TA201A
Manufacturing Processes

Week-2

16 Aug, 2022

2022-2023 Semester-I

Lecture2

Export from India

Automobile sector: India 4th Position

Automobile Manufacture

- Millions of automobile are manufactured every year and each of them contain thousands of components
  - In 2017, a total of 272.48 million vehicles were registered in the U.S.
  - Over 30,000 parts

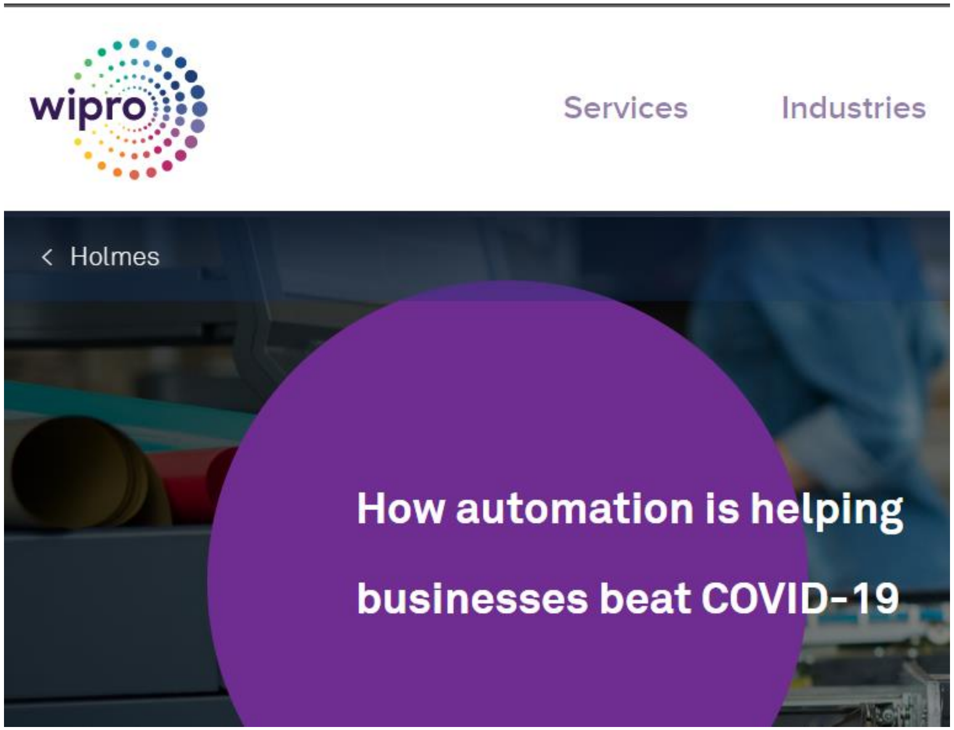
Courtesy: google Images

https://www.mcrsafety.com/

Something Interesting….

This Programmer Hacked His Coffee Machine To Brew Coffee Using Command Line

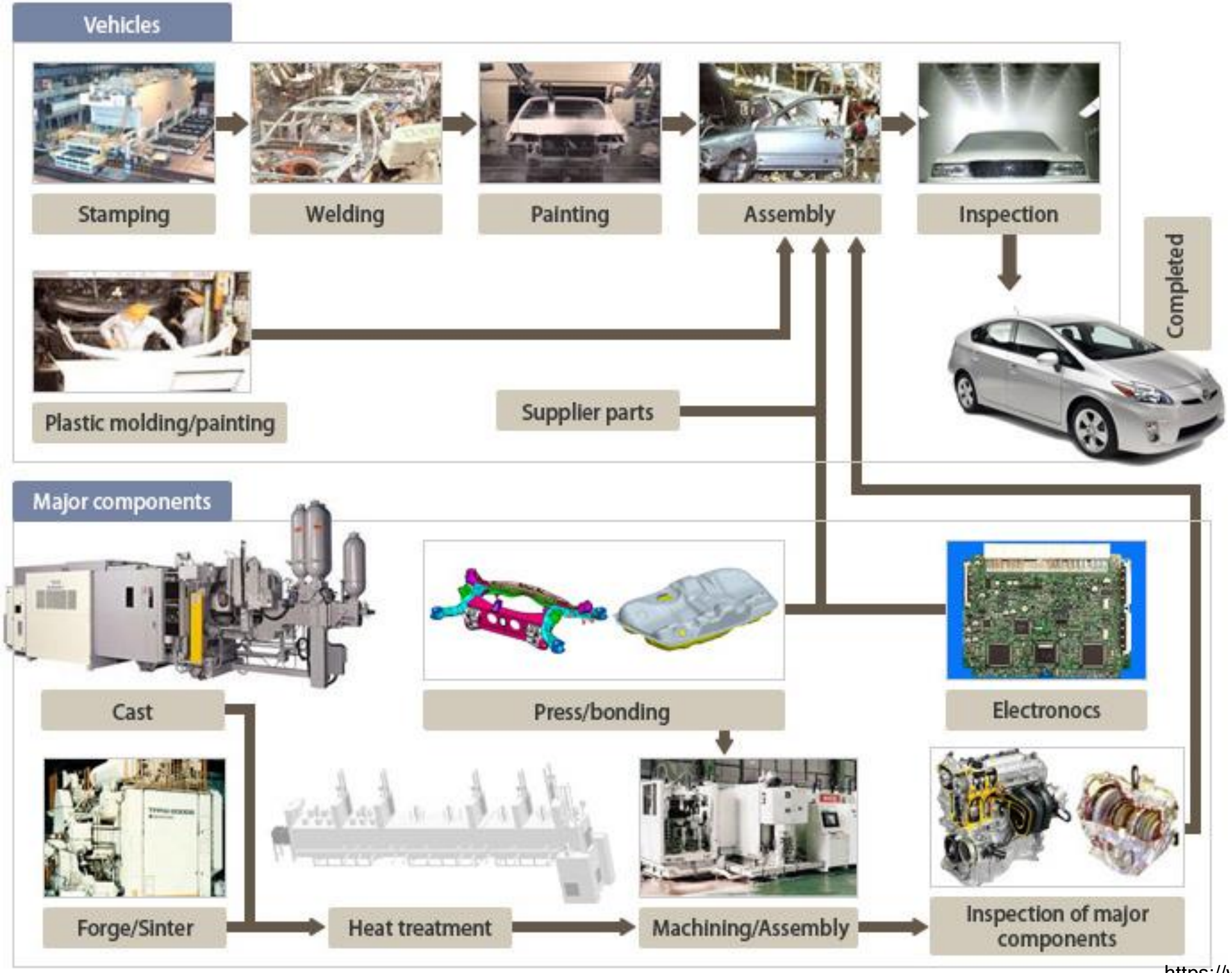
Tomi Engdahl   October 11, 2016   IoT, Open source software   2



Knowledge about manufacturing processes

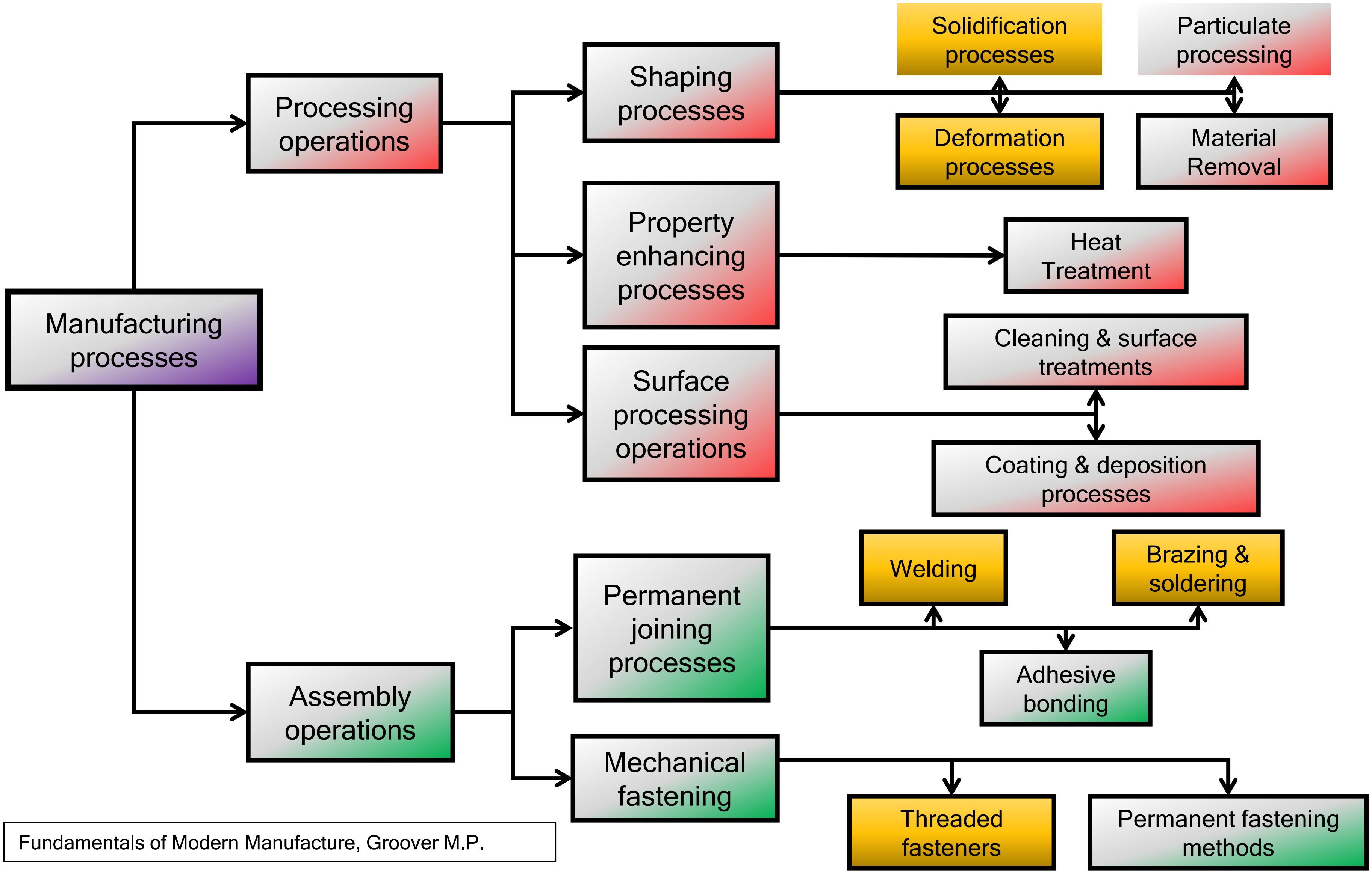
https://www.evilsocket.net/

Automobile: Manufacturing Processes



https://www.toyota-global.com/

Classification of Manufacturing Processes

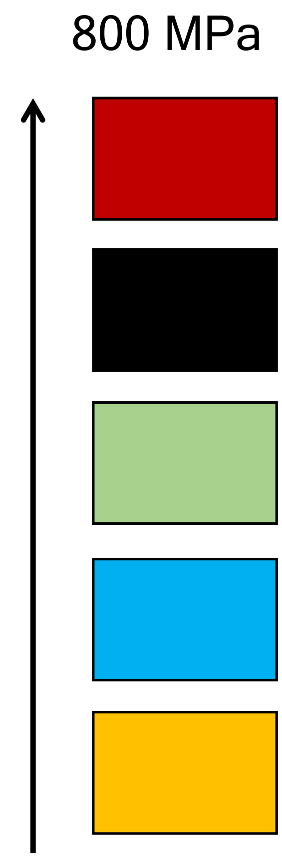


Fundamentals of Modern Manufacture, Groover M.P.

Manufacturing processes used in automobile:

- Engine Block ➔ Sand mold casting
- Body parts ➔ Stamping and other sheet metal working
- Gears and many other small parts ➔ Powder metallurgy
- Plastic components ➔ Plastic injection molding and extrusion
- Assembling ➔ Mechanical joining to welding
- Many load bearing parts ➔ Extrusion

More information on: https://thelibraryofmanufacturing.com/

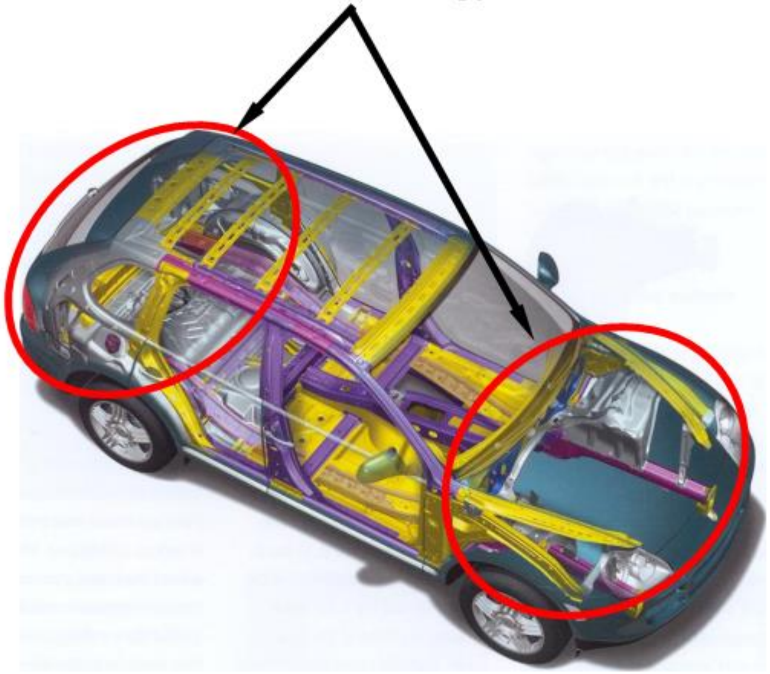


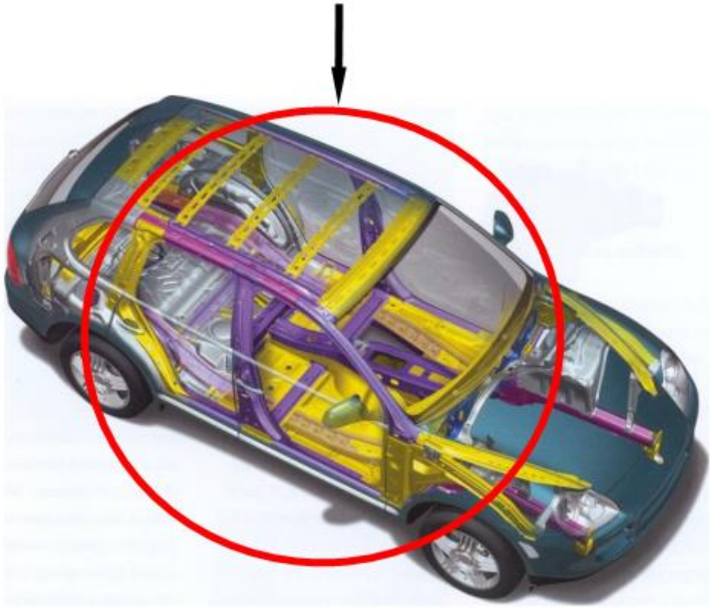
BIW (Body-in-white) for a typical automobile

Crashworthiness Fundamentals – Two Key Zones

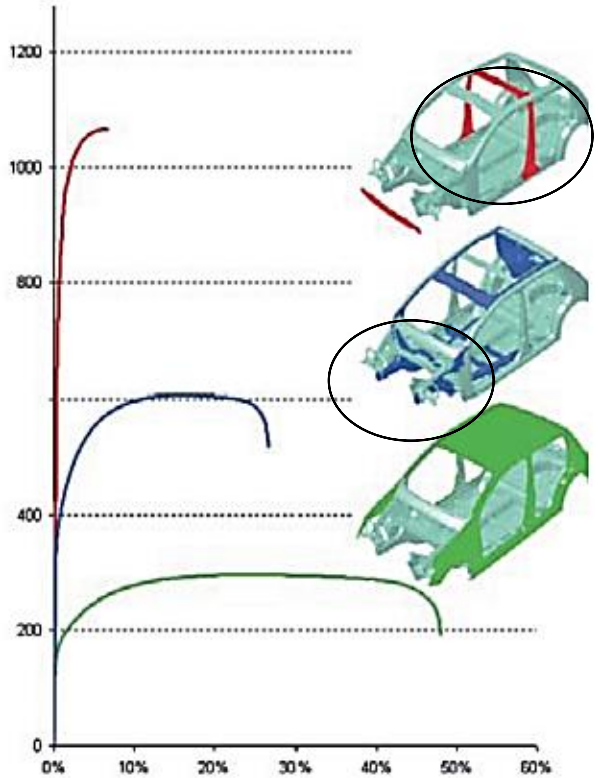
Energy Management Zones (engine compartment, trunk) deform to absorb energy

Passenger Compartment resists deformation to prevent intrusion





Safety and Materials



> Steels for safety-critical parts, especially for maintaining a passenger survival space in crash events

> High-strength steels with a good balance of strength, formability, energy absorption and durability

> Steels with excellent formability (eg. for deep drawing)

Figure 8.2: Stress (in MPa) vs. percent elongation for different steel types and their applications in body structure [Adapted from 19]

Carrie M Tamarelli, Steel Market Development Institute

Automobile Materials

Grey is mild steel
Blue is high-strength steel
Yellow is very high-strength steel
Orange is extra high-strength steel
Red is ultra-high-strength steel
Green is Aluminium

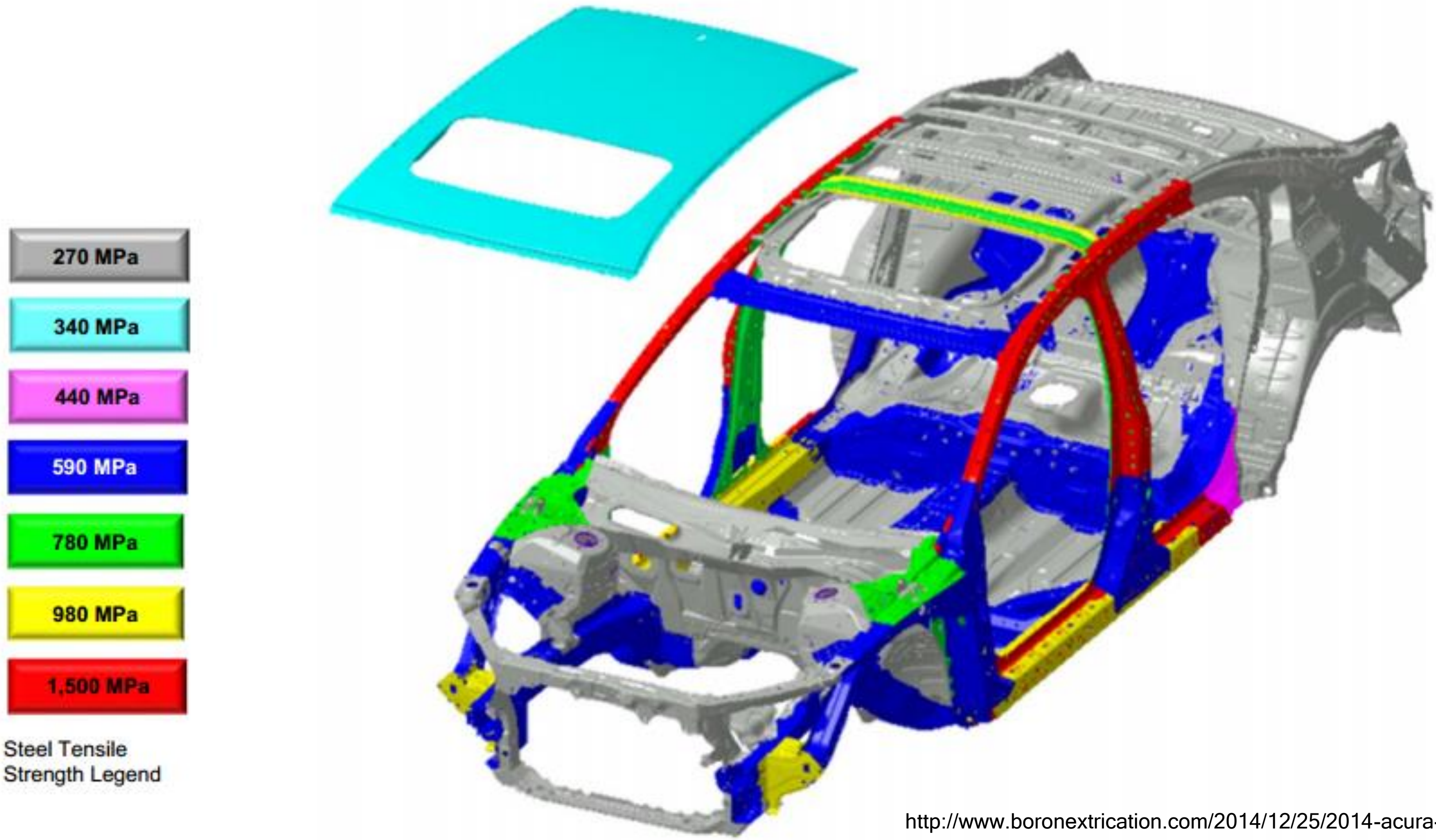
2017 Volvo V90 Body Structure

http://www.boronextrication.com/2017/08/05/2017-volvo-v90-body-structure/

Automobile Materials

High Strength Steel

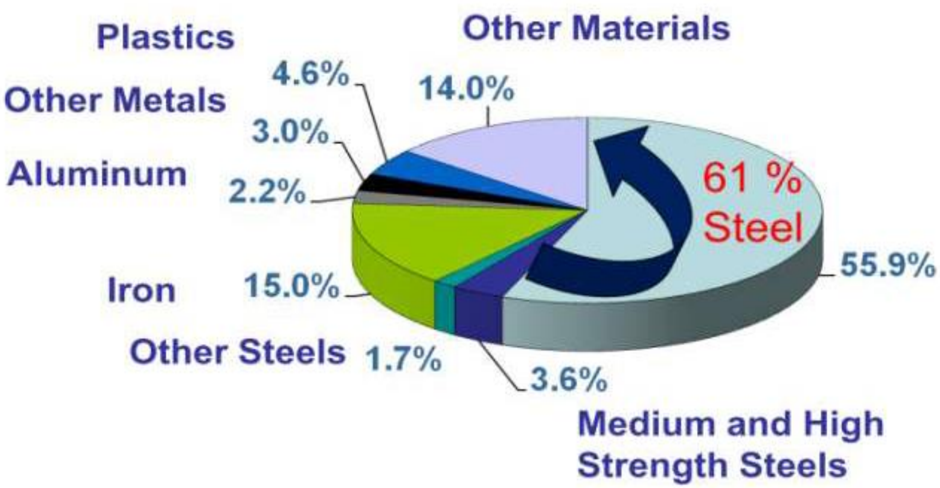
High strength steel is used in the colored areas.



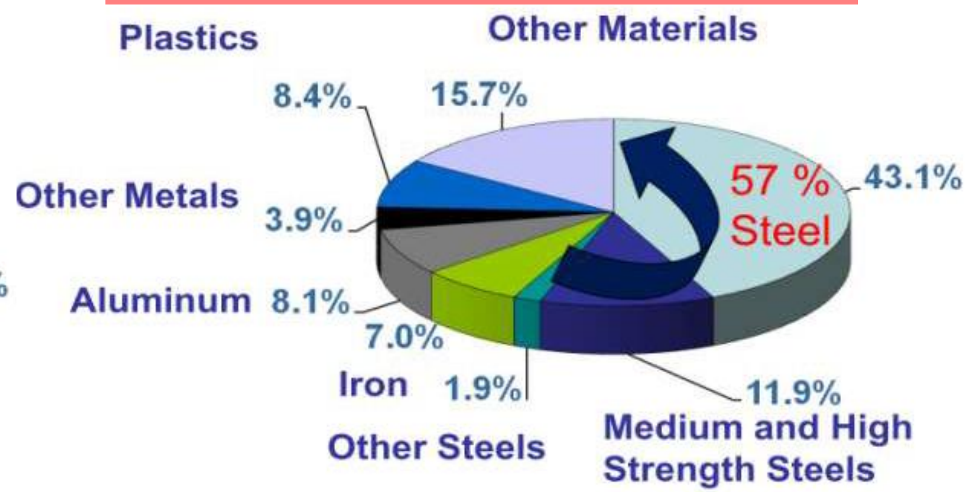
http://www.boronextrication.com/2014/12/25/2014-acura-rlx-sport-hybrid/

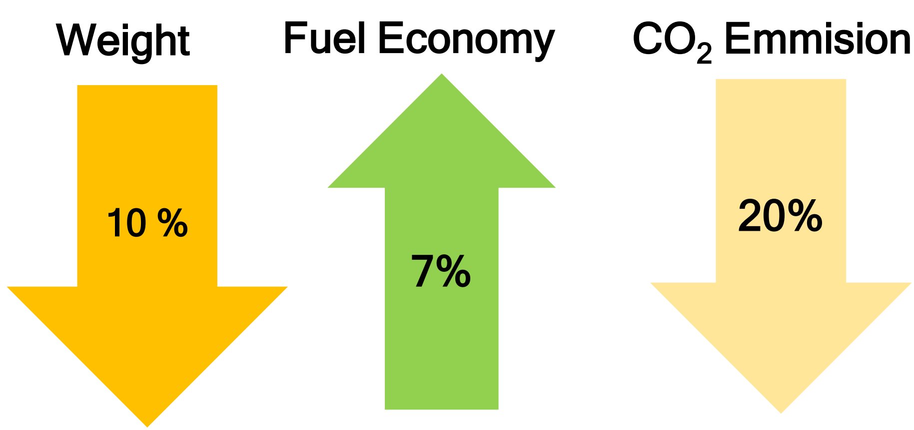
Why Newer Materials???

Materials Used for car components - 1975



Materials Used for car components - 2007

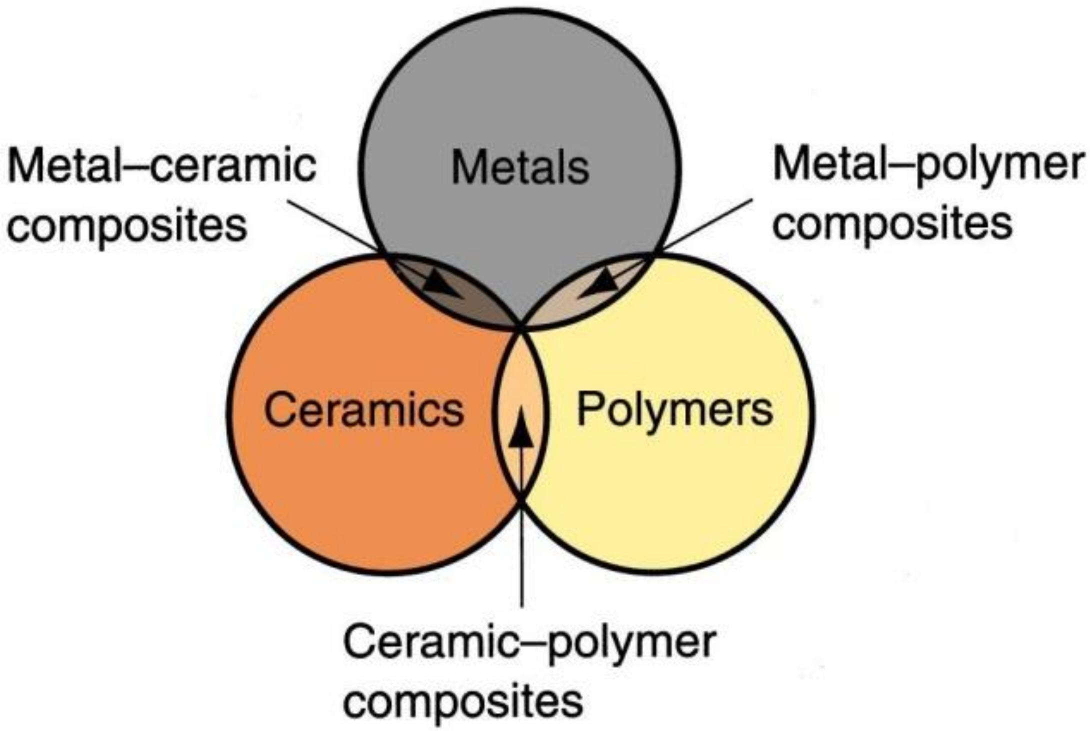




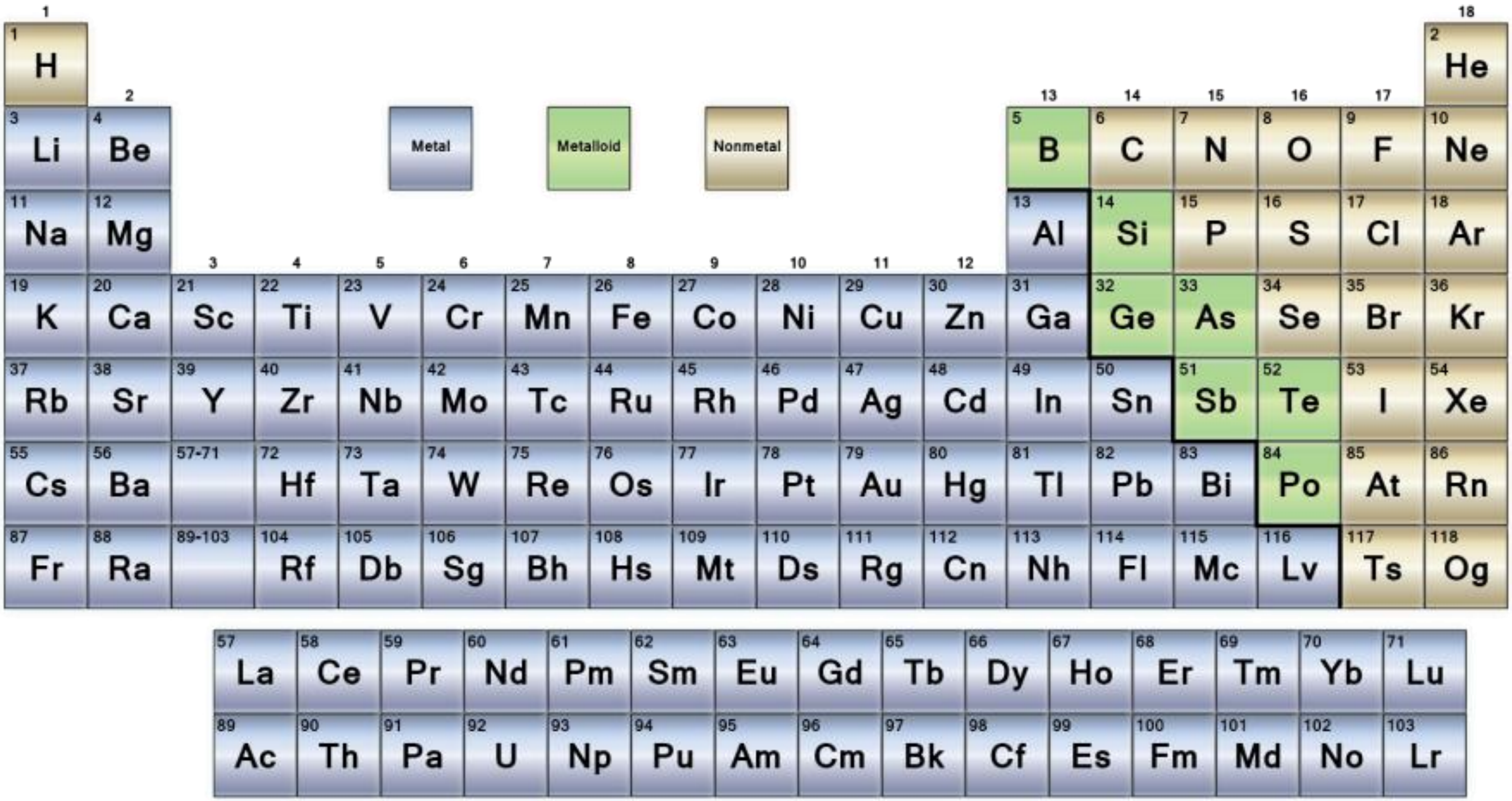
Source: www.autosteel.org

Engineering Materials: Materials in Manufacturing

- Metals
  - Ferrous (steel and cast iron) and nonferrous (Al, Ti, Ni…)
- Ceramics
  - Compounds of metallic and
- Polymers
  - Thermoplastic
  - Elastomers
  - Thermosetting
- Composites
  - Matrix & Second phases



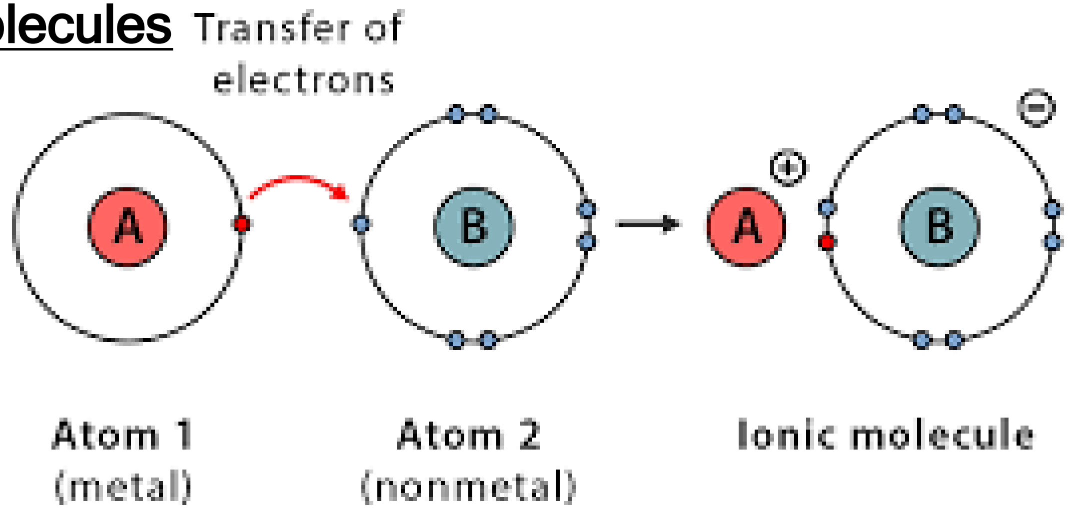
Atomic Structure and Elements

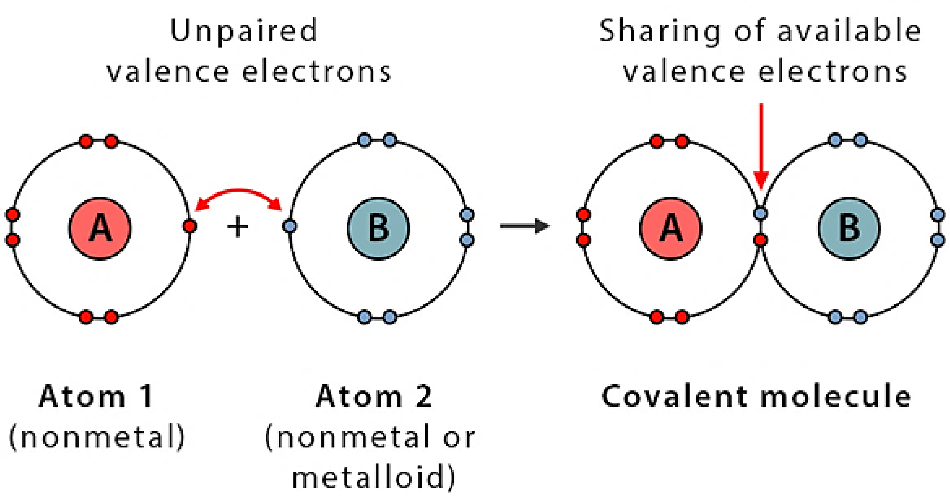


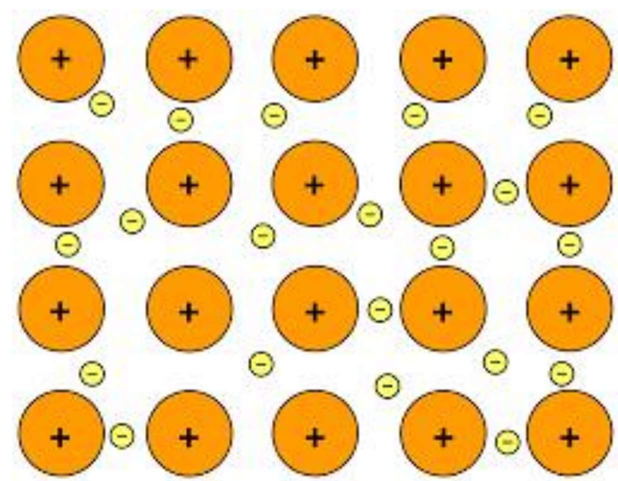
Courtesy: google Images

Bonding between atoms and molecules

- Primary
  - Ionic
  - Covalent
  - Metallic



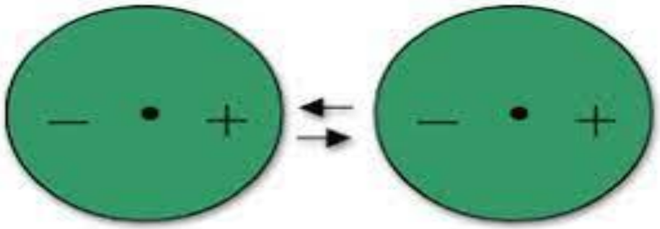




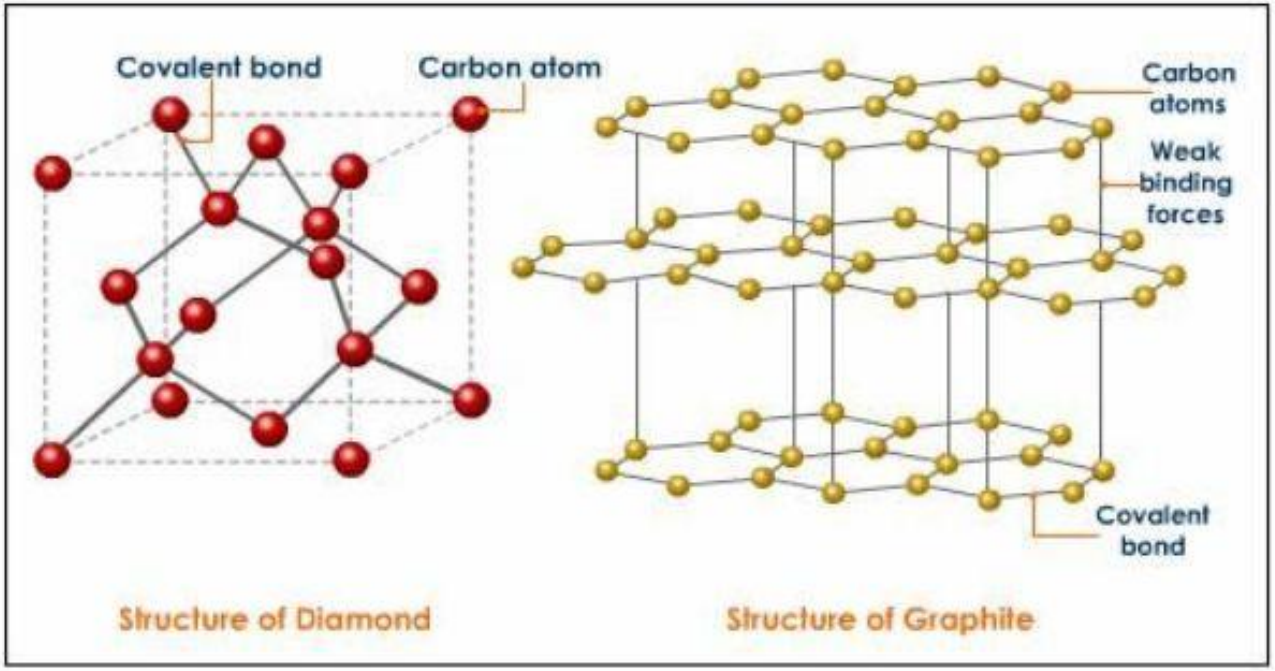
Courtesy: google Images

Atomic Structure and Elements

- Secondary
  - van der Waals forces
  - Hydrogen bonding



- Bond type Vs properties
  - Electrical conductivity
  - Ductility
  - Hardness



Courtesy: google Images

Classifications of Solids

Solids

Crystalline

Long-range Order (LRO)

Amorphous

No Long-range Order

Short range order (SRO)

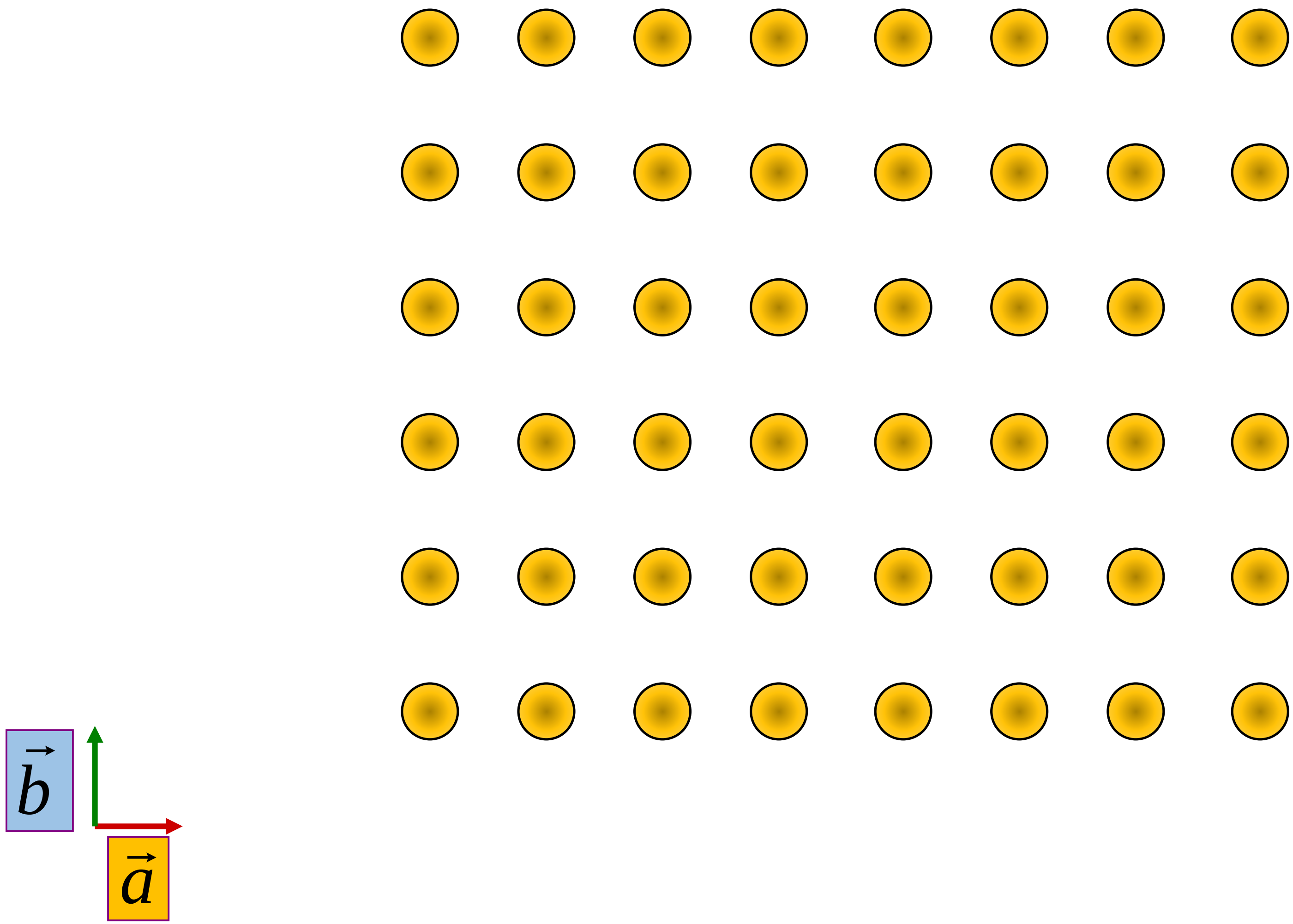
Crystalline Structures

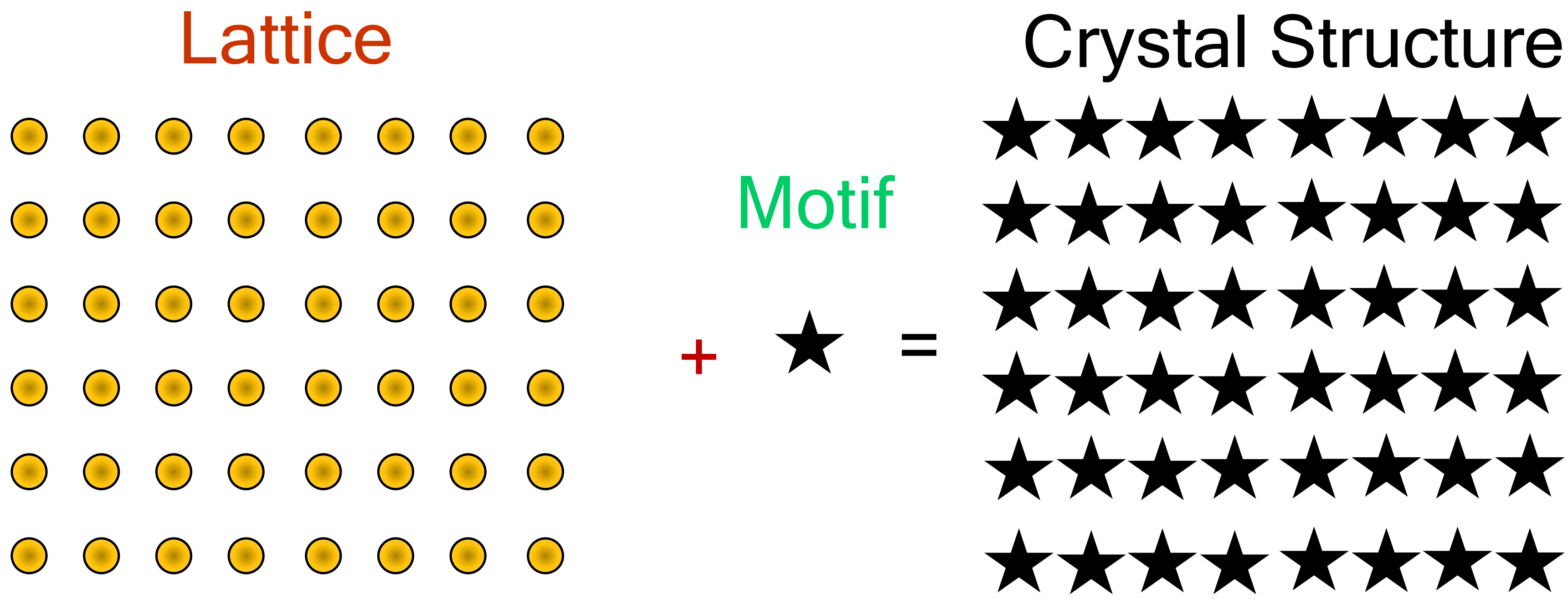
- Crystalline Structures: Atoms are located at regular and recurring positions

  Crystal structure = Motif + Lattice

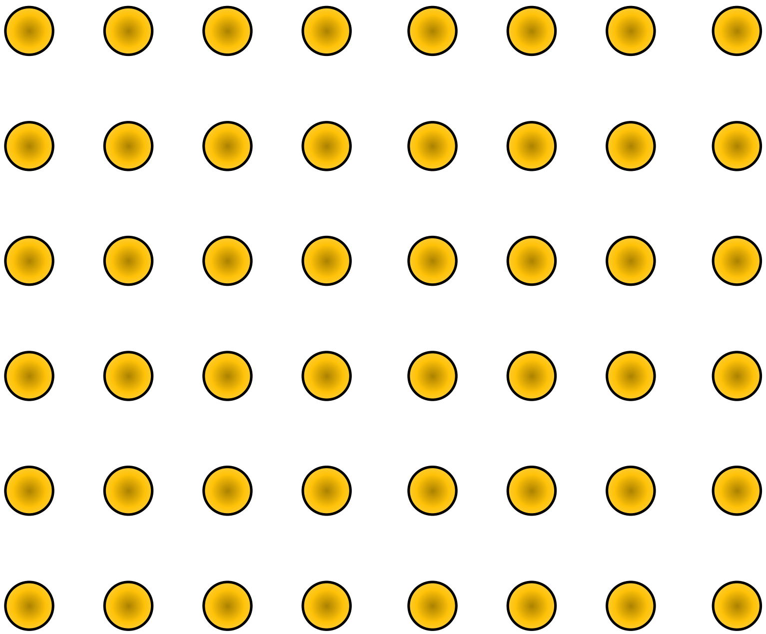
- <u>Motif:</u> atom, group of atoms associated with each lattice point
- <u>Lattice:</u> infinite arrangement of points in space (1D, 2D or 3D) in which all points have same surrounding
- Lattice: how to repeat
- Motif (basis): what to repeat

2D Lattice




Lattice
Motif
+
=
Crystal Structure

Symmetry

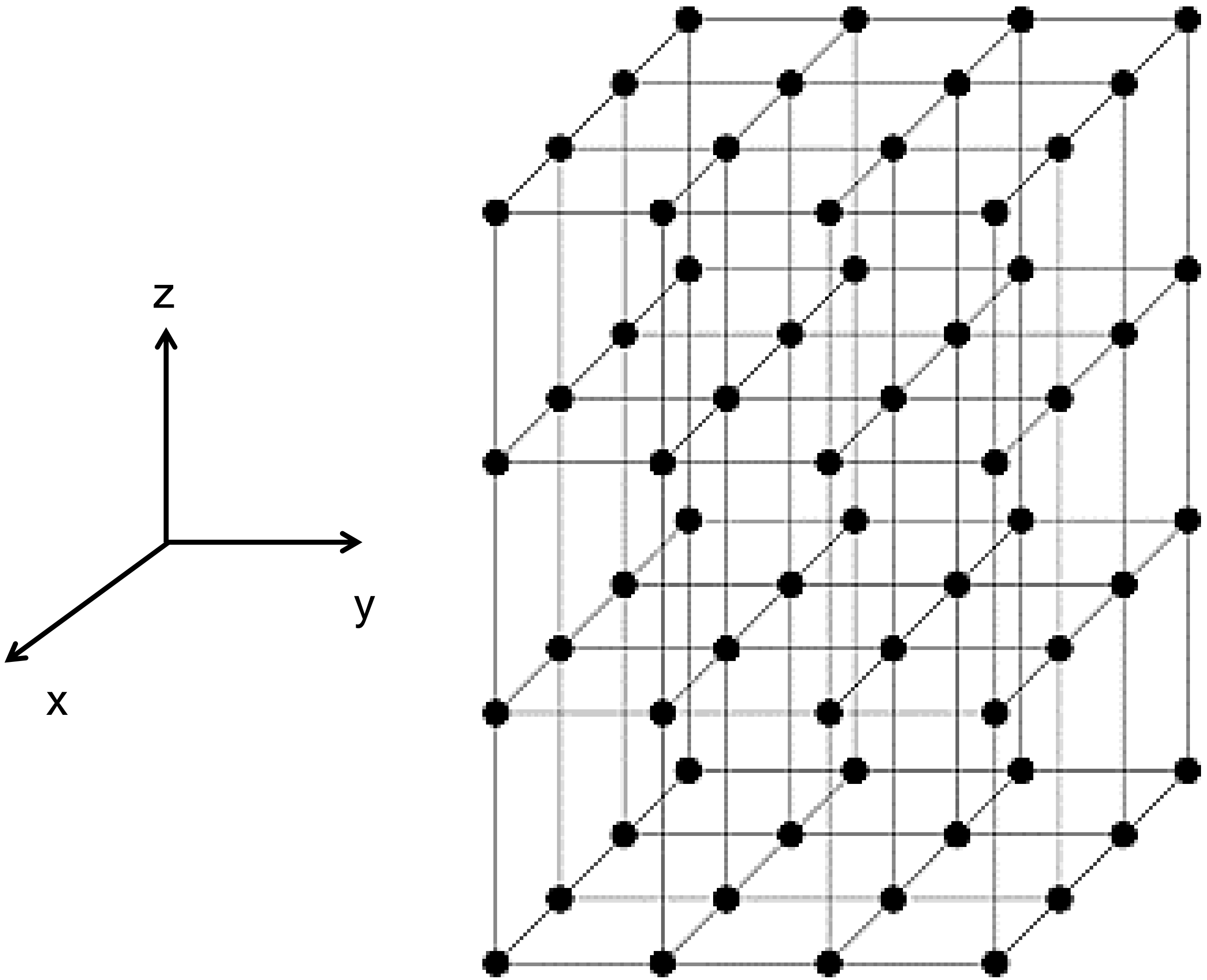


Translational Symmetry

Rotational Symmetry

Long-Range Order

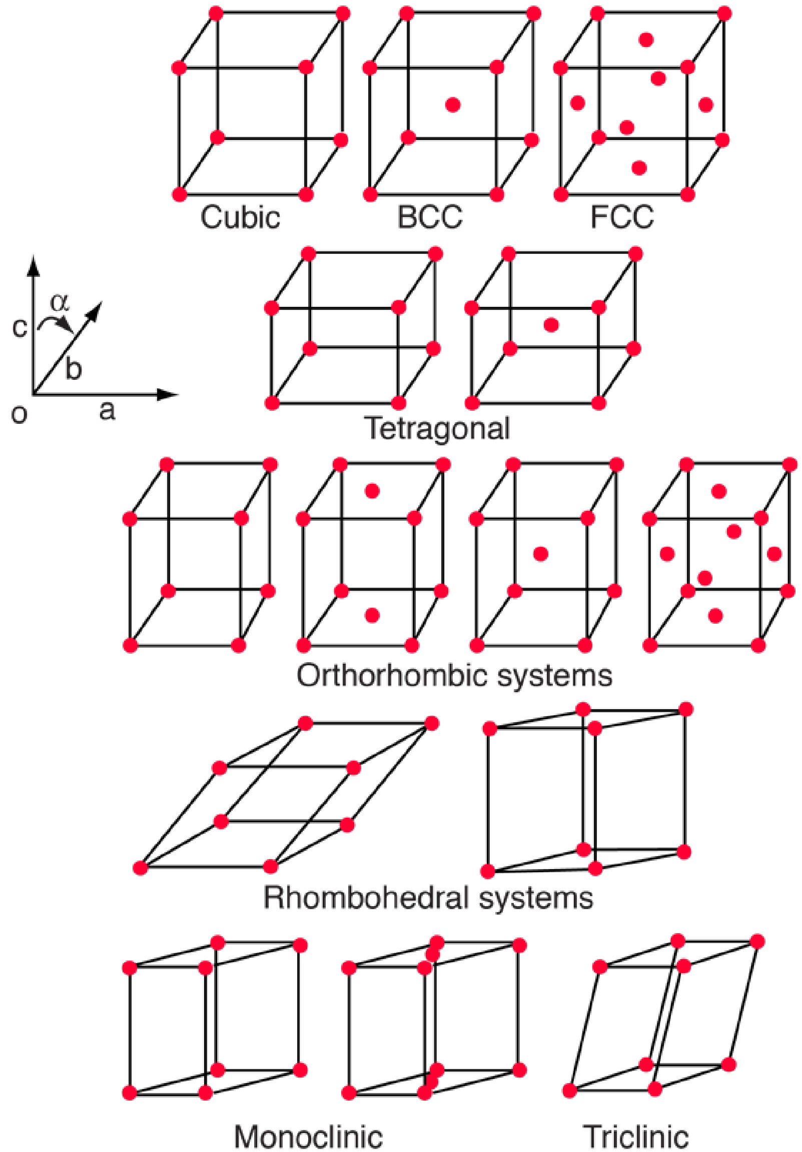
3D crystal structure



Bravais Lattices

- Crystal Systems

  → according to the shape of the elementary cell
- Bravais Lattices → 14



Crystal Systems

No.	Crystal System	Axes	Angles
1.	Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90^o$
2.	Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90^o$
3.	Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^o$
4.	Rhombohedral	$a = b = c$	$\alpha = \beta = \gamma \neq 90^o < 120^o$
5.	Hexagonal	$a = b \neq c$	$\alpha = \beta = 90^o, \gamma = 120^o$
6.	Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90^o, \beta > 90^o$
7.	Triclinic	$a \neq b \neq c$	$\alpha \neq \beta = \gamma \neq 90^o$

CT OR HMT

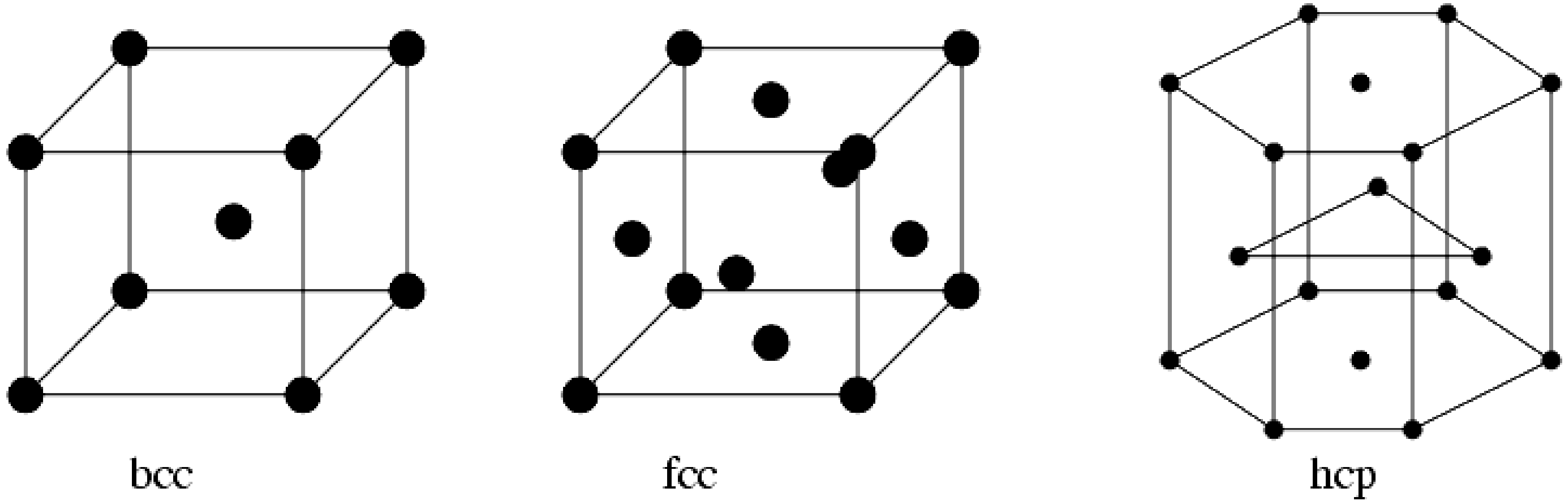
Periodic Table and Crystal structures

1 H HEX																		2 He HCP
3 Li BCC	4 Be HCP												5 B RHO	6 C HEX	7 N HEX	8 O SC	9 F SC	10 Ne FCC
11 Na BCC	12 Mg HCP												13 Al FCC	14 Si DC	15 P ORTH	16 S ORTH	17 Cl ORTH	18 Ar FCC
19 K BCC	20 Ca FCC		21 Sc HCP	22 Ti HCP	23 V BCC	24 Cr BCC	25 Mn BCC	26 Fe BCC	27 Co HCP	28 Ni FCC	29 Cu FCC	30 Zn HCP	31 Ga ORTH	32 Ge DC	33 As RHO	34 Se HEX	35 Br ORTH	36 Kr FCC
37 Rb BCC	38 Sr FCC		39 Y HCP	40 Zr HCP	41 Nb BCC	42 Mo BCC	43 Tc HCP	44 Ru HCP	45 Rh FCC	46 Pd FCC	47 Ag FCC	48 Cd HCP	49 In TETR	50 Sn TETR	51 Sb RHO	52 Te HEX	53 I ORTH	54 Xe FCC
55 Cs BCC	56 Ba BCC	*	71 Lu HCP	72 Hf HCP	73 Ta BCC/TETR	74 W BCC	75 Re HCP	76 Os HCP	77 Ir FCC	78 Pt FCC	79 Au FCC	80 Hg RHO	81 Tl HCP	82 Pb FCC	83 Bi RHO	84 Po SC/RHO	85 At [FCC]	86 Rn FCC
87 Fr [BCC]	88 Ra BCC	**	103 Lr [HCP]	104 Rf [HCP]	105 Db [BCC]	106 Sg [BCC]	107 Bh [HCP]	108 Hs [HCP]	109 Mt [FCC]	110 Ds [BCC]	111 Rg [BCC]	112 Cn [HCP]	113 Nh [HCP]	114 Fl [FCC]	115 Mc	116 Lv	117 Ts	118 Og [FCC]
		*	57 La DHCP	58 Ce DHCP/FCC	59 Pr DHCP	60 Nd DHCP	61 Pm DHCP	62 Sm RHO	63 Eu BCC	64 Gd HCP	65 Tb HCP	66 Dy HCP	67 Ho HCP	68 Er HCP	69 Tm HCP	70 Yb FCC		
		**	89 Ac FCC	90 Th FCC	91 Pa TETR	92 U ORTH	93 Np ORTH	94 Pu MON	95 Am DHCP	96 Cm DHCP	97 Bk DHCP	98 Cf DHCP	99 Es FCC	100 Fm [FCC]	101 Md [FCC]	102 No [FCC]		

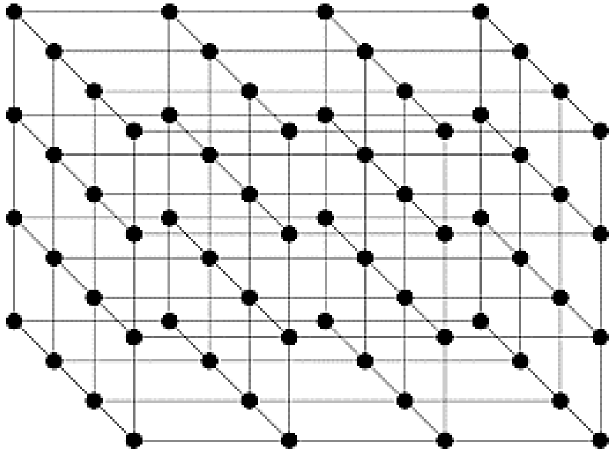
- 90% of metals have Body centred cubic (BCC), face centred cubic (FCC) or hexagonal close packing (HCP) crystal structure

Wikipedia

BCC, FCC and HCP crystal structure



Imperfections in Crystals

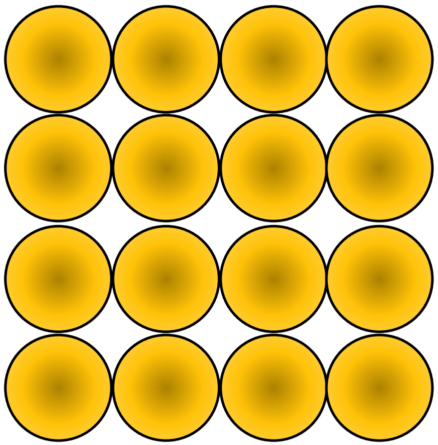


- Naturally due to the inability of the solidifying material to continue the replication of the unit cell indefinitely without interruption

- Intentionally introduced (alloying)

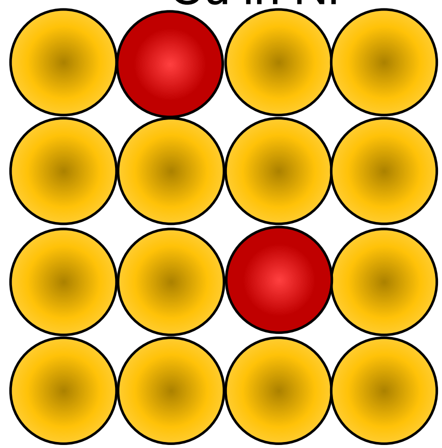
- Type of defects
  - Point (0D)
  - Line (1D)
  - Surface (2D)
  - Volume (3D)

Point Defects



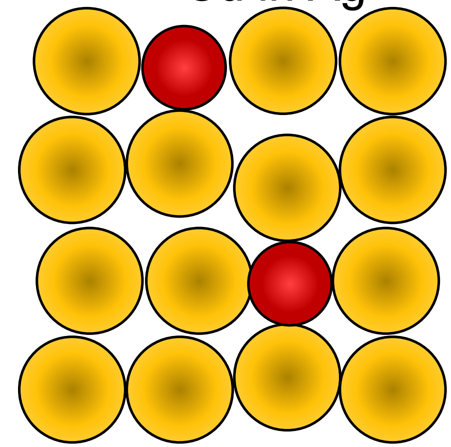
Pure Metal

Cu in Ni



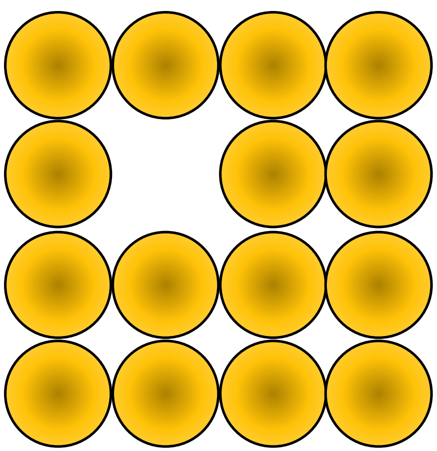
Alloying

Cu in Ag

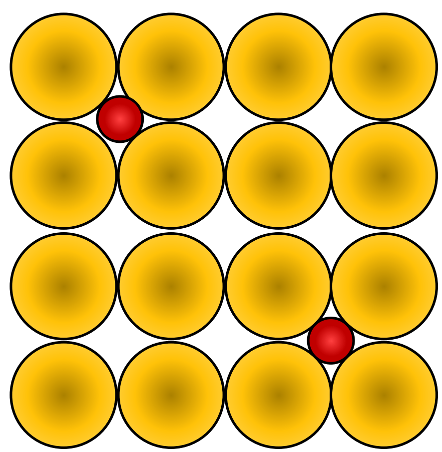


Substitutional

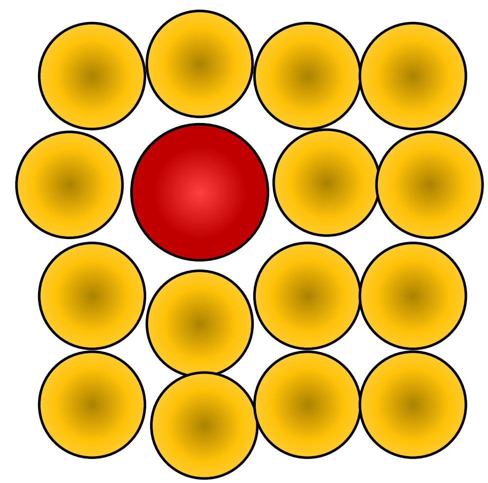
Solid Solution



Vacancy



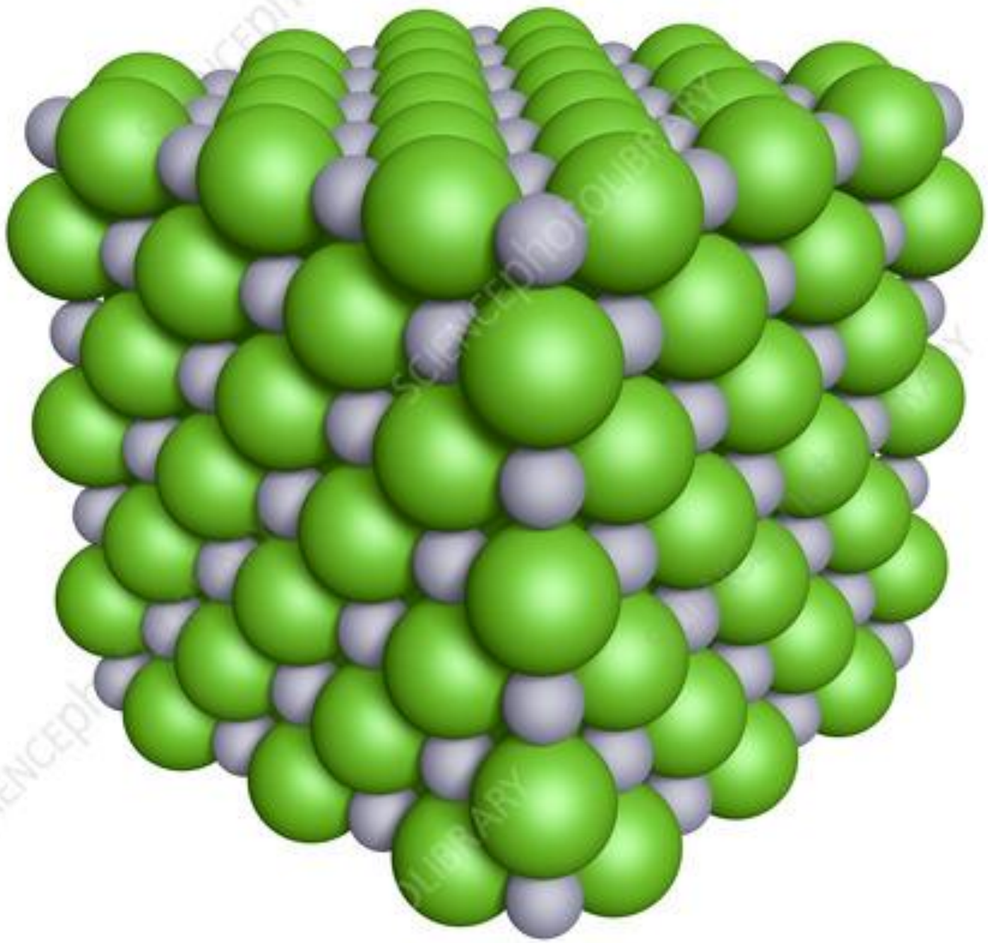
Interstitial C in Fe



Zn in Cu

NaCl crystal structure

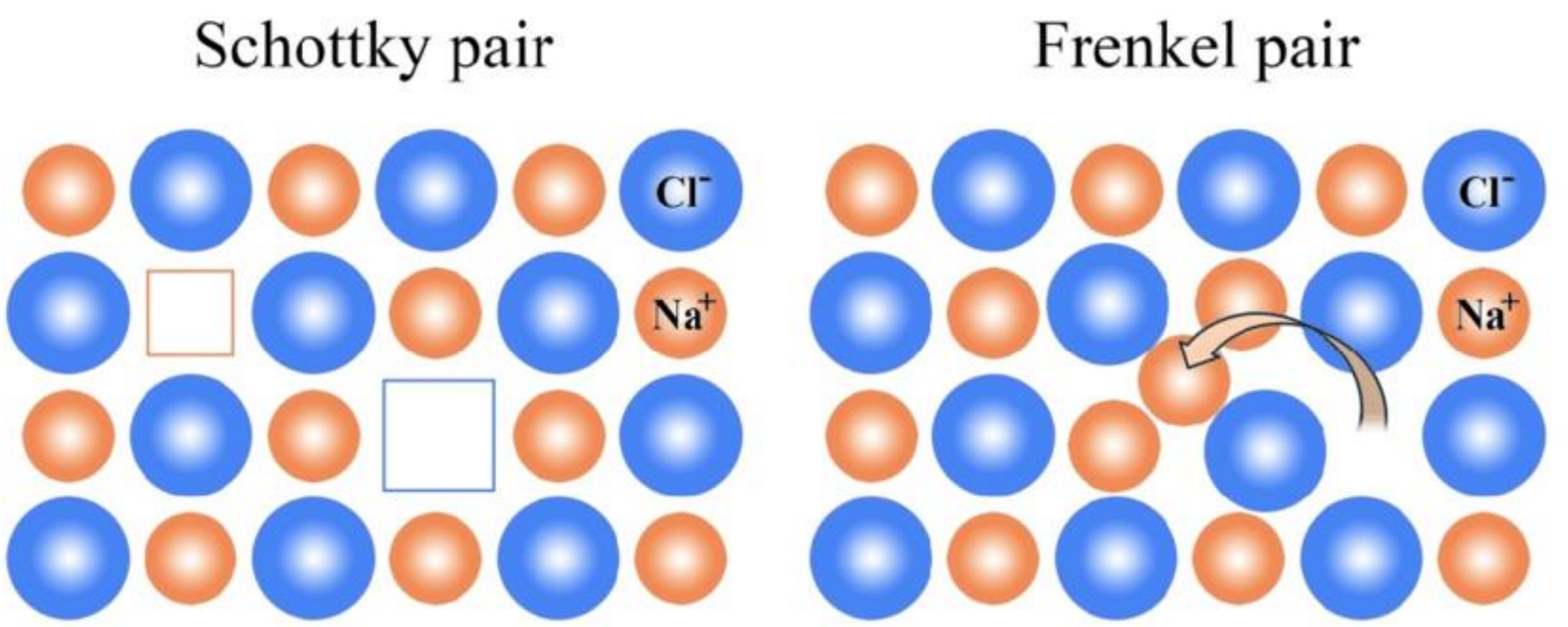
sodium cations (Na+, grey) and chloride anions (Cl-, green)



FCC

https://www.sciencephoto.com/

Imperfections in Crystals

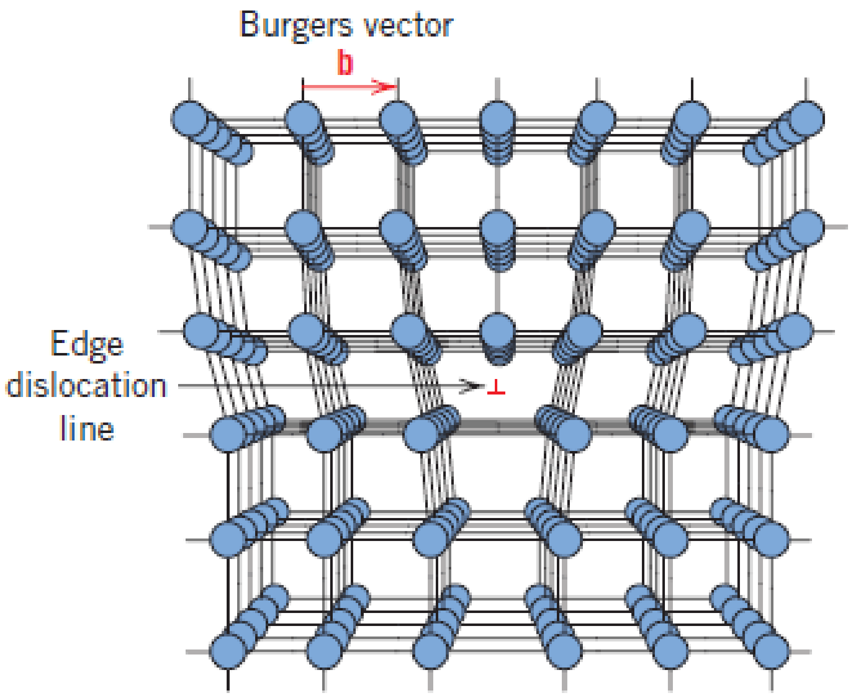


- They disturb the perfect arrangement
- Their concentration depends on their formation energy
- On external parameters such as temperature and pressure

Courtesy: google Images

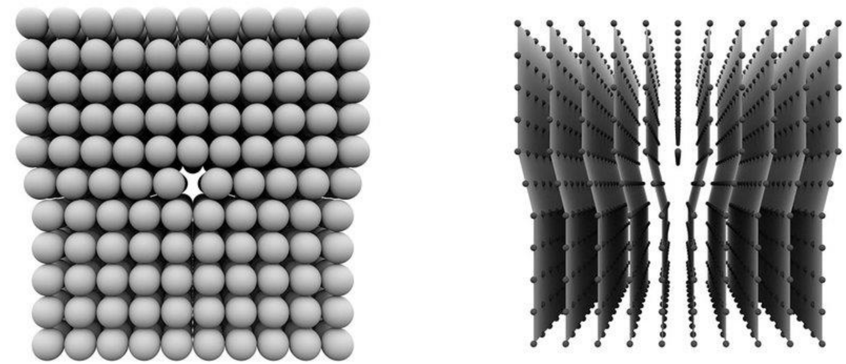
Line defects (1D)

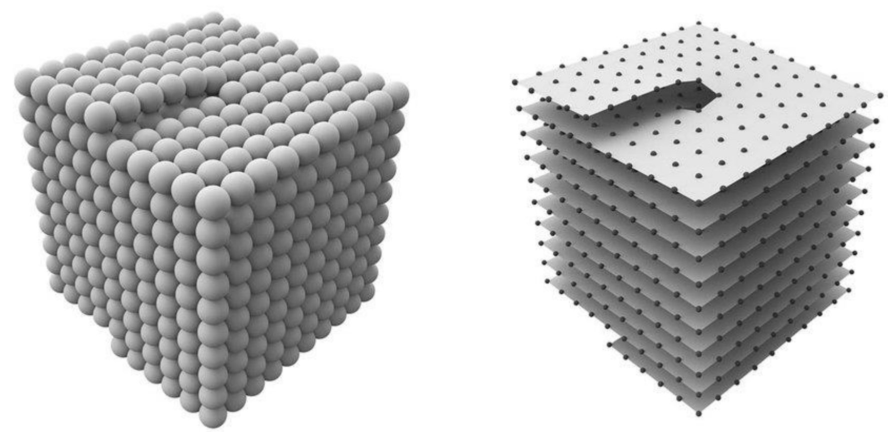
- Line defect: connected group of point defects that form a line



Edge Dislocation

Edge Dislocation





Screw Dislocation

Introduction to dislocations: Hull and Bacon book

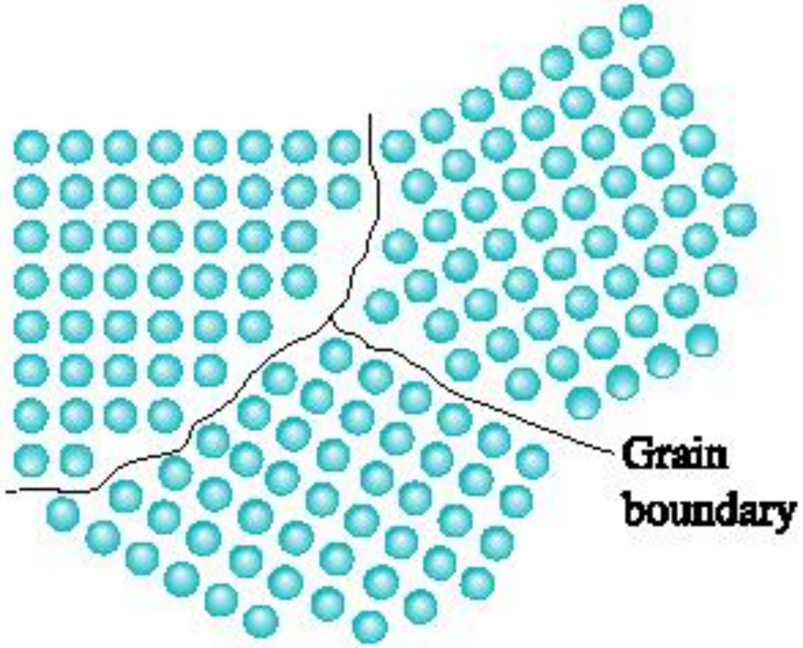
www.beautifulchemistry.net

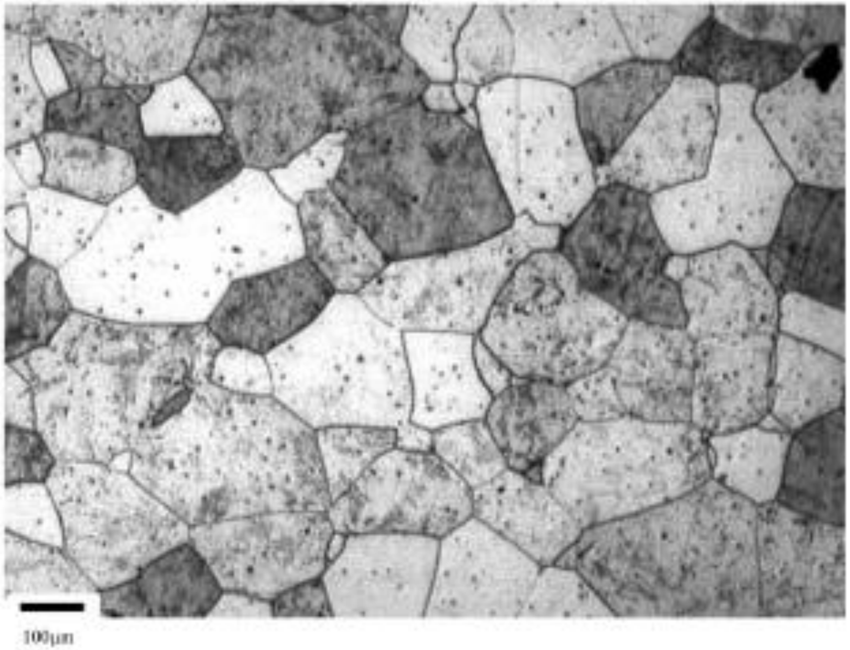
Solidification

https://www.youtube.com/shorts/n811aTMkZiQ

Types of Imperfections in Crystals

- Surface defect:
  - Imperfection extending in two directions to form a boundary





Volume Defects:

- Voids and internal cracks

Courtesy: google Images

Non-crystalline (Amorphous) Structures

Non-crystalline

- No long-range order
- Generally, translational symmetry is absent

- Rapidly cooling through the freezing temperature favors the formation of a non-crystalline solid, since little time is allowed for the ordering process

- Non-crystalline solids lack a **systematic and regular** arrangement of atoms over relatively large atomic distances. Also called amorphous (meaning literally **without form**), or supercooled liquids, as structure resembles that of a liquid
  - Metals normally form crystalline solids
  - Some ceramic materials are crystalline, whereas others, the inorganic glasses, are amorphous
  - Polymers may be completely non-crystalline and semi-crystalline consisting of varying degrees of crystallinity

Crystalline versus Non-crystalline

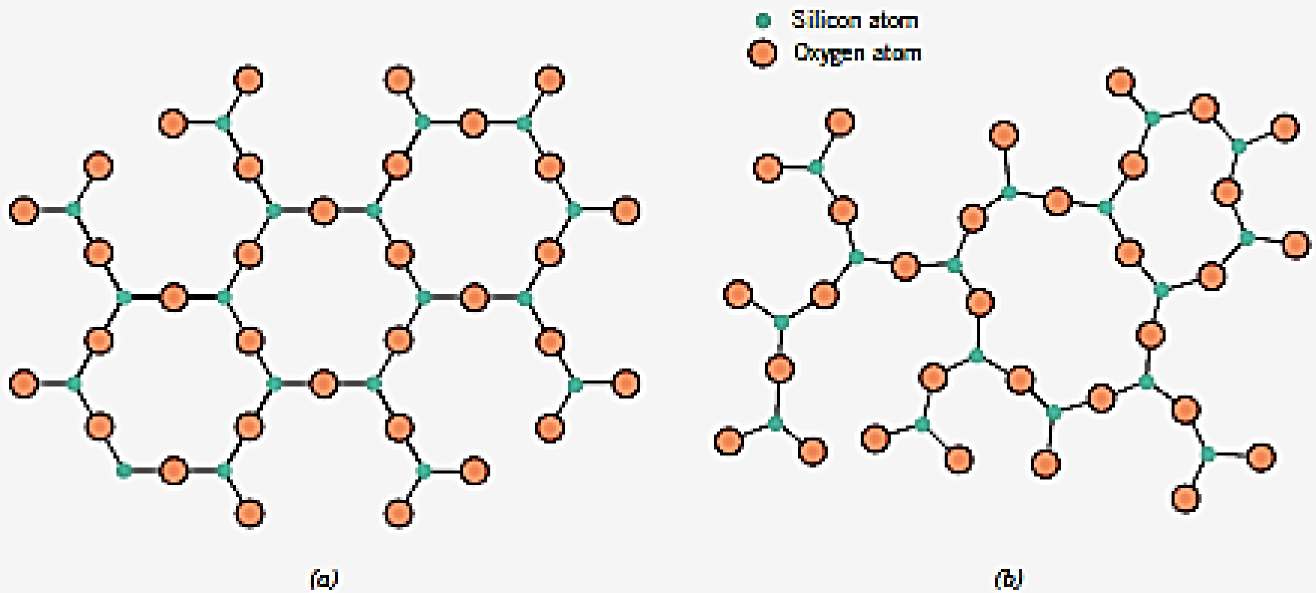


Figure 3.22 Two-dimensional schemes of the structure of (*a*) crystalline silicon dioxide and (*b*) noncrystalline silicon dioxide.

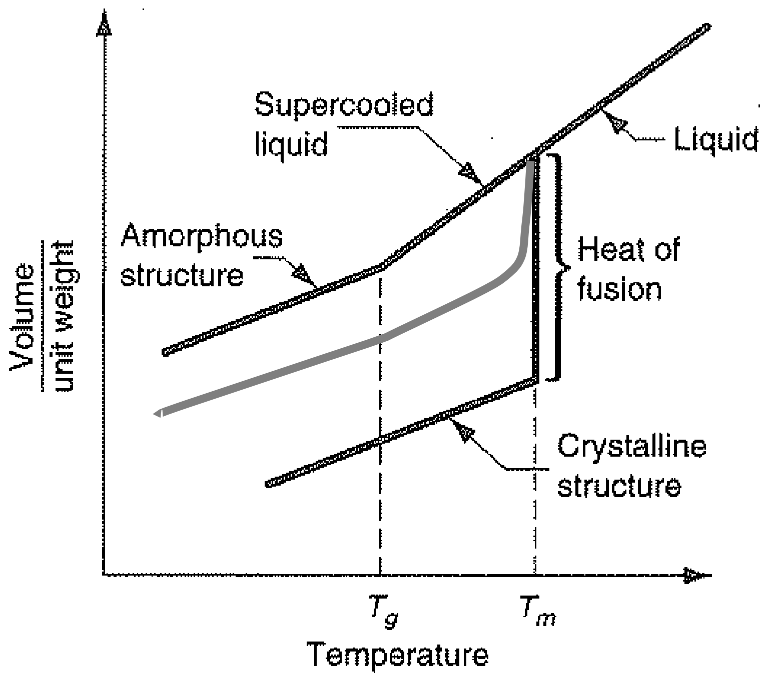
- An amorphous condition may be illustrated by comparison of the crystalline and noncrystalline structures of the ceramic compound silicon dioxide (SiO_2 in silicates), which may exist in both states.
- Even though each silicon ion bonds to four oxygen ions for both states, however similarity ends beyond this. The structure can be ordered or disordered depending on how they interconnect

Glass Properties

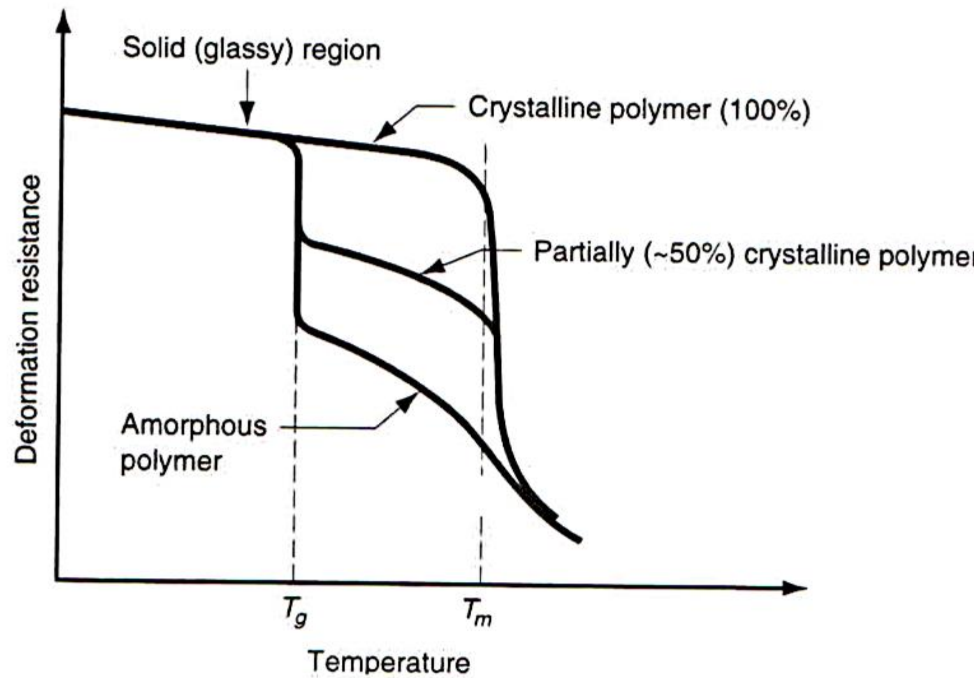
- **<u>Glassy, or non-crystalline</u>**, materials do not solidify in the same sense as do those that are crystalline. There is no definite temperature at which the liquid transforms to a solid as with crystalline materials
- One of the distinctions between crystalline and non-crystalline materials lies in the dependence of specific volume (or volume per unit mass, the reciprocal of density) on temperature.
- A slight decrease in slope of the curve occurs at what is called the **<u>glass transition temperature, Tg</u>**. Below this temperature, the material is considered to be a glass; above, it is first a supercooled liquid, and finally a liquid

Glass Properties

- Glass transition temperature



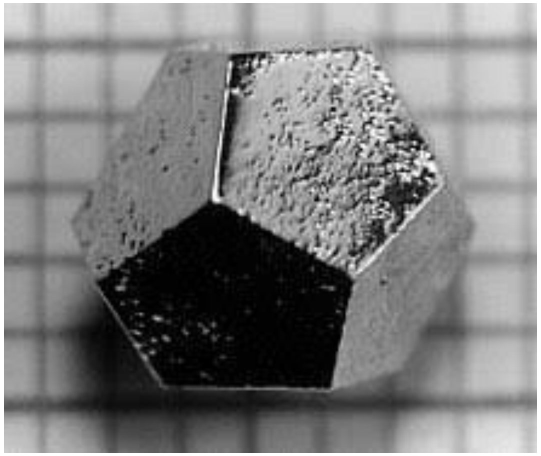
Characteristic change in Specific volume for a pure metal, compared with glass and semi-crystalline material

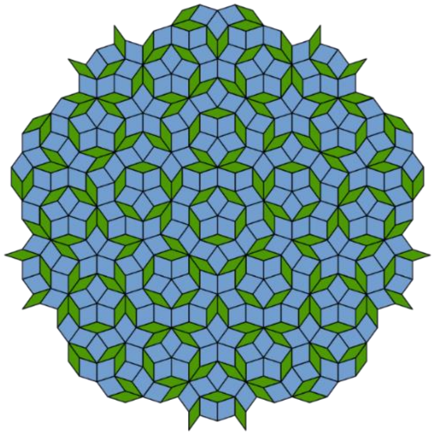


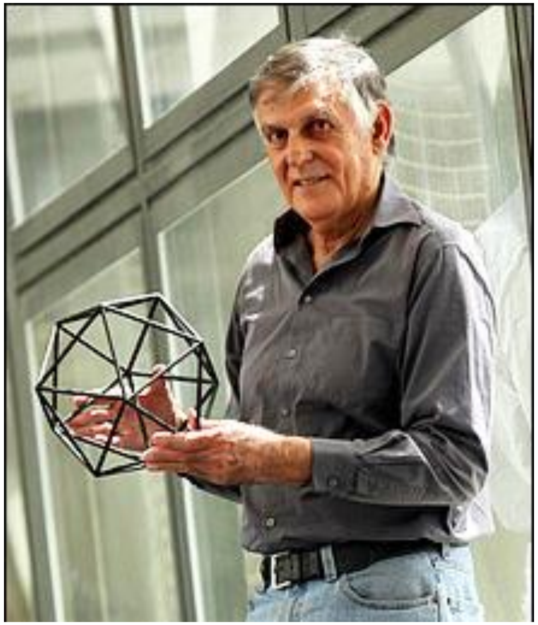
Relationship of mechanical properties, portrayed as deformation resistance, as a function of temperature for an amorphous thermoplastic, a 100% crystalline thermoplastic, and a partially crystallized thermoplastic

Fundamentals of Modern Manufacturing: Materials, Mikell P. Groover

Quasi….Quasi….







IUCr: In 1991, changed the definition of crystals

Courtesy: google Images