UNIT-III

PART A

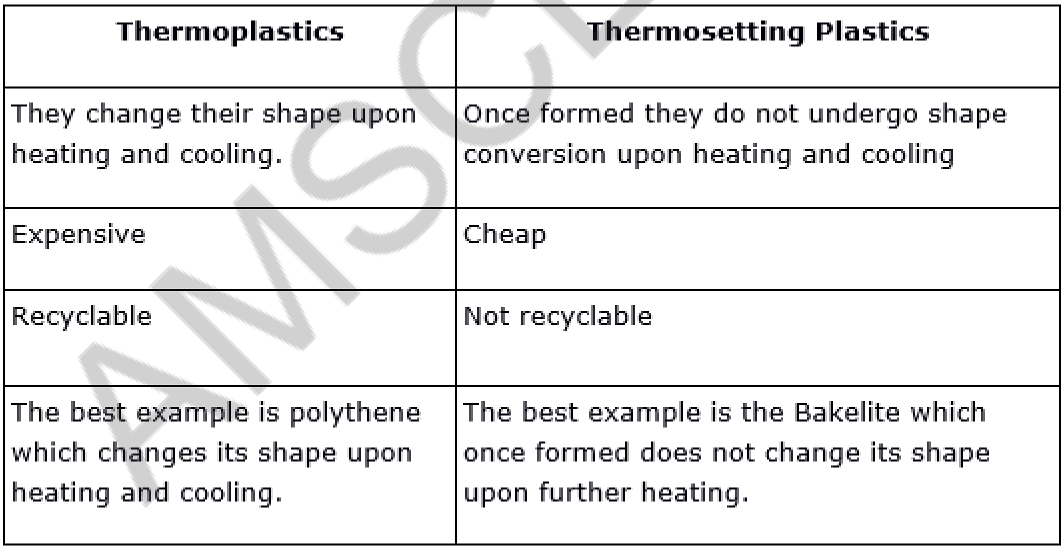
1. What are outstanding properties of PSZ?

- High toughness.
- Increased wear resistance.

2. List the typical applications of PTFE.

The major application of PTFE, consuming about 50% of production, is for the insulation of wiring in aerospace and computer applications (e.g. hookup wire, coaxial cables). This application exploits the fact that PTFE has excellent dielectric properties, especially at high radio frequencies, making it suitable for use as an excellent insulator in connector assemblies and cables, and in printed circuit boards used at microwave frequencies. Combined with its high melting temperature, this makes it the material of choice as a high-performance substitute for the weaker and lower-melting-point polyethylene commonly used in low-cost applications.In industrial applications, owing to its low friction, PTFE is used for plain bearings, gears, slide plates, seals, gaskets, bushings, and more applications with sliding action of parts, where it outperforms acetal and nylon.Its extremely high bulk resistivity makes it an ideal material for fabricating long-life electrets, the electrostatic analogues of permanent magnets.

3. Distinguish between thermoplastics and thermosetting plastics.



Thermoplastics	**Thermosetting Plastics**
They change their shape upon heating and cooling.	Once formed they do not undergo shape conversion upon heating and cooling
Expensive	Cheap
Recyclable	Not recyclable
The best example is polythene which changes its shape upon heating and cooling.	The best example is the Bakelite which once formed does not change its shape upon further heating.

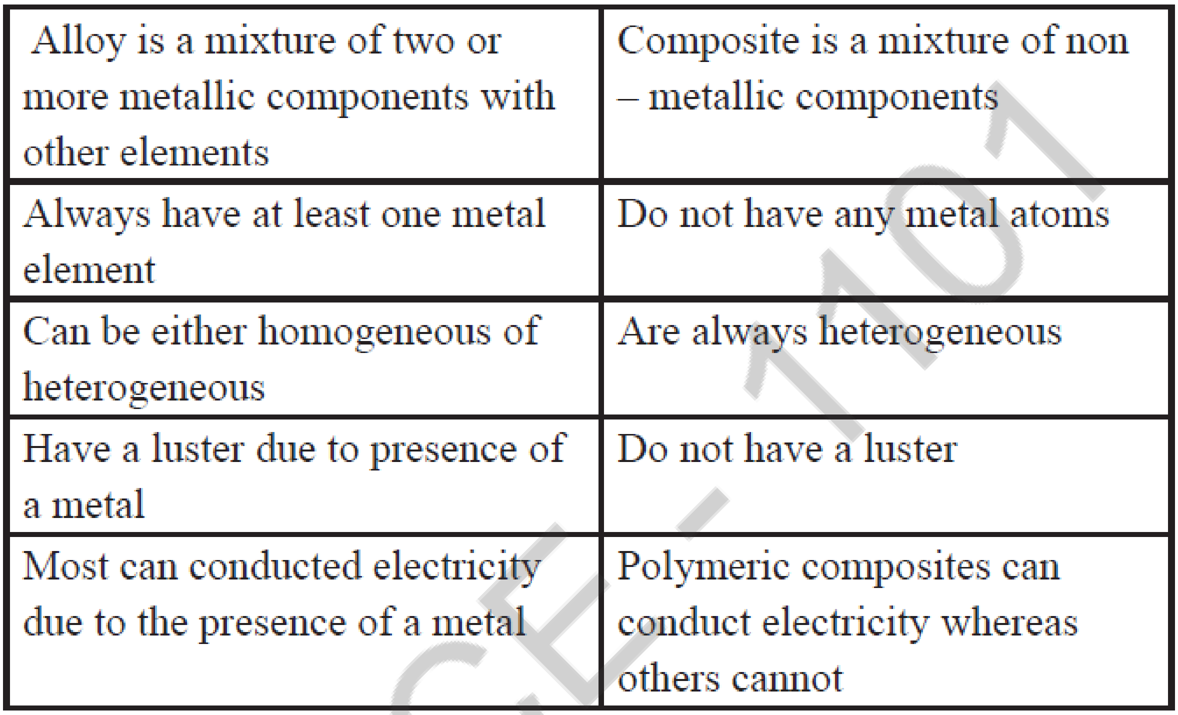
4. What is meant by PSZ?

It is a ceramic in which the cubic crystal structure of zirconium dioxide is made stable at room temperature by an addition of yttrium oxide. These oxides are commonly called "zirconia" (ZrO_2) and "yttria" (Y_2O_3), hence the name.

5. What is the primary physical difference between thermo and thermosetting plastics.

The primary physical difference is that thermoplastics can be remelted back into a liquid, whereas thermoset plastics always remain in a permanent solid state.

6. What are the primary constituent of MMC.
   MMC is composit material with at least two constituent parts, one being a metal necessaritly the other material may be a different metal or another material. Such as a ceramic or organic compound.
7. Differentiate between composite and alloy.



Alloy is a mixture of two or more metallic components with other elements	Composite is a mixture of non – metallic components
Always have at least one metal element	Do not have any metal atoms
Can be either homogeneous of heterogeneous	Are always heterogeneous
Have a luster due to presence of a metal	Do not have a luster
Most can conducted electricity due to the presence of a metal	Polymeric composites can conduct electricity whereas others cannot

8. **Write a short note on pet. (Apr/May 2017)**

PET (also abbreviated PETE) is short for polyethylene terephthalate, the chemical name for polyester. PET is a clear, strong, and lightweight plastic that is widely used for packaging foods and beverages, especially convenience-sized soft drinks, juices and water. Polyethylene terephthalate polyester (PETP) is a hard, stiff, strong, dimensionally stable material that absorbs very little water. It has good gas barrier properties and good chemical resistance except to alkalis (which hydrolyse it). Its crystallinity varies from amorphous to fairly high crystalline.

9. **What are outstanding properties of PTFE? (Nov/Dec 2017)**

The outstanding properties of PTFE are its high flexural strength, even in low temperatures, high electrical resistance and dielectric strength, resistance to water and low coefficient of friction. PTFE's density is also very high, at 2200 kg/m3.

10. **List the typical applications of SiC. (Nov/Dec 2017)**

Silicon carbide is used as an abrasive in many industrial applications. In the electronics industry, the main use is in lapping films which are used for polishing the ends of fiber-optic strands prior to splicing.

11. **Differentiate thermosteering and thermoplastic polumers.**

Refer question 7.

12. **What is meant by metal matrix composite? Give one example each to matrix material and reinforcements used.**

A metal matrix composite (MMC) is composite material with at least two constituent parts, one being a metal necessarily, the other material may be a different metal or another material, such as a ceramic or organic compound.carbon fibers are commonly used in aluminium matrix to synthesize composites showing low density and high strength. However, carbon reacts with aluminium to generate a brittle and water-soluble compound Al4C3 on the surface of the fibre. To prevent this reaction, the carbon fibres are coated with nickel or titanium boride.

13. **What are the outstanding properties of PMMA**

It is a rigid, transparent material and better at transmitting light than inorganic glass. PMMA is moretransparent than glass. When glass windows are made too thick, they become difficult to seethrough. But PMMA windows can be made as much as 13 inches (33 cm) thick, and they're stillperfectly transparent. This makes PMMA ideal in the construction of large aquariums wherewindows must be thick in order to withstand the pressure of millions of gallons of water. Thematerial is often used in place of glass. These optical qualities are the basis for its principalapplications: from building to furniture, road signs, the car industry, navy, electrical appliances,laboratory equipment. Unlike glass, PMMA does not filter UV light. Some manufacturers coat theirPMMA with UV films to add this property. Up to wavelengths of 2800 nm, PMMA allows most IR(infrared) light to pass. Longer wavelengths of IR energy, up to 25,000 nm are essentially blocked.Special formulations of colored PMMA exist to allow specific IR wavelengths to pass whileblocking visible light (for remote control or heat sensor applications, for example). PMMA can bejoined using cyanoacrylate cement (so-called "Superglue"), or by using liquid dichloromethane todissolve the plastic at the join which then fuses and sets, forming an almost invisible weld. PMMAcan also be easily polished, by which method cut edges (which turn opaque) can be returned totransparency.

14. **List the typical applications of Al2O3.**

The composition of the ceramic body can be changed to enhance particular desirable materialcharacteristics. An example would be additions of chrome oxide or manganese oxide to improvehardness and change color. Other additions can be made to improve the ease and consistency ofmetal films fired to the ceramic for subsequent brazed and soldered assembly.

15. **What is meant by the term 'unsaturated molecules'. State its significance in plastics.**

An unsaturated compound is a chemical compound that contains carbon-carbon double bonds or triple bonds, such as those found in alkenes or alkynes, respectively. Saturated and unsaturated compounds need not consist only of a carbon atom chain. They can form straight chain, branched chain, or ring arrangements. They can have functional groups, as well. It is in this sense that fatty acids are classified as saturated or unsaturated. The amount of unsaturation of a fatty acid can be determined by finding its iodine number. Unsaturated compounds are those in which addition reaction can be obtained.In a chain of carbons, such as a fatty acid, a double or triple bond will cause a kink in the chain. These kinks have macro-structural implications. Unsaturated fats tend to be liquid at room temperature, rather than solid, as the kinks in the chain prevent the molecules from packing closely together to form a solid. These fats are called oils and are present in fish and plants. In other unsaturated hydrocarbons, the double bond between two carbons prevents rotation of the atoms about the bond, lockingthem into specific structural formations. When attached atoms occupy similar positions on each carbon, they are referred to as CIS, and when they are on opposite sides, they are called “trans”. Most natural hydrocarbons exist in the cis state, but artificially manufactured hydrocarbons are trans. The body lacks the enzymes to properly break down the trans configuration. This is why trans fats are viewed as dangerous and unhealthy, as they tend to build up. Unsaturated compounds of the two formations are classified as geometric isomers of one another.

16. **What are sialons. What are their application.**

It is a ceramic by the combination of Aluminium, silica, oxygen and nitrogen. It is used in crucibles and in melting of ferrous alloys.

17. **What is polymer**

A substance which has a molecular structure built up chiefly or completely from a large number of similar units bonded together, e.g. many synthetic organic materials used as plastics and resins.

18. **What is fibre reinforced plastics**

Fibre-reinforced plastic (FRP) is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass, carbon, aramid, or basalt. Rarely, other fibres such as paper or wood or asbestos have been used. The polymer is usually an epoxy, vinylester or polyester thermosetting plastic; and phenol formaldehyde resins are still in use.

FRPs are commonly used in the aerospace-, automotive-, marine- and construction industries; and in ballistic armor.

19. Define the term polymer.

Poly-many

Mer-single unit

Polymer – many units joined together

20. What are the naturally occurring polymers?

Wood, rubber, leather, etc.

PART B

1. Classify composite materials and list properties and application of FRP and metal matrix.

Refer question no. 19 and 17.

2. Classify engineering ceramics and list properties and applicaitions of SiC and Si3N4.

Refer question no. 9, 12 and 11

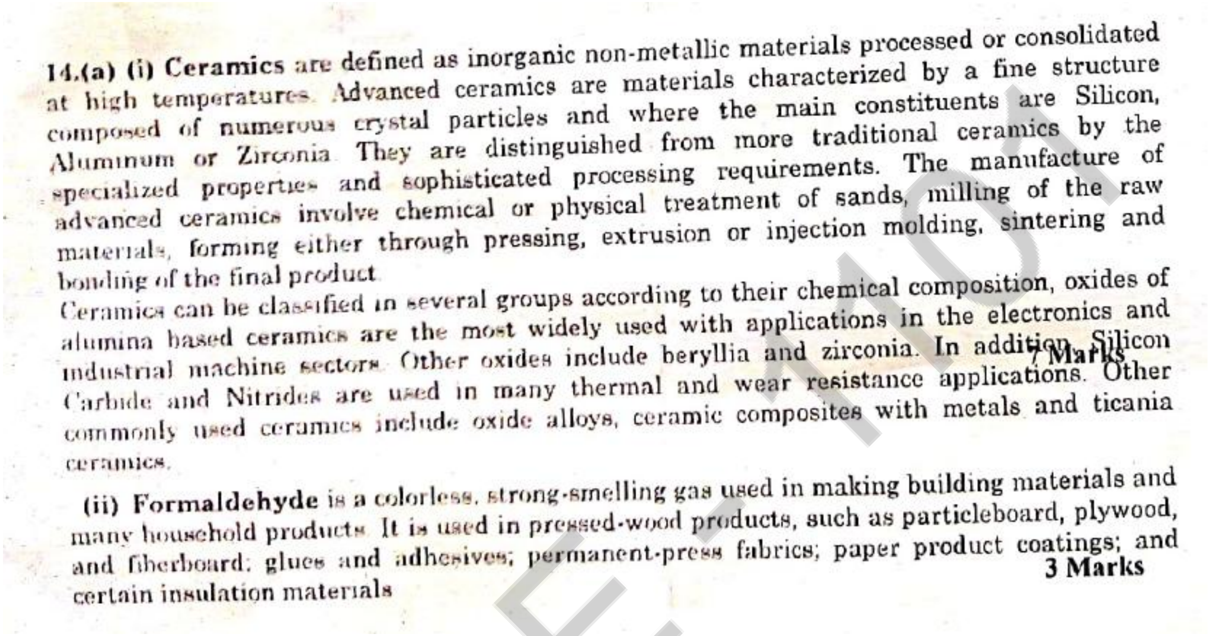
3. Brief on properties and applications of any two polymers from the list: PTFE, PC, PET, ABS and PS.

Refer question no. 8

4. Explain the properties and applications of the following polymer materials. Polystyrene, polyethylene, polypropylene.

Refer question no. 8

5. Explain in detail about Ceramics, Formaldehyde and Poly methyl methacrylate (PMMA)



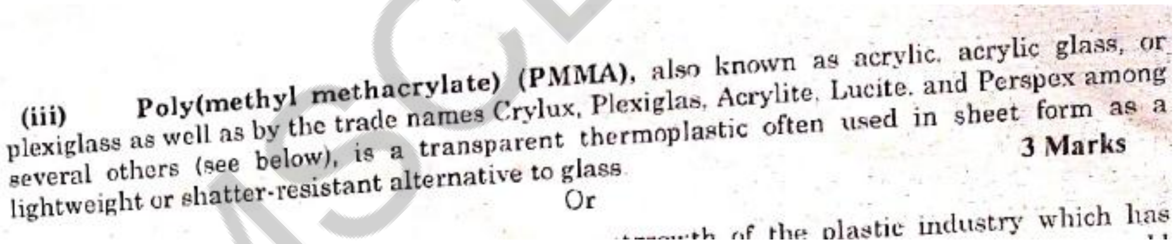
14.(a) (i) **Ceramics** are defined as inorganic non-metallic materials processed or consolidated at high temperatures. Advanced ceramics are materials characterized by a fine structure composed of numerous crystal particles and where the main constituents are Silicon, Aluminum or Zirconia. They are distinguished from more traditional ceramics by the specialized properties and sophisticated processing requirements. The manufacture of advanced ceramics involve chemical or physical treatment of sands, milling of the raw materials, forming either through pressing, extrusion or injection molding, sintering and bonding of the final product.

Ceramics can be classified in several groups according to their chemical composition, oxides of alumina based ceramics are the most widely used with applications in the electronics and industrial machine sectors. Other oxides include beryllia and zirconia. In addition, Silicon Carbide and Nitrides are used in many thermal and wear resistance applications. Other commonly used ceramics include oxide alloys, ceramic composites with metals and ticania ceramics.

7 Marks

(ii) **Formaldehyde** is a colorless, strong-smelling gas used in making building materials and many household products. It is used in pressed-wood products, such as particleboard, plywood, and fiberboard; glues and adhesives; permanent-press fabrics; paper product coatings; and certain insulation materials

3 Marks



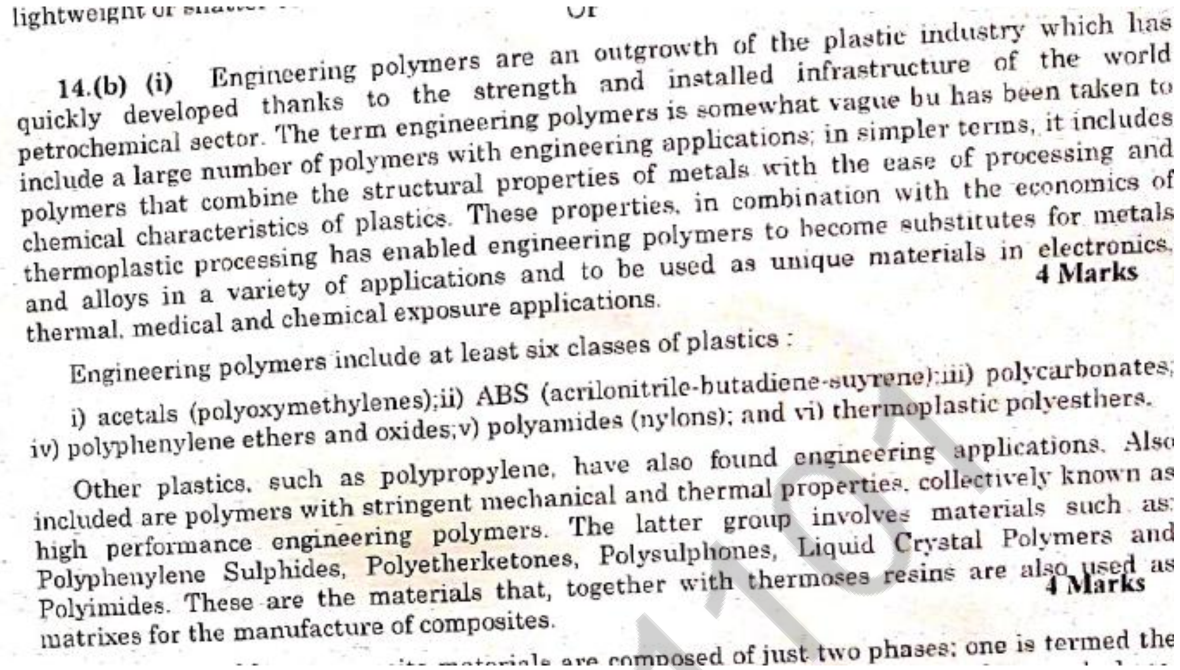
(iii) **Poly(methyl methacrylate) (PMMA)**, also known as acrylic, acrylic glass, or plexiglass as well as by the trade names Crylux, Plexiglas, Acrylite, Lucite, and Perspex among several others (see below), is a transparent thermoplastic often used in sheet form as a lightweight or shatter-resistant alternative to glass.

3 Marks

Or

of the plastic industry which has

6. Explain the engineering polymers in details



lightweight or Or

14.(b) (i) Engineering polymers are an outgrowth of the plastic industry which has quickly developed thanks to the strength and installed infrastructure of the world petrochemical sector. The term engineering polymers is somewhat vague bu has been taken to include a large number of polymers with engineering applications; in simpler terms, it includes polymers that combine the structural properties of metals with the ease of processing and chemical characteristics of plastics. These properties, in combination with the economics of thermoplastic processing has enabled engineering polymers to become substitutes for metals and alloys in a variety of applications and to be used as unique materials in electronics, thermal, medical and chemical exposure applications. **4 Marks**

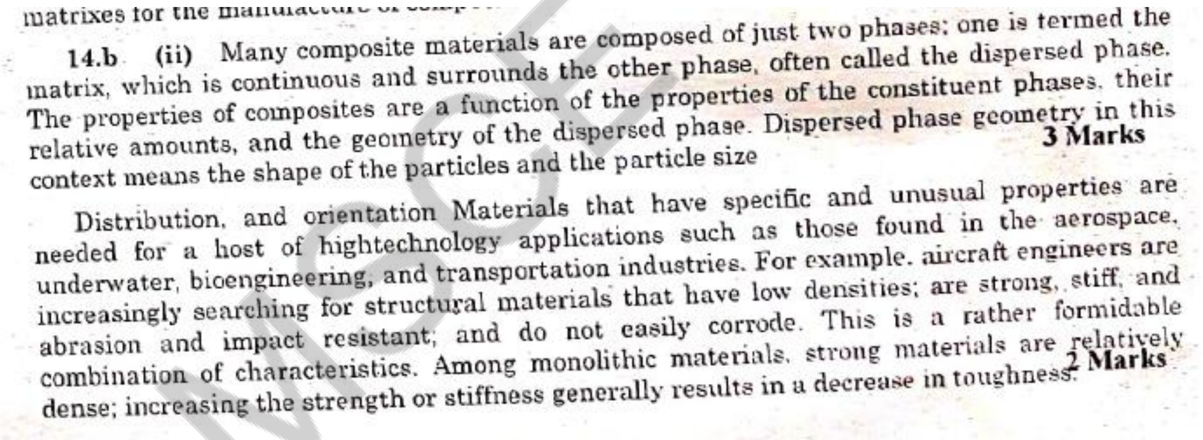
Engineering polymers include at least six classes of plastics :

i) acetals (polyoxymethylenes);ii) ABS (acrilonitrile-butadiene-suyrene);iii) polycarbonates; iv) polyphenylene ethers and oxides;v) polyamides (nylons); and vi) thermoplastic polyesthers.

Other plastics, such as polypropylene, have also found engineering applications. Also included are polymers with stringent mechanical and thermal properties, collectively known as high performance engineering polymers. The latter group involves materials such as: Polyphenylene Sulphides, Polyetherketones, Polysulphones, Liquid Crystal Polymers and Polyimides. These are the materials that, together with thermoses resins are also used as matrixes for the manufacture of composites. **4 Marks**

composite materials are composed of just two phases; one is termed the

7. State the properties and uses of reinforced composites.



matrixes for the manufacture of compo

14.b (ii) Many composite materials are composed of just two phases; one is termed the matrix, which is continuous and surrounds the other phase, often called the dispersed phase. The properties of composites are a function of the properties of the constituent phases, their relative amounts, and the geometry of the dispersed phase. Dispersed phase geometry in this context means the shape of the particles and the particle size **3 Marks**

Distribution, and orientation Materials that have specific and unusual properties are needed for a host of hightechnology applications such as those found in the aerospace, underwater, bioengineering, and transportation industries. For example, aircraft engineers are increasingly searching for structural materials that have low densities; are strong, stiff, and abrasion and impact resistant; and do not easily corrode. This is a rather formidable combination of characteristics. Among monolithic materials, strong materials are relatively dense; increasing the strength or stiffness generally results in a decrease in toughness. **2 Marks**

8. **What is meant by ‘Polymers’? discuss the properties, applications and chemical structure of any four types of polymers. (Apr/May 2017)**

i) PET

The majority of the world’s PET production is for synthetic fibers (in excess of 60%), with bottle production accounting for about 30% of global demand.[5] In the context of textile applications, PET is referred to by its common name, *polyester*, whereas the acronym *PET* is generally used in relation to packaging. Polyester makes up about 18% of world polymer production and is the fourth-most-produced polymer; polyethylene (PE), polypropylene (PP) and polyvinyl chloride (PVC) are first, second and third, respectively.

PET consists of polymerized units of the monomer ethylene terephthalate, with repeating (C10H8O4) units. PET is commonly recycled, and has the number “1” as its recycling symbol.

Depending on its processing and thermal history, polyethylene terephthalate may exist both as an amorphous (transparent) and as a semi-crystalline polymer. The semicrystalline material might appear transparent (particle size < 500 nm) or opaque and white (particle size up to a few micrometers) depending on its crystal structure and particle size.

The monomer bis(2-hydroxyethyl) terephthalate can be synthesized by the esterification reaction between terephthalic acid and ethylene glycol with water as a byproduct, or by transesterification reaction between ethylene glycol and dimethyl terephthalate with methanol as a byproduct. Polymerization is through a polycondensation reaction of the monomers (done immediately after esterification/transesterification) with water as the byproduct.

PET in its natural state is a colorless, semi-crystalline resin. Based on how it is processed, PET can be semi-rigid to rigid, and it is very lightweight. It makes a good gas and fair moisture barrier, as well as a good barrier to alcohol (requires additional “barrier” treatment) and solvents. It is strong and impact-resistant. PET becomes white when exposed to chloroform and also certain other chemicals such as toluene.

About 60% crystallization is the upper limit for commercial products, with the exception of polyester fibers. Clear products can be produced by rapidlycooling molten polymer below Tg glass transition temperature to form an amorphous solid. Like glass, amorphous PET forms when its molecules are not given enough time to arrange themselves in an orderly, crystalline fashion as the melt is cooled. At room temperature the molecules are frozen in place, but, if enough heat energy is put back into them by heating above Tg, they begin to move again, allowing crystals to nucleate and grow. This procedure is known as solid-state crystallization.

When allowed to cool slowly, the molten polymer forms a more crystalline material. This material has spherulites containing many small crystallites when crystallized from an amorphous solid, rather than forming one large single crystal. Light tends to scatter as it crosses the boundaries between crystallites and the amorphous regions between them. This scattering means that crystalline PET is opaque and white in most cases. Fiber drawing is among the few industrial processes that produce a nearly single-crystal product.

Because PET is an excellent water and moisture barrier material, plastic bottles made from PET are widely used for soft drinks(see carbonation). For certain specialty bottles, such as those designated for beer containment, PET sandwiches an additional polyvinyl alcohol (PVOH) layer to further reduce its oxygen permeability.

Biaxially oriented PET film (often known by one of its trade names, «Mylar») can be aluminized by evaporating a thin film of metal onto it to reduce its permeability, and to make it reflective and opaque (MPET). These properties are useful in many applications, including flexible food packaging and thermal insulation. See: “space blankets”. Because of its high mechanical strength, PET film is often used in tape applications, such as the carrier for magnetic tape or backing for pressure-sensitive adhesive tapes.

Non-oriented PET sheet can be thermoformed to make packaging trays and blister packs. If crystallizable PET is used, the trays can be used for frozen dinners, since they withstand both freezing and oven baking temperatures. As opposed to amorphous PET, which is transparent, crystallizable PET or CPET tends to be black in colour.

When filled with glass particles or fibres, it becomes significantly stiffer and more durable.

PET is also used as a substrate in thin film solar cells. Terylene (a trademark formed by inversion of (polyeth)ylene ter(ephthalate)) is also spliced into bell rope tops to help prevent wear on the ropes as they pass through the ceiling.

ii) PC

Polycarbonates (**PC**) are a group of thermoplastic polymers containing carbonate groups in their chemical structures. Polycarbonates used in engineering are strong, tough materials, and some grades are optically transparent. They are easily worked, molded, and thermoformed. Because of these properties, polycarbonates find many applications. Polycarbonates do not have a unique resin identification code (RIC) and are identified as «Other», 7 on the RIC list. Products made from polycarbonate can contain the precursor monomer bisphenol A (BPA). Polycarbonate is also known by a variety of trademarked names, including Lexan, Makrolon, Hammerglass and others.

Polycarbonate is a durable material. Although it has high impact-resistance, it has low scratch-resistance. Therefore, a hard coating is applied to polycarbonate eyewear lenses and polycarbonate exterior automotive components. The characteristics of polycarbonate compare to those of polymethyl methacrylate (PMMA, acrylic), but polycarbonate is stronger and will hold up longer to extreme temperature. Polycarbonate is highly transparent to visible light, with better light transmission than many kinds of glass.

Polycarbonate has a glass transition temperature of about 147 °C (297 °F), so it softens gradually above this point and flows above about 155 °C (311 °F). Tools must be held at high temperatures, generally above 80 °C (176 °F) to make strain-free and stress-free products. Low molecular mass grades are easier to mold than higher grades, but their strength is lower as a result. The toughest grades have the highest molecular mass, but are much more difficult to process.

Unlike most thermoplastics, polycarbonate can undergo large plastic deformations without cracking or breaking. As a result, it can be processed and formed at room temperature using sheet metal techniques, such as bending on a brake. Even for sharp angle bends with a tight radius, heating may not be necessary. This makes it valuable in prototyping applications where transparent or electrically non-conductive parts are needed, which cannot be made from sheet metal. PMMA/Acrylic, which is similarin appearance to polycarbonate, is brittle and cannot be bent at room temperature.

Main transformation techniques for polycarbonate resins:

- Extrusion into tubes, rods and other profiles including multiwall
- Extrusion with cylinders (calenders) into sheets (0.5–20 mm (0.020– 0.787 in)) and films (below 1 mm (0.039 in)), which can be used directly or manufactured into other shapes using thermoforming or secondary fabrication techniques, such as bending, drilling, or routing. Due to its chemical properties it is not conducive to laser-cutting.
- Injection molding into ready articles

Polycarbonate may become brittle when exposed to ionizing radiation above 25 kGy (J/kg).

iii) ABS

Acrylonitrile butadiene styrene (**ABS**) (chemical formula (C8H8)x· (C4H6)y· (C3H3N)z) is a common thermoplastic polymer. Its glass transition temperature is approximately 105 °C (221 °F). ABS is amorphous and therefore has no true melting point.

ABS is a terpolymer made by polymerizing styrene and acrylonitrile in the presence of polybutadiene. The proportions can vary from 15 to 35% acrylonitrile, 5 to 30% butadiene and 40 to 60% styrene. The result is a long chain of polybutadiene criss-crossed with shorter chains of poly(styrene-co-acrylonitrile). The nitrile groups from neighboring chains, being polar, attract each other and bind the chains together, making ABS stronger than pure polystyrene. The styrene gives the plastic a shiny, impervious surface. The polybutadiene, a rubbery substance, provides toughness even at low temperatures. For the majority of applications, ABS can be used between −20 and 80 °C (−4 and 176 °F) as its mechanical properties vary with temperature. The properties are created by rubber toughening, where fine particles of elastomer are distributed throughout the rigid matrix.

The most important mechanical properties of ABS are impact resistance and toughness. A variety of modifications can be made to improve impact resistance, toughness, and heat resistance. The impact resistance can be amplified by increasing the proportions of polybutadiene in relation to styrene and also acrylonitrile, although this causes changes in other properties. Impact resistance does not fall off rapidly at lower temperatures. Stability under load is excellent with limited loads. Thus, by changing the proportions of its components, ABS can be prepared in different grades. Two major categories could be ABS for extrusion and ABS for injection moulding, then high and medium impact resistance. Generally ABS would have useful characteristics within a temperature range from −20 to 80 °C (−4 to 176 °F).

Lego bricks are made from ABS.

The final properties will be influenced to some extent by the conditions under which the material is processed to the final product. For example, molding at a high temperature improves the gloss and heat resistance of the product whereas the highest impact resistance and strength are obtained by molding at low temperature. Fibers (usually glass fibers) and additives can be mixed in the resin pellets to make the final product strong and raise the operating range to as high as 80 °C (176 °F). Pigments can also be added, as the raw material original color is translucent ivory to white. The aging characteristics of the polymers are largely influenced by the polybutadiene content, and it is normal to include antioxidants in the composition. Other factors include exposure to ultraviolet radiation, for which additives are also available to protect against.

ABS polymers are resistant to aqueous acids, alkalis, concentrated hydrochloric and phosphoric acids, alcohols and animal, vegetable and mineral oils, but they are swollen by glacial acetic acid, carbon tetrachloride and aromatic hydrocarbons and are attacked by concentrated sulfuric and nitric acids. They are soluble in esters, ketones, ethylene dichloride and acetone.

Even though ABS plastics are used largely for mechanical purposes, they also have electrical properties that are fairly constant over a wide range of frequencies. These properties are little affected by temperature and atmospheric humidity in the acceptable operating range of temperaturesABS is flammable when it is exposed to high temperatures, such as a wood fire. It will melt then boil, at which point the vapors burst into intense, hot flames. Since pure ABS contains no halogens, its combustion does not typically produce any persistent organic pollutants, and the most toxic products of its combustion or pyrolysis are carbon monoxide and hydrogen cyanide. ABS is also damaged by sunlight. This caused one of the most widespread and expensive automobile recalls in US history due to the degradation of the seatbelt release buttons.

ABS can be recycled, although it is not accepted by all recycling facilities.

A Super Nintendo Entertainment System with its outer casing made of ABS. Over time, the casing changed colour from light grey to yellow as a result of oxidation.

When exposed to sunlight for a prolonged period of time, ABS will sometimes experience yellowing as a result of oxidation. This yellow colour can be cleaned through the use of hydrogen peroxide and UV light.

iv) Phenol formaldehydes

Phenol formaldehyde resins (PF) or **phenolic resins** are synthetic polymers obtained by the reaction of phenol or substituted phenol with formaldehyde. Used as the basis for Bakelite, PFs were the first commercial synthetic resins (plastics). They have been widely used for the production of molded products including billiard balls, laboratory countertops, and as coatings and adhesives. They were at one time the primary material used for the production of circuit boards but have been largely replaced with epoxy resins and fiberglass cloth, as with fire-resistant FR-4 circuit board materials.

There are two main production methods. One reacts phenol and formaldehyde directly to produce a thermosetting network polymer, while

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There are two main production methods. One reacts phenol and formaldehyde directly to produce a thermosetting network polymer, whilethe other restricts the formaldehyde to produce a prepolymer known as **novolac** which can be moulded and then cured with the addition of more formaldehyde and heat. There are many variations in both production and input materials that are used to produce a wide variety of resins for special purposes.

Phenolic resins are found in myriad industrial products. Phenolic laminates are made by impregnating one or more layers of a base material such as paper, fiberglass or cotton with phenolic resin and laminating the resin-saturated base material under heat and pressure. The resin fully polymerizes (cures) during this process. The base material choice depends on the intended application of the finished product. Paper phenolics are used in manufacturing electrical components such as punch-through boards, in household laminates, and in paper composite panels. Glass phenolics are particularly well suited for use in the high speed bearing market. Phenolic micro-balloons are used for density control. Snooker balls as well as balls from many table-based ball games are also made from phenol formaldehyde resin. The binding agent in normal (organic) brake pads, brake shoes and clutch disks are phenolic resin. Synthetic resin bonded paper, made from phenolic resin and paper, is used to make countertops.

Phenolic resins are also used for making exterior plywood commonly known as WBP (Weather & boil proof) Plywood because phenolic resins have no melting point but only a decomposing point in the temperature zone of 220 degree Celsius and above.

Phenolic resin is used as a binder in loudspeaker driver suspension components which are made of cloth.

Sometimes people select phenolic resin parts because their coefficient of thermal expansion closely matches that of the aluminum used for other parts of a system, as in early computer systems\ and Duramold.

The Dutch forger Han van Meegeren mixed phenol formaldehyde with his oil paints before baking the finished canvas in order to fake the drying out of the paint over the centuries.

9. Give any two important properties of ceramics. Write short **notes on any four ceramic materials. (Apr/May 2017)**

Ceramic materials are inorganic, nonmetallic materials. Most ceramics are compounds between metallic and nonmetallic elements for which the interatomic bonds are either totally ionic or predominantly ionic but having some covalent character. The term ceramic comes from the Greek word keramikos, which means burnt stuff, indicating that desirable properties of these materials are normally achieved through a high-temperature heat treatment process called firing. Ceramic materials are important in today's society. Consider the ceramic engine and what advantages it offers in terms of fuel economy, efficiency, weight savings and performance. Below are three gif's showing a montage of a prototype ceramic engine and some of the internal automotive components made from ceramics.

Aluminum Oxide, Al2O3

Alumina is the most cost effective and widely used material in the family of engineering ceramics. The raw materials from which this high performance technical grade ceramic is made are readily available and reasonably priced, resulting in good value for the cost in fabricated alumina shapes. With an excellent combination of properties and an attractive price, it is no surprise that fine grain technical grade alumina has a very wide range of applications.

Key Properties

Hard, wear-resistant

Excellent dielectric properties from DC to GHz frequencies

Resists strong acid and alkali attack at elevated temperatures

Good thermal conductivity

Excellent size and shape capability

High strength and stiffness

Available in purity ranges from 94%, an easily metallizable composition, to 99.5% for the most demanding high temperature applications.

Typical Uses

Gas laser tubes

Wear pads

Seal rings

High temperature electrical insulators
High voltage insulators

Furnace liner tubes
Thread and wire guides
Electronic substrates
Ballistic armor
Abrasion resistant tube and elbow liners
Thermometry sensors
Laboratory instrument tubes and sample holders
Instrumentation parts for thermal property test machines
Grinding media

General Information

Aluminum oxide, commonly referred to as alumina, possesses strong ionic interatomic bonding giving rise to it’s desirable material characteristics. It can exist in several crystalline phases which all revert to the most stable hexagonal alpha phase at elevated temperatures. This is the phase of particular interest for structural applications and the material available from Accuratus. Alpha phase alumina is the strongest and stiffest of the oxide ceramics. Its high hardness, excellent dielectric properties, refractoriness and good thermal properties make it the material of choice for a wide range of applications. High purity alumina is usable in both oxidizing and reducing atmospheres to 1925°C. Weight loss in vacuum ranges from 10–7 to 10–6 g/cm2.sec over a temperature range of 1700° to 2000°C. It resists attack by all gases except wet fluorine and is resistant to all common reagents except hydrofluoric acid and phosphoric acid. Elevated temperature attack occurs in the presence of alkali metal vapors particularly at lower purity levels.

The composition of the ceramic body can be changed to enhance particular desirable material characteristics. An example would be additions of chrome oxide or manganese oxide to improve hardness and change color. Other additions can be made to improve the ease and consistency of metal films fired to the ceramic for subsequent brazed and soldered assembly.

Silicon Carbide
Background

Sintered alpha silicon carbide is produced by initially mixing fine (sub-micron) and pure silicon carbide powder with non-oxide sintering aids. The powdered material is formed or compacted by using most of the conventional ceramic forming processes such as die pressing, isostatic pressing and injection moulding. Following the forming stage the material is sintered in an inert atmosphere at temperatures above 2000°C. The sintered silicon carbide can then be machined to precise tolerances using a range of precision diamond grinding or lapping techniques. As with most advanced ceramics the cost of the component is reduced if the amount of diamond grinding is reduced i.e. either the material manufacturer can achieve the required tolerances “as sintered” or the designer removes unnecessary tolerances.

Key Properties

The major properties of sintered silicon carbide of interest to the engineer or designer, are as follows:

High hardness (second only to diamond)
Low density 40% the density of steel – approximately the same as aluminium

Low porosity

Good wear resistance in sliding and abrasive environments

Excellent corrosion resistance in most chemical environments

Low thermal expansion and high thermal conductivity leading to excellent thermal shock resistance.

Applications

Automotive Components and Seal Faces

Due to their greater resistance to both wear and thermal shock, sintered silicon carbide seal faces for automotive water pumps are replacing seal faces made of materials such as aluminium oxide. In many cases the material has proven more suitable in meeting the performance demands of U.S. and European vehicles – i.e. lasting the lifetime of the vehicle without leaking. These components are manufactured by conventional high volume pressing and injection moulding methods to meet the economic constraints of the application.

Armour

Sintered Silicon Carbide has demonstrated an excellent performance record as ceramic material in composite armour protection systems. The propertiesof sintered silicon carbide, such as its high hardness, compressive strength and elastic modulus, provide superior ballistic capability.

Fused Silica, SiO2

Fused silica is a noncrystalline (glass) form of silicon dioxide (quartz, sand). Typical of glasses, it lacks long range order in its atomic structure. It's highly cross linked three dimensional structure gives rise to it's high use temperature and low thermal expansion coefficient.

Key Properties

Near zero thermal expansion

Exceptionally good thermal shock resistance

Very good chemical inertness

Can be lapped and polished to fine finishes

Low dielectric constant

Low dielectric loss

Good UV transparency

Typical Uses

High temperature lamp envelopes

Temperature insensitive optical component supports

Lenses, mirrors in highly variable temperature regimes

Microwave and millimeter wave components

Aeronautical radar windows

Silicon Nitride, Si3 N4

Silicon nitride is a man made compound synthesized through several different chemical reaction methods. Parts are pressed and sintered by well developed methods to produce a ceramic with a unique set of outstanding properties. The material is dark gray to black in color and can be polished to a very smooth reflective surface, giving parts with a striking appearance.

High performance silicon nitride materials were developed for automotive engine wear parts, such as valves and cam followers and proven effective. The cost of the ceramic parts never dropped enough to make the ceramics feasible in engines and turbochargers. The very highquality bodies developed for these demanding high reliability applications are available today and can be used in many severe mechanical, thermal and wear applications.

Key Properties

High strength over a wide temperature range
High fracture toughness
High hardness
Outstanding wear resistance, both impingement and frictional modes
Good thermal shock resistance
Good chemical resistance

Typical Uses

Rotating bearing balls and rollers
Cutting tools
Engine moving parts - valves, turbocharger rotors
Engine wear parts - cam followers, tappet shims
Turbine blades, vanes, buckets
Metal tube forming rolls and dies

Sialon

Sialon, a fine grain nonporous technical grade engineering material, is a silicon nitride ceramic with a small percentage of aluminum oxide added. Sialon is outstanding in nonferrous metal contact. It is highly thermal shock resistant, strong, and is not wet or corroded by aluminum, brass, bronze, and other common industrial metals.

Key Properties

Excellent thermal shock resistance
Not wetted or corroded by nonferrous metals
High strength
Good fracture toughness
Good high temperature strength

Low thermal expansion
Good oxidation resistance

Typical Uses

Thermocouple protection tubes for nonferrous metal melting
Immersion heater and burner tubes
Degassing and injector tubes in nonferrous metals
Metal feed tubes in aluminum die casting
Welding and brazing fixtures and pins

Precision shafts and axles in high wear environments

10. **Classify composite materials based on the type of reinforcement and state an example of each. (Nov/Dec 2017)**

Composite materials can be classified into the following types

- Metal Matrix Composite
- Fibre reinforced Composite
- Laminate Composite

a) Metal Matrix Composite:

A metal matrix composite (MMC) is composite material with at least two constituent parts, one being a metal necessarily, the other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite. An MMC is complementary to a cermets. Metal Matrix Composites are made by dispersing a reinforcing material into a metal matrix.

The reinforcement surface can be coated to prevent a chemical reaction with the matrix. For example, carbon fibers are commonly used in aluminium matrix to synthesize composites showing low density and high strength. However, carbon reacts with aluminium to generate a brittle and water-soluble compound Al_4C_3 on the surface of the fibre. To prevent this reaction, the carbon fibres are coated with nickel or titanium boride.

The matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materialssandwiched together. In structural applications, the matrix is usually a lighter metal such as aluminum, magnesium, or titanium, and provides a compliant support for the reinforcement. In high-temperature applications, cobalt and cobalt–nickel alloy matrices are common.

The reinforcement material is embedded into a matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity. The reinforcement can be either continuous, or discontinuous. Discontinuous MMCs can be isotropic, and can be worked with standard metalworking techniques, such as extrusion, forging, or rolling. In addition, they may be machined using conventional techniques, but commonly would need the use of polycrystaline diamond tooling (PCD).

Continuous reinforcement uses monofilament wires or fibers such as carbon fiber or silicon carbide. Because the fibers are embedded into the matrix in a certain direction, the result is an anisotropic structure in which the alignment of the material affects its strength. One of the first MMCs used boron filament as reinforcement. Discontinuous reinforcement uses «whiskers», short fibers, or particles. The most common reinforcing materials in this category are alumina and silicon carbide.

b) Fibre reinforced composite

A fiber-reinforced composite (FRC) is a composite building material that consists of three components: (i) the fibers as the discontinuous or dispersed phase, (ii) the matrix as the continuous phase, and (iii) the fine interphase region, also known as the interface. This is a type of advanced composite group, which makes use of rice husk, rice hull, and plastic as ingredients.

This technology involves a method of refining, blending, and compounding natural fibers from cellulosic waste streams to form a high-strength fiber composite material in a polymer matrix. The designated waste or base raw materials used in this instance are those of waste thermoplastics and various categories of cellulosic waste including rice husk and saw dust.

FRC is high-performance fiber composite achieved and made possible by cross-linking cellulosic fiber molecules with resins in the FRC material matrix through a proprietary molecular re-engineering process, yielding a product of exceptional structural properties. Through this feat of molecularre-engineering selected physical and structural properties of wood are successfully cloned and vested in the FRC product, in addition to other critical attributes to yield performance properties superior to contemporary wood.

This material, unlike other composites, can be recycled up to 20 times, allowing scrap FRC to be reused again and again. The failure mechanisms in FRC materials include delamination, intralaminar matrix cracking, longitudinal matrix splitting, fiber/matrix debonding, fiber pull-out, and fiber fracture.

c) Laminate Composites

A laminate composite is an assembly of layers of fibrous composite materials which can be joined to provide required engineering properties, including in-plane stiffness, bending stiffness, strength, and coefficient of thermal expansion. The individual layers consist of high-modulus, high-strength fibers in a polymeric, metallic, or ceramic matrix material. Typical fibers used include cellulose, graphite, glass, boron, and silicon carbide, and some matrix materials are epoxies, polyimides, aluminium, titanium, and alumina.

Layers of different materials may be used, resulting in a hybrid laminate. The individual layers generally are orthotropic (that is, with principal properties in orthogonal directions) or transversely isotropic (with isotropic properties in the transverse plane) with the laminate then exhibiting anisotropic (with variable direction of principal properties), orthotropic, or quasi-isotropic properties.

Quasi-isotropic laminates exhibit isotropic (that is, independent of direction) in plane response but are not restricted to isotropic out-of-plane (bending) response. Depending upon the stacking sequence of the individual layers, the laminate may exhibit coupling between in plane and out-of-plane response. An example of bending-stretching coupling is the presence of curvature developing as a result of in-plane loading.

11. State the properties and applications of two ceramics from **the list: PSZ, Si3N4, Al2O3 and SAILON (Nov/Dec 2017)**

PSZ:

Zirconia (ZrO2) may look like a an excellent engineering ceramic on paper due to its desirable physical properties such as extremely high melting temperature, high strength and fracture toughness. However thephase changes that it undergoes during sintering are deleterious to these properties and hence pure zirconia is not a useful engineering material.

Zirconia Phase Transformations

At room temperature, zirconia exists on the monoclinic phase. When heated to about 1170°C, it undergoes a phase transformation from monoclinic to tetragonal and a volume shrinkage of more than 3-5%. Further heating produces another change to cubic at 2370°C. The cubic phase is maintained until the melting point or zirconia is reached 2680°C.

On cooling from sintering temperatures and/or high temperature exposure, zirconia undergoes the tetragonal to monoclinic transformation at 950°C and an expansion similar in magnitude of the shrinkage during heat up.The large volumetric change associated with this phase transformation is a large enough to affect the structural integrity of the material. Repeated heating and cooling cycles would result in further erosion of mechanical integrity and properties.

Producing Stabilized and Partially Stabilized Zirconia

The additions of cubic oxides such as MgO, CaO, Y2O3, CeO2 and other rare earth oxides stabilize the high temperature cubic phase all the way back to room temperature. They also tend to decrease the transformation temperature. In partially stabilized zirconias, similar additions are made, except, not enough to stabilize all of the material, hence the name "partially stabilized zirconia" or "PSZ".

These materials typically consist of two or more of the phases cubic, tetragonal and monoclinic. If produced properly, the resultant microstructure consists of lens or elliptical-shaped precipitates of tetragonal zirconia within the cubic grains. Normally the tetragonal phase would transform into the monoclinic phase at low enough temperatures, but the high strength of the cubic phase prevents the required expansion from happening, freezing in the tetragonal precipitates.

Monoclinic zirconia may also be present in the cubic grains and at the grain boundaries. The toughening mechanism comes into play when a crack is encountered. The cubic grains are constraining the tetragonal precipitates that want to expand and release associated energy. When these grains are faced with a propagating crack tip, the tetragonal phase is released and allowed to change back to the more stable monoclinic phase. This results in the associated volumetric expansion, effectively closing the advancing crack. This is called transformation toughening and is a stress induced martensitic transformation to the monoclinic phase.

Transformation Toughening in Partially Stabilized Zirconias

Typical Properties of Partially Stabilized Zirconias

Typical properties of PSZ materials include:

Excellent fracture toughness
Excellent wear resistance
Excellent impact resistance
Good resistance to thermal shock
Good chemical resistance
Good corrosion resistance

Applications of Partially Stabilized Zirconias

Typical application of PSZ materials include:

Dies and tooling
Knives, scissors and blades
Wear resistant components including bearings and linings
Pump parts
Grinding media

Al2O3 :

Aluminium oxide is a chemical compound of aluminium and oxygen with the chemical formula Al2O3. It is the most commonly occurring of several aluminium oxides, and specifically identified as aluminium(III) oxide. It is commonly called alumina, and may also be called aloxide, aloxite, or alundum depending on particular forms or applications.

It occurs naturally in its crystalline polymorphic phase α-Al_2O_3 as the mineral corundum, varieties of which form the precious gemstones ruby and sapphire. Al_2O_3 is significant in its use to produce aluminium metal, as an abrasive owing to its hardness, and as a refractory material owing to its high melting point.

12. List the properties and applications of any three types of **ceramics.**

(i) Silicon Carbide:

The major properties of sintered silicon carbide of interest to the engineer or designer, are as follows:

- High hardness (second only to diamond)
- Low density 40% the density of steel – approximately the same as aluminium
- Low porosity
- Good wear resistance in sliding and abrasive environments
- Excellent corrosion resistance in most chemical environments
- Low thermal expansion and high thermal conductivity leading to excellent thermal shock resistance.

Fused Silica, SiO_2

Fused silica is a noncrystalline (glass) form of silicon dioxide (quartz, sand). Typical of glasses, it lacks long range order in its atomic structure. It’s highly cross linked three dimensional structure gives rise to it’s high use temperature and low thermal expansion coefficient.

Key Properties

Near zero thermal expansion
Exceptionally good thermal shock resistance
Very good chemical inertness
Can be lapped and polished to fine finishes
Low dielectric constant
Low dielectric loss
Good UV transparency

(ii) Silicon Nitride (Si_3N_4) :

Silicon nitride is a man made compound synthesized through several different chemical reaction methods. Parts are pressed and sintered by well developed methods to produce a ceramic with an unique set of outstanding properties. The material is dark gray to black in color and canbe polished to a very smooth reflective surface, giving parts with a striking appearance. High performance silicon nitride materials were developed for automotive engine wear parts, such as valves and cam followers and proven effective. The cost of the ceramic parts never dropped enough to make the ceramics feasible in engines and turbochargers. The very high quality bodies developed for these demanding high reliability applications are available today and can be used in many severe mechanical, thermal and wear applications.

Key Properties:

High strength over a wide temperature range

High fracture toughness

High hardness

Outstanding wear resistance, both impingement and frictional modes

Good thermal shock resistance

Good chemical resistance

(iii) Titanium di-oxide (TiO_2):

Titanium dioxide occurs in nature as the well-known minerals rutile, anatase and brookite, and additionally as two high pressure forms, a monoclinic baddeleyite-like form and an orthorhombic α-PbO_2-like form. One of these is known as akaogiite and should be considered as an extremely rare mineral. It is mainly sourced from ilmenite ore.

This is the most widespread form of titanium dioxide-bearing ore around the world. Rutile is the next most abundant and contains around 98% titanium dioxide in the ore. The metastable anatase and brookite phases convert irreversibly to the equilibrium rutile phase upon heating above temperatures in the range 600–800 °C.

Titanium dioxide has eight modifications – in addition to rutile, anatase, and brookite, three metastable phases can be produced synthetically (monoclinic, tetragonal and orthorombic), and five high-pressure forms (α-PbO_2-like, baddeleyite-like, cotunnite-like, orthorhombic OI, and cubic phases) also exist.

The most important application areas are paints and varnishes as well as paper and plastics, which account for about 80% of the world’s titaniumdioxide consumption. Other pigment applications such as printing inks, fibers, rubber, cosmetic products and food account for another 8%. The rest is used in other applications, for instance the production of technical pure titanium, glass and glass ceramics, electrical ceramics, catalysts, electric conductors

13. Brief on properties and applications of any two polymers **from the list. PP, PC, PEEK, ABS and PS (Nov/Dec 2017)**

(i) PC:

Polycarbonates (PC) are a group of thermoplastic polymers containing carbonate groups in their chemical structures. Polycarbonates used in engineering are strong, tough materials, and some grades are optically transparent. They are easily worked, molded, and thermoformed. Because of these properties, polycarbonates find many applications. Polycarbonates do not have a unique resin identification code (RIC) and are identified as «Other», 7 on the RIC list. Products made from polycarbonate can contain the precursor monomer bisphenol A (BPA). Polycarbonate is also known by a variety of trademarked names, including Lexan, Makrolon, Hammerglass and others.

Polycarbonate is a durable material. Although it has high impact-resistance, it has low scratch resistance. Therefore, a hard coating is applied to polycarbonate eyewear lenses and polycarbonate exterior automotive components. The characteristics of polycarbonate compare to those of polymethyl methacrylate (PMMA, acrylic), but polycarbonate is stronger and will hold up longer to extreme temperature. Polycarbonate is highly transparent to visible light, with better light transmission than many kinds of glass.

Polycarbonate has a glass transition temperature of about 147 °C (297 °F), so it softens gradually above this point and flows above about 155 °C (311 °F). Tools must be held at high temperatures, generally above 80 °C (176 °F) to make strain-free and stress-free products. Low molecular mass grades are easier to mold than higher grades, but their strength is lower as a result. The toughest grades have the highest molecular mass, but are much more difficult to process.

Unlike most thermoplastics, polycarbonate can undergo large plastic deformations without cracking or breaking. As a result, it can be processedand formed at room temperature using sheet metal techniques, such as bending on a brake. Even for sharp angle bends with a tight radius, heating may not be necessary.

This makes it valuable in prototyping applications where transparent or electrically non-conductive parts are needed, which cannot be made from sheet metal. PMMA/Acrylic, which is similar in appearance to polycarbonate, is brittle and cannot be bent at room temperature.

Main transformation techniques for polycarbonate resins:

Extrusion into tubes, rods and other profiles including multiwall

Extrusion with cylinders (calenders) into sheets (0.5–20 mm (0.020– 0.787 in)) and films (below 1 mm (0.039 in)), which can be used directly or manufactured into other shapes using thermoforming or secondary fabrication techniques, such as bending, drilling, or routing. Due to its chemical properties it is not conducive to laser-cutting.

Injection molding into ready articles

Polycarbonate may become brittle when exposed to ionizing radiation above 25J/kg.

(ii) ABS :

Acrylonitrile butadiene styrene (ABS) (chemical formula (C8H8)x· (C4H6) y· (C3H3N)z) is a common thermoplastic polymer. Its glass transition temperature is approximately 105 °C (221 °F). ABS is amorphous and therefore has no true melting point.

ABS is a terpolymer made by polymerizing styrene and acrylonitrile in the presence of polybutadiene. The proportions can vary from 15 to 35% acrylonitrile, 5 to 30% butadiene and 40 to 60% styrene. The result is a long chain of polybutadiene criss-crossed with shorter chains of poly(styrene-co-acrylonitrile).

The nitrile groups from neighboring chains, being polar, attract each other and bind the chains together, making ABS stronger than pure polystyrene. The styrene gives the plastic a shiny, impervious surface. The polybutadiene, a rubbery substance, provides toughness even at low temperatures.

For the majority of applications, ABS can be used between −20 and 80 °C (−4 and 176 °F) as its mechanical properties vary with temperature. The properties are created by rubber toughening, where fine particles of elastomer are distributed throughout the rigid matrix.

The most important mechanical properties of ABS are impact resistance and toughness. A variety of modifications can be made to improve impact resistance, toughness, and heat resistance. The impact resistance can be amplified by increasing the proportions of polybutadiene in relation to styrene and also acrylonitrile, although this causes changes in other properties.

Impact resistance does not fall off rapidly at lower temperatures. Stability under load is excellent with limited loads. Thus, by changing the proportions of its components, ABS can be prepared in different grades. Two major categories could be ABS for extrusion and ABS for injection moulding, then high and medium impact resistance. Generally ABS would have useful characteristics within a temperature range from −20 to 80 °C (−4 to 176 °F).

The final properties will be influenced to some extent by the conditions under which the material is processed to the final product. For example, molding at a high temperature improves the gloss and heat resistance of the product whereas the highest impact resistance and strength are obtained by molding at low temperature. Fibers (usually glass fibers) and additives can be mixed in the resin pellets to make the final product strong and raise the operating range to as high as 80 °C (176 °F). Pigments can also be added, as the raw material original color is translucent ivory to white.

The aging characteristics of the polymers are largely influenced by the polybutadiene content, and it is normal to include antioxidants in the composition. Other factors include exposure to ultraviolet radiation, for which additives are also available to protect against. ABS polymers are resistant to aqueous acids, alkalis, concentrated hydrochloric and phosphoric acids, alcohols and animal, vegetable and mineral oils, but they are swollen by glacial acetic acid, carbon tetrachloride and aromatic hydrocarbons and are attacked by concentrated sulfuric and nitric acids.

They are soluble in esters, ketones, ethylene dichloride and acetone. Even though ABS plastics are used largely for mechanical purposes, they also have electrical properties that are fairly constant over a wide range of frequencies. These properties are little affected by temperature and atmospheric humidity in the acceptable operating range of temperatures. wood fire. It will melt then boil, at which point the vapors burst into intense, hot flames. Since pure ABS contains no halogens, its combustion does not typically produce any persistent organic pollutants, and the most toxic products of its combustion or pyrolysis are carbon monoxide and hydrogen cyanide. ABS is also damaged by sunlight. This caused one of the most widespread and expensive automobile recalls in US history due to the degradation of the seatbelt release buttons. ABS can be recycled, although it is not accepted by all recycling facilities.

A Super Nintendo Entertainment System with its outer casing made of ABS. Over time, the casing changed colour from light grey to yellow as a result of oxidation. When exposed to sunlight for a prolonged period of time, ABS will sometimes experience yellowing as a result of oxidation. This yellow colour can be cleaned through the use of hydrogen peroxide and UV light.

14. **Explain the properties and application of any eight varieties of polymers used as engineering materials.**

PEEK is an abbreviation for PolyEther Ether-Ketone, a high performance engineering thermoplastic and is an excellent material for a wide spectrum of applications where thermal, chemical, and combustion properties are critical to performance. The tensile properties of PEEK exceed those of most engineering plastics and can be reinforced with carbon fiber resulting in a tensile strength of over 29,000 psi (200 MPa) with excellent properties being retained up to570°F(300°C). The exceptional stiffness of PEEK™ is reflected in its flexural modulus which is among the best of any thermoplastic. Glass or carbon fiber reinforcement gives further improvement up to very high temperatures. These semi-crystalline polymers have excellent mechanical properties, good thermal stability and good chemical resistance. Despite a Tg of 145°C, the continuous service rating of PEEK is 250°C. PEEK is inherently fire retardant. It is easier to burn a hole through an aluminium sheet than through one made from PEEK. These materials are, however, very expensive and difficult to process. They find application in high temperature wire covering and printed circuit boards. Fibre reinforced grades are used in demanding applications that include valves, pumps and missile nose cones

PEEK combines excellent tribological properties with moldability and outstanding performance at high temperatures. Carbon fiber-reinforced PEEK is probably the only injection moldable bearing material that has a measurable wear factor at over 500°F (260°C), all the thermoplastics fail at or below this temperature. PEEK can retain its flexural and tensile properties at very high temperatures -- in excess of 250”C (482”F). The addition of glass fiber and carbon fiber reinforcements enhances the mechanical and thermal properties of the basic PEEK material. Superior chemical resistance has allowed them to work effectively as a metal replacement in harsh environments. They are inert to all common solvents and resist a wide range of organic and inorganic liquids. When extensive machining is required, a secondary annealing process should be considered.

MECHANICAL

At room temperature, PEEK™ functions as a typical engineering thermoplastic. It is tough, strong, rigid, has good load bearing properties over long periods, and it is resistance to both abrasion and dynamic fatigue. **THERMAL**

PEEK continuous service UV rating is 482°F (250°C) for unfilled and 500°F (260°C) for glass filled grades. PEEK™ also offers high temperature mechanical properties making it suitable for some application up to 600°F (315°C).

FLAMMABILITY

PEEK™ has a high “Oxygen Index” and meets UL 94 -VO requirements, and demonstrates extremely low smoke emission. It contains no flame-retardant additives or halogens.

CHEMICAL RESISTANCE

PEEK™ has good resistance to aqueous reagents and long-term performance in superheated water at 500°F. (260°C.). Its resistance to attack is good over a wide pH range from 60% sulfuric acid to 40% sodium hydroxide at elevated temperatures. Attack can occur with some concentrated acids.

HYDROLYSIS RESISTANCE

PEEK can be used for thousands of hours at temperatures in excess of 480°F(250°C). in steam or high-pressure water environments without significant degradation in properties.

Polytetra fluoroethylene [Teflon, –(CF2-CF2)n-] is obtained by polymerizing (emulsion polymereization) tetra floroethylene (ie., When all the hydrogen atoms in polyethylene have been replaced by fluorine, polytetra fluoroethylene (PTFE) is obtained). It is a tough, flexible, non resilient material of moderate tensile strength but with excellent resistance to heat, chemicals and tothe passage of electric current. It is resistant to many chemicals, including acetic acid, ammonia, sulfuric acid, and hydrochloric acid It remains ductile in compression at temperatures as low as 4K(-269°C). The coefficient of friction is low and is reported to be lower than that of any other solid. PTFE is an outstanding insulator over a wide range of temperature and frequency. Its volume resistively exceeds 1020 ohm meter. Any current measured is a polarization current rather than a conduction current. It has a low dielectric constant (2.1 at 60 Hz). A melt viscosity of 1010-1011poises has been measured at about 350°C. A slow rate of decomposition has been detected at the melting point and this increases with increase in temperature. There are no solvent for PTFE anditis attacked by molten alkali metal at room temperature and in some cases by fluorine. Treatment with solution of sodium metal in liquid ammonia will sufficiently alter the surface of PTFE so that itcan be cemented to other materials using epoxy adhesives. Although it has good weathering resistance, it is degraded by high energy radiation. The polymer is not wetted by water and does not absorb measurably. The permeability to gases is very low and water vapour transmission is only half that of low density polyethylene. It has a high bulk density and exceptional chemical properties.. It can temporarily with stand temperatures of 260°C and still have the same chemical properties. Teflon also retains its chemical properties in cryogenic temperatures of -240°C . It is a chemical inert material, making it relatively safe to use and handle. It has an initial melting point of 342 +- 10°C and a secondary melting point of 327 +- 10°C . Teflon has a low coefficient of friction, and is leophobic (resistant to oil) and hydrophobic, making it useful in cookware. This property of a non-wetting surface to both oils and water comes from Teflon being a polytetra fluoroethylene, which has an ultra low surface energy value of 18.6 Newtons per meter squared. Teflon has a high dielectric strength over many different frequencies, a low dissipation factor, and a high surface resistivity. The electro conductivity can be increased high enough to allow Teflon to be used as an anti-static coating. Teflon possesses outstanding optical clarity and transmission. Teflon® AF has outstanding light transmission from the deep UV range out through and including a significant portion of the IR range. Also, because it does not absorb light, Teflon® AF will not deteriorate with exposure to light. These optical properties, over such a wide range of wavelength and possible exposure conditions, are unmatched by any other polymer. PTFE is a tough, flexible, crystalline polymer that retains ductility down to -150°C. Its solvent and chemical resistance is the best of all the thermoplastics and it has the lowest coefficient of friction of any known solid (0.02). On the downside, it has to be moulded by a powder sintering technique, although it can be extruded very slowly, and it is very expensive with low strength and stiffness. Applications of PTFE are therefore limited to those that make use of its special properties, for example, bearings, chemical vessel linings, gaskets and non-stick coatings.

Teflon has the lowest known dielectric constant of any plastic material. It exhibits excellent mechanical and physical properties at end-use temperatures up to 300°C It has good dimensional stability, reduced mold shrinkage, a smooth surface, and rigidity at high-use temperatures. Teflon isused for gasket and packaging materials in chemical processing equipment, as electrical insulation, as bearings, seals, and piston rings in mechanical applications, especially those requiring anti-stick characteristics. In addition to chemical, heat, corrosion, and impact resistance. Teflon is weather resistant, flexible, non-flammable, etc. Ionized oxygen in oxygen plasma is often sufficiently energetic to react with the polymer chain. Electron bombardment at the mega rad level can sever the polymer chain. Techniques for molding polytetra fluoroethylene resemble those of powder metallurgy or ceramics rather than those of polymer fabrication. It may be extruded in a ram or screw extruder. The high degree of cohesion between cold pressed particles of PTFE is utilized in a calendering process for making tape and coating wire.

Polyethylene terephthalate (PET) and polybutylene terephthalate (PBT) are the most common thermoplastic polyesters. They are similar to PA6 and PA66 in many respects but with much lower water absorption. However, they are prone to hydrolysis, and prolonged contact with water at temperatures as low as 50°C has a detrimental effect on properties. Polyethylene terephthalate (PET) is often called just “polyester”. Polybutylene terephthalate (PBT) also a (thermoplastic) polyester, the most common resin system used in glass reinforced plastic (GRP) is also a polyester system.

General Properties

Polyethylene terephthalate (PET) is a hard, stiff, strong, dimensionally stable material that absorbs very little water. It has good gas barrier properties and good chemical resistance except to alkalis (which hydrolyse it). Its crystallinity varies from amorphous to fairly high crystalline. It can be highly transparent and colourless but thicker sections are usually opaque and off-white.

The “MylarR-type” films are used for capacitators, graphics, film base and recording tapes etc. PET is also used for fibres for a very wide range of textile and industrial uses (Dacron®, Trevira®, Terylene®). Other applications include bottles and electrical components.

Its melting and glass transition temperature are 265°C and 74°C respectively. PET is used in the manufacture of biaxially oriented film and bottles, the latter suitable for carbonated drinks. The purpose of the orientation is to enhance rigidity, strength and toughness and also to improve barrier properties, which allows thinner bottles to be made. PBTdisplays a good combination of stiffness and toughness and can withstand continuous service at 120°C. The most important grades are those reinforced with glass. Applications for PBT include electrical connectors, pump components, and gears, as well as under bonnet and exterior parts for cars.

Polyimides (PI) are noted for their high temperature performance, retaining their mechanical properties to 250°C. They exhibit low flammability and smoke emission characteristics and offer the lowest minimum service temperature of thermoplastics. They are relatively expensive and can be difficult to process. Thermoplastic polyimide requires high temperatures and pressures and is usually processed by autoclave or compression moulding. They are susceptible to attack by halogenated solvents Polyimides are a very interesting group of incredibly strong and astoundingly heat and chemical resistant polymers. Their strength and heat and chemical resistance are so great that these materials often replace glass and metals, such as steel, in many demanding industrial applications. Polyimides are even used in many everyday applications. They are used for the struts and chassis in some cars as well as some parts under-the-hood because they can withstand the intense heat and corrosive lubricants, fuels, and coolants cars require. They are also used in the construction of many appliances as well as microwave cookware and food packaging because of their thermal stability, resistance to oils, greases, and fats and their transparency to microwave radiation. They can also be used in circuit boards, insulation, fibers for protective clothing, composites, and adhesives. These polymers have excellent resistant to oxidative degradation, chemicals, strong bases and high energy radiation. It possesses good flame and abrasion resistances. But unfortunately these polymers cannot be moulded by conventional thermoplastic techniques. They are used as wire enamels, insulating varnishes, as coatings for glass cloth etc. Polyimide foams have been used for sound deadening of jet engines. They are used in space craft construction, rockets and weapons technology.

These polymers consists predominantly of ring structures and hence possesses high softening point. They are used in the manufacture of seals, gaskets, piston rings and as a binder in the diamond grinding wheels. Glass and carbon fibre reinforced polyimides are used in aircraft industry. It is also used in soldering and welding equipments. Kapton is a polyimide film made from pyromelltic anhydride and aromatic ether amine. Polyesterimides and polybismaleinimides are modified polyimides. **Polyvinyl chloride(PVC)(VINYL Plastic)**

Polyvinyl chloride is obtained by suspension or bulk free radical polymerization of vinyl chloride. . It is an amorphous polymer(thermo plastic) having glass transition temperature around 87°C. It is an unstable polymer compared to the other commodity polymers like PE, PP etc. Its commercial success is attributed to the discovery of suitable stabilizers and other additives. Lead compounds (lead stearate etc), organo tin compounds(dibutyl tin dilaurate etc) etc are used as stabilizers. About 50% of produced PVC is used as rigid resins (ex in PVC pipes etc). Flexible PVC is made via plasticization using plasticizers such as dioctyl phthalate, dioctyl adipate, tricresyl phosphate etc. Building construction market account for 30 % of its production. which include pipe and fittings, siding, carpet backing, windows gutters, wall coverings etc . Bottles and packaging sheet are also major rigid markets. Flexible vinyl is used in wire and cable insulation, film and sheet, floor coverings, synthetic leather products, coatings, blood bags, medical tubing and many other applications. Plasticized PVC is melt processed. PVC has a good resistance to hydrocarbons. Its application is widened using fillers, pigments, impact modifiers etc.

15. **Name explain the properties and application of any four type of ceramics.**

Alumina

Alumina is the most cost effective and widely used material in the family of engineering ceramics.

The raw materials from which this high performance technical grade ceramic is made are readily available and reasonably priced, resulting in good value for the cost in fabricated alumina shapes.

With an excellent combination of properties and an attractive price, it is no surprise that fine grain technical grade alumina has a very wide range of applications.

Key Properties

- Hard, wear-resistant
- Excellent dielectric properties from DC to GHz frequencies
- Resists strong acid and alkali attack at elevated temperatures

- Good thermal conductivity
- Excellent size and shape capability
- High strength and stiffness

Available in purity ranges from 94%, an easily metallizable composition, to 99.5% for the most demanding high temperature applications.

Silicon Carbide

Background

Sintered alpha silicon carbide is produced by initially mixing fine (sub-micron) and pure silicon carbide powder with non-oxide sintering aids. The powdered material is formed or compacted by using most of the conventional ceramic forming processes such as die pressing, isostatic pressing and injection moulding. Following the forming stage the material is sintered in an inert atmosphere at temperatures above 2000°C. The sintered silicon carbide can then be machined to precise tolerances using a range of precision diamond grinding or lapping techniques. As with most advanced ceramics the cost of the component is reduced if the amount of diamond grinding is reduced i.e. either the material manufacturer can achieve the required tolerances “as sintered” or the designer removes unnecessary tolerances.

Key Properties

The major properties of sintered silicon carbide of interest to the engineer or designer, are as follows:

- High hardness (second only to diamond)
- Low density 40% the density of steel – approximately the same as aluminium
- Low porosity

Good wear resistance in sliding and abrasive environments

Excellent corrosion resistance in most chemical environments

Low thermal expansion and high thermal conductivity leading to excellent thermal shock Resistance**.**

Fused Silica, SiO2

Fused silica is a noncrystalline (glass) form of silicon dioxide (quartz, sand). Typical of glasses, it lacks long range order in its atomic structure. It’s highly cross linked three dimensional structure gives rise to it’s high use temperature and low thermal expansion coefficient.

Key Properties

Near zero thermal expansion

Exceptionally good thermal shock resistance

Very good chemical inertness

Can be lapped and polished to fine finishes

Low dielectric constant

Low dielectric loss

Good UV transparency

Silicon nitride

Silicon nitride is a man made compound synthesized through several different chemical reaction methods. Parts are pressed and sintered by well developed methods to produce a ceramic with a unique set of outstanding properties. The material is dark gray to black in color and can be polished to a very smooth reflective surface, giving parts with a striking appearance. High performance silicon nitride materials were developed for automotive engine wear parts, such as valves and cam followers and proven effective. The cost of the ceramic parts never dropped enough to make the ceramics feasible in engines and turbochargers. The very high quality bodies developed for these demanding high reliability applications are available today and can be used in many severe mechanical, thermal and wear applications.

Key Properties

High strength over a wide temperature range

High fracture toughness

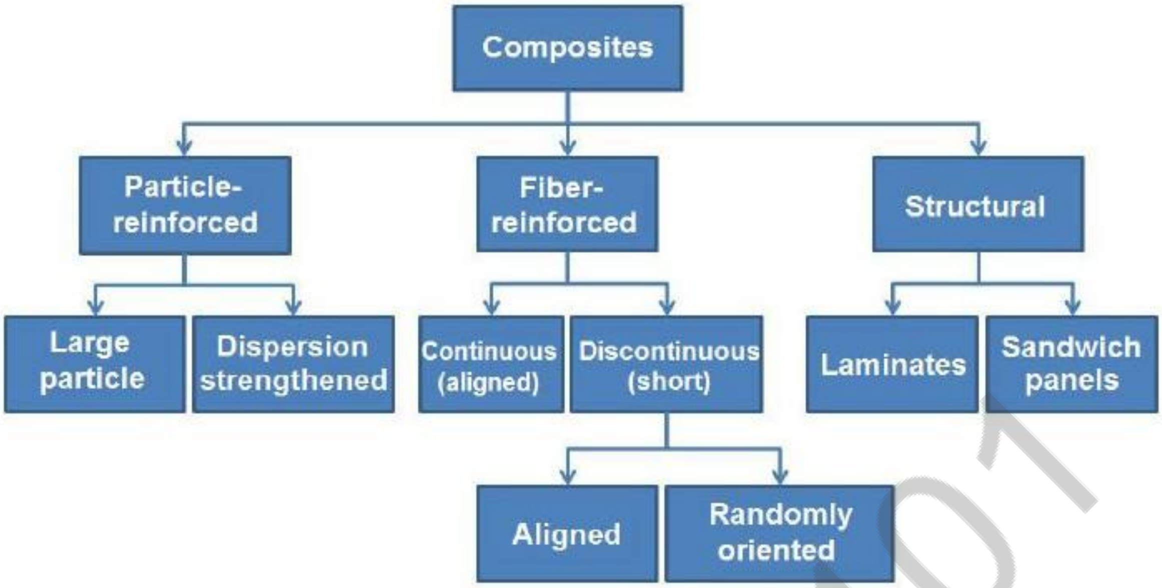
High hardness

Outstanding wear resistance, both impingement and frictional modes

Good thermal shock resistance

Good chemical resistance

16. **Classify composite materials and list two properties and application of them.**



State the properties and application of PSZ or SiC.

Zirconia (ZrO2) may look like a an excellent engineering ceramic on paper due to its desirable physical properties such as extremely high melting temperature, high strength and fracture toughness. However the phase changes that it undergoes during sintering are deleterious to these properties and hence pure zirconia is not a useful engineering material.

Zirconia Phase Transformations

At room temperature, zirconia exists on the monoclinic phase. When heated to about 1170°C, it undergoes a phase transformation from monoclinic to tetragonal and a volume shrinkage of more than 3-5%. Further heating produces another change to cubic at 2370°C. The cubic phase is maintained until the melting point or zirconia is reached 2680°C. On cooling from sintering temperatures and/or high temperature exposure, zirconia undergoes the tetragonal to monoclinic transformation at 950°C and an expansion similar in magnitude of the shrinkage during heat up.The large volumetric change associated with this phase transformation is a large enough to affect the structural integrity of the material. Repeated heating and cooling cycles would result in further erosion of mechanical integrity and properties. **Producing Stabilized and Partially Stabilized Zirconia**

The additions of cubic oxides such as MgO, CaO, Y2O3, CeO2 and other rare earth oxides stabilize the high temperature cubic phase all the way back to room temperature. They also tend to decrease the transformation temperature. In partially stabilized zirconias, similar additions are made, except, not enough to stabilize all of the material, hence the name “partially stabilized zirconia” or “PSZ”. These materials typically consist of two or more of the phases cubic, tetragonal and monoclinic. If produced properly, the resultant microstructure consists of lens or elliptical-shaped precipitates of tetragonal zirconia within the cubic grains. Normally the tetragonal phase would transform into the monoclinic phase at low enough temperatures, but the high strength of the cubic phase prevents the required expansion from happening, freezing in the tetragonal precipitates. Monoclinic zirconia may also be present in the cubic grains and at the grain boundaries. The toughening mechanism comes into play when a crack is encountered. The cubic grains are constraining the tetragonal precipitates that want to expand and release associated energy. When these grains are faced with a propagating crack tip, the tetragonal phase is released and allowed to change back to the more stable monoclinic phase. This results in the associated volumetric expansion, effectively closing the advancing crack. This is called transformation toughening and is a stress induced martensitic transformation to the monoclinic phase.

Transformation Toughening in Partially Stabilized Zirconias

Typical Properties of Partially Stabilized Zirconias

Typical properties of PSZ materials include:

Excellent fracture toughness
Excellent wear resistance
Excellent impact resistance
Good resistance to thermal shock
Good chemical resistance
Good corrosion resistance

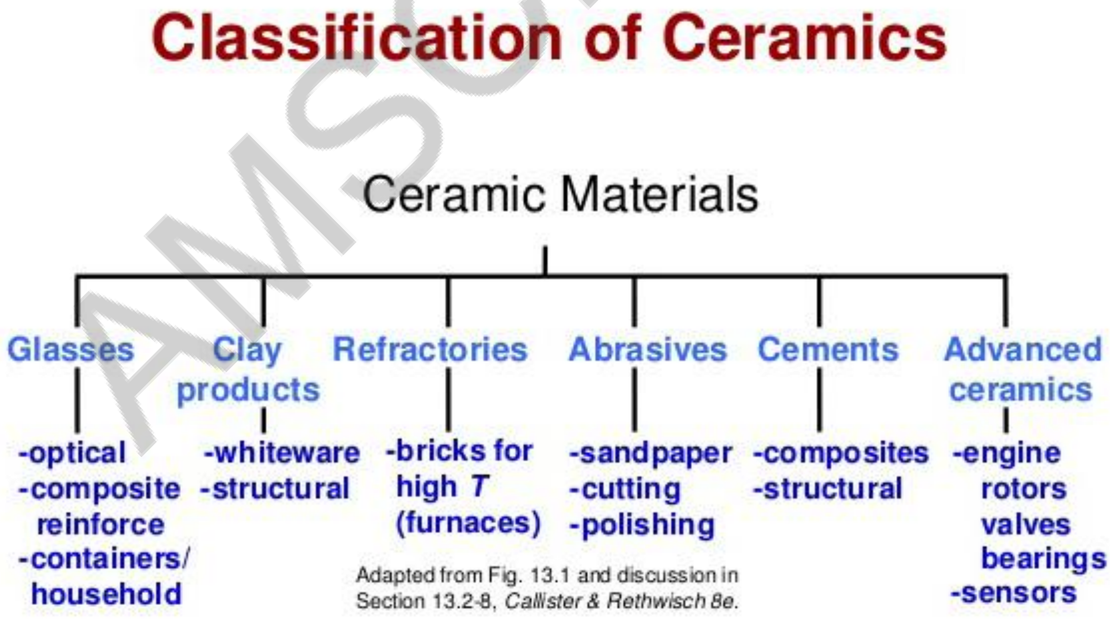
Applications of Partially Stabilized Zirconias

Typical application of PSZ materials include:

Dies and tooling

Knives, scissors and blades
Wear resistant components including bearings and linings
Pump parts
Grinding media

17. **Classify engineering ceramics and list properties and applications of any two of them.**



Adapted from Fig. 13.1 and discussion in Section 13.2-8, *Callister & Rethwisch 8e.*

Refractories:

Used to make furnace lining, and in domestic buildings.

Abrasives:
Used for fine machining and for delaminating for biological application.

18. **Brief on properties and application of any two polymers from the list: PTFE, PC, PET, ABS and PS.**

i) PET
The majority of the world's PET production is for synthetic fibers (in excess of 60%), with bottle production accounting for about 30% of global demand.[5] In the context of textile applications, PET is referred to by its common name, *polyester*, whereas the acronym *PET* is generally used in relation to packaging. Polyester makes up about 18% of world polymer production and is the fourth-most-produced polymer; polyethylene (PE), polypropylene (PP) and polyvinyl chloride (PVC) are first, second and third, respectively.

PET consists of polymerized units of the monomer ethylene terephthalate, with repeating (C10H8O4) units. PETDepending on its processing and thermal history, polyethylene terephthalate may exist both as an amorphous (transparent) and as a semi-crystalline polymer. The semicrystalline material might appear transparent (particle size < 500 nm) or opaque and white (particle size up to a few micrometers) depending on its crystal structure and particle size.

The monomer bis(2-hydroxyethyl) terephthalate can be synthesized by the esterification reaction between terephthalic acid and ethylene glycol with water as a byproduct, or by transesterification reaction between ethylene glyco and dimethyl terephthalate with methanol as a byproduct. Polymerization is through a polycondensation reaction of the monomers (done immediately after esterification/transesterification) with water as the byproduct.

PET in its natural state is a colorless, semi-crystalline resin. Based on how it is processed, PET can be semi-rigid to rigid, and it is very lightweight. It makes a good gas and fair moisture barrier, as well as a good barrier to alcohol (requires additional "barrier" treatment) and solvents. It is strong and impact-resistant. PET becomes white when exposed to chloroform and also certain other chemicals such as toluene. About 60% crystallization is the upper limit for commercial products, with the exception of polyester fibers. Clear products can be produced by rapidly cooling molten polymer below Tg glass transition temperature to form an amorphous solid. Like glass, amorphous PET forms when its molecules are not given enough time to arrange themselves in an orderly, crystalline fashion as the melt is cooled. At room temperature the molecules are frozen in place, but, if enough heat energy is put back into them by heating above Tg, they begin to move again, allowing crystals to nucleate and grow. This procedure is known as solid-state crystallization.

When allowed to cool slowly, the molten polymer forms a more crystalline material. This material has spherulites containing many small crystallites when crystallized from an amorphous solid, rather than forming one large single crystal. Light tends to scatter as it crosses the boundaries between crystallites and the amorphous regions between them. This scattering means that crystalline PET is opaque and white in most cases. Fiber drawing is among the few industrial processes that produce a nearly single-crystal product.

Because PET is an excellent water and moisture barrier material, plastic bottles made from PET are widely used for soft drinks(see carbonation). For certain specialty bottles, such as those designated for beer containment, PET sandwiches an additional polyvinyl alcohol (PVOH) layer to further reduce its oxygen permeability.

Biaxially oriented PET film (often known by one of its trade names, "Mylar") can be aluminized by evaporating a thin film of metal onto it to reduce its permeability, and to make it reflective and opaque (MPET). These properties are useful in many applications, including flexible food packaging and thermal insulation. See: “space blankets”. Because of its high mechanical strength, PET film is often used in tape applications, such as the carrier for magnetic tape or backing for pressure-sensitive adhesive tapes.

Non-oriented PET sheet can be thermoformed to make packaging trays and blister packs[6]. If crystallizable PET is used, the trays can be used for frozen dinners, since they withstand both freezing and oven baking temperatures. As opposed to amorphous PET, which is transparent, crystallizable PET or CPET tends to be black in colour.

When filled with glass particles or fibres, it becomes significantly stiffer and more durable.

PET is also used as a substrate in thin film solar cells.

Terylene (a trademark formed by inversion of (polyeth)ylene ter(ephthalate)) is also spliced into bell rope tops to help prevent wear on the ropes as they pass through the ceiling.

ii) PC

Polycarbonates (PC) are a group of thermoplastic polymers containing carbonate groups in their chemical structures. Polycarbonates used in engineering are strong, tough materials, and some grades are optically transparent. They are easily worked, molded, and thermoformed. Because of these properties, polycarbonates find many applications. Polycarbonates do not have a unique resin identification code (RIC) and are identified as “Other”, 7 on the RIC list. Products made from polycarbonate can contain the precursor monomer bisphenol A (BPA). Polycarbonate is also known by a variety of trademarked names, including Lexan, Makrolon, Hammerglass and others.

Polycarbonate is a durable material. Although it has high impact-resistance, it has low scratch-resistance. Therefore, a hard coating is applied to polycarbonate eyewear lenses and polycarbonate exterior automotivecomponents. The characteristics of polycarbonate compare to those of polymethyl methacrylate (PMMA, acrylic), but polycarbonate is stronger and will hold up longer to extreme temperature. Polycarbonate is highly transparent to visible light, with better light transmission than many kinds of glass.

Polycarbonate has a glass transition temperature of about 147 °C (297 °F),[6] so it softens gradually above this point and flows above about 155 °C (311 °F).[7] Tools must be held at high temperatures, generally above 80 °C (176 °F) to make strain-free and stress-free products. Low molecular mass grades are easier to mold than higher grades, but their strength is lower as a result. The toughest grades have the highest molecular mass, but are much more difficult to process.

Unlike most thermoplastics, polycarbonate can undergo large plastic deformations without cracking or breaking. As a result, it can be processed and formed at room temperature using sheet metal techniques, such as bending on a brake. Even for sharp angle bends with a tight radius, heating may not be necessary. This makes it valuable in prototyping applications where transparent or electrically non-conductive parts are needed, which cannot be made from sheet metal. PMMA/Acrylic, which is similar in appearance to polycarbonate, is brittle and cannot be bent at room temperature.

Main transformation techniques for polycarbonate resins:

Extrusion into tubes, rods and other profiles including multiwall

Extrusion with cylinders (calenders) into sheets (0.5–20 mm (0.020– 0.787 in)) and films (below 1 mm (0.039 in)), which can be used directly or manufactured into other shapes using thermoforming or secondary fabrication techniques, such as bending, drilling, or routing. Due to its chemical properties it is not conducive to laser-cutting.

Injection molding into ready articles

Polycarbonate may become brittle when exposed to ionizing radiation above 25 kGy (J/kg).

iii) ABS

Acrylonitrile butadiene styrene (ABS) (chemical formula $(C_8H_8)_x\cdot(C_4H_6)_y\cdot(C_3H_3N)_z$) is a common thermoplastic polymer. Its glass transitiontemperature is approximately 105°C (221°F). ABS is amorphous and therefore has no true melting point.

ABS is a terpolymer made by polymerizing styrene and acrylonitrile in the presence of polybutadiene. The proportions can vary from 15 to 35% acrylonitrile, 5 to 30% butadiene and 40 to 60% styrene. The result is a long chain of polybutadiene criss-crossed with shorter chains of poly(styrene-co-acrylonitrile). The nitrile groups from neighboring chains, being polar, attract each other and bind the chains together, making ABS stronger than pure polystyrene. The styrene gives the plastic a shiny, impervious surface. The polybutadiene, a rubbery substance, provides toughness even at low temperatures. For the majority of applications, ABS can be used between −20 and 80 °C (−4 and 176 °F) as its mechanical properties vary with temperature. The properties are created by rubber toughening, where fine particles of elastomer are distributed throughout the rigid matrix.

The most important mechanical properties of ABS are impact resistance and toughness. A variety of modifications can be made to improve impact resistance, toughness, and heat resistance. The impact resistance can be amplified by increasing the proportions of polybutadiene in relation to styrene and also acrylonitrile, although this causes changes in other properties. Impact resistance does not fall off rapidly at lower temperatures. Stability under load is excellent with limited loads. Thus, by changing the proportions of its components, ABS can be prepared in different grades. Two major categories could be ABS for extrusion and ABS for injection moulding, then high and medium impact resistance. Generally ABS would have useful characteristics within a temperature range from −20 to 80 °C (−4 to 176 °F).

The final properties will be influenced to some extent by the conditions under which the material is processed to the final product. For example, molding at a high temperature improves the gloss and heat resistance of the product whereas the highest impact resistance and strength are obtained by molding at low temperature. Fibers (usually glass fibers) and additives can be mixed in the resin pellets to make the final product strong and raise the operating range to as high as 80 °C (176 °F). Pigments can also be added, as the raw material original color is translucent ivory to white. The aging characteristics of the polymers are largely influenced by the polybutadiene content, and it is normal to include antioxidants in the composition. Other factors include exposure to ultraviolet radiation, for which additives arealso available to protect against. ABS polymers are resistant to aqueous acids, alkalis, concentrated hydrochloric and phosphoric acids, alcohols and animal, vegetable and mineral oils, but they are swollen by glacial acetic acid, carbon tetrachloride and aromatic hydrocarbons and are attacked by concentrated sulfuric and nitric acids. They are soluble in esters, ketones, ethylene dichloride and acetone. Even though ABS plastics are used largely for mechanical purposes, they also have electrical properties that are fairly constant over a wide range of frequencies. These properties are little affected by temperature and atmospheric humidity in the acceptable operating range of temperatures.

ABS is flammable when it is exposed to high temperatures, such as a wood fire. It will melt then boil, at which point the vapors burst into intense, hot flames. Since pure ABS contains no halogens, its combustion does not typically produce any persistent organic pollutants, and the most toxic products of its combustion or pyrolysis are carbon monoxide and hydrogen cyanide. ABS is also damaged by sunlight. This caused one of the most widespread and expensive automobile recalls in US history due to the degradation of the seatbelt release buttons. ABS can be recycled, although it is not accepted by all recycling facilities. A Super Nintendo Entertainment System with its outer casing made of ABS. Over time, the casing changed colour from light grey to yellow as a result of oxidation. When exposed to sunlight for a prolonged period of time, ABS will sometimes experience yellowing as a result of oxidation. This yellow colour can be cleaned through the use of hydrogen peroxide and UV light. bond (unsaturated compounds, e.g., alkenes and their derivatives) that can participate in a chain reaction A chain reaction consists of three stages, Initiation, Propagation and Termination. In the Initiation step an initiator molecule is thermally decomposed or allowed to undergo a chemical reaction to generate an “active species” “ This “active species,” which can be a free radical or a cation or an anion, then initiates the polymerization by adding to the monomer’s carbon-carbon double bond The reaction occurs in such a manner that a new free radical or cation or anion is generated The initial monomer becomes the first repeat unit in the incipient polymer chain In the Propagation step, the newly generated “active species” adds to another monomer in the same manner as in the initiation step This procedure is repeated over and over again until the final step of the process, termination, occurs In the Termination step, the growing chain terminates through reaction with another growing chain, by reaction with another species in the polymerization mixture, or by the spontaneous decomposition of the active site Under certain conditions, anionic can be carried out without the termination step to generate so-called “living” polymers General characteristics of addition polymerization [1] Once initiation occurs, the polymer chain forms very quickly [2] The concentration of active species is very low. Hence, the polymerisation mixture consists of primarily of newly-formed polymer and unreacted monomer Since the carbon-carbon double bonds in the monomers are, in effect, converted to two single carbon-carbon bonds in the polymer, so energy is released making the polymerization exothermic with cooling often required.

Condensation Polymerisation:

This type of polymerisation generally involves a repetitive condensation reaction (two molecules join together, resulting loss of small molecules) between two bi-functional monomers These polycondensation reactions may result in the loss of some simple molecules as water, alcohol, etc., and lead to the formation of high molecular mass condensation polymers In these reactions, the product of each step is again a bi-functional species and the sequence of condensation goes on Since, each step produces a distinct functionalised species and is independent of each other; this process is also called as step growth polymerisation The type of end polymer product resulting from a condensation polymerization is dependent on the number of functional end groups of the monomer which can react Monomers with only one reactive group terminate a growing chain, and thus give end products with a lower molecular weight Linear polymers are created using monomers with two reactive end groups and monomers with more than two end groups give three dimensional polymers which are cross linked. Polyester Polyester is created created through through ester linkages linkages between between monomers, monomers, which involve the functional groups carboxyl and hydroxyl (an organic acid and an alcohol monomer) The formation of polyester like terylene or dacron by the interaction of ethylene glycol and terephthalic acid is an example of this type of polymerisation Polyamide is created through amide linkages between monomers, which involve the functional groups carboxyl and amine (an organic acid and an amine monomer) Nylon-6 is an example which can be manufactured by the condensation polymerisation of hexamethylenediamine with adipic acid under high pressure and at high temperature. This type of polymerization normally employs two difunctional monomers that are capable of undergoing typical organic reactions. For example, a diacid can be allowed to react with a diol in the presence of an acid catalyst to afford polyester, in this case, chain growth is initiated by the reaction of one of the diacid's carboxyl groups with one of the diol's hydroxyl groups The free carboxyl or hydroxyl group of the resulting dimer can then react with an appropriate functional group in another monomer or dimer, this process is repeated throughout the polymerization mixture until all of the monomers are converted to low molecular weight species, such as dimers, trimers, tetramers, etc These molecules, which are called oligomers, can then further react with each other through their free functional groups Polymer chains that have moderate molecular weight can he built in this manner. The following are several general characteristics of this type of polymerization: (1) The polymer chain forms slowly, sometimes requiring several hours to several days (2) All of the monomers are quickly converted to oligomers, thus, the concentration of growing chains is high (3) Since most of the chemical chemical reactions reactions employed employed have relatively relatively high energies energies of activation, the polymerization mixture is usually heated to high temperatures (4) Step-reaction polymerizations normally afford polymers with moderate molecular weights, i.e., Condensation Polymerisation This type of polymerisation generally involves a repetitive condensation reaction (two molecules join together, resulting loss of small molecules) between two bi-functional monomers These polycondensation reactions may result in the loss of some simple molecules as water, alcohol, etc., and lead to the formation of high molecular mass condensation polymers In these reactions, the product of each step is again a bi-functional species and the sequence of condensation goes on Since, each step produces a distinct functionalised species and is independent of each other; this process is also called as step growth polymerisation The type of end polymer product resulting from a condensation polymerization is dependent on the number of functional end groups of the monomer which can react Monomers with only one reactive group terminate a growing chain, and thus give end products with a lower molecular weight Linear polymers are created using monomers with two reactive end groups and monomers with more than two end groups give three dimensional polymers which are cross linked. 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19. **Write short note about the different types of matrix materials and reinforcement materials used to make polymer matrix composites.**

Fibre-reinforced plastic (FRP) (also *fibre-reinforced polymer*) is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass, carbon, aramid, or basalt. Rarely, other fibres such as paper or wood or asbestos have been used. The polymer is usually an epoxy, vinylester or polyester thermosetting plastic; and phenol formaldehyde resins are still in use.

FRPs are commonly used in the aerospace-, automotive-, marine- and construction industries; and in ballistic armor.

Fibre preforms are how the fibres are manufactured before being bonded to the matrix. Fibre preforms are often manufactured in sheets, continuous mats, or as continuous filaments for spray applications. The four major ways to manufacture the fibre preform is through the textile processing techniques of weaving, knitting, braiding and stitching.

1. Weaving

Weaving can be done in a conventional manner to produce two-dimensional fibres as well in a multilayer weaving that can create three-dimensional fibres. However, multilayer weaving is required to have multiple layers of warp yarns to create fibres in the z- direction creating a few disadvantages in manufacturing,namely the time to set up all the warp yarns on the loom. Therefore, most multilayer weaving is currently used to produce relatively narrow width products, or high value products where the cost of the preform production is acceptable. Another one of the main problems facing the use of multilayer woven fabrics is the difficulty in producing a fabric that contains fibres oriented with angles other than 0” and 90” to each other respectively.

2. Braiding

1. The second major way of manufacturing fibre preforms is Braiding. Braiding is suited to the manufacture of narrow width flat or tubular fabric and is not as capable as weaving in the production of large volumes of wide **What do you understand by polymerization. With the help of suitable examples, compare and contrast the process of addition polymerization and condensation polymerization.**

In polymer chemistry, polymerization is a process of reacting monomer molecules together in a chemical reaction to form polymer chains or three-dimensional networks. There are many forms of polymerization and different systems exist to categorize them.

Addition Polymerisation:

In this type of polymerisation, the molecules of the same monomer or different monomers add together on a large scale to form a polymer The monomers monomers normally normally employed employed in this type of polymerization polymerization contain a carbon-carbon doublefabrics. Braiding is done over top of mandrels that vary in cross-sectional shape or dimension along their length. Braiding is limited to objects about a brick in size. Unlike standard weaving, braiding can produce fabric that contains fibres at 45 degrees angles to one another. Braiding three-dimensional fibres can be done using four step, two-step or Multilayer Interlock Braiding.Four step or row and column braiding utilizes a flat bed containing rows and columns of yarn carriers that form the shape of the desired preform. Additional carriers are added to the outside of the array, the precise location and quantity of which depends upon the exact preform shape and structure required. There are four separate sequences of row and column motion, which act to interlock the yarns and produce the braided preform. The yarns are mechanically forced into the structure between each step to consolidate the structure in a similar process to the use of a reed in weaving. Two-step braiding is unlike the four-step process because the two-step includes a large number of yarns fixed in the axial direction and a fewer number of braiding yarns. The process consists of two steps in which the braiding carriers move completely through the structure between the axial carriers. This relatively simple sequence of motions is capable of forming preforms of essentially any shape, including circular and hollow shapes. Unlike the four-step process, the two-step process does not require mechanical compaction the motions involved in the process allows the braid to be pulled tight by yarn tension alone. The last type of braiding is multi-layer interlocking braiding that consists of a number of standard circular braiders being joined together to form a cylindrical braiding frame. This frame has a number of parallel braiding tracks around the circumference of the cylinder but the mechanism allows the transfer of yarn carriers between adjacent tracks forming a multilayer braided fabric with yarns interlocking to adjacent layers. The multilayer interlock braid differs from both the four step and two-step braids in that the interlocking yarns are primarily in the plane of the structure and thus do not significantly reduce the in-plane properties of the preform. The four-step and two-step processes produce a greater degree of interlinking as the braiding yarns travel through the thickness of the preform, but therefore contribute less to the in-plane performance of the preform. A disadvantage of the multilayer interlock equipment is that due to the conventional sinusoidal movement of the yarn carriers to form the preform, the equipment is not able to have the density of yarn carriers that is possible with the two step and four step machines. **3. Knitting**

Knitting fibre preforms can be done with the traditional methods of Warp and [Weft] Knitting, and the fabric produced is often regarded by many as two-dimensional fabric, but machines with two or more needle beds are capable of producing multilayer fabrics with yams that traverse between the layers. Developments in electronic controls for needle selection and knit loop transfer, and in the sophisticated mechanisms that allow specific areas of the fabric to be held and their movement controlled. This has allowed the fabric to form itself into the required three-dimensional preform shape with a minimum of material wastage.

4. Stitching

Stitching is arguably the simplest of the four main textile manufacturing techniques and one that can be performed with the smallest investment in specialized machinery. Basically stitching consists of inserting a needle, carrying the stitch thread, through a stack of fabric layers to form a 3D structure. The advantages of stitching are that it is possible to stitch both dry and prepreg fabric, although the tackiness of the prepreg makes the process difficult and generally creates more damage within the prepreg material than in the dry fabric. Stitching also utilizes the standard two-dimensional fabrics that are commonly in use within the composite industry therefore there is a sense of familiarity concerning the material systems. The use of standard fabric also allows a greater degree of flexibility in the fabric lay-up of the component than is possible with the other textile processes, which have restrictions on the fibre orientations that can be produced.

Forming processes

A rigid structure is usually used to establish the shape of FRP components. Parts can be laid up on a flat surface referred to as a “caul plate” or on a cylindrical structure referred to as a “mandrel”. However most fibre-reinforced plastic parts are created with a mold or “tool.” Molds can be concave female molds, male molds, or the mold can completely enclose the part with a top and bottom mold.

The moulding processes of FRP plastics begins by placing the fibre preform on or in the mold. The fibre preform can be dry fibre, or fibre that already contains a measured amount of resin called “prepreg”. Dry fibres are “wetted” with resin either by hand or the resin is injected into a closed mold. The part is then cured, leaving the matrix and fibres in the shapecreated by the mold. Heat and/or pressure are sometimes used to cure the resin and improve the quality of the final part. The different methods of forming are listed below.

Bladder moulding

Individual sheets of prepreg material are laid up and placed in a female-style mould along with a balloon-like bladder. The mould is closed and placed in a heated press. Finally, the bladder is pressurized forcing the layers of material against the mould walls.

Compression moulding

When the raw material (plastic block,rubber block, plastic sheet, or granules) contains reinforcing fibres, a compression molded part qualifies as a fibre-reinforced plastic. More typically the plastic preform used in compression molding does not contain reinforcing fibres. In compression molding, a “preform” or “charge”, of SMC, BMC is placed into mould cavity. The mould is closed and the material is formed & cured inside by pressure and heat. Compression moulding offers excellent detailing for geometric shapes ranging from pattern and relief detailing to complex curves and creative forms, to precision engineering all within a maximum curing time of 20 minutes.[20]

Autoclave and vacuum bag

Individual sheets of prepreg material are laid-up and placed in an open mold. The material is covered with release film, bleeder/breather material and a vacuum bag. A vacuum is pulled on part and the entire mould is placed into an autoclave (heated pressure vessel). The part is cured with a continuous vacuum to extract entrapped gasses from laminate. This is a very common process in the aerospace industry because it affords precise control over moulding due to a long, slow cure cycle that is anywhere from one to several hours.[21] This precise control creates the exact laminate geometric forms needed to ensure strength and safety in the aerospace industry, but it is also slow and labour-intensive, meaning costs often confine it to the aerospace industry.

Mandrel wrapping

Sheets of prepreg material are wrapped around a steel or aluminium mandrel. The prepreg material is compacted by nylon or polypropylene cello tape. Parts are typically batch cured by vacuum bagging and hangingin an oven. After cure the cello and mandrel are removed leaving a hollow carbon tube. This process creates strong and robust hollow carbon tubes.

Wet layup

Wet layup forming combines fibre reinforcement and the matrix as they are placed on the forming tool.n Reinforcing Fibre layers are placed in an open mould and then saturated with a wet resin by pouring it over the fabric and working it into the fabric. The mould is then left so that the resin will cure, usually at room temperature, though heat is sometimes used to ensure a proper cure. Sometimes a vacuum bag is used to compress a wet layup. Glass fibres are most commonly used for this process, the results are widely known as fibreglass, and is used to make common products like skis, canoes, kayaks and surf boards.

Chopper gun

Continuous strands of fibreglass are pushed through a hand-held gun that both chops the strands and combines them with a catalysed resin such as polyester. The impregnated chopped glass is shot onto the mould surface in whatever thickness and design the human operator thinks is appropriate. This process is good for large production runs at economical cost, but produces geometric shapes with less strength than other moulding processes and has poor dimensional tolerance.

Filament winding

Machines pull fibre bundles through a wet bath of resin and wound over a rotating steel mandrel in specific orientations Parts are cured either room temperature or elevated temperatures. Mandrel is extracted, leaving a final geometric shape but can be left in some cases.

Pultrusion

Fibre bundles and slit fabrics are pulled through a wet bath of resin and formed into the rough part shape. Saturated material is extruded from a heated closed die curing while being continuously pulled through die. Some of the end products of pultrusion are structural shapes, i.e. I beam, angle, channel and flat sheet. These materials can be used to create all sorts of fibreglass structures such as ladders, platforms, handrail systems tank, pipe and pump supports. **Resin transfer molding**

Also called resin infusion. Fabrics are placed into a mould into which wet resin is then injected. Resin is typically pressurized and forced into a cavity which is under vacuum in resin transfer molding. Resin is entirely pulled into cavity under vacuum in vacuum-assisted resin transfer molding. This moulding process allows precise tolerances and detailed shaping but can sometimes fail to fully saturate the fabric leading to weak spots in the final shape.

Advantages and limitations

FRP allows the alignment of the glass fibres of thermoplastics to suit specific design programs. Specifying the orientation of reinforcing fibres can increase the strength and resistance to deformation of the polymer. Glass reinforced polymers are strongest and most resistive to deforming forces when the polymers fibres are parallel to the force being exerted, and are weakest when the fibres are perpendicular. Thus this ability is at once both an advantage or a limitation depending on the context of use. Weak spots of perpendicular fibres can be used for natural hinges and connections, but can also lead to material failure when production processes fail to properly orient the fibres parallel to expected forces. When forces are exerted perpendicular to the orientation of fibres the strength and elasticity of the polymer is less than the matrix alone. In cast resin components made of glass reinforced polymers such as UP and EP, the orientation of fibres can be oriented in two-dimensional and three-dimensional weaves. This means that when forces are possibly perpendicular to one orientation, they are parallel to another orientation; this eliminates the potential for weak spots in the polymer.

Failure modes

Structural failure can occur in FRP materials when:

Tensile forces stretch the matrix more than the fibres, causing the material to shear at the interface between matrix and fibres.

Tensile forces near the end of the fibres exceed the tolerances of the matrix, separating the fibres from the matrix.

Tensile forces can also exceed the tolerances of the fibres causing the fibres themselves to fracture leading to material failure.

Material requirements

Basalt fibre

The matrix must also meet certain requirements in order to first be suitable for FRPs and ensure a successful reinforcement of itself. The matrix must be able to properly saturate, and bond with the fibres within a suitable curing period. The matrix should preferably bond chemically with the fibre reinforcement for maximum adhesion. The matrix must also completely envelop the fibres to protect them from cuts and notches that would reduce their strength, and to transfer forces to the fibres. The fibres must also be kept separate from each other so that if failure occurs it is localized as much as possible, and if failure occurs the matrix must also debond from the fibre for similar reasons. Finally the matrix should be of a plastic that remains chemically and physically stable during and after the reinforcement and moulding processes. To be suitable as reinforcement material, fibre additives must increase the tensile strength and modulus of elasticity of the matrix and meet the following conditions; fibres must exceed critical fibre content; the strength and rigidity of fibres itself must exceed the strength and rigidity of the matrix alone; and there must be optimum bonding between fibres and matrix

Glass fibre material

"Fibreglass reinforced plastics" or FRPs (commonly referred to simply as fibreglass) use textile grade glass fibres. These textile fibres are different from other forms of glass fibres used to deliberately trap air, for insulating applications (see glass wool). Textile glass fibres begin as varying combinations of SiO2, Al2O3, B2O3, CaO, or MgO in powder form. These mixtures are then heated through direct melting to temperatures around 1300 degrees Celsius, after which dies are used to extrude filaments of glass fibre in diameter ranging from 9 to 17 µm. These filaments are then wound into larger threads and spun onto bobbins for transportation and further processing. Glass fibre is by far the most popular means to reinforce plastic and thus enjoys a wealth of production processes, some of which are applicable to aramid and carbon fibres as well owing to their shared fibrous qualities.

Roving is a process where filaments are spun into larger diameter threads. These threads are then commonly used for woven reinforcing glass fabrics and mats, and in spray applications. Fibre fabrics are web-form fabric reinforcing material that has both warp and weft directions. Fibre mats are web-form non-woven mats of glass fibres. Mats are manufactured in cut dimensions with chopped fibres, or in continuous mats using continuous fibres. Chopped fibre glass is used in processes where lengths of glass threads are cut between 3 and 26 mm, threads are then used in plastics most commonly intended for moulding processes. Glass fibre short strands are short 0.2–0.3 mm strands of glass fibres that are used to reinforce thermoplastics most commonly for injection moulding.

Carbon fibre

Carbon fibres are created when polyacrylonitrile fibres (PAN), Pitch resins, or Rayon are carbonized (through oxidation and thermal pyrolysis) at high temperatures. Through further processes of graphitizing or stretching the fibres strength or elasticity can be enhanced respectively. Carbon fibres are manufactured in diameters analogous to glass fibres with diameters ranging from 4 to 17 µm. These fibres wound into larger threads for transportation and further production processes.[2] Further production processes include weaving or braiding into carbon fabrics, cloths and mats analogous to those described for glass that can then be used in actual reinforcements.[1]

Aramid fibre material

Aramid fibres are most commonly known as Kevlar, Nomex and Technora. Aramids are generally prepared by the reaction between an amine group and a carboxylic acid halide group (aramid);[commonly this occurs when an aromatic polyamide is spun from a liquid concentration of sulphuric acid into a crystallized fibre Fibres are then spun into larger threads in order to weave into large ropes or woven fabrics (Aramid). Aramid fibres are manufactured with varying grades to based on varying qualities for strength and rigidity, so that the material can be somewhat tailored to specific design needs concerns, such as cutting the tough material during manufacture.

20. **Discuss the properties and application of Al2O3 and SiC.**

Aluminium oxide is a chemical compound of aluminium and oxygen with the chemical formula Al2O3. It is the most commonly occurring of several aluminium oxides, and specifically identified as aluminium(III) oxide. It is commonly called alumina, and may also be called aloxide, aloxite, oralundum depending on particular forms or applications. It occurs naturally in its crystalline polymorphic phase α-Al2O3 as the mineral corundum, varieties of which form the precious gemstones ruby and sapphire. Al2O3 is significant in its use to produce aluminium metal, as an abrasive owing to its hardness, and as a refractory material owing to its high melting point.

Silicon carbide (SiC), also known as carborundum , is a compound of silicon and carbon with chemical formula SiC. It occurs in nature as the extremely rare mineral moissanite. Silicon carbide powder has been mass-produced since 1893 for use as an abrasive. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests. Electronic applications of silicon carbide such as light-emitting diodes (LEDs) and detectors in early radios were first demonstrated around 1907. SiC is used in semiconductor electronics devices that operate at high temperatures or high voltages, or both. Large single crystals of silicon carbide can be grown by the Lely method; they can be cut into gems known as synthetic moissanite. Silicon carbide with high surface area can be produced from SiO2 contained in plant material.

21. **Write short notes on:**

i) Phenol formaldehydes

Phenol formaldehyde resins (PF) or phenolic resins are synthetic polymers obtained by the reaction of phenol or substituted phenol with formaldehyde. Used as the basis for Bakelite, PFs were the first commercial synthetic resins (plastics). They have been widely used for the production of molded products including billiard balls, laboratory countertops, and as coatings and adhesives. They were at one time the primary material used for the production of circuit boards but have been largely replaced with epoxy resins and fiberglass cloth, as with fire-resistant FR-4 circuit board materials.

There are two main production methods. One reacts phenol and formaldehyde directly to produce a thermosetting network polymer, while the other restricts the formaldehyde to produce a prepolymer known as novolac which can be moulded and then cured with the addition of more formaldehyde and heat. There are many variations in both production andinput materials that are used to produce a wide variety of resins for special purposes.

Phenolic resins are found in myriad industrial products. Phenolic laminates are made by impregnating one or more layers of a base material such as paper, fiberglass or cotton with phenolic resin and laminating the resin-saturated base material under heat and pressure. The resin fully polymerizes (cures) during this process. The base material choice depends on the intended application of the finished product. Paper phenolics are used in manufacturing electrical components such as punch-through boards, in household laminates, and in paper composite panels. Glass phenolics are particularly well suited for use in the high speed bearing market. Phenolic micro-balloons are used for density control. Snooker balls as well as balls from many table-based ball games are also made from phenol formaldehyde resin. The binding agent in normal (organic) brake pads, brake shoes and clutch disks are phenolic resin. Synthetic resin bonded paper, made from phenolic resin and paper, is used to make countertops.

Phenolic resins are also used for making exterior plywood commonly known as WBP (Weather & boil proof) Plywood because phenolic resins have no melting point but only a decomposing point in the temperature zone of 220 degree Celsius and above.

Phenolic resin is used as a binder in loudspeaker driver suspension components which are made of cloth.

Sometimes people select phenolic resin parts because their coefficient of thermal expansion closely matches that of the aluminum used for other parts of a system, as in early computer systems[3] and Duramold.

The Dutch forger Han van Meegeren mixed phenol formaldehyde with his oil paints before baking the finished canvas in order to fake the drying out of the paint over the centuries.

Application of PMMA and PPO.

Poly(methyl acrylate)

The polymer of methyl acrylate, PMA or poly(methyl acrylate), is similar to poly(methyl methacrylate), except for the lack of methyl groups on the backbone carbon chain.[23] PMA is a soft white rubbery material that is softer than PMMA because its long polymer chains are thinner and smoother and can more easily slide past each other. **Uses**

Being transparent and durable, PMMA is a versatile material and has been used in a wide range of fields and applications such as: rear-lights and instrument clusters for vehicles, appliances and lenses for glasses. PMMA in the form of sheets affords shatter resistant panels for building windows, skylights, bullet proof security barriers, signs & displays, sanitary ware (bathtubs), LCD screens, furniture and many other applications. It is also used for coating polymers based on MMA provides outstanding stability against environmental conditions with reduced emission of VOC. Methacrylate polymers are used extensively in medical and dental applications where purity and stability are critical to performance Close-up of pressure sphere of Bathyscaphe Trieste, with single conical window of PMMA (Plexiglas) set into sphere hull. The very small black circle (smaller than the man’s head) is the inner side of the plastic “window,” and is only a few inches in diameter. The larger circular clear black area represents the larger outer-side of the thick one-piece plastic cone “window.”

PMMA acrylic glass is commonly used for constructing residential and commercial aquariums. Designers started building big aquariums when poly(methyl methacrylate) could be used. It is less-used in other building types due to incidents such as the Summerland disaster.

Acrylic is used for viewing ports and even complete pressure hulls of submersibles, such as the Alicia submarine’s viewing sphere and the window of the bathyscaphe Trieste.

PMMA is used in the lenses of exterior lights of automobiles.[24]

The spectator protection in ice hockey rinks is made from PMMA.

Historically, PMMA was an important improvement in the design of aircraft windows, making possible such iconic designs as the bombardier’s transparent nose compartment in the Boeing B-17 Flying Fortress.

Police vehicles for riot control often have the regular glass replaced with acrylic to protect the occupants from thrown objects.

Acrylic is an important material in the making of certain lighthouse lenses.[25]

PMMA was used for the roofing of the iconic compound in the Olympic Park for the 1972 Summer Olympics in Munich. It enabled a light and translucent construction underlining the democratic approach to the games.[26]

PMMA (under the brand name “Lucite”) was used for the ceiling of the Houston Astrodome.

Daylight redirection

Laser cut acrylic panels have been used to redirect sunlight into a light pipe or tubular skylight and, from there, to spread it into a room.[27] Their developers Veronica Garcia Hansen, Ken Yeang, and Ian Edmonds were awarded the Far East Economic Review Innovation Award in bronze for this technology in 2003.

Attenuation being quite strong for distances over one meter (more than 90% intensity loss for a 3000 K), acrylic broadband light guides are then dedicated mostly to decorative uses.

Pairs of acrylic sheets with a layer of microreplicated prisms between the sheets can have reflective and refractive properties that let them redirect part of incoming sunlight in dependence on its angle of incidence. Such panels act as miniature light shelves. Such panels have been commercialized for purposes of daylighting, to be used as a window or a canopy such that sunlight descending from the sky is directed to the ceiling or into the room rather than to the floor. This can lead to a higher illumination of the back part of a room, in particular when combined with a white ceiling, while having a slight impact on the view to the outside compared to normal glazing.

Medical technologies and implants

PMMA has a good degree of compatibility with human tissue, and it is used in the manufacture of rigid intraocular lenses which are implanted in the eye when the original lens has been removed in the treatment of cataracts. This compatibility was discovered by the English ophthalmologist Sir Harold Ridley in WWII RAF pilots, whose eyes had been riddled with PMMA splinters coming from the side windows of their Supermarine Spitfire fighters – the plastic scarcely caused any rejection, compared to glass splinters coming from aircraft such as the Hawker Hurricane.[33] Ridley had a lens manufactured by the Rayner company (Brighton & Hove, East Sussex) made from Perspex polymerised by ICI. On 29 November 1949 at St Thomas’ Hospital, London, Ridley implanted the first intraocular lens at St Thomas’s Hospital in London.[34]

In particular, acrylic-type contact lenses are useful for cataract surgery in patients that have recurrent ocular inflammation (uveitis), as acrylic material induce less inflammation.

Eyeglass lenses are commonly made from PMMA.

Historically, hard contact lenses were frequently made of this material. Soft contact lenses are often made of a related polymer, where acrylate monomers containing one or more hydroxyl groupsmake them hydrophilic.

In orthopedic surgery, PMMA bone cement is used to affix implants and to remodel lost bone. It is supplied as a powder with liquid methyl methacrylate (MMA). Although PMMA is biologically compatible, MMA is considered to be an irritant and a possible carcinogen. PMMA has also been linked to cardiopulmonary events in the operating room due to hypotension.[35] Bone cement acts like a grout and not so much like a glue in arthroplasty. Although sticky, it does not bond to either the bone or the implant, it primarily fills the spaces between the prosthesis and the bone preventing motion. A disadvantage of this bone cement is that it heats up to 82.5 °C

(180.5 °F) while setting that may cause thermal necrosis of neighboring tissue. A careful balance of initiators and monomers is needed to reduce the rate of polymerization, and thus the heat generated. A major consideration when using PMMA cement is the effect of stress shielding. Since PMMA has a Young’s modulusbetween 1.8 and 3.1 GPa, which is lower than that of natural bone (around 14 GPa for human cortical bone),[37] the stresses are loaded into the cement and so the bone no longer receives the mechanical signals to continue bone remodeling and so resorption will occur.

Dentures are often made of PMMA, and can be color-matched to the patient’s teeth & gum tissue. PMMA is also used in the production of ocular prostheses, such as the osteo-odonto-keratoprosthesis.

In cosmetic surgery, tiny PMMA microspheres suspended in some biological fluid are injected under the skin to reduce wrinkles or scars permanently. PMMA is also used to create false “muscles” by body builders.

Plombage is an outdated treatment of tuberculosis where the pleural space around an infected lung was filled with PMMA balls, in order to compress and collapse the affected lung.

Emerging biotechnology and Biomedical research uses PMMA to create microfluidic lab-on-a-chip devices, which require 100 micrometre-wide geometries for routing liquids. These small geometries are amenable to using PMMA in a biochip fabrication process and offers moderate biocompatibility.

.Bioprocess chromatography columns use cast acrylic tubes as an alternative to glass and stainless steel. These are pressure rated and satisfy stringent requirements of materials for biocompatibility, toxicity and extractables.

Artistic and aesthetic uses

Acrylic paint essentially consists of PMMA suspended in water; however since PMMA is hydrophobic, a substance with both hydrophobic and hydrophilic groups needs to be added to facilitate the suspension.

Modern furniture makers, especially in the 1960s and 1970s, seeking to give their products a space age aesthetic, incorporated Lucite and other PMMA products into their designs, especially office chairs. Many other products (for example, guitars) are sometimes made with acrylic glass to make the commonly opaque objects translucent.

Perspex has been used as a surface to paint on, for example by Salvador Dalí.

Diasec is a process which uses acrylic glass as a substitute for normal glass in picture frames. This is done for its relatively low cost, light weight, shatter-resistance, aesthetics and because it can be ordered in larger sizes than standard picture framing glass.

As early as 1939, Los Angeles-based Dutch sculptor Jan De Swart experimented with samples of Lucite sent to him by DuPont; De Swart created tools to work the Lucite for sculpture and mixed chemicals to bring about certain effects of color and refraction[40]

From approximately the 1960s onward, sculptors and glass artists such as Jan Kubíček and Leroy Lamis began using acrylics, especially taking advantage of the material’s flexibility, light weight, cost and its capacity to refract and filter light.

In the 1950s and 1960s, Lucite was an extremely popular material for jewelry, with several companies specialized in creating high-quality pieces from this material. Lucite beads and ornaments are still sold by jewelry suppliers.

Acrylic Sheets are produced in dozens of standard colors,[41] most commonly sold using color numbers developed by Rohm & Haas in the 1950s.

Other uses

Acrylic is used in tanning beds as the transparent surface that separates the occupant from the tanning bulbs while tanning. The type of acrylic used in tanning beds is most often formulated from a special type of polymethyl methacrylate, a compound that allows the passage of ultraviolet rays

Sheets of PMMA are commonly used in the sign industry to make flat cut out letters in thicknesses typically varying from 3 to 25 millimeters (0.1 to 1.0 in). These letters may be used alone to represent a company’s name and/or logo, or they may be a component of illuminated channel letters. Acrylic is also used extensively throughout the sign industry as a component of wall signs where it may be a backplate, painted on the surface or the backside, a faceplate with additional raised lettering or even photographic images printed directly to it, or a spacer to separate sign components.

PMMA was used in Laserdisc optical media. (CDs and DVDs use both acrylic and polycarbonate for impact resistance.)

It is used as a light guide for the backlights in TFT-LCDs.

Plastic optical fiber used for short distance communication is made from PMMA, and perfluorinated PMMA, clad with fluorinated PMMA, in situations where its flexibility and cheaper installation costs outweigh its poor heat tolerance and higher attenuation over glass fiber.

PMMA, in a purified form, is used as the matrix in laser dye-doped organic solid-state gain media for tunable solid state dye lasers.[42]

In semiconductor research and industry, PMMA aids as a resist in the electron beam lithography process. A solution consisting of the polymer in a solvent is used to spin coat silicon and other semiconducting and semi-insulating wafers with a thin film. Patterns on this can be made by an electron beam (using an electron microscope), deep UV light (shorter wavelength than the standard

chain scission or (de-cross-linking) within the PMMA, allowing for the selective removal of exposed areas by a chemical developer, making it a positive photoresist. PMMA’s advantage is that it allows for extremely high resolution patterns to be made. Smooth PMMA surface can be easily nanostructured by treatment in oxygen radio-frequency plasma and nanostructured PMMA surface can be easily smoothed by vacuum ultraviolet (VUV) irradiation.

.PMMA is used as a shield to stop beta radiation emitted from radioisotopes

.Small strips of PMMA are used as dosimeter devices during the Gamma Irradiation process. The optical properties of PMMA change as the gamma dose increases, and can be measured with a spectrophotometer.

.A blacklight-reactive tattoo ink using PMMA microcapsules has been developed.

.PMMA can be used as a dispersant for ceramic powders to stabilize colloidal suspensions in non-aqueous media. Due to its high viscosity upon dissolution, it can also be used as binder material for solution deposition processes, e.g. printing of solar cells.[45]

.PMMA has also been used extensively as a hybrid rocket fuel

.In the 1960s, luthier Dan Armstrong developed a line of electric guitars and basses whose bodies were made completely of acrylic. These instruments were marketed under the Ampeg brand. Ibanez and B.C. Rich have also made acrylic guitars.

.Ludwig-Musser makes a line of acrylic drums called Vistalites, well known as being used by Led Zeppelin drummer John Bonham.

.Artificial fingernails are sometimes made of acrylic.

.Some modern briar, and occasionally meerschaum, tobacco pipes sport stems made of Lucite.

.PMMA technology is utilized in roofing and waterproofing applications. By incorporating a polyester fleece sandwiched between two layers of catalyst-activated PMMA resin, a fully reinforced liquid membrane is created *in situ*.

PMMA is a widely used material to create deal toys and financial tombstones.

Poly (*p*-phenylene oxide) or poly(*p*-phenylene ether) (PPE) is a high-temperature thermoplastic. It is rarely used in its pure form due to difficulties in processing. It is mainly used as blend with polystyrene, high impact styrene-butadiene copolymer or polyamide. PPO is a registered trademark of SABIC Innovative Plastics IP B.V. under which various polyphenylene ether resins are sold.

PPE blends are used for structural parts, electronics, household and automotive items that depend on high heat resistance, dimensional stability and accuracy. They are also used in medicine for sterilizable instruments made of plastic. This plastic is processed by injection molding or extrusion; depending on the type, the processing temperature is 260-300 °C. The surface can be printed, hot-stamped, painted or metallized. Welds are possible by means of heating element, friction or ultrasonic welding. It can be glued with halogenated solvents or various adhesives.

This plastic is also used to produce air separation membranes for generating nitrogen. The PPO is spun into a hollow fiber membrane with a porous support layer and a very thin outer skin. The permeation of oxygen occurs from inside to out across the thin outer skin with an extremely high flux. Due to the manufacturing process, the fiber has excellent dimensional stability and strength. Unlike hollow fiber membranes made from polysulfone, the aging process of the fiber is relatively quick so that air separation performance remains stable throughout the life of the membrane. PPO makes the air separation performance suitable for low temperature (35-70F) (2-21C) applications where polysulfone membranes require heated air to increase permeation.

22. **Briefly explain the application and properties of various thermosetting and thermo plastics.**

Refer question number 8.

23. **Enumerate about various engineering ceramic materials.**

Refer question number 2.