Polymer Process Engineering
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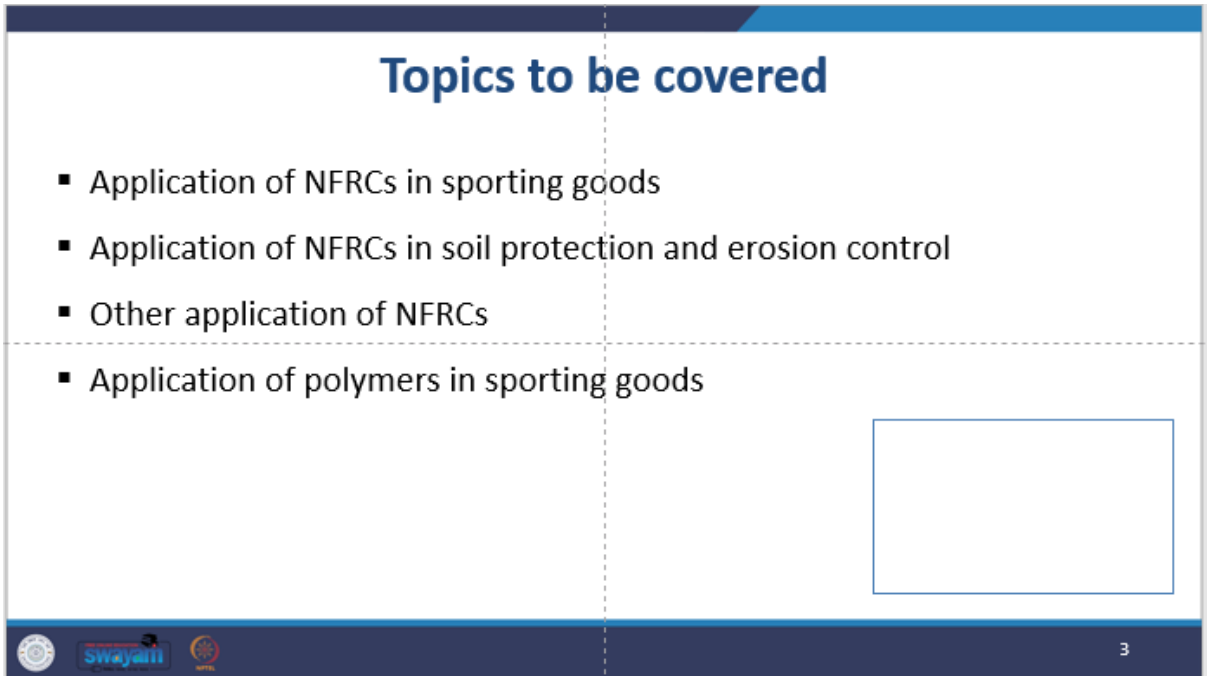
Lecture 56
NFRCs and Polymer Applications

Hello friends, welcome to the next lecture of Natural Fibre Reinforcement. and polymer application under the edges of polymer process engineering. Now, if you recall that previously we have covered the different types of natural fibre reinforced composites. We discussed about the treatment of fibres, we discussed about the advantages and disadvantages of all these natural fibre reinforced composites. Then we discussed the applications in different high-end technology sectors of these natural fibre reinforced composites. In this particular segment we are going to discuss about the application of natural fibre reinforced composite in sports goods.



We are going to discuss about the application of these natural fibre reinforced composites in soil protection and erosion control. Apart from this we discussed some other applications, especially in different parts of the life. Now talk about the application of the polymer reinforced composites, they find a wide application in all aspects of life like from automobile to the sports group to the domestic application to the furniture and all adverse segments, name any segments you will find that there is a natural fibre reinforced composite is there. So, they are utilised into manufacturing of sports gears because of their lightweight, high strength and biodegradability aspect, especially those natural fibre can be easily be biodegradable.

Applications of Polymer reinforced composites

Natural fiber reinforced composites are utilized to manufacture sports gears because of their lightweight, high strength, and biodegradable nature. Flax fiber composites are used in the manufacturing of tennis rackets. Some applications of natural fiber composites are shown:

different applications of flax fiber composites in sporting goods (a) Notox surfboard, (b) Tennis racket, (c) Caperlan fishing rod, (d) ArcWin Archery, (e) Le Ventoux bamboo-flax bike, and (f) Kang flax ski poles (Pil et al., 2016) (with permission)

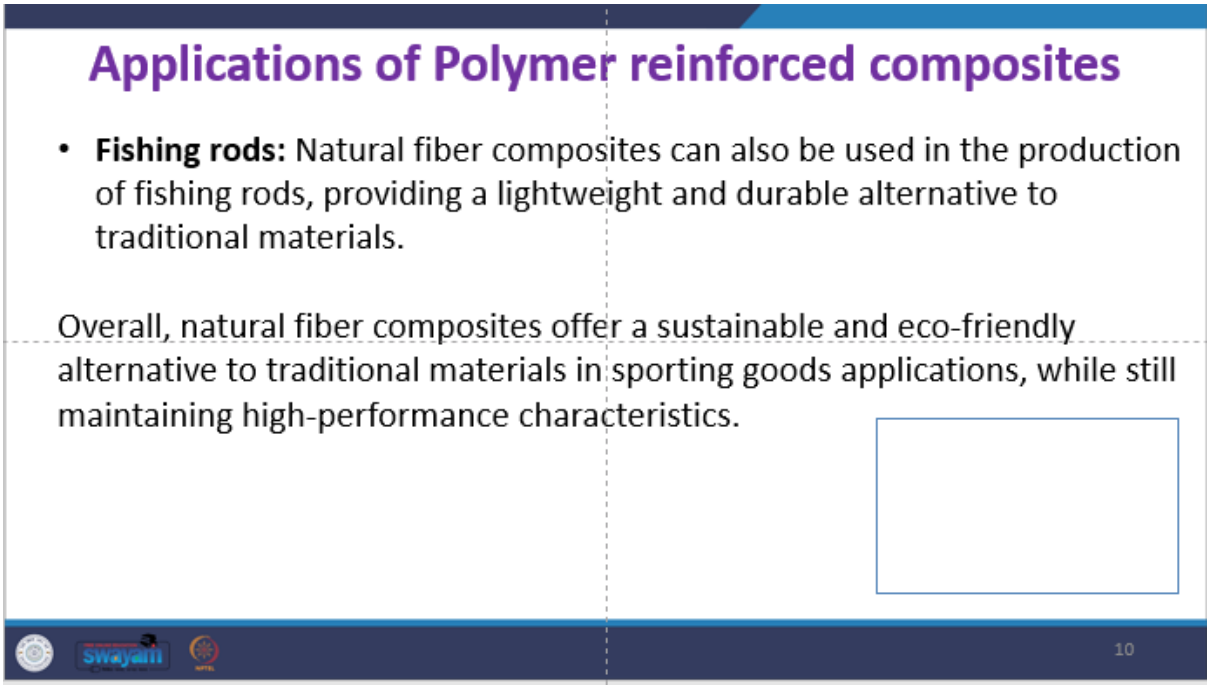
Now flex fibre composites they are used in manufacturing of tennis racquets and some applications they of natural fibre composites are given like bicycle frames. These natural fibre reinforced composites particularly those reinforced with the carbon or flex fibres they are used in the construction of bicycle or manufacturing of bicycle frames. Now these composites offer lightweight alternatives to the traditional metal frames resulting in enhanced manoeuvrability, increased shock absorption and improved overall performance. Tennis racquets because here you need to have a high impact of force and other things so you need to have a different type of a profile with respect to the properties. So natural fibre composites they offer very good alternative for conventional materials.

Applications of Polymer reinforced composites

- **Snowboards and Skis:** NFRCs are used in the construction of snowboards and skis. Natural fibers like flax or bamboo are integrated into the composite layup to provide vibration damping, improved flexibility, and lightweight characteristics. This enhances maneuverability, stability, and overall performance on the slopes.

So natural fibre composites like those reinforced with the flex or hemp fibre they are used in the production of these tennis racquets frames. These composites provide the lightweight and responsive frames with excellent vibration damping characteristics leading to the enhanced player control and

reduced strain on the arm. So, all these things are very important like this you need to have a reduced impact you need to have some sort of flexibility. So that is why these NFRCs they offer a very good substitute to those conventional materials. Then golf clubs these natural fibre reinforced composites they are used in manufacturing of a golf club shaft and heads by utilising the natural fibre composite golf clubs can be designed to have a lower weight while maintaining sufficient stiffness and strength.



This results in increasing swing speeds, improved accuracy and a better feel during the gameplay. Apart from this the surface board, now natural fibre composites such as those reinforced with a bamboo or a core fibre they are employed in the production of surf boards and stand up paddle boards they are very common and very frequently being used by the sports persons. Now these composites offer lightweight durable boards with the good flex and strength properties leading to the improved performance in water sporting. So, you see that all these fibres reinforced plus composites they are having a versatile property apart from this snowboard and skis. Now these NFRCs or natural fibre reinforced composites they are used in the construction of snowboards, skis.

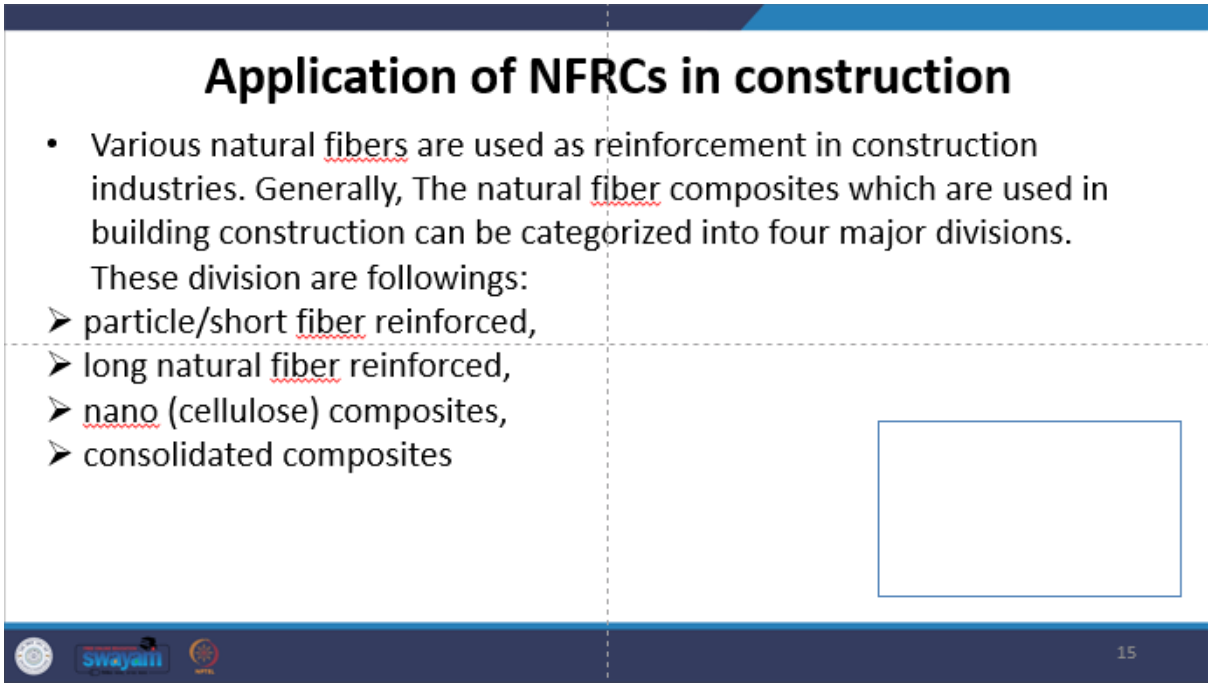
Applications of Polymer reinforced composites

- **Landscaping applications:** Natural fiber composites can be used in various landscaping applications, such as erosion control, soil stabilization, and vegetation establishment. The composites can help reduce soil erosion, improve soil quality, and promote vegetation growth.
- **Geotextiles:** Natural fiber composites can be used to manufacture geotextiles that are used for soil reinforcement, drainage, and filtration. The composites can provide high strength, durability, and resistance to environmental factors.

Now natural fibres like flax, and bamboo they are integrated or they are impregnated into the composite layup to provide vibration damping, improved flexibility and a lightweight characteristic. This enhances the maneuverability, stability and overall performance of on the slopes because slope you need to have slopey characteristics so you need to have some special properties. Then fishing rods, these natural fiber-reinforced composites can also be used in the production of fishing rods providing a lightweight and durable alternative to traditional materials. So overall the natural fibre composites offer a sustainable and eco-friendly alternative to the traditional material in sporting goods application while still maintaining the high-performance characteristics. Another application of the polymer-reinforced composites is soil protection.

Soil protection and erosion control

- **Gabions and retaining walls:** Natural fiber composites can also be used in the construction of gabions and retaining walls. The composites can provide high strength and durability, while still allowing for water and air flow through the structure.



The soil protection utilising plant fibre and other biodegradable material consist of leaves, straws and the plant residues. Now currently woven and a non-woven textile and covers they manufacture from the wheat straw, rice straw, longwood shaving, quire, jute they are utilised as a soil protection products. Now these products are usually divided in two groups. The first one which is manufactured using the quire and jute fibre termed as erosion control meshes like ECM and the second one is manufactured from the natural fibre or synthetic fibre bonded by meshes they are called the erosion control blankets, ECB. So ECM and ECB.

Now the straw or quire fibre bundles they are held together by meshes which can be utilised as a sediment retention natural fibre rods. So sometimes when erosion may occur in the surface then this can be utilised. So erosion control blankets. Now natural fibre composites this can be used to manufacture the erosion control blankets that help stabilise soil and prevent erosion. The composites provide high tensile strength making them ideal for use in steep slope application.

Some of the application attributed to the land escaping. So the natural fibre composite these can be used in various land escaping applications like erosion control, soil stabilisation, vegetation establishment and these composite can help reduce soil erosion, improve soil quality thereby and promote the vegetation growth. Geotextiles they are very common in the construction and road preparation all those things. So these geotextile natural fibre composites these can be used to manufacture the geotextile that are used for the soil reinforcement, drainage and filtration. The composites can provide high strength, durability and resistance to environmental factor.

Let us talk about the soil protection and erosion control. The gabions and retaining wall, the natural fibre reinforced composite can also be used in the construction of gabions and retaining wall and the composite can provide the high strength and durability while still allowing the water and air flow through the structure. So, this is very important to prevent the deformation of the roads during the

rainy season or some some sort of during the temperature variation. So that is why this particular these natural fibres composite they are very important in this particular aspect. Now while we have discussed about the natural fibre reinforced composite in construction, the various natural fibres they are being used in reinforcement in construction industries.

Generally, the natural fibre composites which are used in building construction these can be categorized into four major divisions. One is that particle or short fibre reinforced, long natural fibre reinforced, nano-cellular composites and consolidated composites. So, the natural fibre used for manufacturing of long natural fibre composites they are flax, hemp, sea-cell, jute fibre and many fabrication techniques are used to manufacture these composites like compression, vacuum bagging, injection, filament winding and pultrusion all these things can be used. Long natural fibre composites sometimes referred as NFCs they have a good mechanical property like tensile or flexural properties which are very much important and apart from this keeping in view of present-day scenario they offer a very good biodegradability aspect. Now in roofing structure of the building different kind of natural fiber composites are used like Izoites as a roof beam, LVL that is a laminated veneer lumber and wood-based composite as blocks.

The Izoites are used for insulation and venting purposes, stressed screen panels are manufactured by wood-based polymer composites. They have been used for the offsite manufacturing of roofing parts which improves the efficiency of the building with respect to the construction. Now there are various applications of natural fibre composites in building application or building construction. One is the applications in wall building; these natural fibre composites are used in wall construction. A combination of natural fibre-reinforced composite and a wood composite is used in the development of wall systems in building construction.

Then floor board and a ceiling system, the composites used in flooring and a ceiling system application are divided into two types. One is the load bearing like joist and second one is the semi structural composites for floor and ceiling coating. The Izoites they are utilized to avoid bending and deflection because I shape is effective in bending strength and deflection control. Then composites beam and pillars, the natural fibre composites are commonly utilized for building beams and pillars continually substituting steel. Natural fibres and composites this should be located parallel to the principal stress direction to raise the strength of composites.

Now different kind of natural fibre they are used in construction application. Some of them like flex fibres, flex fibre polymer composites are mainly used for structural applications, automotive applications and customer applications or customized application also. There are many advantages of using flex fibre composites like they are very much durable, they can be further improvised to enhance the mechanical properties and they offer good water resistance. Jute fibre, this is one of the cheapest fiber among all-natural fibre. Now this jute fibre is biodegradable and they possess the high tensile strength.

Application of NFRCs in construction

Jute fibers:

Jute fiber is the cheapest fiber among all natural fibers. The jute fiber is biodegradable and having high tensile strength. The jute fiber is of a very adaptive nature that has been utilized in raw materials for the construction and agricultural sectors.

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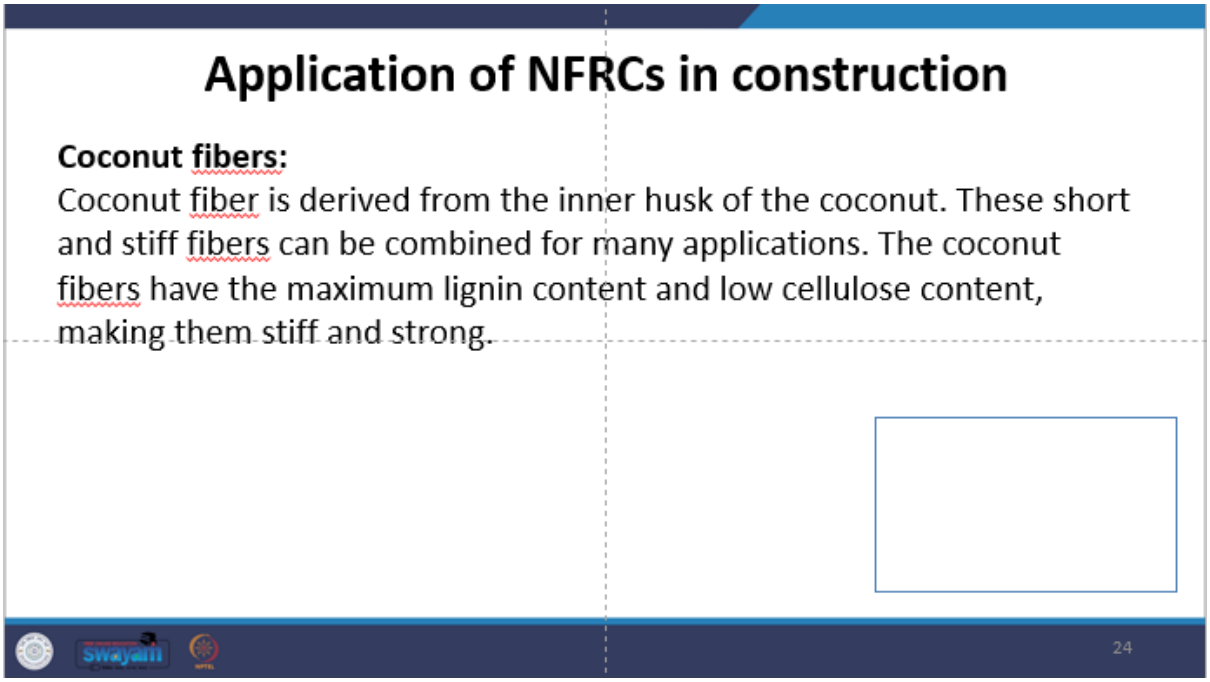
Application of NFRCs in construction

Sisal fibers:

The industry mainly uses sisal fiber in three different categories. The lower grade sisal fiber has a high cellulose and hemicellulose content, used primarily by the paper industries. The medium-grade sisal fibers are extensively used by naval and agricultural sectors. The higher-grade sisal fiber is mainly used by the carpet industry.

Sisal fiber, the industry usually uses the sea cell fibre in three different categories. The lower grade sea cell fibre has a high cellulosic and hemicellulosic content and they use primarily by the paper industries. The medium grade sea cell fibre is extensively used by naval and agricultural sector. The superior grade sea cell fibre is used by the carpet industries.



Coconut fibre, very common in all the coastal area, it is easily available in all coastal area. The coconut fibre is derived from the inner husk of coconut and these short and stiff fibres they can be combined for many applications. The coconut fibre has the maximum lignin content and a low cellulose content. This offers stiffness and strongness in their fibre properties and that is why they are being very much popular in among all the applications of natural fibre reinforced composites. Here you can see the different type of natural fibre composites used in building construction like they can be used in blocks, cladding, straws, flags, hemp, trees, columns, beams, wood based and textural components.

So, this makes them the natural house. Apart from this, these natural fibre reinforced composites offer other uses. One is the electrical and electronics enclosure. The natural fibre composites, they find application in electrical and electronic enclosures like housing for electronic devices, control panels, circuit board casing and they provide the good insulation properties, electrical shielding and protection against electromagnetic interference like EMI. These natural fibre composites can also offer improved thermal management, reducing the risk of overheating in electronic components.

NFRCs: Other Uses

- **Consumer Electronics:** Natural fiber composites are used in the manufacturing of consumer electronic products like laptops, tablets, smartphones, and audio devices. They can be utilized for casings, bezels, and structural components, providing lightweight and eco-friendly alternatives to traditional plastic materials.

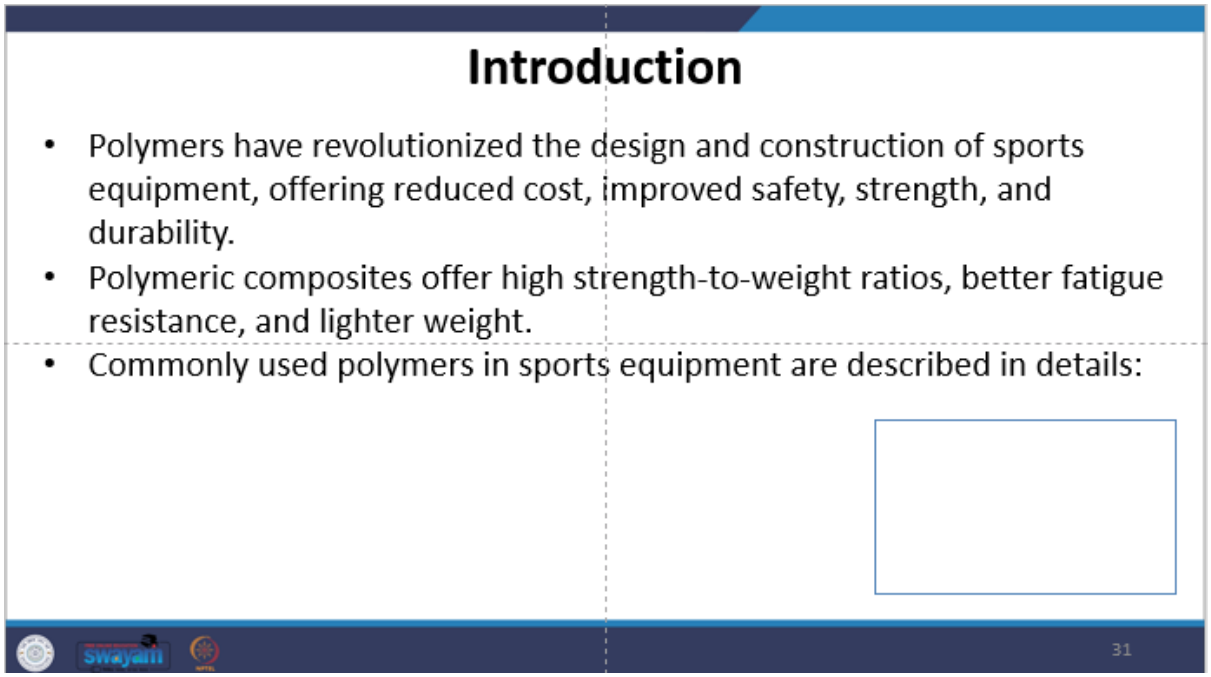
Consumer electric, they are also using these natural fibre reinforced composites. They are using the manufacture of consumer electronic products like laptop, tablets, smartphones, the audio devices and they can also be used in the casing, basils and structural components providing the lightweight and eco-friendly alternatives to the traditional plastic materials. Home appliances, these natural fibre composites are employed in production of home appliances including refrigerators, washing machines, ovens. They can also be used in for the interior component panels, housings, they offer the durability, thermal insulations and improved environmental performance. Now usually when we talk about the materials used in the sports equipment, they have the different properties like mechanical, structural, thermal, chemical.

Introduction

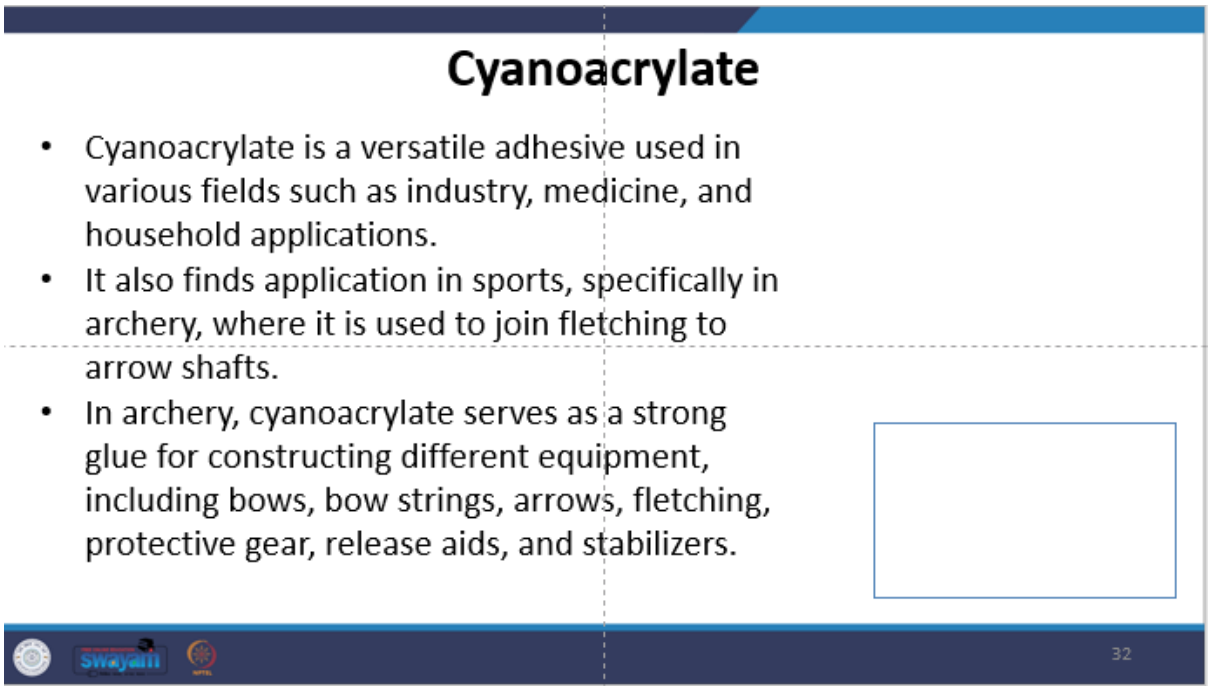
- Materials used in sports equipment have different properties: mechanical, structural, thermal, and chemical.
- Designing sports equipment involves considering properties like mechanical strength, ductility, fatigue resistance, density, hardness, damping modulus, and cost.
- Improved quality and safety features in sports equipment have led to the popularity of various sports.
- Winter sports have gained popularity due to factors like increased leisure, cheaper flights, and improved safety gear.

So, when we talk about the designing of sports equipment, this involves the considering properties like mechanical strength, ductility, fatigue resistance, density hardness, damping, modulus and cost.

So, improved quality and safety features in the sports equipment, they have led to the popularity of the various sports. Winter sports, they have gained the popularity due to the factor like increased laser, cheaper flights, improved safety gears and there are growing demand of winter sports equipment leading to the research and development in this field. The polymers are preferred choice for making sports equipment due to their inherent properties. Now plastic including polymers reinforced with glass, foam, carbon fibre and aramid fibre, they are used in manufacturing of winter sports goods.

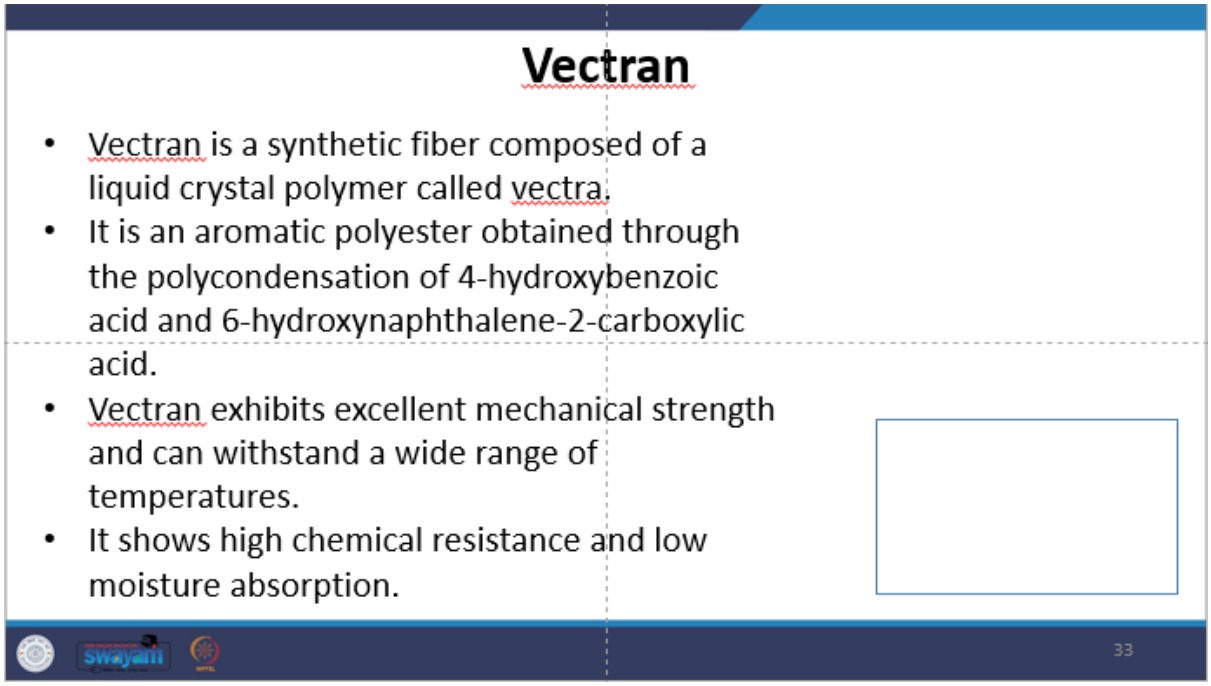


Now polymers, they have a very you can say revolutionized the design and construction of sports equipment by offering the reduced cost, improved safety, strength, durability, all these things and the polymer composite, they offer high strength to weight ratios, better fatigue resistance and lighter weight.



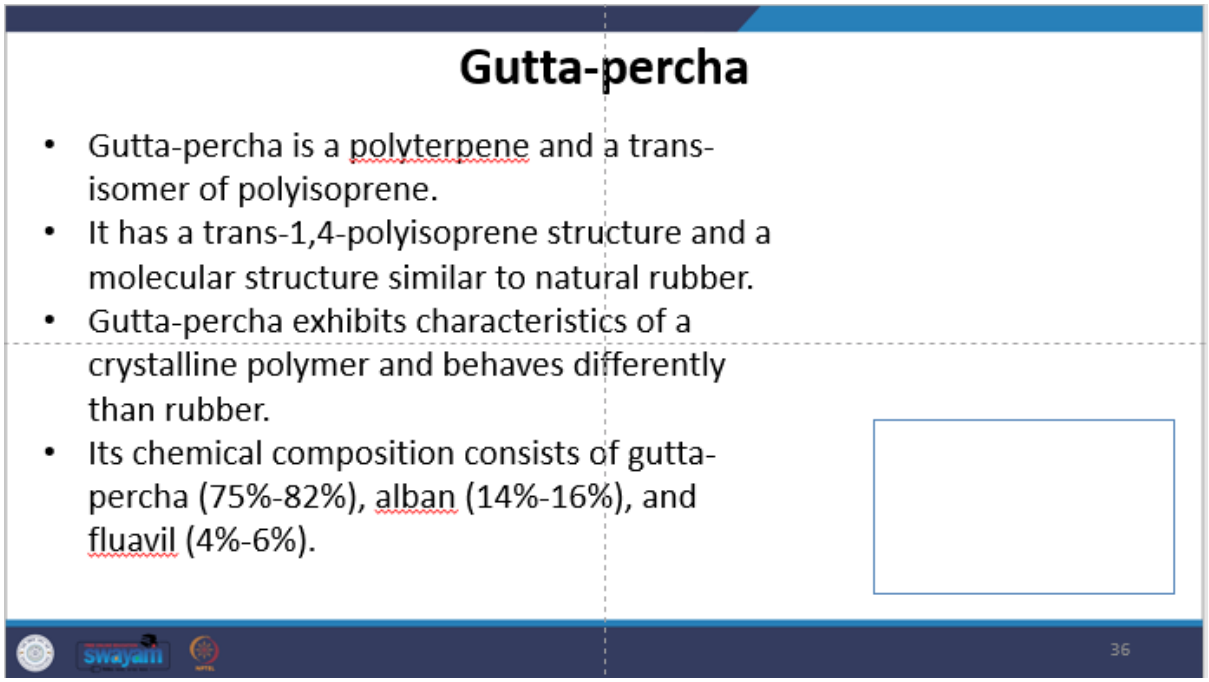
Commonly used polymers in sports equipment like Cyanoacrylate in the versatile adhesives, they used again. So commonly used polymer in sports equipment, we are going to discuss in detail in the subsequent slides like Cyanoacrylate. The Cyanoacrylate, they are a versatile adhesive, they are used in the various field such as industry, medicine and household application. It also finds application in sports especially in archery where it is used to join the fletching to the arrow shaft.

In archery, the Cyanoacrylate serves as a strong glue for constructing different equipments including bows, bow string, arrows, fletching protective gears, releasers and stabilizers.

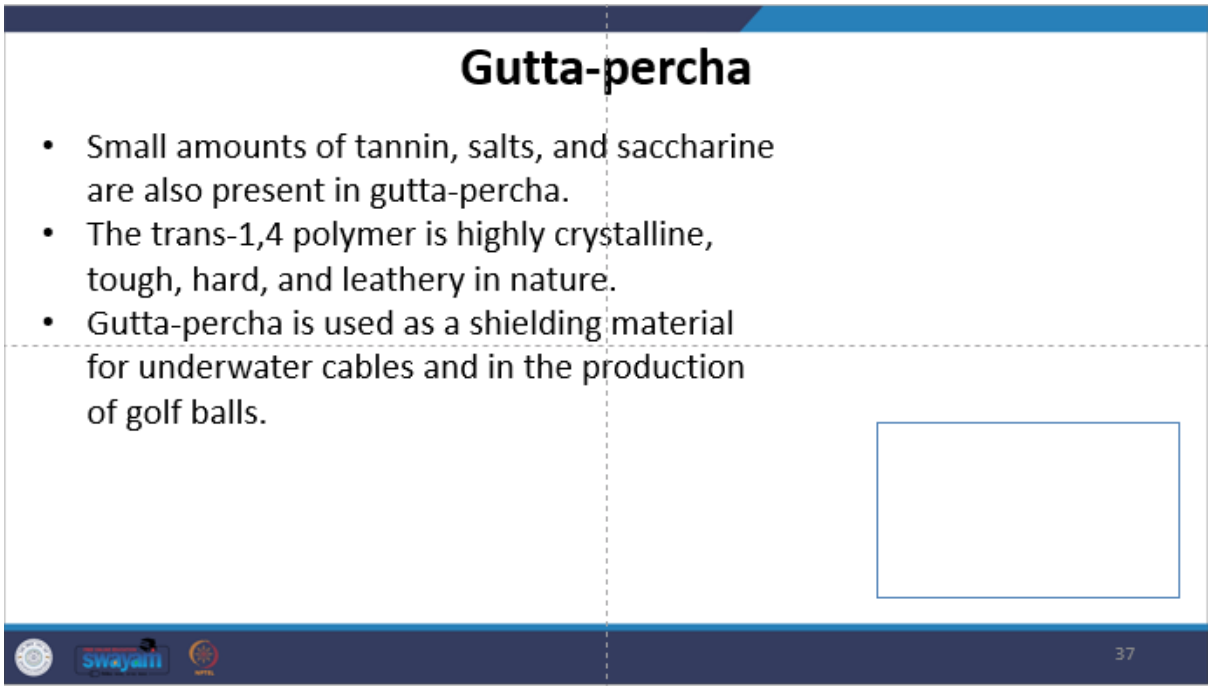


Vectran now, Vectron is a synthetic fibre composed of a liquid crystal polymer, they are called the Vectra. Now, it is an aromatic polyester obtained through the polycondensation of 4-hydroxybenzoic acid and 6-hydroxynaphthalene 2-carboxylic acid. The Vectron exhibits excellent mechanical strength and can withstand a wide range of temperature. It also shows the high chemical resistance and low moisture absorption.

The fibre has high abrasion resistance and negligible creep even under heavy loads, up to the 50 percent of the breaking load. Vectron is a polyester with aromatic ring on both monomer constituents and has a relatively high melting point that is from 276 to 330 degree Celsius. It was initially used in a sporting equipment as a synthetic string for badminton racquets. The use of Vectron in racquets resulted in improved impact resistance, high tensile strength and lighter weight. The racquets had strong head enabling players to deliver more powerful shots.

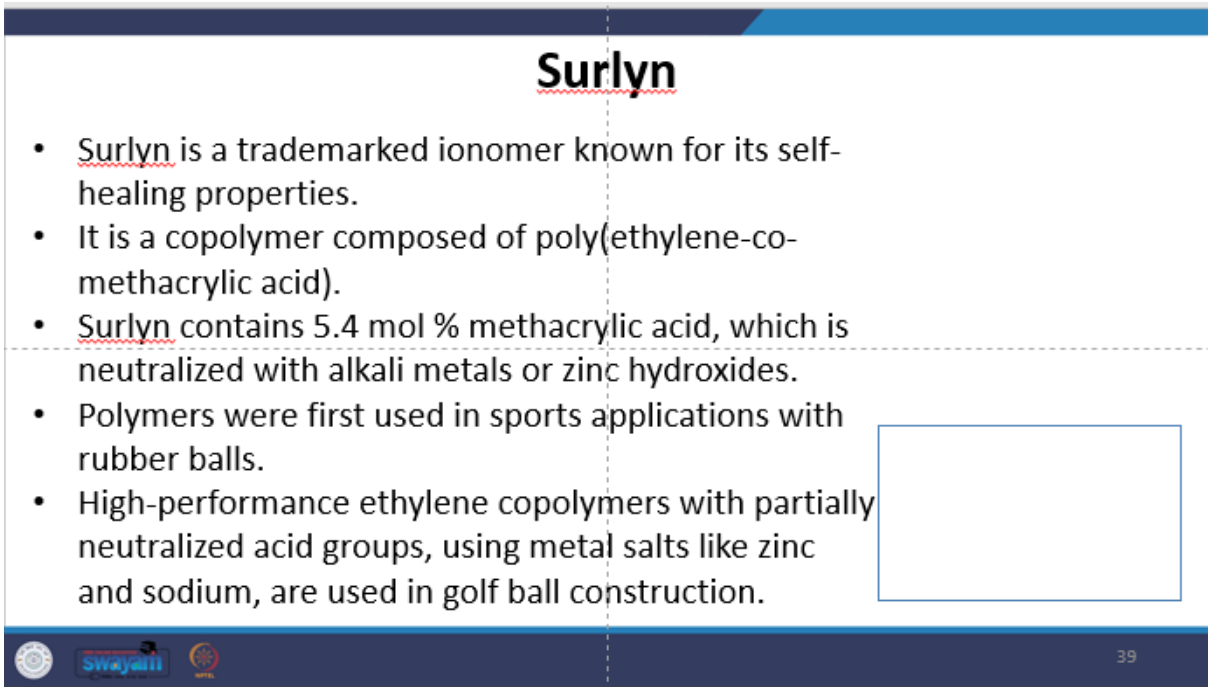


Gutta-percha is a polyterpene and a trans isomer of polyisoprene. It has a trans 1, 4 polyisoprene structure and a molecular structure similar to the natural rubber. Gutta-percha exhibits characteristics of a crystalline polymer and behaves differently than rubber. Its chemical composition consists of Gutta-percha like 75 to 82 percent, then albumin 14 to 16 percent and fluvial 4 to 6 percent. Small amount of tannins, small amount of tannin salts and sacrinol also present in the Gutta-percha.

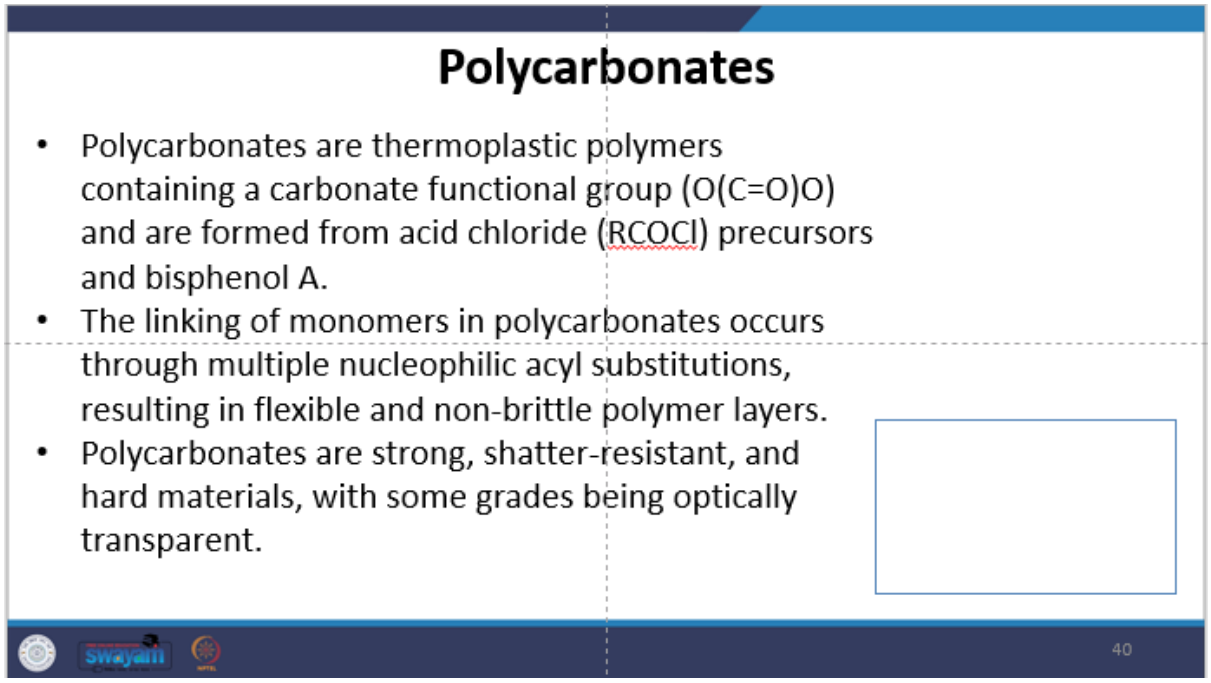


The trans 1, 4 polymers are highly crystalline, tough, hard and leatherly in nature. The Gutta-percha is used as a shielding material for underwater cables and in protection of golf balls. Trans 1, 4 polyisoprene, trans 1, 4 polyisoprenes is used in various sports equipment. It is employed in the production of golf balls. It is also used as an adhesive in the manufacturing of other sports courts.

Serlin, serlin is the trademark monomer known as a self-healing property. It is a copolymer composed of polyethylene, co-methacrylic acid. Serlin contains 5.4 mole percent of methacrylic acid which is neutralized with alkali metal or zinc hydroxides. Polymers were first used in sports application with rubber balls.

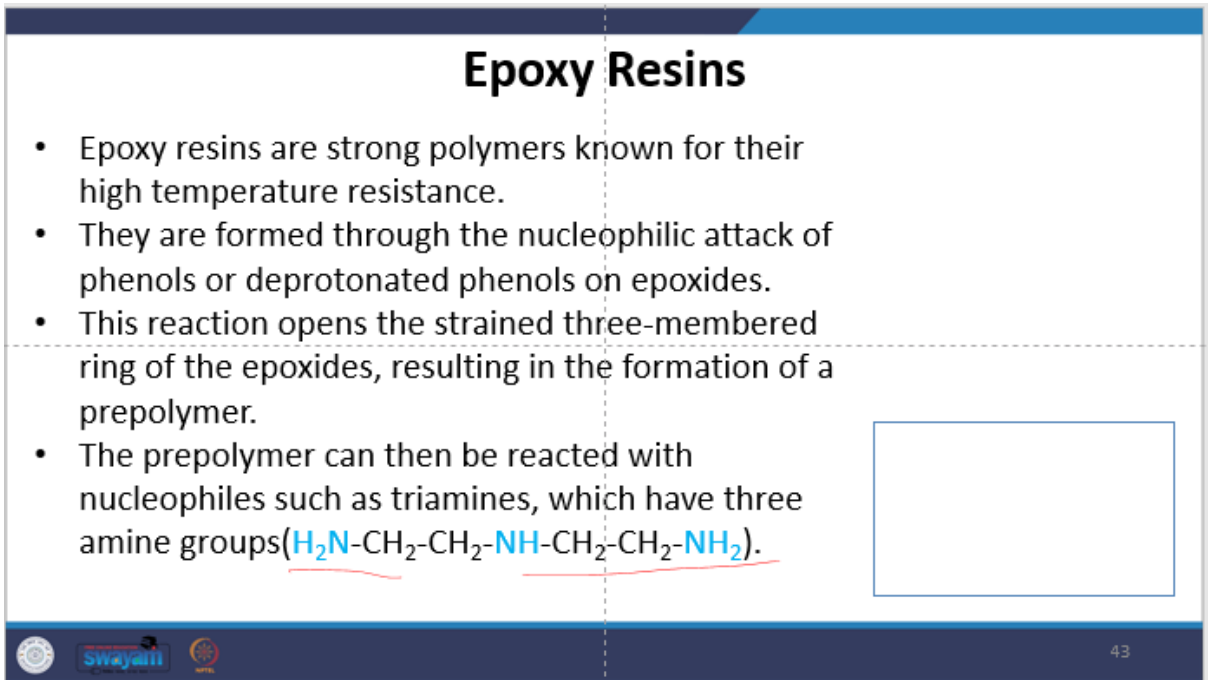


The high-performance ethylene copolymer with partially neutralized acid group using metal salt like zinc, sodium, they are used in golf ball construction. Polycarbonates, they are the thermoplastic polymers contain the carbonate functional group COO and they are formed from the acid chloride RCUCL, precursors and bisphenol A. Linking of monomer in polycarbonate occurs through a multiple nucleophilic acyacyl substitutes resulting the flexible in non-brittle polymer layers.



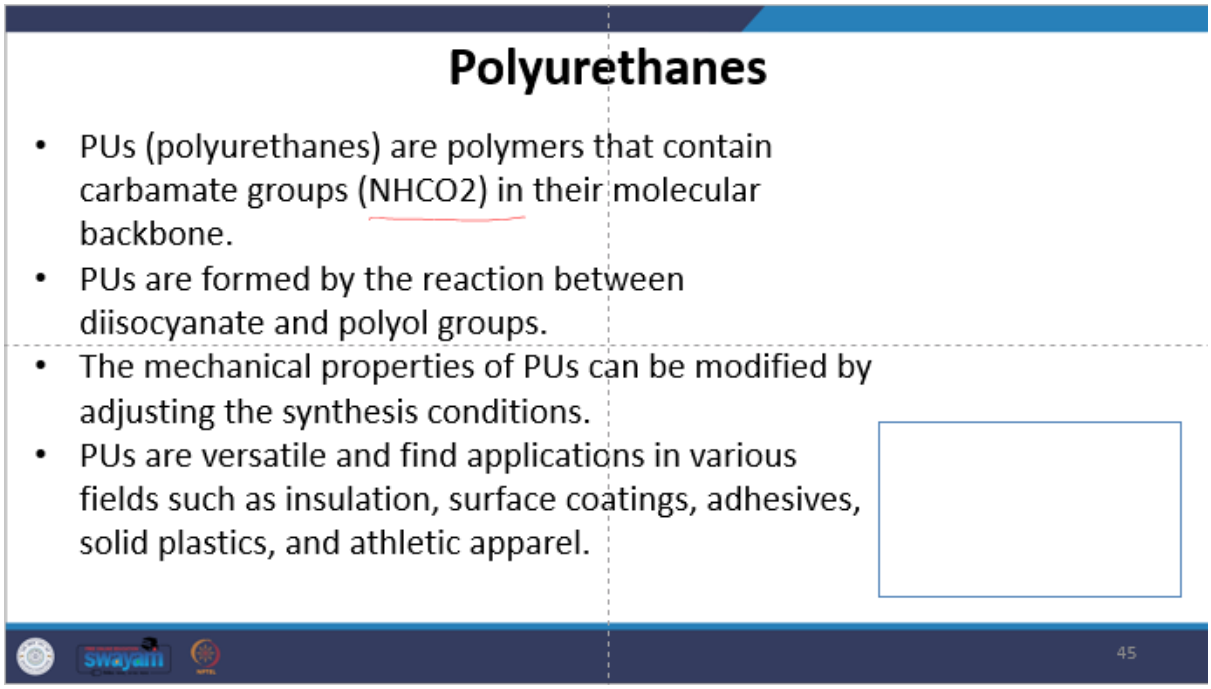
Now polycarbonates, they are a strong shatter resistant and hard material with some grades being optically transparent. They are used in making protective sports equipments like helmets for bikers, riders, cyclists.

It is also used in making sunglasses, protective visors and goggles for clear visibility and shatter resistance. The polycarbonate lenses consist usually consist of two layers with outer layer protecting the base layer from cracking under the environment stress or stress concentration and thus that particular property makes them useful for the polycarbonate lenses. In safety equipments like crash helmet, the slightly malleable polycarbonate shell absorbs impact energy and reduces the impact of collision working in conjunction with foam interior. The polycarbonates find application in various sports equipments due to their properties and ability to absorb impact.



Let us talk about the epoxy resins. Epoxy resins, they are strong polymers known for their high temperature resistance. They are formed through a nucleophilic attack of phenols and deprotonated phenols and epoxides and this reaction opens the strain three membered ring of the epoxides and resulting in the formation of a pre-polymer. The pre-polymer this can be reacted with the nucleophile such as triamines which have three amine groups like H2NCH, CH2NH, CH2CH2NH2. Each amine group can react with an epoxide on the pre-polymer leading to densely cross-linked structure. The cross-linked structure contributes to the epoxy resin exceptional strength.

Now mixing carbon fiber with epoxy resin further enhances its strength, and the combination of carbon fiber and epoxy resin creates composite material with enhanced mechanical properties. Let us talk about the polyurethane. They are very common in household applications to the various high-core industrial applications.



Polyurethanes are polymers that contain the carbamate group NHCO2 in their molecular backbone. The reaction between diisocyanate and polyol groups forms these polyurethanes.

The mechanical properties of polyurethane can be modified by adjusting the synthesis condition and these polyurethanes are versatile and find application in various fields such as insulation, surface coating, adhesives, solid plastics and athletic apparel. In sports, these polyurethanes are commonly used in running shoes and other athletic foot wear due to their flexibility. Polyurethane are also used in production of sports equipment like soccer balls, judo mats, binders on running tracks. Sports flooring and the power in place track surfaces are often made using polyurethane materials including shock pads for maintaining flat surfaces and dimensional stability. The polymers including polyurethanes have greatly improved skiing equipments offering enhanced comfort, safety and reduced cost.

Other common Polymers

Polymer	Chemical Formula	Properties	Applications
ABS	$(C_8H_8)_x(C_4H_6)_y(C_3H_3N)_z$	Thermoplastic, glass transition temp: 105°C	Sports equipment, aircraft, marine fabric
PVC	Polymerization of vinyl chloride	Excellent properties, low cost	Pipes, cable insulation, packaging, medical products
PEVA	Copolymer of ethylene and vinyl acetate	Low permeability, chlorine-free	Sports protection equipment, shoe soles

Polyurethane foams, honeycomb cores or advanced composite material, they are used in the construction of skies. Polyurethane is a preferred material for making skies boot due to the strength, hardness and ability to maintain properties at low temperature. Surf boats, they are made of the polyurethane foam core and polyester layer reinforced with glass providing durability and shape flexibility. Polymers including polyurethanes have greatly improved skiing equipment, they offer the enhanced comfort, safety and reduced cost. Now, there are some other common polymers like ABS, they are having the chemical formula and they are being used for the thermoplastic glass transition, having the glass transition temperature 105 degree Celsius and this can be utilized for the various sports activities as a sports equipment, aircraft, marine fabric.

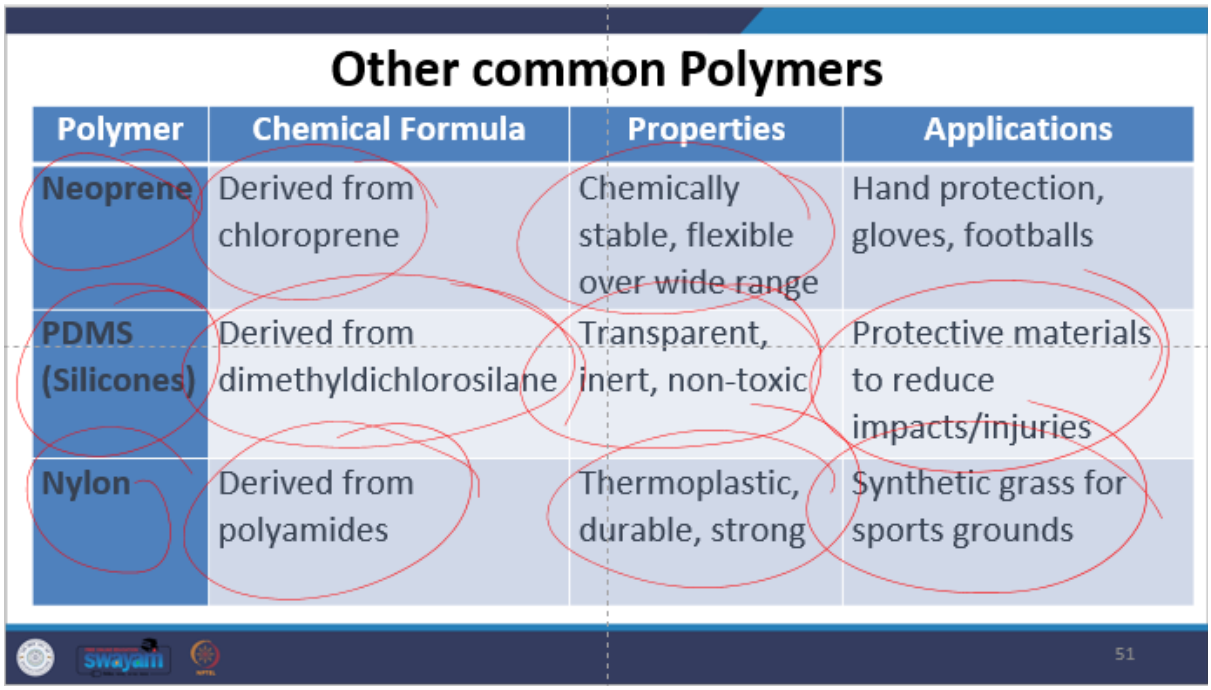
Other common Polymers

Polymer	Chemical Formula	Properties	Applications
CFRP	Main polymer: Poly(acrylonitrile)	Highly resistant, optimal for canoeing	Canoe paddles, oars
PE	(C_2H_4)	Chemically stable, flexible, low toxicity	Packaging, sports equipment (shoulder pads)
Polymeric foams	Various compositions	Impact absorption, resilience, stiffness	Mats for high jump, martial arts, pole vault

Then PVC, they are formed by the polymerization of vinyl chloride, they possess a very excellent properties and a low cost and they find their uses in the pipe, cable, insulation, packaging materials,

medical products, all this. Then BEVA, this the polyethylene vinyl acetate, these are the copolymer of ethylene and vinyl acetate. They possess the low permeability and they are offering the good option of chlorine free component. They are used as a sports protection equipment and shoe soles. CFRP usually prepared from the poly acrylonitrile and they are having a highly resistance and optimal for canoeing and they can be used as a canoeing pedals and ores.

Polyethylene, they are having the chemical formula of C2H4 and they are chemically stable, flexible and they possess the low toxicity. They can be used in the packaging, sports equipment, the shoulder pads. Then polymeric foams, they usually prepared with the help of various components and they possess the impact absorption ability, resilience and they are very much stiff in nature and their application mats for high jump, martial arts, pole vaults, all these things. Neoprene, this is derived from the chloroprene and they are chemically stable and they are very much flexible in natures. So, they are being used as the hand protection gloves, football and artificial glass.



The PDMS, silicones, they are derived from the dimethyl dichlorosilane. They are transparent in nature, they are inert and they are non-toxic and the protective, they can be used as a protective material to reduce the impacts and injuries. Nylon, they are derived from the polyamides and they are thermoplastic in nature, very much durable and very much strong and they can be used as a synthetic glass for various sports grounds.

Other common Polymers

Polymer	Chemical Formula	Properties	Applications
Polyamides	Repeating units linked by amide bonds	Natural and artificial polyamides	Textiles, automobiles, sportswear
Polyolefins	Polymerization of olefin monomer units	PP and PE for stadium turfs	Sports hall floors, foam pads, carpets

Then polyimides, they are the repeating units linked by the amide bonds and the properties, they are natural and artificial polyimides can be used in textile, automobile, sportswear. Then polyolefins, these can be prepared through the polymerization of olefinic monomers and they are having the properties of polypropylene, polyethylenes and this can be used in the sports hall floors, foam pads, carpets, etc.

So, dear friends, in this particular segment, we discussed various application of the natural fibre reinforced composites.

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Apart from this, we discussed their application in the sports activities and different aspects of the uses and for your convenience, we have enlisted various references which you can utilize. Thank you very much.