

Materials in Engineering Applications

2.1] Polymers :- Classifications, Molecular Mass of Polymers, Compounding of Plastics, Fabrication of Polymers, Biodegradable Polymers, Conducting Polymers.

2.2] Nanotechnology :- Nano materials, surface effect, Quantum effects, Quantum dots, CNTs, applications

2.3] Biomaterials :- Biomaterials, Metals & Alloys, Bio-Ceramics, Nano-Composites

2.4] MEMS :-

Polymers

1] Based on molecular forces :-

- Thermoplastic Polymers :
- Solid Materials at room temp but viscous liquids when heated to temp of only a few hundred degrees.
- Can be easily & economically shaped into products.
- Can be subjected to heating and cooling cycles repeatedly w/o significant degradation

Eg:- Polyethylene , Polyvinyl chloride (PVC) , Polypropylene , polystyrene etc.

• Thermosetting Polymers :

- Cannot tolerate repeated heating cycles.
- Initially when heating, they soften & flow for molding.

But at elevated temp it produces a chemical rxn that hardens the material into infusible solid.

- If reheated , it degrades and char rather than soften.

Eg: Phenolics, epoxides and certain polyesters.

• Elastomers :

- These exhibits extreme elastic extensibility when subjected to relatively low mechanical stress.

Some elastomers can be stretched by a factor of 10 & yet completely recover to their original shape.

- Although their properties are quite diff from thermosets, they share a similar molecular structure that is different from thermoplastics.

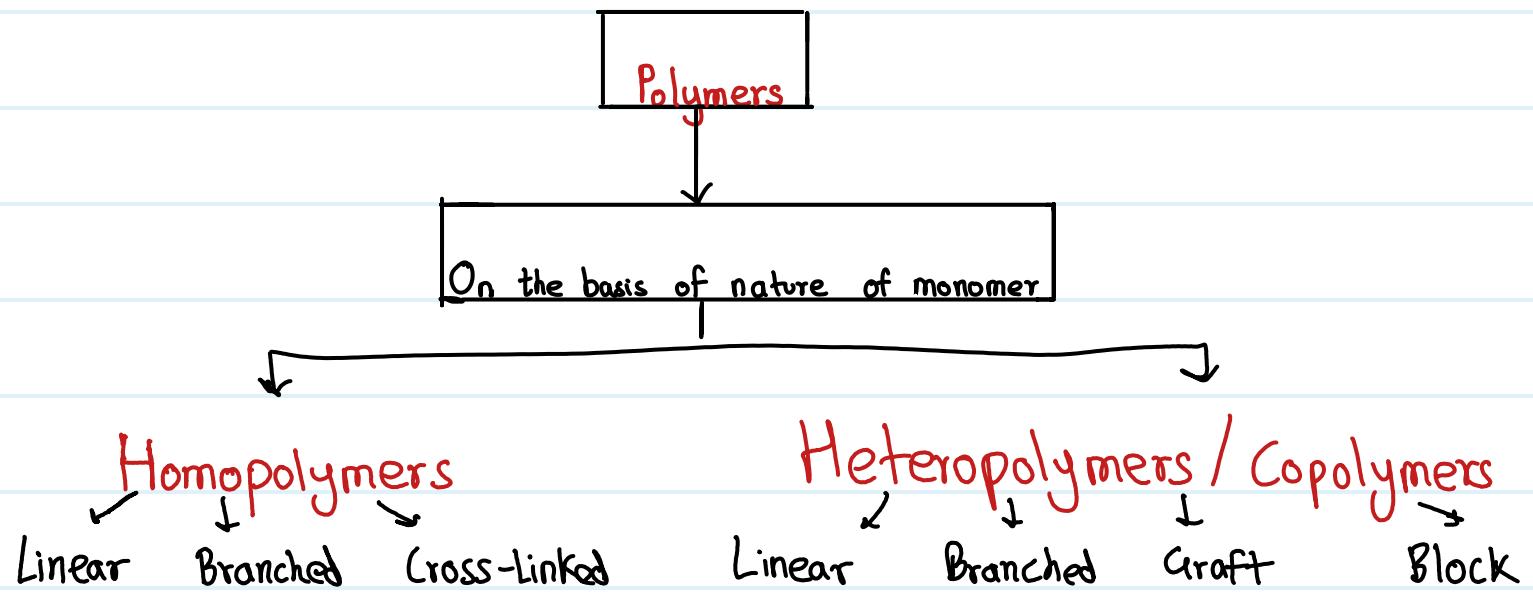
Eg: Natural rubber, (vulcanized) synthetic rubbers.

Difference between thermoplastic & thermosetting resins:-

Thermoplastic resins (or) Polymers		Thermosetting resins	
(1)	These are produced by addition polymerization	(1)	These are produced by condensation polymerization.
(2)	The resins are made of long chains attached by weak Vander Waal's force of attraction	(2)	The resins have three dimensional network structure connected bonds.
(3)	On heating they soften and on cooling become stiff chemical nature won't change.	(3)	On heating they become stiff & hard. No change on cooling. Chemical nature changes.
(4)	They can be remoulded	(4)	They cannot be remoulded because once set means they are permanently set
(5)	Scrap (waste product) can be used	(5)	Scrap cannot be used
(6)	The resins are soft, weak and less brittle	(6)	The resins are usually hard, strong tough & more brittle
(7)	These are easily soluble in some organic substances E.g.: PVC, polyethylene etc.,	(7)	Resins are not soluble in organic Solvents E.g.: Nylon, Bakelite etc.,
(8)	Contain long chain polymer with no cross linkage.	(8)	They have 3D network structure.

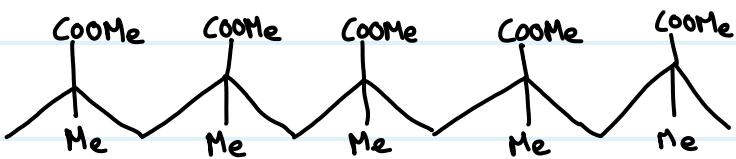
2] Based on structure:-

- Linear structure: chain-like structure, characteristic of thermosetting polymers.
- Branched Structure: chain-like but with side branches, found in thermosetting polymers.
- Cross-Linked structure: loosely cross-linked, as in an elastomer & tightly cross-linked as in thermoset.

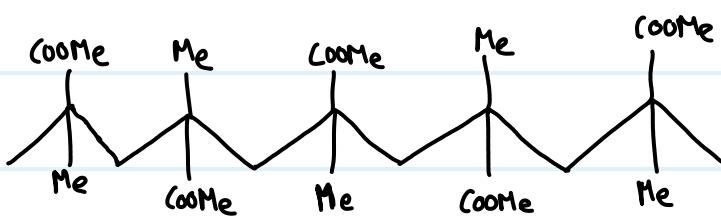


- Depending on tacticity:

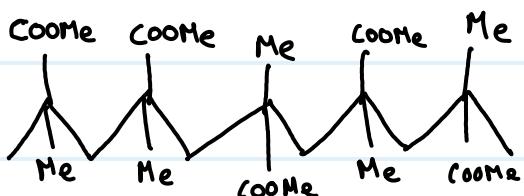
1] Isotactic - Similar groups on same side of chain



2] Syndiotactic - Two groups alternate



3] Atactic - Displays no regular pattern

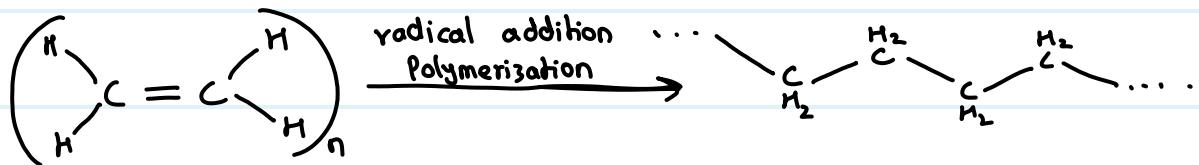


- Every other carbon in the chain is a stereocenter

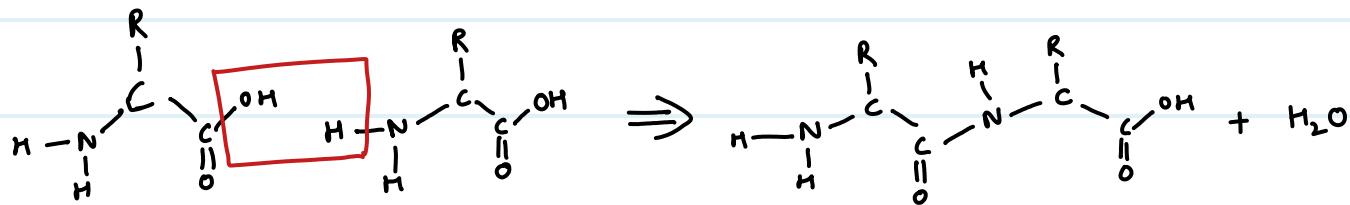
* Classification based Polymerization

- Addition Polymer: Direct repeated addition of monomers is called addition polymers.

Monomers are unsaturated compounds or derivatives of alkenes.



- Condensation Polymer: Involves condensation of two different monomers which are normally bifunctional group.



Difference between condensation and addition polymerisation:-

	Condensation polymerisation		Addition polymerisation
(1)	It is also known as step growth polymerisation	(1)	It is also known as chain growth polymerization
(2)	It takes place in monomers having reactive functional groups	(2)	It takes place only in monomers having multiple bonds.
(3)	It takes place with elimination of simple molecule like $\text{H}_2\text{O}, \text{NH}_3, \text{HCl}$ etc.,	(3)	It takes place without elimination of simple molecule.
(4)	Repeat units of monomers are different	(4)	Repeat units & monomers are same.
(5)	The polymer is formed in gradual steps	(5)	Reaction is fast and polymer is formed at once.
(6)	The molecular mass of polymer increases throughout the reaction	(6)	There is very little change in the molecular mass throughout the reaction
(7)	Product obtained may be thermosetting/thermoplastic	(7)	Product obtained are thermoplastic
(8)	E.g.: Bakelite, polyester ,polyamides etc.,	(8)	E.g.:Polyethylene, PVC, poly styrene.

* Molecular Mass of Polymer

1] Number Average Molecular Mass (M_n)

In this no. of molecules are involved in molecular weight measurements. Hence, the molecular weight is obtained by colligative property measurements.

Let us consider $N_1, N_2, N_3 \dots$ be no. of molecules of polymer in sample soln & $M_1, M_2, M_3 \dots$ be their molecular weight

$$\overline{M}_n = \frac{\sum_{i=1}^n N_i M_i}{\sum_{i=1}^n N_i} = \frac{\sum_{i=1}^n W_i}{\sum_{i=1}^n W_i / M_i}$$

$$N_i = \frac{W_i}{M_i}$$

2] Weight Average molecular Weight (M_w)

$$\overline{M}_w = \frac{\sum_{i=1}^n N_i M_i^2}{\sum_{i=1}^n N_i M_i} = \frac{\sum_{i=1}^n W_i M_i}{\sum_{i=1}^n W_i}$$

3] Z-average molecular Weight (M_z)

$$M_z = \frac{\sum_i N_i M_i^3}{\sum_i N_i M_i^2}$$

4] Viscosity-average molecular weight (M_v)

$$M_v = \left[\sum_{i=1}^{\infty} w_i M_i^\alpha \right]^{1/\alpha} = \left[\frac{\sum_{i=1}^{\infty} N_i M_i^{\alpha+1}}{\sum_{i=1}^{\infty} N_i M_i} \right]^{1/\alpha}$$

w = weight fraction

N = no. of moles

M = molecular weight

- When $\alpha=1$, $M_v=M_w$, usually $\alpha \sim 0.5-0.9$ $\alpha = A \text{ constt}$
- α is measure of the hydrodynamic volume of polymer
- Varies with polymer, solvent & temp.

* Mark-Houwink eqn :-

- Valid for broad molecular weight distribution.

$$[\eta] = K_m \overline{M}_v^\alpha$$

$[\eta]$ = intrinsic viscosity

\overline{M}_v = viscosity average molec. wt.

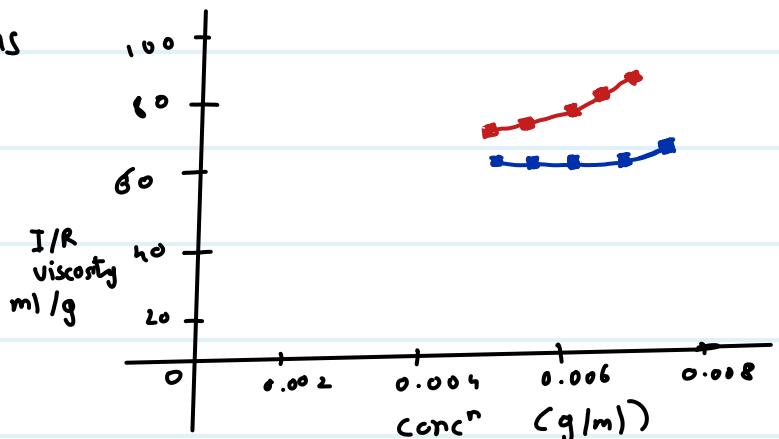
K_m, α = constt for particular polymer-solvent combination

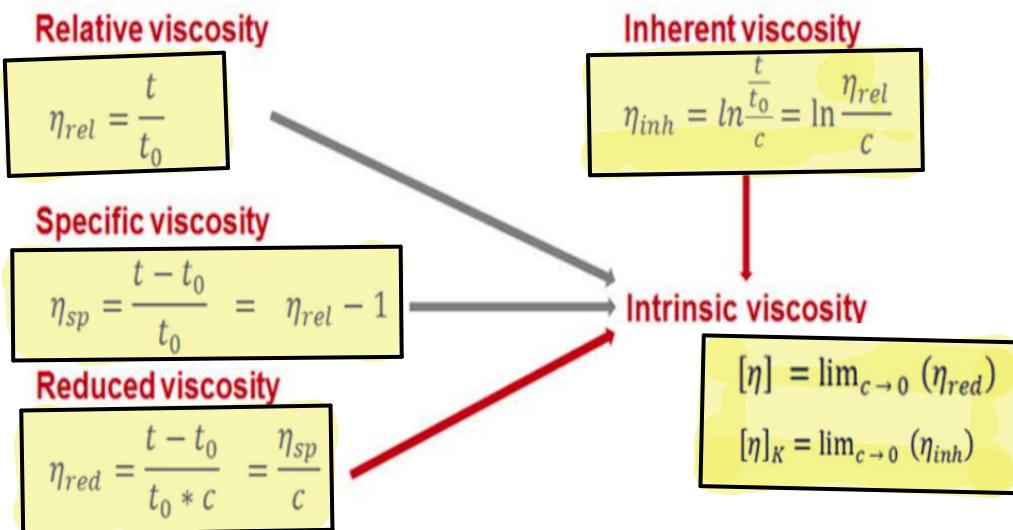
α is 0.5-0.8 for flexible polymer chains

α is 2 for stiff & rod like chains

Reduced viscosity

Inherent viscosity





Red arrows: Parameter used for intrinsic viscosity determination for multi concentration measurements

Grey arrows: Parameter used for intrinsic viscosity determination for single concentration measurements

$$\eta_{rel} = \frac{t}{t_0}$$

single concentration measurement

$$\eta_{sp} = \eta_{rel} - 1 = \frac{t - t_0}{t_0}$$

$$\eta_{red} = \frac{\eta_{rel} - 1}{c} = \frac{t - t_0}{t_0 c}$$

multiconcentration measurement

$$\eta_{inh} = \ln \eta_{rel} = \ln \frac{t}{t_0}$$

* Compounding of Plastics

In order to impart certain definite properties to the finished products, resins are compounded with certain other substances. This process is called compounding of plastics.

1] Binders or Resins

- The product of polymerization is called resins & this forms the major portion of the body of plastics.
- Binder holds diff constituents together.
- Thermosetting resins are usually, supplied as linear-polymer of comparatively low molecular weight, because at this stage they are fusible & hence, mouldable.
- Conversion of fusible form into cross-linked infusible form takes place, during moulding itself, in presence of catalysts.
- A binder may compose of 30-100%.
- Binders used may be natural or synthetic or cellulose derivatives.

2] Fillers

- Fillers are generally added to thermosetting plastics to ↑ elasticity & crack resistance.

- Fillers improve thermal stability, strength, non-combustibility, water resistance, electrical insulation properties & external appearance.
- Eg:- Mica (Hardness), cotton (shock resistance), carbon (electrical conductivity), black, graphite, BaSO_4 etc. Asbestos (Heat resistance)

3] Plasticizers

- These are added to enhance the plasticity of material and to reduce the cracking on the surface.
- Plasticizers are added to the plastics to increase the flexibility & toughness. Plasticizers also ↑ the flow property of plastics.
- Eg:- vegetable oils, camphor, esters of steric & oleic acid, tributyl phosphate, triphenyl phosphate etc.

4] Dyes & Pigments

- These are added to impart the desired colour to the plastics & give decorative effect.
- Eg.. Iod pigment:- Lead chromate (yellow), ferrocyanide (blue)
- OC pigments:- Alizarin Red, Indigo Dye, Azo dyes.

5] Lubricants

- Includes oils, waxes & soaps.
- They help in easy moulding & glossy finish to final product.
- The lubricant prevent the plastic material from sticking to the mould.

6] Catalysts

- They are added to plastics to accelerate polymerizations reaction.
- $ZnCl_2$, CaO , ammonia, benzoyl peroxides.

7] Stabilizers

- They are added to improve thermal stability during processing.

Eg:- Polymers of vinyl chloride show tendency to undergo decomposition at moulding temps. Hence, heat stabilizers are added.

i] Opaque moulding stabilizers:- Salts of lead like white lead, lead chromate, red lead, lead silicate etc.

ii] Transparent Moulding Stabilizers:- Stearates of Lead, chromium & barium.

- In addition some antioxidants, antiseptics, fungicides, flame retardants etc are also added.

* Fabrication of Plastics

- Giving any desired shape to the plastics (granules or powders) by using mould under the application of heat & pressure.
- In case of thermo-plasts molten resin is introduced in mould & desired shape could be achieved by compression & further cooling.
The curing is done at room temperature (low temp)
- In case of thermo-sets partially polymerized mass or raw materials are introduced in the mould, which further cured at high temp in the mould itself to achieve desired shape.
The curing is done at high temp to obtain desired cross-linking

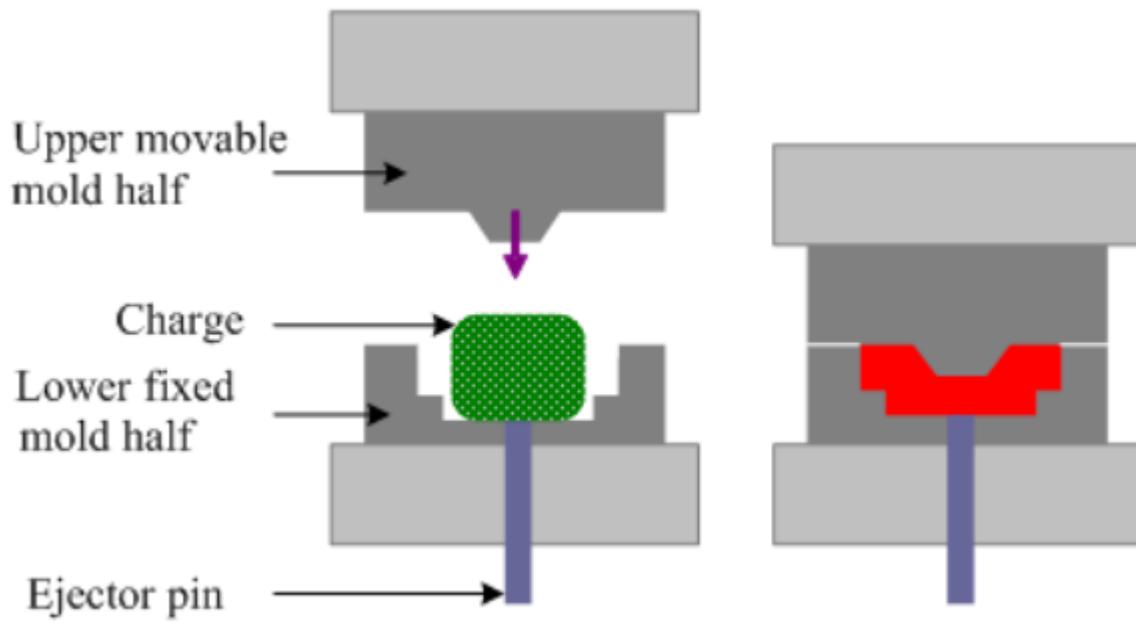
* Types of Fabrication

- 1] Compression Molding (Both)
- 2] Injection Molding (Thermoplasts)
- 3] Transfer Molding (Thermosets)
- 4] Extrusion Molding (Thermoplasts)

1] Compression Moulding

This is used for both thermosetting & thermoplastic materials.

Compression of raw material or soften resinous mass is done in the mould under heat & pressure.

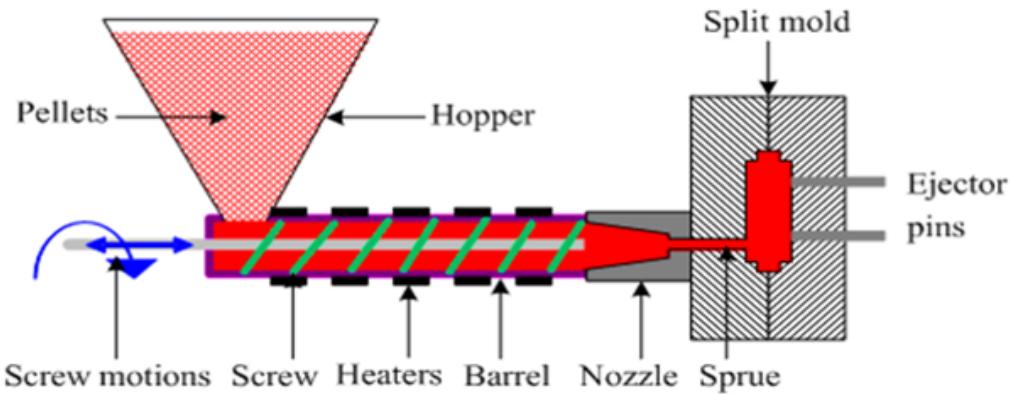


- a] Predetermined quantity of raw material is introduced carefully in the mould & further compressed by hydraulic pressure (2000 to 10,000 psi).
- b] Molten or soften resinous mass gets filled in the cavity of mould.
- c] Curing is done by heating (Thermosetting) or by cooling (Thermoplastics)
- d] Finally moulded article is separated from the mould by opening the mould apart.

Applications: Electric switch boxes, Ash trays, T.Vs, Computers , Cabinets for radio.

2]

Injection Moulding

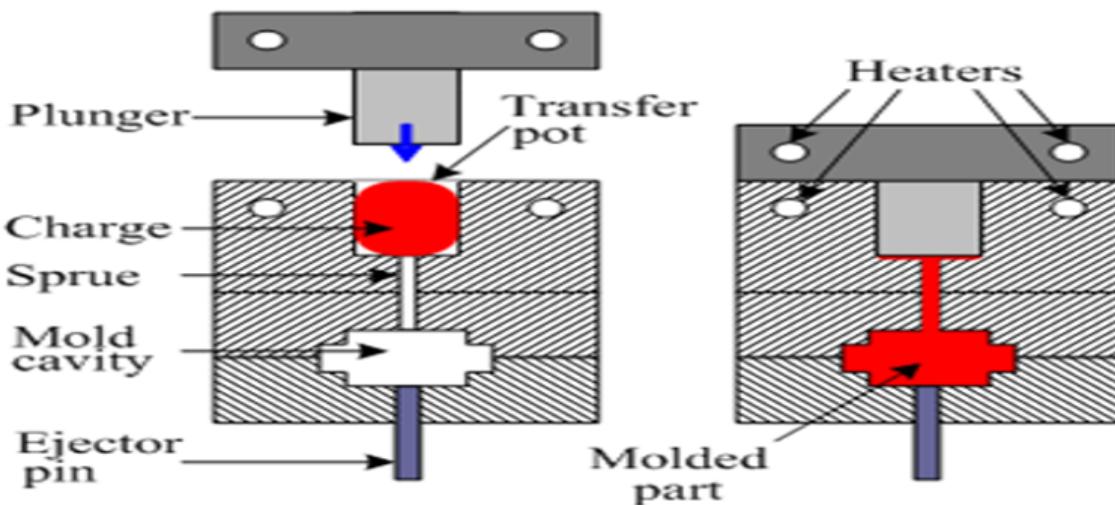


- a] This method is especially used for thermoplastic materials.
- b] Powder or granular resin is heated in a cylinder and injected at controlled rate in a mould with the help of screw.
- c] Screw is used to force the material in mould .
- d] Once the article is formed mould is cooled & half mould is opened to remove the finished article.
- e] Disadvantage of this method is formation of air bubbles or cavities in the articles

Applications:- Smaller but large volume article such as, pen caps, bottle caps, cups, containers, mechanical parts.

3

Transfer Moulding



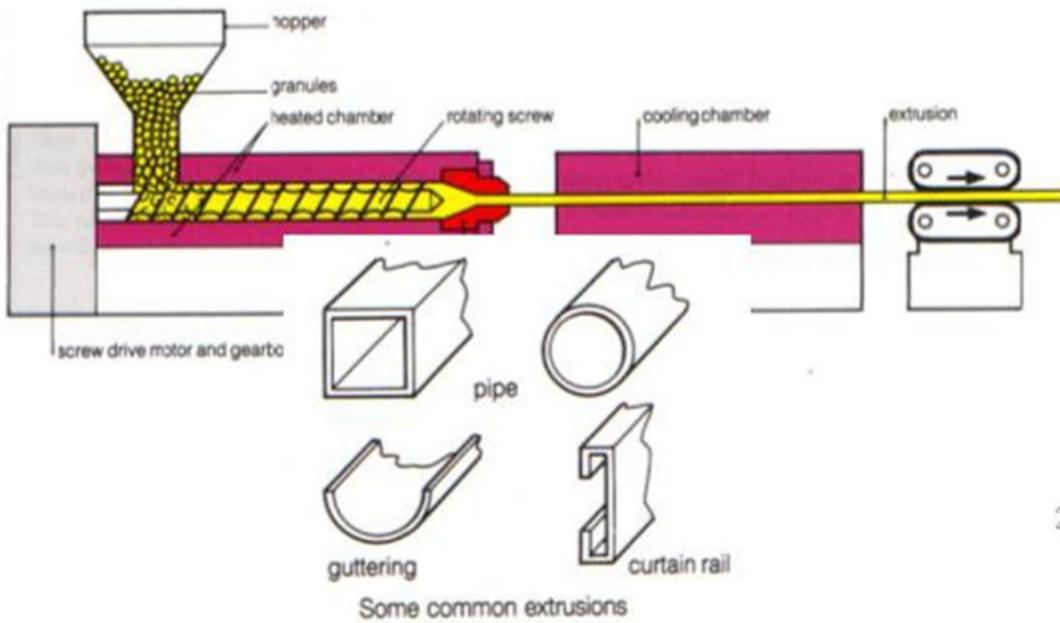
- a] This method combines features of both Compression Moulding & Injection Moulding.
- b] Used Especially for moulding thermosetting resins.
- c] Powdered raw materials are heated at certain low temp to soften & then introduced through an orifice in the mould.
- d] Then it is cured in the mould at high temp for certain time.
- e] Finally the moulded article is removed by separation of mould.

Advantages :-

- a] Articles with intricate shapes could be designed.
- b] Article is free from flow marks.
- c] The articles produced are blister free.

Applications :- IOL circuits, thick wires, plugs, connector pins etc.

4] Extrusion Moulding



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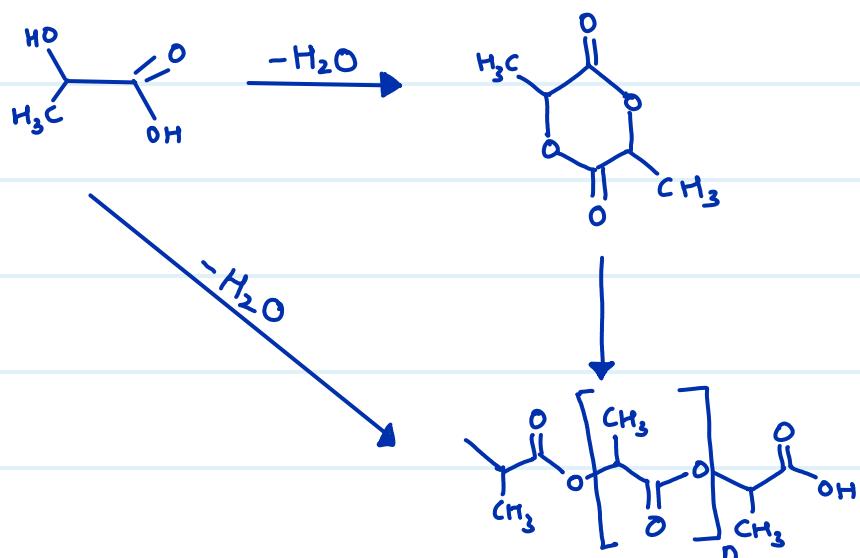
- a] The thermoplastic materials are moulded by this method.
- b] In this method, the thermoplastic material are heated to plastic condition and pushed by means of screw conveyor in to a mould cavity having required outer shape of articles to be manufactured.
- c] Here the plastic mass gets cooled due to atmosphere exposure.
- d] A long conveyor carries away the cooled products continuously.

Applications:- PVC pipes, wires, cables & sheets.

* Biodegradable polymers

1] Polylactic acid

- Also called as poly(lactic acid) or polylactide (PLA) is a thermoplastic polyester with backbone formula $(C_3H_4O_2)_n$ or $[-C(CH_3)HC(=O)O-]_n$ formally obtained by condensation of lactic acid



Properties:-

- It is linear thermoplastic polymer
- It is crystalline in nature.
- It has glass transition temp of 50°C - 80°C.
- It can be converted in to fiber.
- It is soluble in many organic solvent.
- Because of chiral atoms it shows stereo isomers.
- It is biodegradable.

Synthesis :-

The monomer is typically made from fermented plant starch as from corn, cassava, sugarcane

- Common route to PLA is ring-opening polymerization of lactide with various metal catalyst in soln.

This causes racemization of PLA.

- Direct condens' of lactic acid monomer can produce PLA less than 200°C. This rxn generates 1 eq of water for every condens'. Alcohols & COOH end groups are thus converted in amorphous region of solid polymers.

Applications of PLA:-

- PLA is used in disposable tableware, cutlery, laptop parts, microwavable trays.
- PLA is used for monofilament fishing line and netting for vegetation & weed prevention. Sandbags, planting pots, binding tape and ropes.
- PLA can degrade into innocuous lactic acid, so it is used as medical implants in the form of anchors, screws, plates, pins, rods & mesh.
- Depending on the exact type used, it breaks down inside the body within 6 months - 2 years. The gradual degradation is desirable for a support structure.

★ Conducting Polymers

Polymers are known to have insulating materials. The biggest advantage of conductive polymers is their processability, mainly by dispersion. The electrical properties can be fine-tuned using the methods of organic synthesis and by advanced dispersion techniques.

These are following conducting polymers.

- 1] Intrinsically conducting polymers (ICP)
- 2] Doped Conducting Polymer (DCP)
- 3] Extrinsically Conducting Polymer (ECP)

1] Intrinsically conducting polymers (ICP)

- These possess conjugated "pi" (π) e^- backbone.
- When such polymer faces electric field, these e^- gets excited & hence move through polymeric materials.
- The orbital of πe^- get overlapped on backbone & hence valence band & conduction are developed which get distributed over entire surface of polymer.
- Appropriate proportion of conjugated 'pi' (π) e^- makes polymer to conduct electricity very efficiently.

Aromatic: Poly aniline, Poly anththrylene

Aromatic heterocyclic: Poly pyrrole, poly thiophene, poly butadiene

2] Doped Conducting Polymer (DCP)

- These are prepared by exposure of the polymer to a charged transfer agent either in gas phase or in liquid phase (soln).
- As compared to plain ICP, these have low I.P. but high E.A. hence can be easily oxidized or reduced.

This technique is called doping.



3

Extrinsically conducting polymer (ECP)

- These are the conducting polymers which posses conductivity due to externally added ingredient in them.
- Conducting element filled polymer

In this type resin or polymer is filled up with conducting element

e.g.: carbon black, metal fibres, metal oxide etc.

- The polymer holds the metallic elements thus acting as a binder.
- Their conducting is reasonable high.

Applications of conducting Polymer

- Super capacitor
- In wiring in aircraft & aerospace component
- In telecommunication system.
- Solar cell, photovoltaic device.

Nanotech

* Nanomaterials

- Contains nanoparticles which are smaller than 100 nm in atleast 1D.

• Surface Effect

As size of particle \downarrow greater proportion of atom are found at the surface for eg:-

Size 30 nm - 5% of atom on its surface.

Size 10 nm - 20% of atom on its surface.

Size 3 nm - 50% of atom on its surface.

Nanomaterials have a much greater surface area to volume ratio than their conventional forms, which can lead to greater chemical reactivity and affect their strength.

• Quantum Effect

- When we reduce the size of material to nano range then the properties of material changes, this effect is known as Quantum Size Effect.

- As you make things smaller and smaller, you eventually reach a point where the averaging no longer works and you have to deal with the specific behavior of individual atoms or molecules - behavior that can be very different compared to bulk material of same stuff.
- Eg:- Opaque substance becomes transparent (copper) ; inert materials becomes catalysts (platinum) ; stable materials turn combustible (aluminium) ; solids turn into liquids at room temp (gold) ; insulators become conductors (silicon).

Quantum Confinement

When size of semiconductor decreases, then energy gap increases, due to which electron / Hole (Exciton) confined in a discrete energy level

This confinement of Electron & Hole is called Quantum Confinement

* Classification of Nano Materials :-

- Zero dimension (Quantum dots)
- One dimension (Quantum wires, rods)
- Two dimension (plates, network, quantum wells)
- Three dimension (fullerenes - C_{60} , haekelites)

(a) 0D spheres & clusters, (b) 1D nanofibres, wires, and rods, (c) 2D films, plates and networks, (d) 3D nanomaterials

* Fullerenes

- Spherical carbon-cage molecules C_{60} .
- 0.7 - 1.5 nm in diameter.

* Quantum Dots

- They are tiny semiconductor crystal, this means these particles can either conduct or resist depending on temp & purity of lab.
- Their size ranges b/w 2-10 nm.
- One of the unique property of Quantum dots is their emission colour depend upon their size not the material.
- size of quantum dot \propto wavelength $\propto \frac{1}{\text{frequency}}$ emitted.
- \therefore Larger quantum dot will emit red light and smaller will emit blue.
- The avg distance b/w e^- & a hole in a exciton is called Excited Bohr Radius. When size of the semiconductors falls below Bohr's radius, the semiconductor is called a quantum dot.
- Calcium selenide, cadmium sulphide, indium arsenide etc. can be used to

prepare Quantum dots.

- Useful in medical imaging, energy efficient lighting displays and photovoltaic cell.

• Tuning Quantum Dots

By changing size, shape & composition, quantum dots can change their absorptive and emissive property dramatically.

Applications:-

1] Medicine :-

- Useful tool for monitoring cancerous cells .
- Qdots could also be armed with tumor-fighting toxic therapies to provide the diagnosis & treatment of cancer.

2] LEDs:-

- Used to produce inexpensive , industrial quality white light.
- Better than traditional LED-phosphor integration by dot's ability to absorb & emit at any desired wavelength.

3] Solar Cell & Photovoltaic:-

- Traditional solar cells were expensive & only 33% efficient for conversion of sunlight to electricity.
- Using Qdots we get 60% efficiency in electricity production

Other futuristic applications are Anticounterfeiting capabilities & counter-espionage / defence applications.

* Carbon nanotubes (CNT)

Carbon nanotubes are hollow cylinders of C-atoms. A carbon nanotube consist of a sheet of C-atoms that are sp^2 hybridized and have a hexagonal symmetry. Such a two dimensional sheet is called graphene. A carbon nanotube is produced by rolling a graphene sheet into a cylinder shape. Their appearance is like rolled tubes of graphite. The ends of CNT have domed structure of six membered ring capped by five membered ring.

CNT



Single walled CNT (SWNT)
armchair - metallic
zigzag - semiconducting
chiral - semiconducting



Multiwalled CNT (MWNT)
multiwalled - metallic

• Properties of CNT

- 1] CNTs are extremely strong, about 100 times stronger than steel but six times lighter.
- 2] They have unique electronic & mechanical properties.
- 3] They are 1,00,000 times thinner than the human hair.
- 4] They possess very high tensile strength and stiffness.
- 5] CNTs can also act as conductors or semi-conductors depending on their chirality.

• Method of preparation

- 1] Arc Method
- 2] Laser Method
- 3] Chemical Deposition Method

• Applications of CNTs

- 1] Nanotubes led to new generation of electronic devices.
- 2] MWCNT are used in lithium ion batteries
- 3] CNT are used as an alternative to tungsten filaments in light bulbs.
- 4] CNTs can be used to produce nanowires of other metals such as gold & zinc oxide.
- 5] In Combat jacket, the CNTs are used as ultrastrong fibres.

Nano mechanics and lubricants

Carbon nanotubes are stiff and hard like diamond but flexible due to this they find several mechanical application. Cutting tools made up of Nano crystalline materials such as tungsten carbide titanium carbide are more wear resistant than convectional counter parts. They find application in drill, helmets, bullet proof cloth, etc. At present fastest known oscillators are made up of nanotubes.

Nanotubes develop material which are slicker than Teflon and also waterproof. Membrane made up of CNTs allow liquid flow up to five times faster than conventional membrane.

Nano sphere of inorganic material can act as nano sized ball bearing. They also find application in high performance engine and drivers.

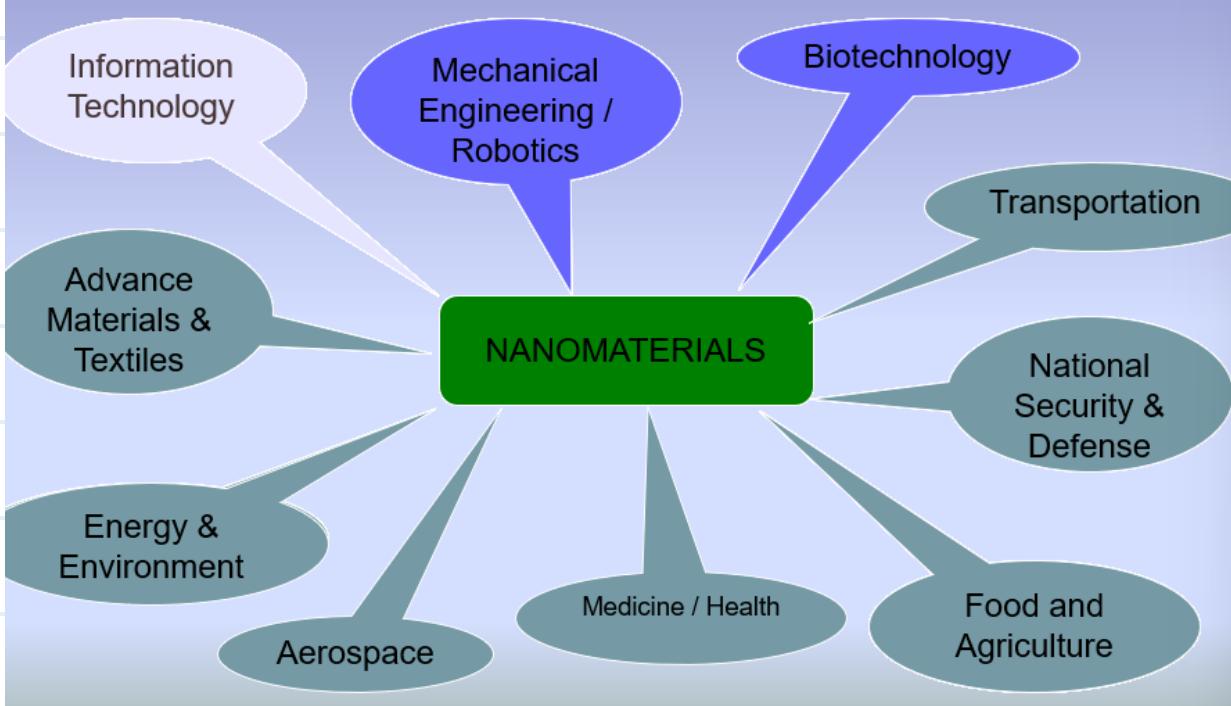
Medicine

- Nanomaterials are of the size 10^{-9} . Hence they are smaller or comparable than single cell, virus, protein. Thus materials can freely move through tissue or bind to biological system. Endothelium layers are porous thus nano particle can penetrate through them and can be used as medicine or carrier. Many of magnetic nano particles have been used in cancer therapy like hyperthermia. Magnetic particle are also used for tagging cancer cells, bacteria red blood cells. They are also used in contrast enhancing agent in MRI. Thus they can be used to detect brain tumor liver tumor and lymph nodes.

Nano shells as Cancer Therapy

Nano shells are injected into cancer area and they recognize cancer cells. Then by applying near-infrared light, the heat generated by the light-absorbing Nano shells has successfully killed tumor cells while leaving neighboring cells intact.

Application of nanomaterials



Environment & Catalyst

- With nano technology it is possible to synthesize metal nano particles of highly ordered mono dispersed film. These nano catalyst greater activity and specific in action. It is possible to achieve specific or selective activity. This will reduce huge requirement of all rare earth metal in the production of catalyst
- Nano porous aluminum silicates(zeolites) are used in water treatment. Nano porous membrane with definite and desired pore are used as nano filters for dust and impurities from air and water. Gold nano particles are used for degradation of toilet odor. Nano ZnO is used for degradation of chlorinated phenol. Nano photo catalyst are used for degradation of pollutant present in waste water.

Bio Material

- Metals, ceramics, plastics, glass & even living cells and tissue all can be used in creating a bio-material

* Metals and alloys for biomedical applications

They are used as bio material for their excellent strength and biocompatibility

1] Stainless Steel

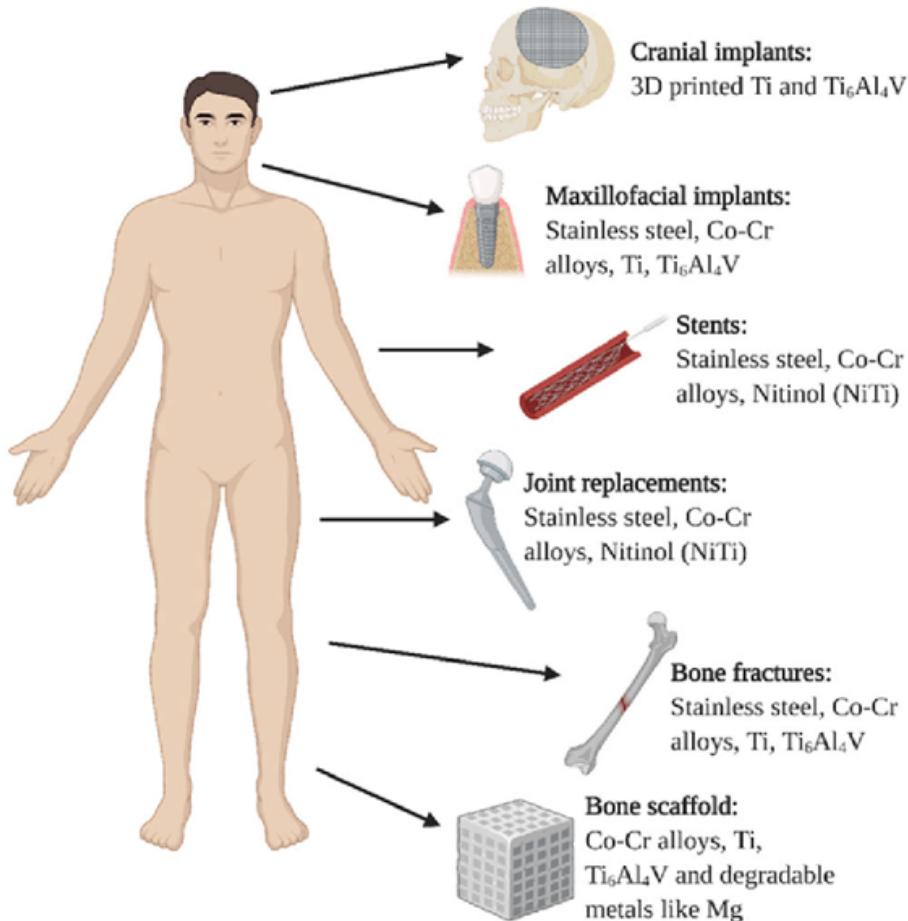
- Alloys of Fe, Cr, Ni & C.
- It has good corrosion resistance due to formation of passive layer on these material (due to Cr)
- Used as permanent surgical implant for decades.

Eg:- 316 L (316 Low Carbon Steel)

- The biocompatibility in this implants due to protective layer of chromium oxide.
- The advantage of stainless steel is that it is cheap, easily available and has excellent fabrication properties & is biocompatible & has great strength
- Most of internal fixation devices like wires, pin, screws, plates and intramedullary nails or rods are made up of SS.

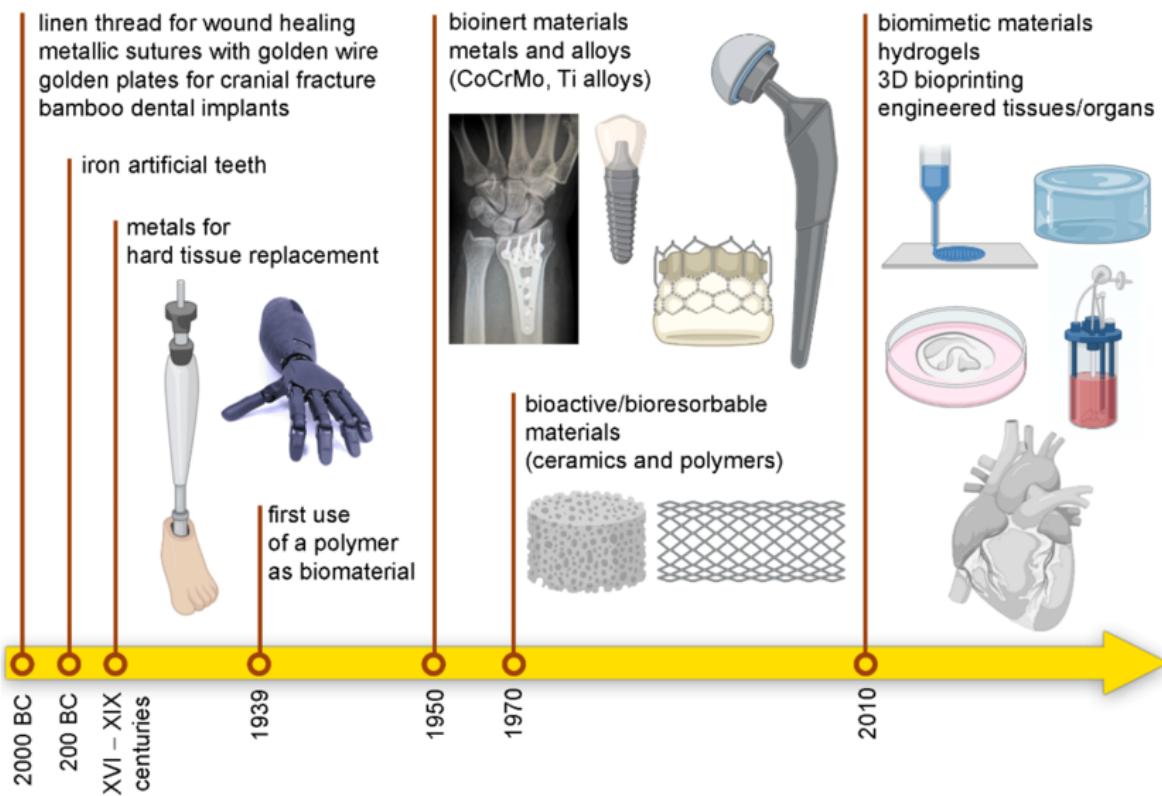
- Limitations:-

- Within the body, SS implants are exposed to complex body fluids, which contain chloride ions, reduced sulfur etc. & when SS reacts with these ions, toxic elements like Ni & Cr are released.
- Another major concern in using SS as a biomedical implant is presence of Ni, which is toxic and many patients are Ni-sensitive. Research is also going on in developing Ni-free SS.



2] Cobalt - Chromium alloys

- The alloys are generally combination of cobalt, chromium, and molybdenum, or cobalt, nickel, chromium & molybdenum.
- They are often used as components in modular prosthetic devices such as hip or knee joints, particularly in the ball & socket joint where movement occurs.
- Other applications of this alloy include implants like tribal trays, acetabular cups, dental parts, pacemaker lead castings, as well as cardiovascular stents.





Bio-Ceramics

Ceramics are refractory polycrystalline compounds

* Classification of Bio-ceramics

1] The first generation would correspond to bio-inert bio-ceramics such as alumina and zirconia, which are mostly used for inert orthopedic & dental implants.

2] The second generation comprises bioactive and bioabsorbable ceramics, such as calcium phosphates or bioglasses.

3] The third generation is scaffolds for tissue engineering which aim to drive the regeneration of living tissues.

When ceramic length scales in the nano range better and unusual material properties can be achieved.

- Applications

- Ceramics are broadly used in a large variety of technology applications.
- bone-related biomedical applications are the most demanding of bio ceramics.
- Nanophased ceramics are being investigated as a way of solving some of the structural & bio-related problems
- For example, nanometric features in the surface of a prosthesis seem to reduce the risk of rejection & enhance the proliferation of osteoblasts (bone-forming cells).
- Nanophased or nanostructured ceramics can be obtained either by nanocrystalline materials or with nano composites.

* Properties and Application of nanocrystalline ceramics.

- In case of nanocrystalline ceramics, as grain size is reduced, the grain volume at grain boundaries is increased.
- Due to high density of interfaces, an important fraction of atoms will be at interface.

This allows nanocrystalline materials to offer unusual & improved properties when compared microscale materials

• Advantages:-

- a) ↑ resistance / hardness
- b) ↑ toughness

- ② lower elastic modulus & lower ductility
- ③ reduced risk of rejection
- ④ enhanced proliferation of osteoblasts
- ⑤ promotion of osseointegration

* Nano-Composites

- Nanocomposites based on ceramic materials have been studied in order to improve mechanical properties and alter functional properties.
- Enhancements in stability, hardness, strength, toughness & creep resistance compared to the unreinforced matrix material have been reported in Nanocomposites

Examples :-

- 1] Alumina-based nanocomposites : with addition in nanocomposites, alumina matrix material with improved mechanical properties have been obtained.
- 2] Alumina / Zirconia nanocomposites also known as zirconia-toughened alumina (ZTA) nanocomposites, they consist of alumina matrix reinforced with zirconia particles. It increases the toughness of alumina matrix.
- 3] Alumina/titania nanocomposites : Increases hardness, fracture toughness & resistance
- 4] Zirconia/Alumina nanocomposites also known as alumina-toughened zirconia (ATZ), zirconia matrix reinforced with alumina nanoparticles, they show exceptional resistance & toughness.
- 5] CNT composite : mechanical & electrical properties are enhanced.

