Properties of Materials
BTM 2413

CHAPTER 2:

THE ORIGIN OF ENGINEERING MATERIALS

by

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Introduction

- Aims
  - To introduce the origin of engineering materials, their method of formation and distinguish between different materials ….
- Expected Outcomes
  - Know the origin of engineering material…..
  - Summarize the methods of formation of engineering materials from elements
  - Distinguish the nature of metals, ceramics, polymers and composites
- Other related Information
- References

- Kenneth G Budinsky & Michael G Biddinsky, Engineering Materials: Properties and Selection, Ed 9, Prentice Hall

Organic versus Inorganic

ORGANIC materials derived from living things usually contain carbon and hydrogen

Eg : Petroleum, Foods, Polymer

INORGANIC materials those substances not derived from living things

Eg : sand, rock, water, metals,

The composition or component of materials is *element*

Elements

- Defined as pure substance that cannot be broken down by chemical means to a simpler substance.
- An element consists of atom
- Atom composed of proton, neutron and electrons
- Example of element : Aluminum, Carbon, Iron

Periodic Table of Elements

hydrogen 1 **H** 1.0079																		helium 2 **He** 4.0026
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.0122												boron 5 **B** 10.811	carbon 6 **C** 12.011	nitrogen 7 **N** 14.007	oxygen 8 **O** 15.999	fluorine 9 **F** 18.998	neon 10 **Ne** 20.180
sodium 11 **Na** 22.990	magnesium 12 **Mg** 24.305												aluminium 13 **Al** 26.982	silicon 14 **Si** 28.086	phosphorus 15 **P** 30.974	sulfur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.948
potassium 19 **K** 39.098	calcium 20 **Ca** 40.078		scandium 21 **Sc** 44.956	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.942	chromium 24 **Cr** 51.996	manganese 25 **Mn** 54.938	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.933	nickel 28 **Ni** 58.693	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.39	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.61	arsenic 33 **As** 74.922	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.80
rubidium 37 **Rb** 85.468	strontium 38 **Sr** 87.62		yttrium 39 **Y** 88.906	zirconium 40 **Zr** 91.224	niobium 41 **Nb** 92.906	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.91	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.87	cadmium 48 **Cd** 112.41	indium 49 **In** 114.82	tin 50 **Sn** 118.71	antimony 51 **Sb** 121.76	tellurium 52 **Te** 127.60	iodine 53 **I** 126.90	xenon 54 **Xe** 131.29
caesium 55 **Cs** 132.91	barium 56 **Ba** 137.33	57-70 *	lutetium 71 **Lu** 174.97	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.95	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.21	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.22	platinum 78 **Pt** 195.08	gold 79 **Au** 196.97	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.38	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.98	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	89-102 * *	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	ununnilium 110 **Uun** [271]	unununium 111 **Uuu** [272]	ununbium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]				

*Lanthanide series	lanthanum 57 **La** 138.91	cerium 58 **Ce** 140.12	praseodymium 59 **Pr** 140.91	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.96	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.93	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.93	erbium 68 **Er** 167.26	thulium 69 **Tm** 168.93	ytterbium 70 **Yb** 173.04
* *Actinide series	actinium 89 **Ac** [227]	thorium 90 **Th** 232.04	protactinium 91 **Pa** 231.04	uranium 92 **U** 238.03	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]

Importance of Atom

- Periodic table, electron configuration, atomic number is not so important for technologist in manufacturing
- Sufficient to be aware that

  - atoms play an important role in forming usable compound

  - atoms determine the properties of materials

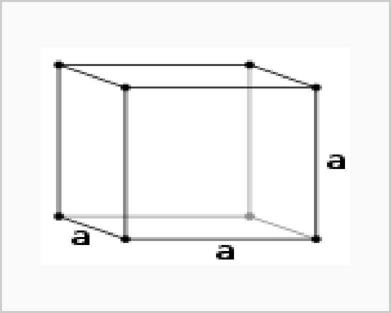
Forming Engineering Materials from the Elements

Materials form from

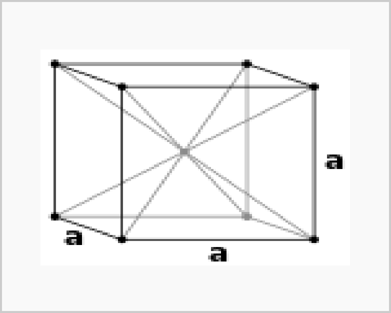
- pure elemental state. eg: gold, silver, mercury are metallic forms, Carbon nonmetal, Inert gases such as He, Ar
- *Alloy* – a metal combined with one or more other elements e g brass, bronze, stainless steel
- Compound – chemically combined elements
- Mixture – physically blend of two or more elements

The solid state crystalline and amorphous

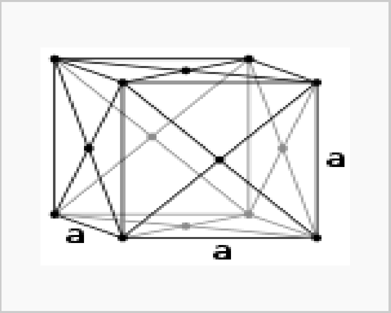
- Solids that do not have a repetitive three D pattern of atoms are amorphous
- Solid have crystalline structure – repetitive 3D pattern of atom
- most metal and inorganics have crystalline structure
- Figures above show crystal structure called *unit cell* or *crystal cell*



Simple cubic (P)



Body-centered cubic (I)



Face-centered cubic (F)

The solid state

- cells form a crystal
- If many crystals are growing, the crystals will meet and form grains
- Interface between two grains called *grain boundary*.

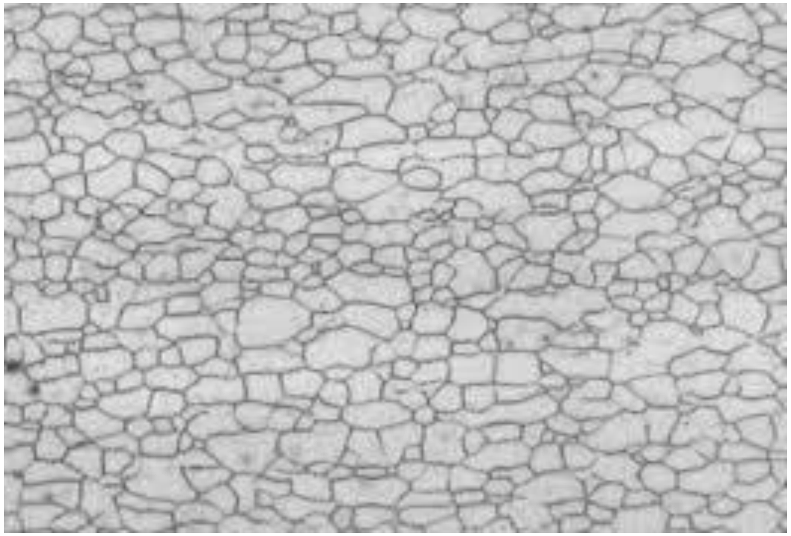
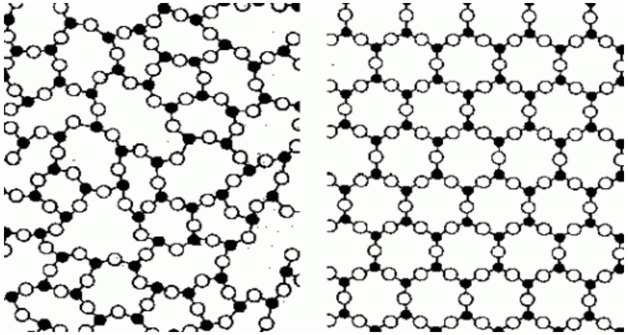


Figure : grain structure of metal

The solid state

- The properties of crystalline materials are affected by
  - i) type of crystal structure (BCC, FCC, HCP)
  - ii) grain size
  - iii) strength of the bond between atoms
- Solid that has not crystalline structure is called *amorphous*
- *Non crystalline* solid lack a systematic and a regular arrangement of atoms
- Glasses and plastic are amorphous
- Figure shows atomic structure of silicon dioxcide (SiO_2)



The solid state

Crystalline vs amorphous

- Crystalline solids are the most stable solid
- Strength of all the bond of crystalline atom are same, whereas strength of different bond is different for amorphous
- Crystalline solids have sharp melting point whereas amorphous solid don't have sharp melting point

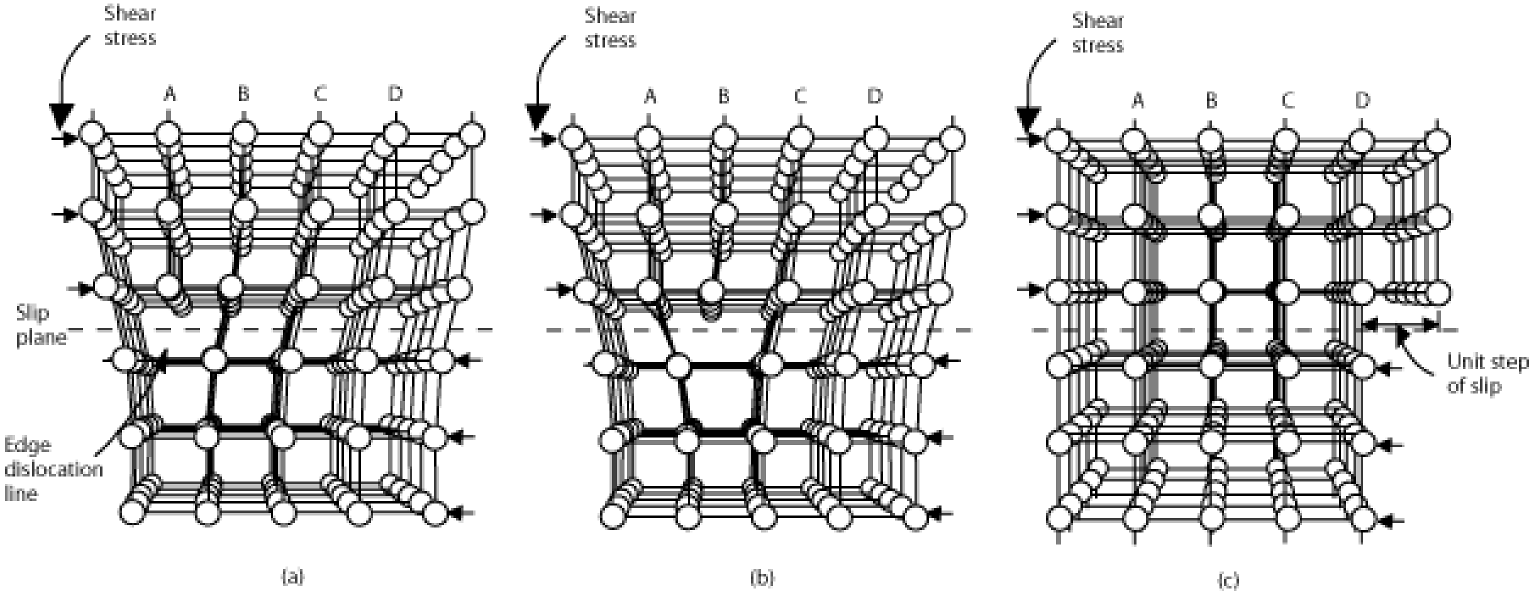
The nature of Metals

- Metals are elements with valence of 1, 2 or 3
- Solid composed atoms held together by matrix of electron.
- The electrons associated are free to move throughout the volume of crystal; that makes metals a good conductor heat and electricity
- Other properties that distinguish metals are malleability, opacity and ability to be strengthened

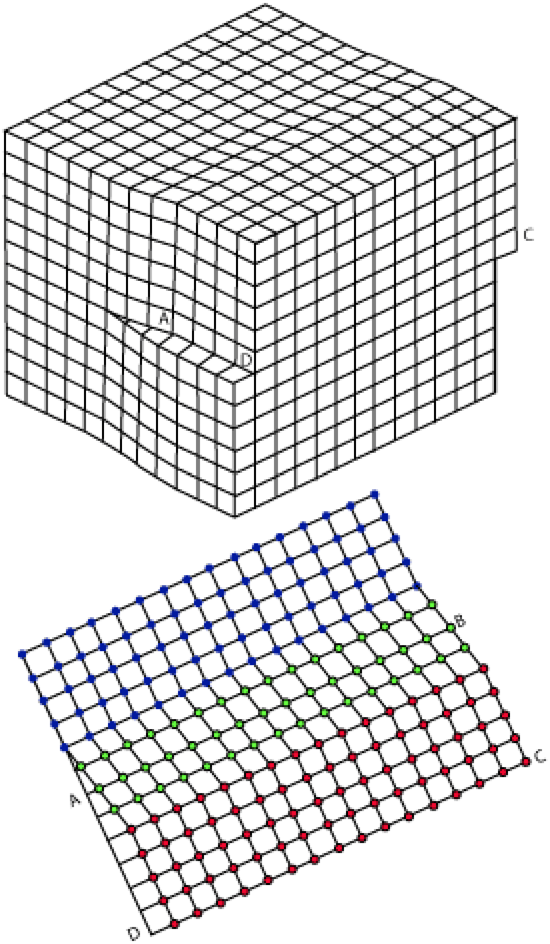
Dislocations in Crystals

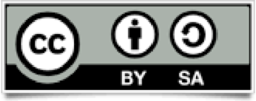
- Dislocations are areas were the atoms are out of position in the crystal structure. Dislocations are generated and move when a stress is applied. The motion of dislocations allows slip – plastic deformation to occur.
- Deformation by dislocation is one of the characteristics of metals that makes them most useful engineering material

Edge dislocations

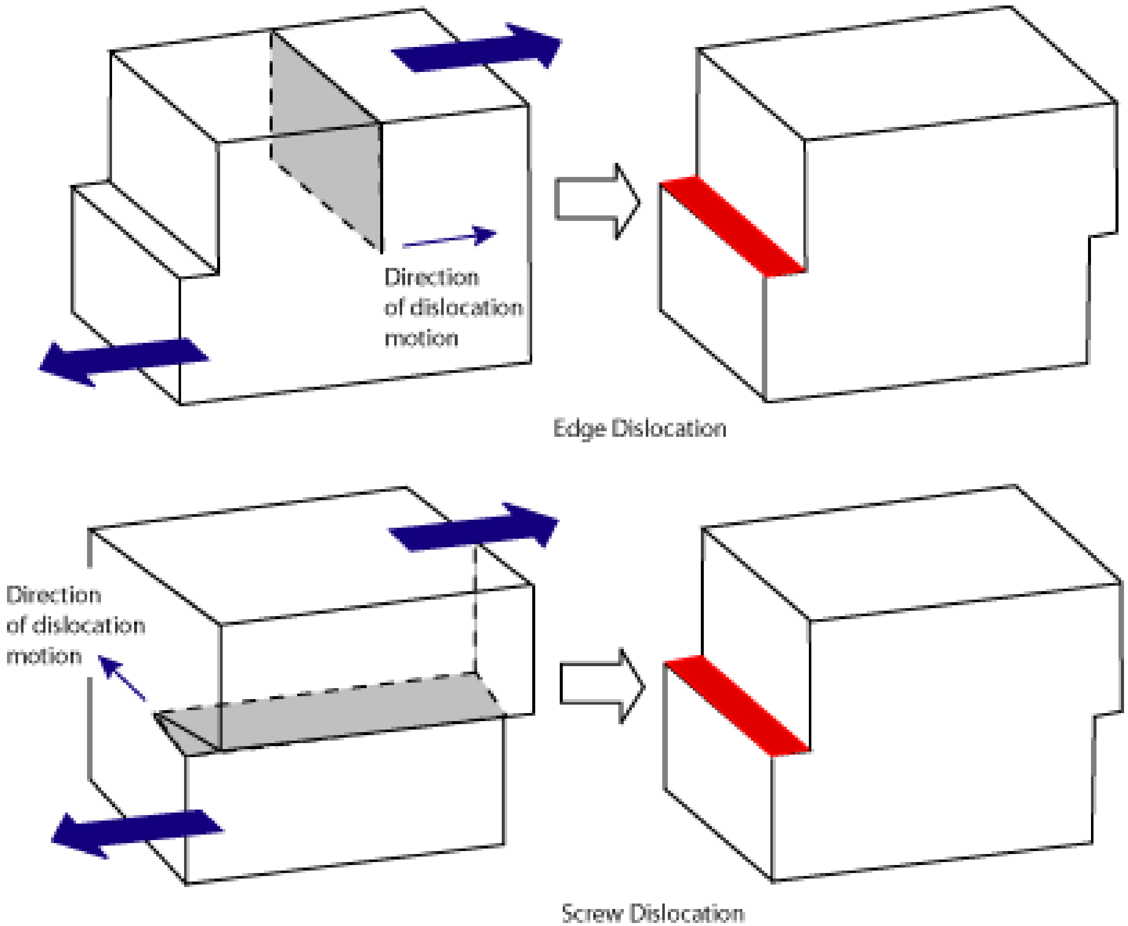


Screw Dislocations





Edge and Screw Dislocations



Nature of Ceramics

- Elements with valence 5,6,7 are nonmetals and with valence 8 are inert
- Elements with valence of 4 are metalloids; sometimes behave as metals, sometimes as nonmetals
- Ceramic can be defined as a combination or compound of one or more metals with nonmetallic elements. They usually have very rigid covalent or ionic bonds between adjacent items

Ceramics

- In ceramics the bonds are very strong between neighboring atoms making crystalline ceramic very brittle
- Deformation by dislocation motion or atomic slip is very difficult
- Ceramics tend to be electronic insulators because electrons are tied up in bonding and are not free to move throughout the crystal
- Usually can not be strengthened by cold working or precipitation hardening
- Fibers and other materials are added to strengthen the ceramics

Nature of Polymers

- Engineering materials known as plastics are more correctly called polymers
- Polymers are substances composed of long chain repeating molecules
- Long chain polymers usually are weaker than ceramics and metals because the molecular chains are bounded to each other only with weak electrostatic force called Van der Waals bonds

Nature of Composites

- A composite is a combination of two or more materials that has properties that the component materials do not have by themselves
- Wood is a composite of cellulose fiber held together with a glue or matrix of soft lignin
- In engineering materials composites are formed by coatings, internal additives and laminating
- Applications are sports equipment, aircraft, chemical process industry etc

Global Considerations

- Chemists and chemical engineers are in demand to work at finding new feedstock for bio-based fuels
- A great deal of chemistry research and development is aimed at changing processes so as they emit less carbon
- Substantial work being done to find substitutes for engineering materials that are becoming scarce or too costly to use