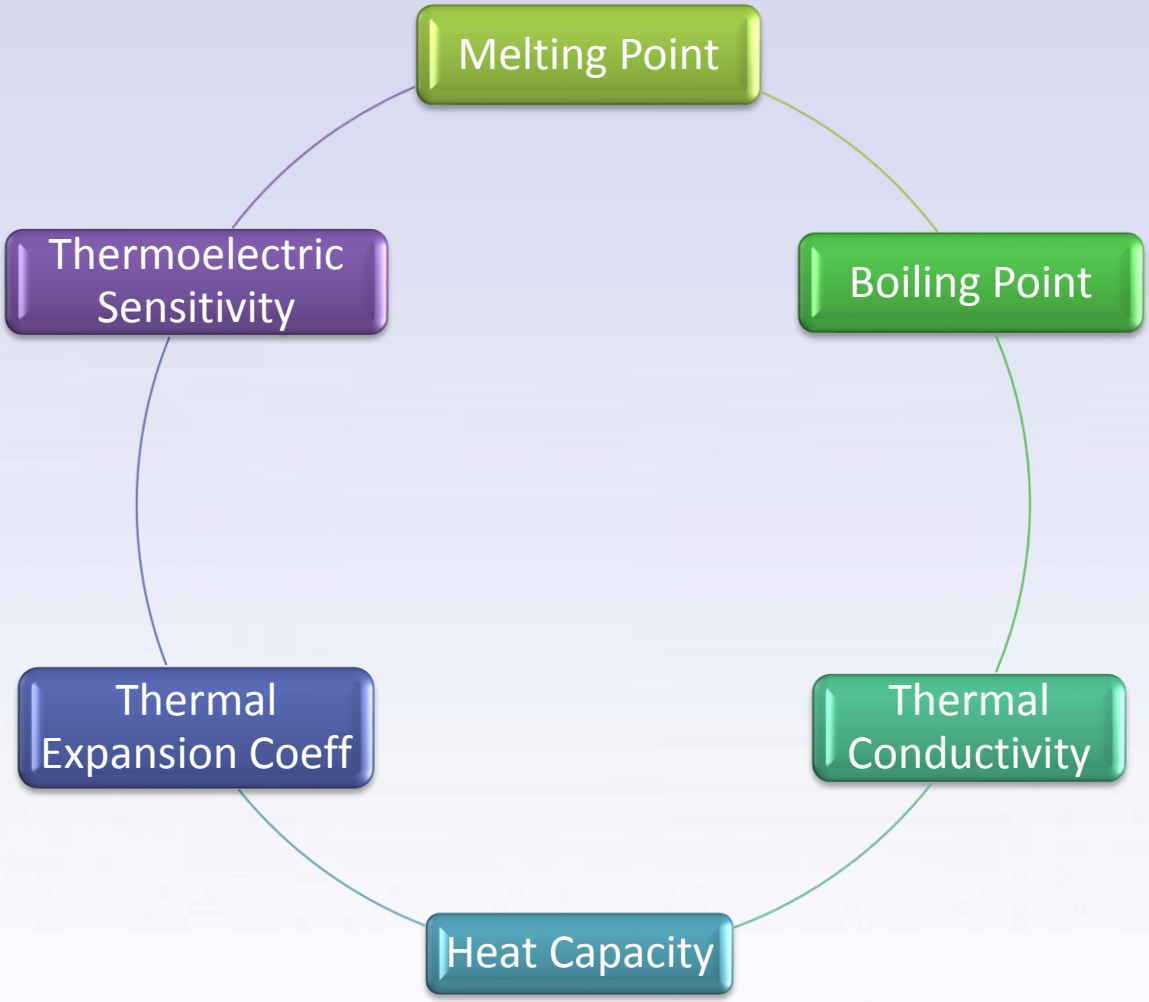
Functionality

Mechanical Properties



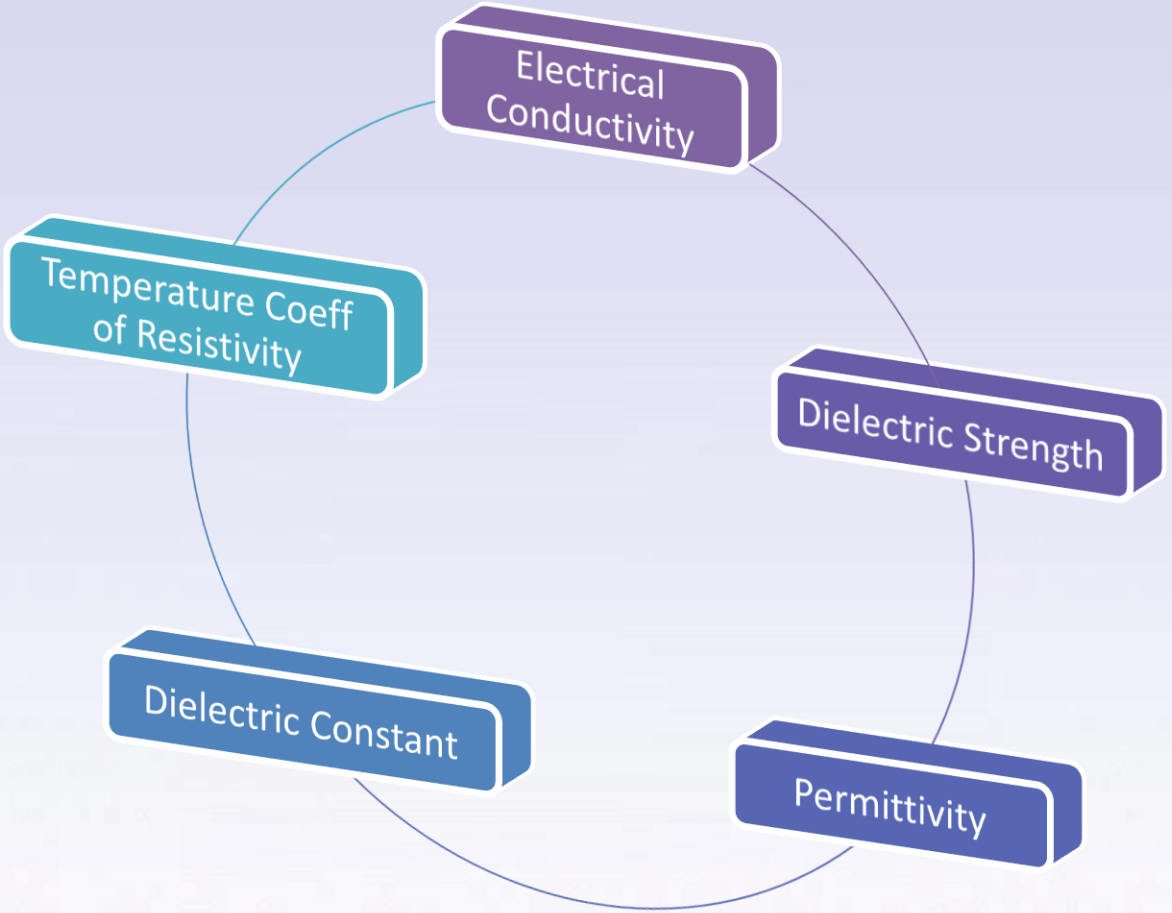
Functionality

Thermal Properties

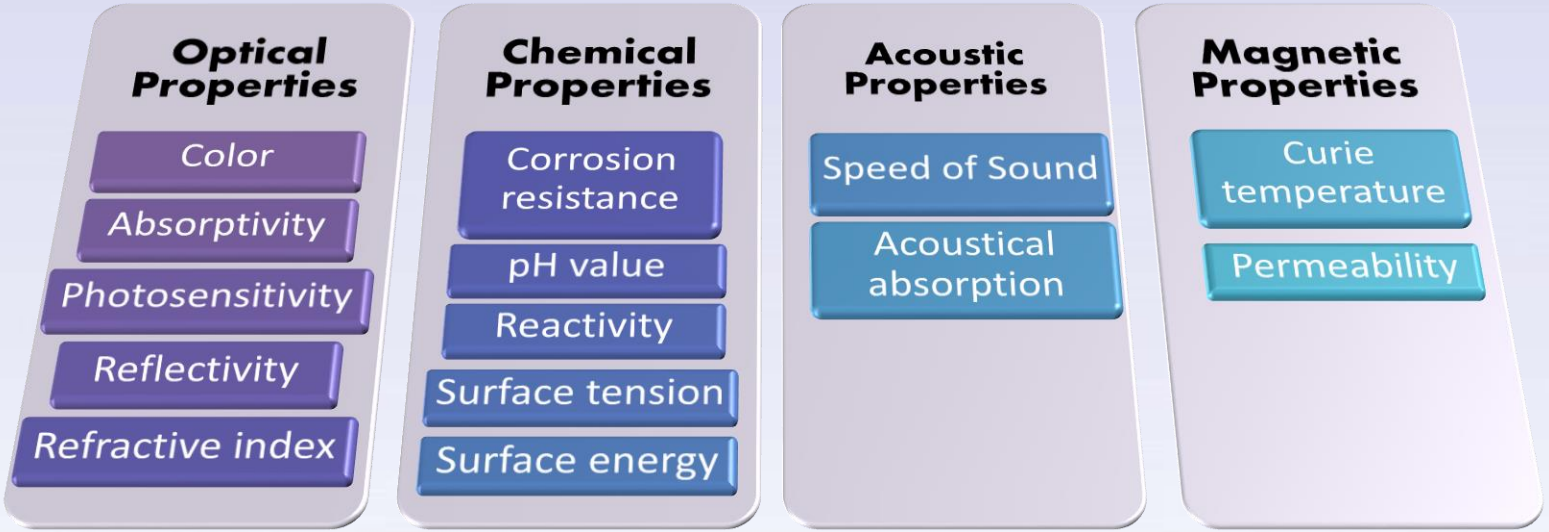


Functionality

Electrical Properties



More Properties (all are intensive properties on quantifying the relationship and interaction between mass, energy, and space time)



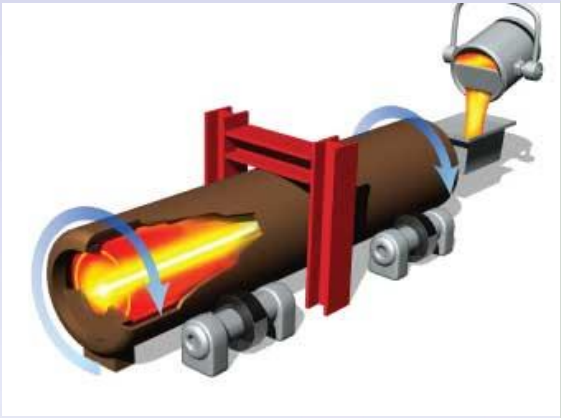
What is Manufacturing

Make **Functional** **Stuff**

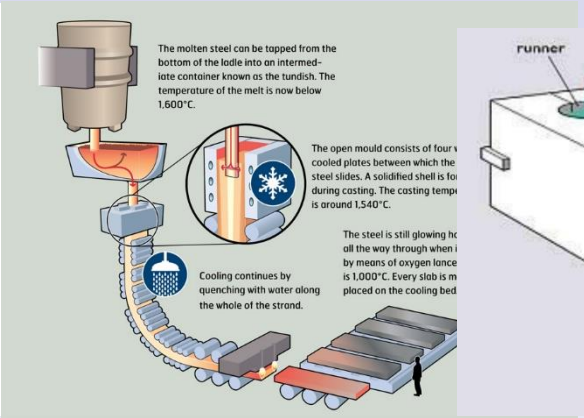
Out of **Raw Materials**

How to make

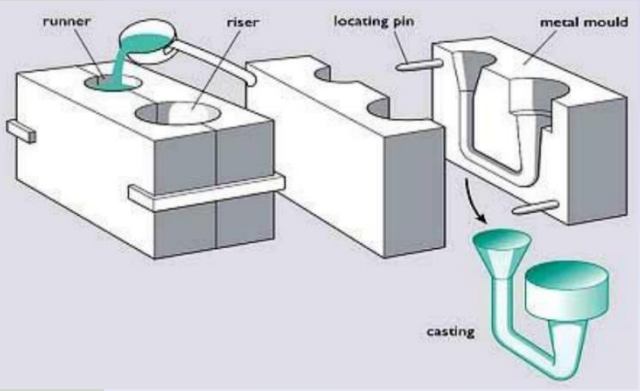
- **Casting**



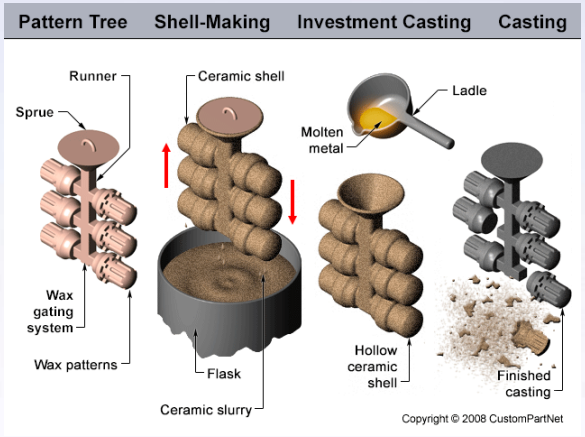
Centrifugal Casting



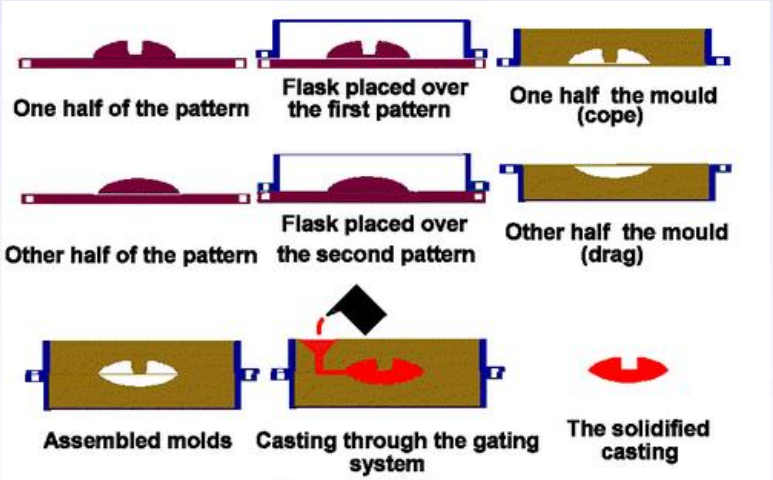
Continuous Casting



Die Casting



Investment Casting

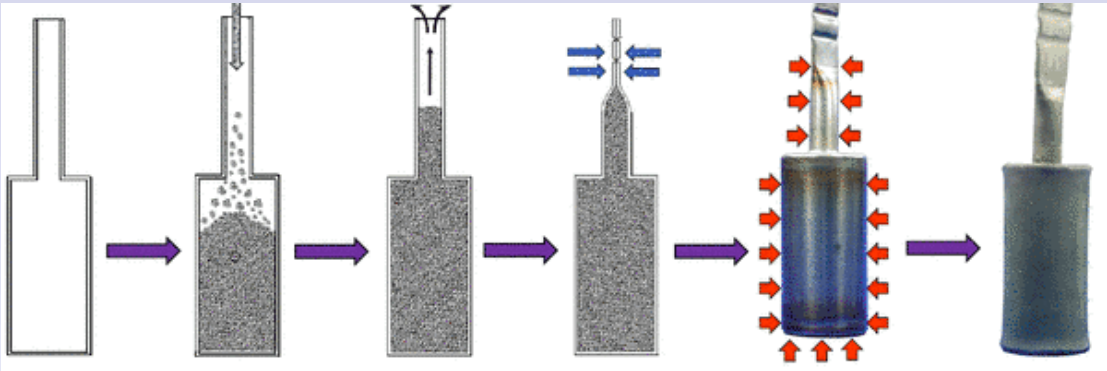


Sand Casting

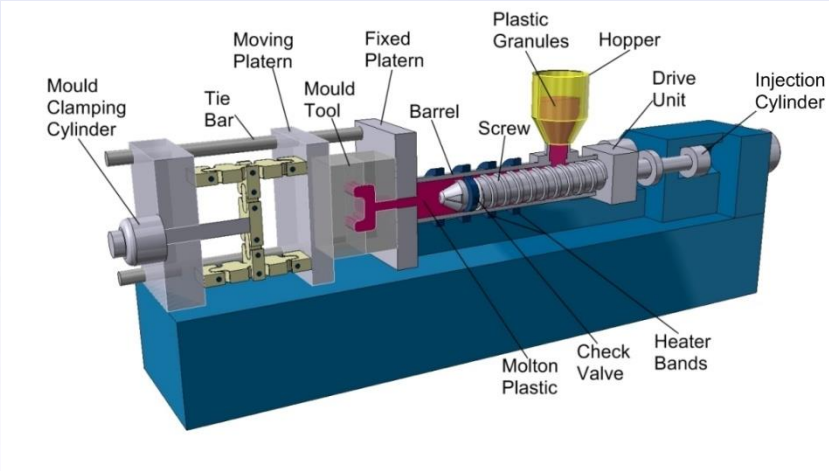
Manufacturing Processes

How to make

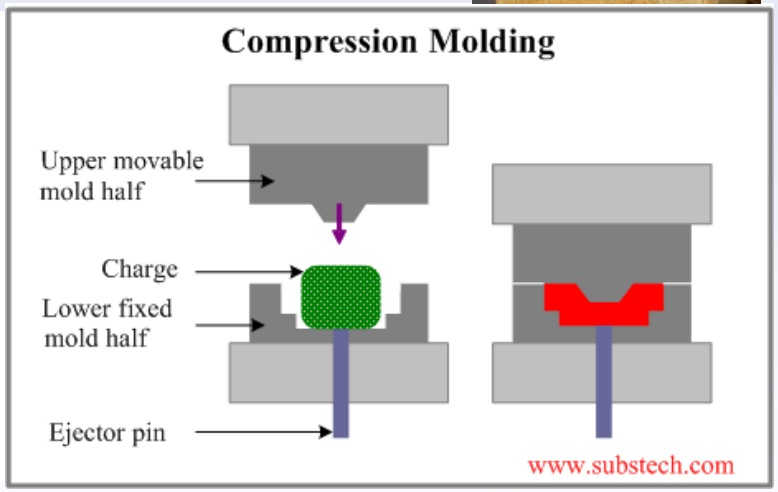
- **Molding**



Hot Isostatic Pressing



Injection Molding



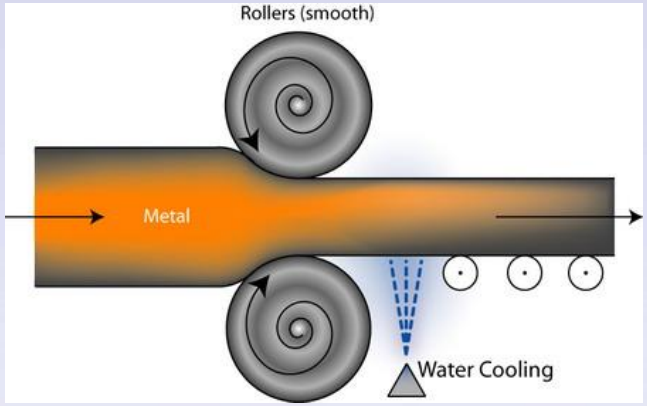
Compression Molding

Manufacturing Processes

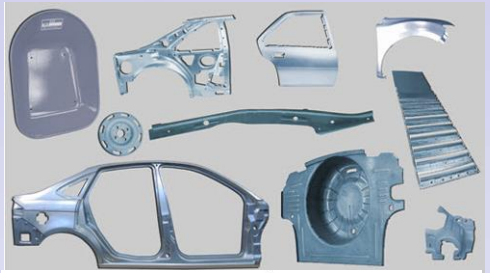
How to make

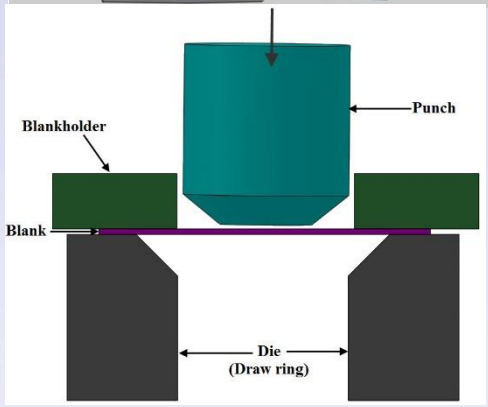
- **Forming**

Forging (a sword)

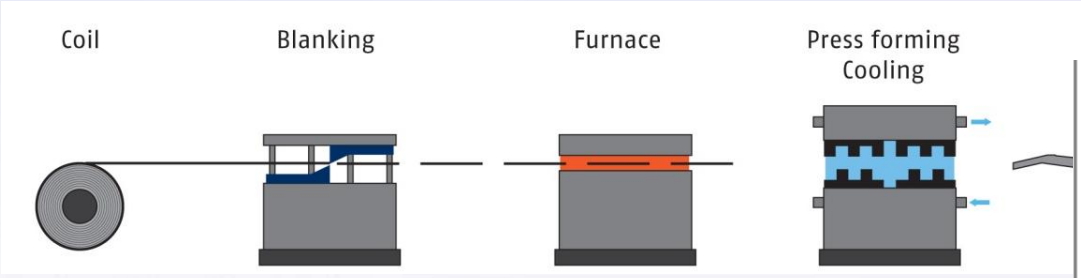


Rolling (metal sheets)

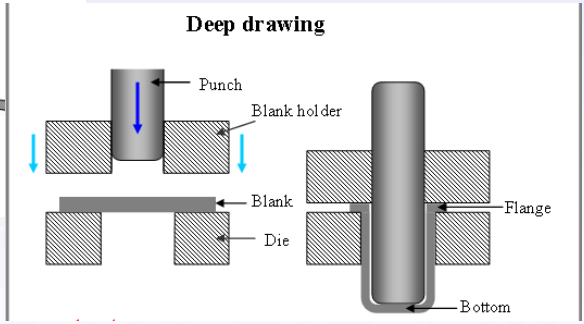




Piercing (holes)



Stamping (molding metal sheets)

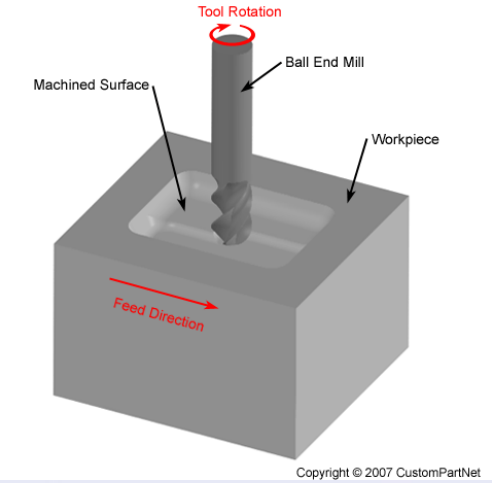


Deep drawing

Manufacturing Processes

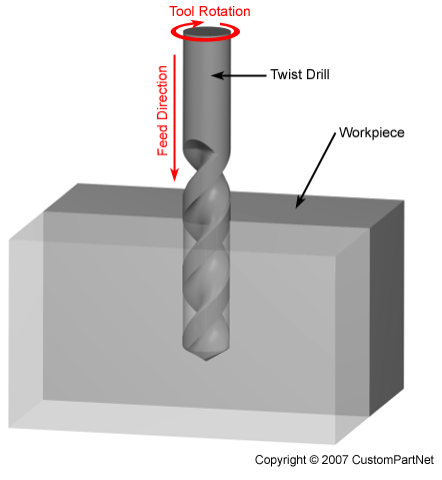
How to make

- **Machining**

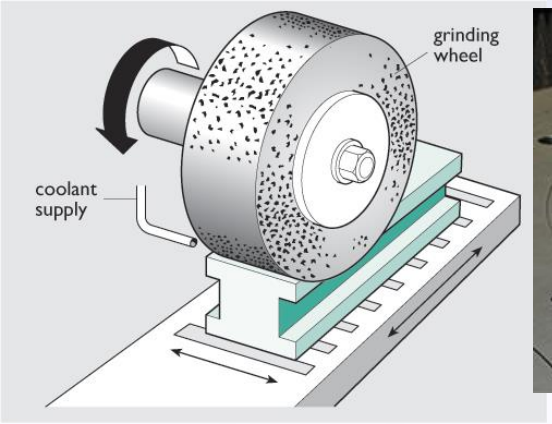


Milling

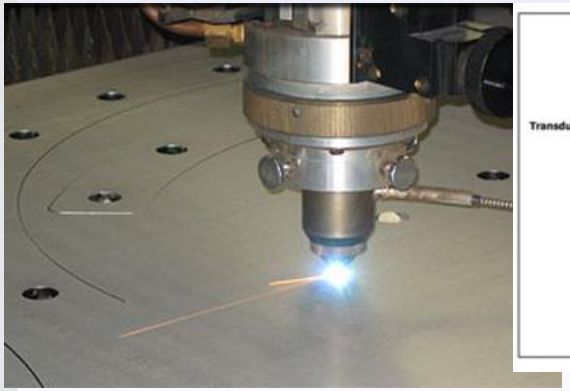
Lathing



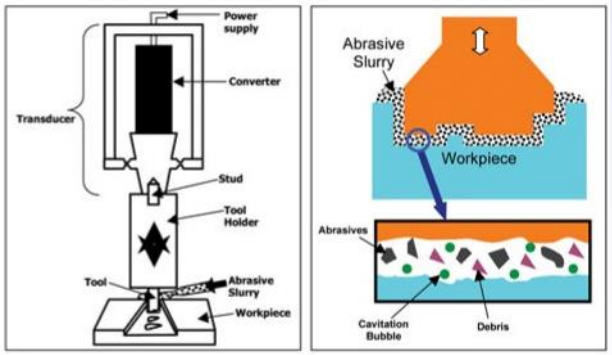
Drilling



Grinding



Laser Cutting

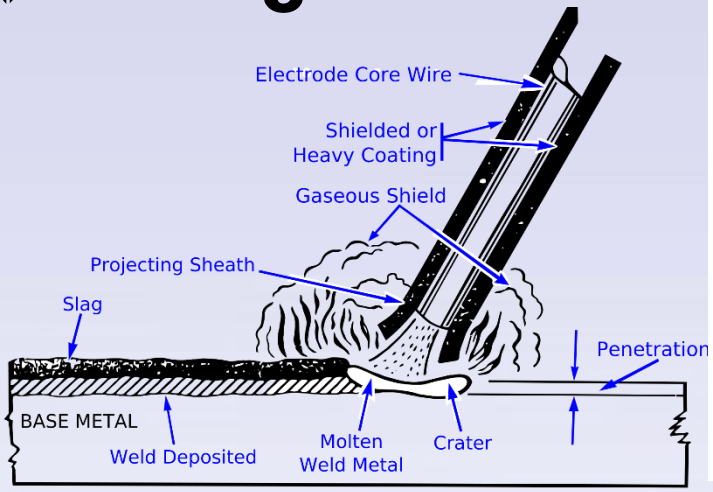


Ultrasonic Machining

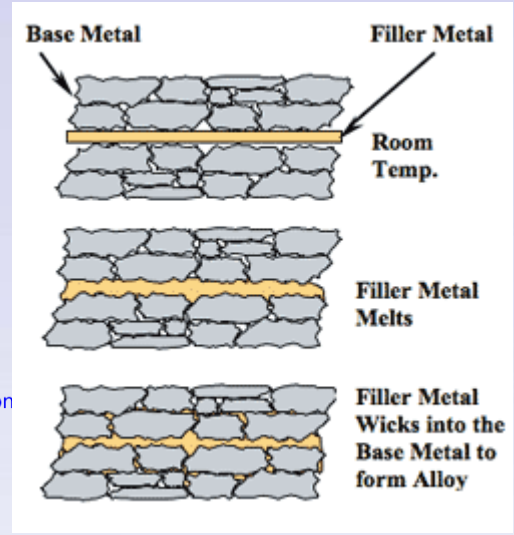
Manufacturing Processes

How to make

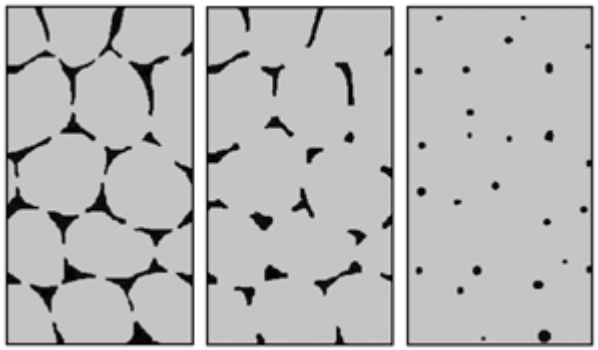
- Joining



Welding

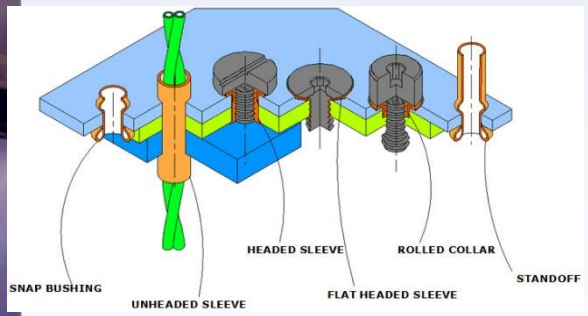


Brazing



Sintering

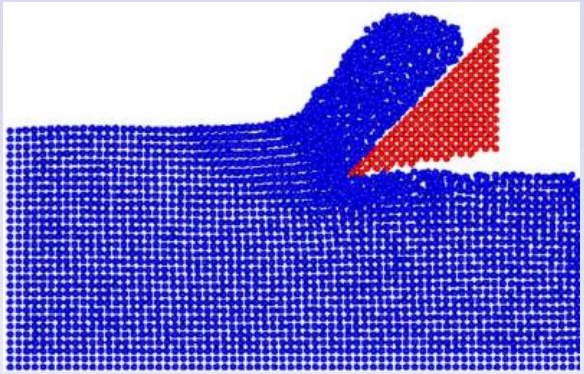
Adhesive Bonding



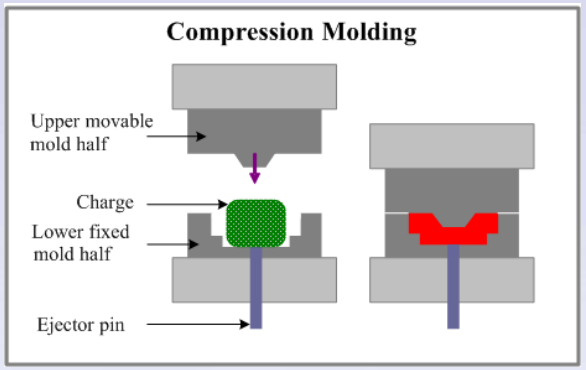
Fastening

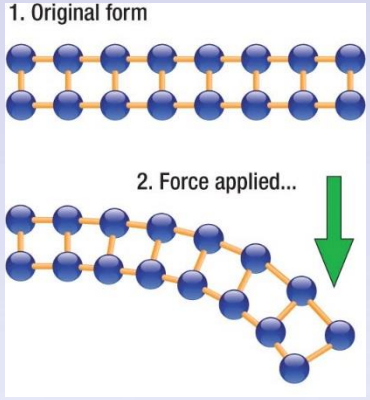
How to make

- **Patterning: Defining material interface**

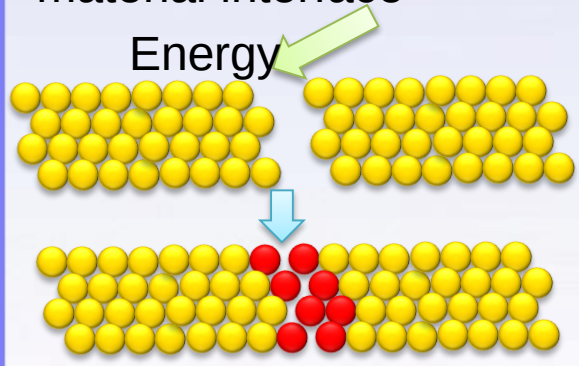


Subtractive: creating new material interface

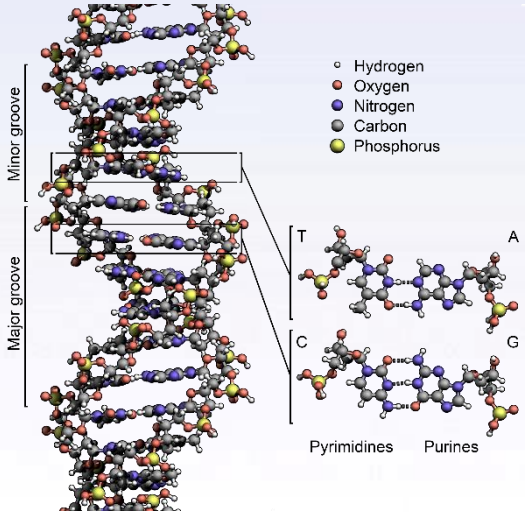




Deformative: Deforming material interface



Additive: reducing material interface between material particles



Process is HIGHLY dependent on materials (Constraints imposed by laws of physics)

What is Manufacturing

Make **Functional** **Stuff**

Out of **Raw Materials**

Design