Science and Technology of Polymers
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Lecture - 2
Basic Concepts on Polymers (Contd.)

Our lecture on basic concept on polymers, today we are going to start with polymer classification.

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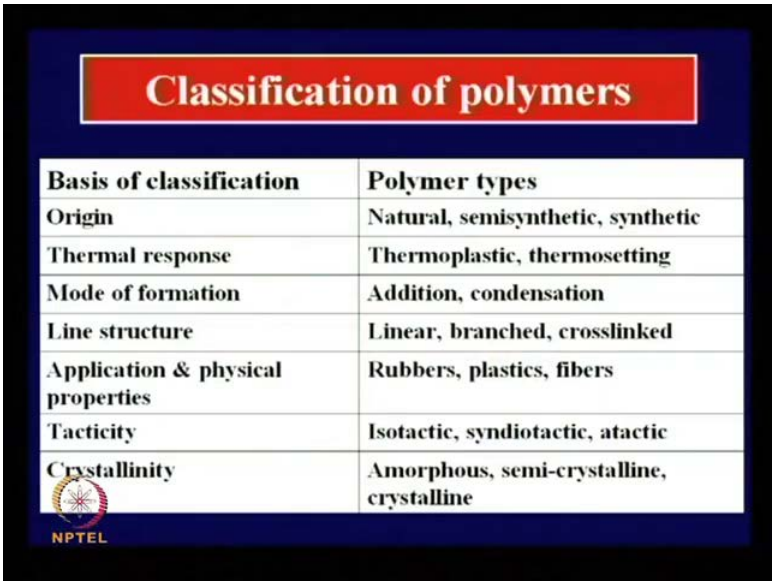

You are accounted with some names of polymers in different ways; sometimes plastics, sometimes fibers, sometimes rubbers, sometimes thermoplastic polymers, sometimes thermoset polymers, sometimes natural polymers, sometimes synthetic polymers like that. So, let us see the classification scheme of polymers, how the polymers are classified from various angles? So, there are basis of classification accordingly, and we find different polymers, polymer types are known to us. Say, if we classify the polymers on the basis of origin, that may the source genesis of the polymer. We will find there are three categories of polymers; natural polymers, semi synthetic polymers and synthetic polymers.

What are natural polymers? We will see later, let us see, what are the different classes of polymers here; On the basis origin it is natural, semi synthetic and synthetic polymers,

from thermal behavior of polymers. We find there are two categories thermoplastic polymers and thermoset polymers. On the basis of mode of formation, means how these polymers are synthesized the basis of principles of polymers synthesis. We find there are two categories of polymers; addition chain polymers and condensation chain polymers or condensation polymers.

On the basis of line structure, we find there are linear polymers, there are branched polymers and there are cross linked polymers. And on the basis of application and physical properties, we find rubbers, plastics and fibers of course, there are differences in these different names in each category, we will explain later. Then on the basis of tacticity, tacticity means if you think of a polymer molecule there may be side groups, that means the disposition of side groups that gives a geometric safe to the molecule confi-geometric configuration to the molecule and we get three different types of polymers isotactic polymers, syndiotactic polymers and atactic polymers.

Then crystallinity, on the basis of crystalline structure, on the basis of morphology, we can say we can have amorphous polymers, semi crystalline polymers and crystalline polymers. Polymers can also we classified in other ways too I am not shown here, but you can note down, say polymers can be homo polymers and co polymers. And co polymers can be again; alternating co polymers, random co polymers, block co polymers, graft co polymers, so various homo polymers and co polymers are existing.

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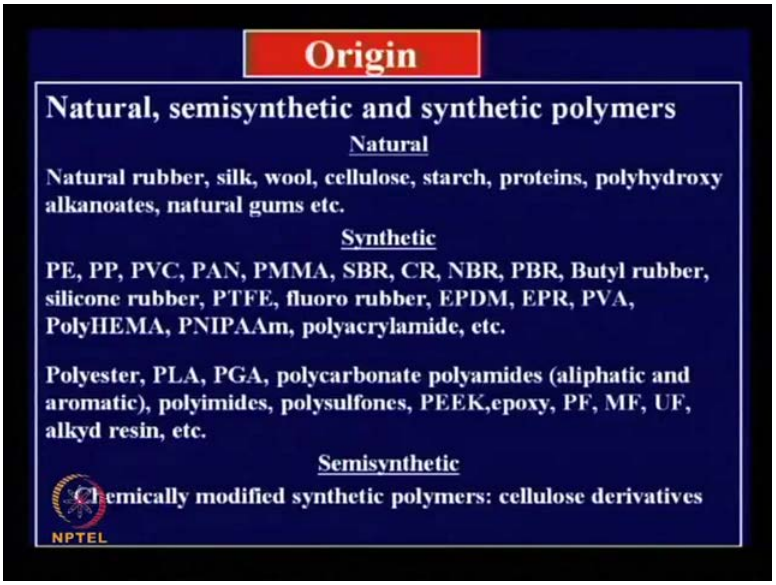

Now, let us come to little little of these classifications, on the basis of origin I told you there are natural polymers, semisynthetic polymers and synthetic polymers. In the natural category you know, there are many polymers naturally occurring, that pins synthesized a prepared by various agencies of nature. What are the agencies plants and animals; plants synthesize some polymers. So, likes a natural gum is a polymer, you see there are various plants available, if you make a incision on the bark you will find some exudation is there, some fluid is come out now, that fluid contents certain polymers.

You are accounted with a fluid coming out from jackfruit tree, if you make an incision on the jackfruit on the bark of the jackfruit tree, you find a milky fluid is coming out and that also contains a polymer. And there is another plant known as moringa oleifera, say we get a vegetable from that drumstick drumstick vegetable. If you again their make a incision on the bark you will find that some gum is coming out, that is also that also contents some polymers. Apart from all those things if we look into the plant kingdom other way, say wood wood contents spolymer cellulose. Wood is a composite of cellulose and lignin, where cellulose is the fiber this first in a continuous matrix of lignin.

Lignin is the binder and cellulose fiber is the reinforcement, reinforcing member with their. So, we will find there are cellulose starch also is a polymer and in animal origin we find proteins different types of proteins they are also polymer. That day somebody was asking me sir, how can we define this as a polymer that can be a random copolymer type, because different amino acids are linked in one molecule in different sequences. So, that is also a polymer we can consider that is a co polymer, but that is a polymer having peptide linkages. So, we call that a polypeptide.

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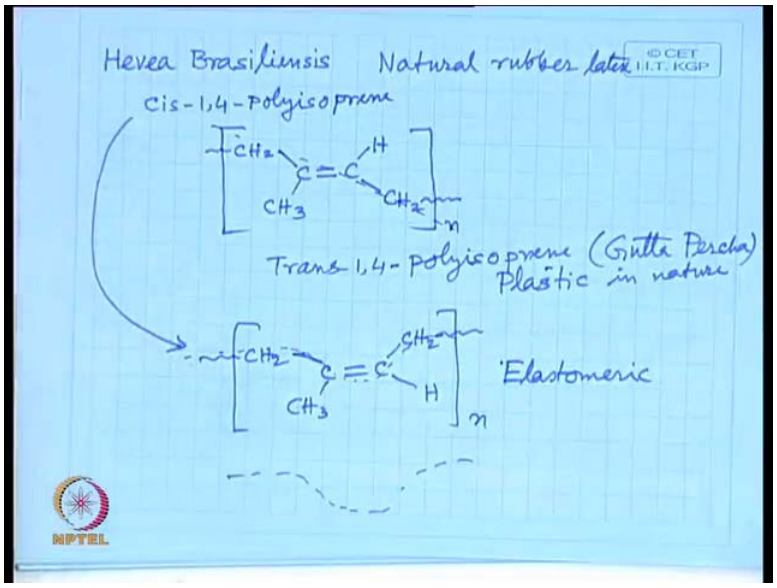

Silk wool these are from animal origin silk wool and natural rubber, natural rubber is made from, is obtain from a tree known a Heve tree, Hevea Brasiliensis this is a tree big tree, if you make an make an incision on the bark, it whose out exuded it out a liquid known as a latex, where the polymer constituent of this latex is cis 1, 4 polyisoprene. This excellent polymer is a unique gift of nature the molecularate of this polymer present in this natural rubber latex, is very high may be 10 lakhs, 15 lakhs like that. And it is chemical formula is, this is the one unit of cis 1, 4 isoprene unit repeated in sequences, that is why it is called cis 1, 4 polyisoprened, this is trans, this is trans.

Trans 1, 4 polyisoprene and cis form is, this transform is known as gutta percha, it is plastic in nature and this is this is form is elastomeric, that is because of this cis trans configuration. How, you see this is cis configuration show if you look into this molecule will find it looks like this, that means this segment or this unit gives a bent configuration. Whereas, in case of this trans wan you see there is a linear configuration, show it leads to higher molecular packing. So, it gives a plastic type of molecules material whereas, this is elastomeric. Now, you will understand the details of this thing later, it is little difficult to understand this, from the molecular configuration. Why we are calling this as elastomeric this is a plastic, but just I have mentioned this thing.

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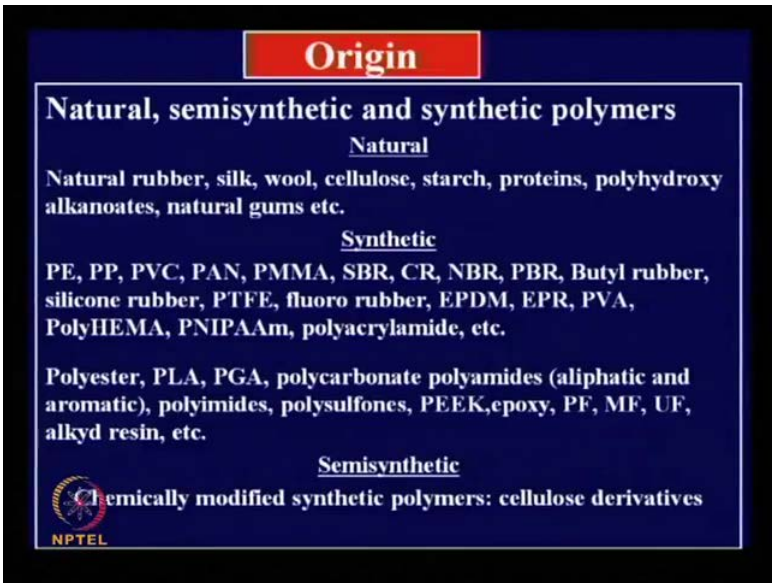

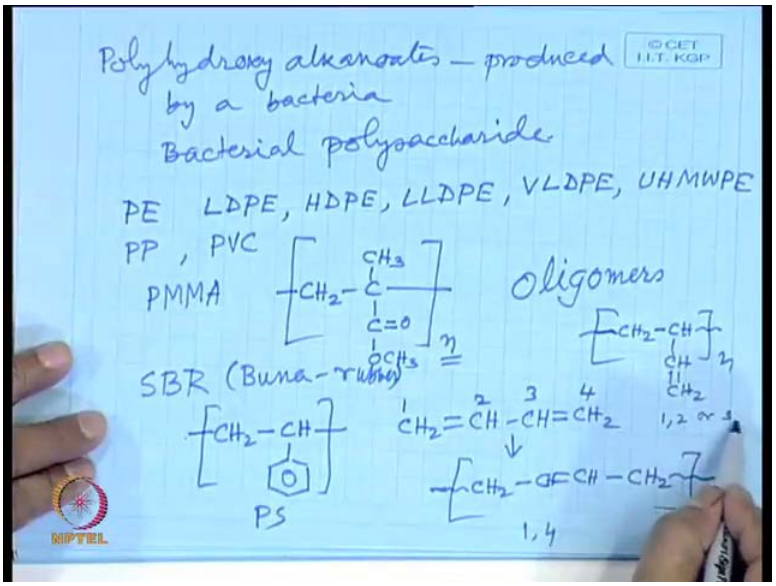

Polyhydroxy alkanoates, water polyhydroxy alkanoates these are bacterial polysaccharides, known as bacterial polysaccharide, this is a natural occurring polymer. These polymer finds extensive use today in bio medical engineering field, this is bio degradable, bacterial polysaccharide, so on and so forth. So, we will find plenty of examples of naturally occurring polymers which are friendly to nature, degradable by natural organisms by organism's bacteria fungi insects that means these this can this can be as a food for those micro organisms, so they are degradable.

Next category a synthetic polymers, when the demand for polymers could not be supported by the natural occurring naturally occurring polymers, natural polymers in natural laver and other gums extra was you not sufficient enough. Then people thought off preparing in a by an artificial route different types of polymers and for which they found some petroleum's products, petroleum bes. If time is permitted then I shall discuss something about petro chemicals; what are petrochemicals? How these polymeric raw materials or monomers are obtained from petrochemicals? I will discuss some of you might be read have might have read in your previous course.

So, synthetic polymers since, these are prepared by synthetic route artificial means in the laboratory in the industry, in chemical reactors in polymerization reactors with all them synthetic polymers. Plenty of examples can be sighted, say polyethylene with the first example polyethylene PE, there are various grades of polyethylene; low density polyethylene, high density polyethylene, linear low density polyethylene, very low density polyethylene and ultra high molecular weight polyethylene. You see large number of grades are possible from polyethylene.

Next comes polypropylene, you know the formula of polyethylene, you know the formula of polypropylene. How they are synthesized, they are synthesized from ethylene for polyethylene and propylene for polypropylene, by applying sufficient polymerization conditions in presence of catalyst and temperature. There are various grades of polypropylene again, you will see in next classification atactic polypropylene, isotactic propylene and syndiotactic polypropylene polypropylene, through this way you can get various grades of polypropylene; PVC polyvinyl critic, synthetic polymer maid from vinyl cord monomer.

PAN polyacrylonitrile, PAN you have to be accounted with these abbreviations of this polymers, PAN polyacrylonitrile, PMMA polymethylmethacrylate. How to write this structure of PMMA, formula of PMMA repeating in it formula of PMMA, CH 2 C substitute 1 hydrogen of this curve one by methyl group, substitute another carbon another hydrogen of this curve 1 by an ester n number of times. Where this n is the degree of polymerization, n is the degree of polymerization. Depending on the value of n we can have an idea of the monocular size, how big it is, very big high value high monocular weight, low value low monocular weight.

Low monocular at polymer is call oligomers, oligo means lower oligo means lower number, smaller number, oligomers. Say SBR, what is SBR? It is a buna rubber, it is a co polymer of styrene and butadiene. What is polystyrene? Again to write the formula of styrene polystyrene is very easy, you write this C H 2, CH finail this is polystyrene. What is polybutadiene, you know what is butadiene, it is an polymerize, again it can undergo cis trans configuration.

So, that can be linkage this one, two, three, four; one four linkage, this is one four cis polybutadiene, one four trans polybutadiene. You can have either one two linkage or there four linkage there you will have one two polybutadiene or three four polymer polybutadiene, that is called v line unit like this. This is also polybutadiene one two or three four, this is one four this is one four, this is one two or three four, any of same thing, same c matrix one two or three four both you can say polybutadiene.

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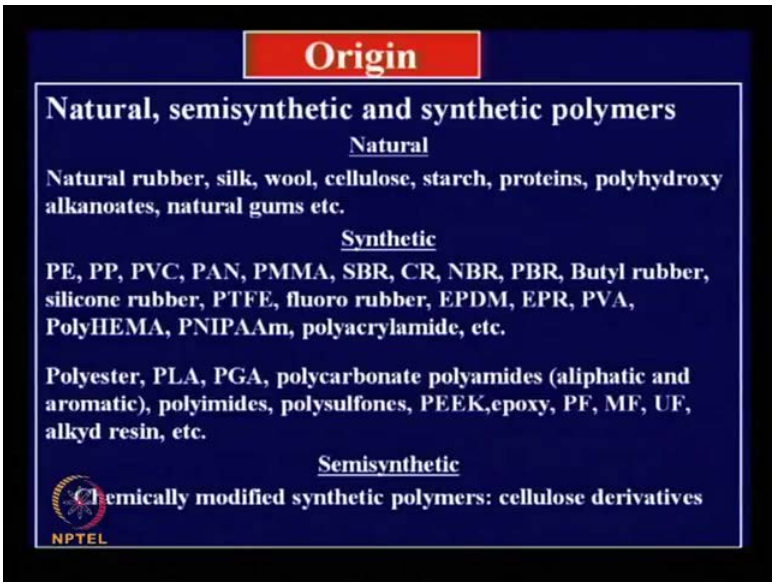

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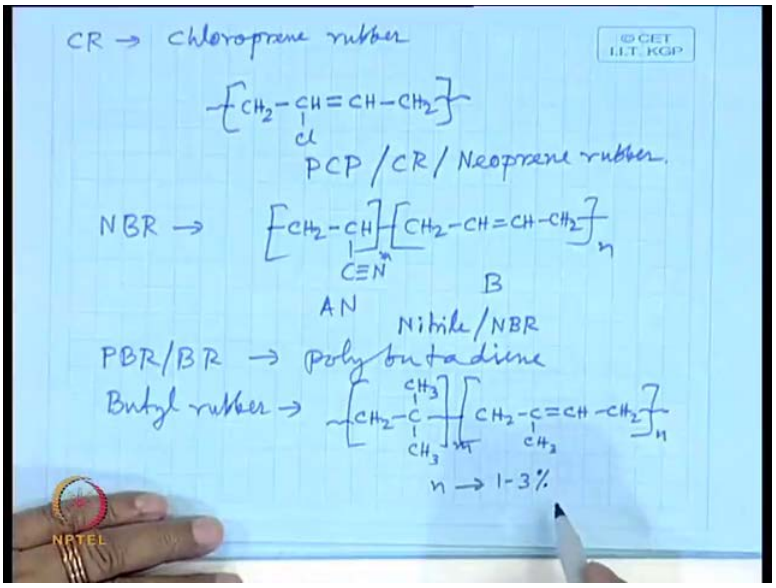

And CR this chloroprene rubber polychloroprene rubber, Polychloroprene rubber, you know what is the chloroprene, if you can remember formula isoprene, we can remember the formula of chloroprene. CH 2, this polychloroprene PCP or CR or neoprene, trade name is neoprene, neoprene rubber. NBR it is a co polymer of acrylonitrile, this acrylonitrile and co polymer of acrylonitrile and butadiene nitrile rubber, nitrile or NBR rubber NBR.

PBR polybutadiene, you have seen earlier polybutadiene PBR or BR, polybutadiene rubber, butyl rubber it is again a co polymer. Here the common over percentage is very small, butyl rubber it is a polymer of polyisobutylene. Here n is only 1 to 3 percent commoner percent, this is actually butail rubber.

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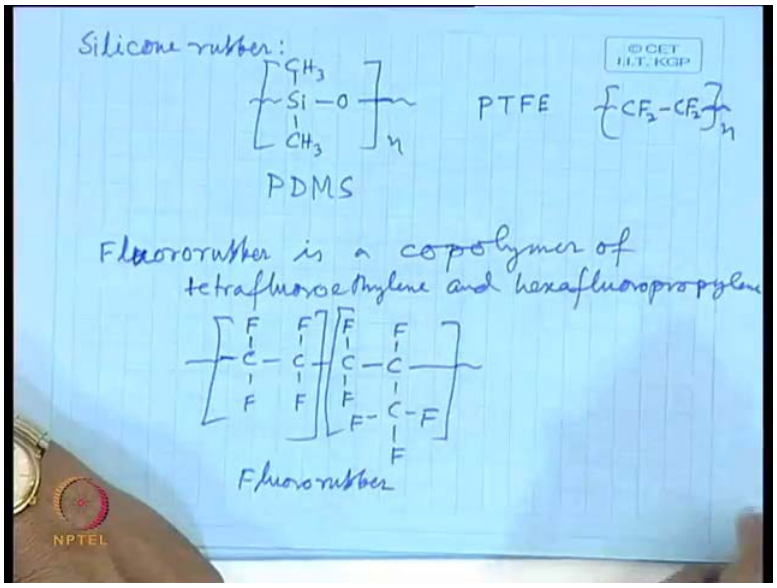

Silicon rubber; polydimethylsiloxane polydimethylsiloxane it is a hit rigesten polymer, hit rigesten rubber. Polytetrafluoroethylene, you know what is polytetrafluoroethylene. Fluoro rubber, say fluoro rubber is a co polymer of… say may be say x tetraflouoroethylene and hexafluoropropylene. There may be other types of fluoro rubber possible, again we can have fluoro silicon rubber. Just remove replace this hydrogen atoms by fluoroing you will have fluoro silicon rubber.

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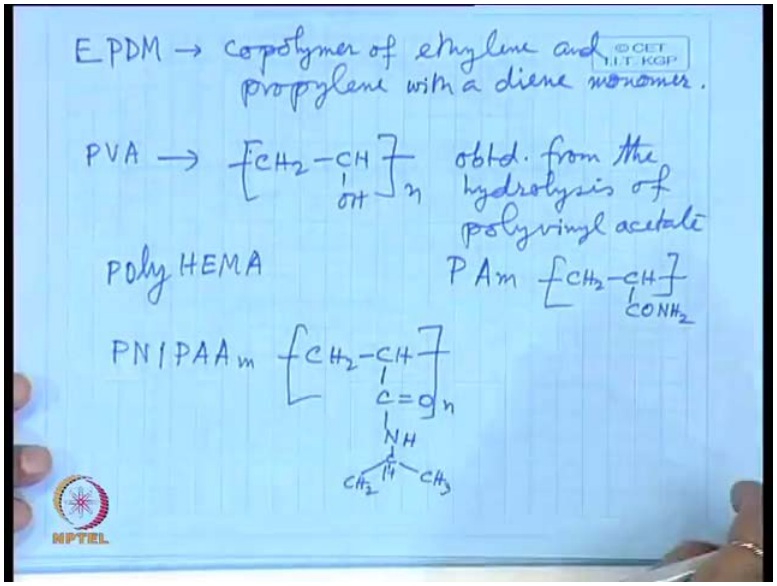

EPDM ethylene propylene rubber; EPDM is a co polymer of ethylene and propylene; ethylene leads to polyethylene, propylene leads to polypropylene both are plastic. But when these two monomers are polymerized together, they form a co polymer known as ethylene propylene co polymer and that is elastomeric in nature. It develops rubber properties there is in I will explain later. And there is another monomer present; that is actually a diene monomer, for the purpose of introduction introducing some cross linking sight a diene monomer introduced along with ethylene and propylene. So, that is known as EPDM rubber and EPR.

Polyvinyl alcohol polyvinyl alcohol, it is obtained from say 90 percent hydrolysis 8 to 10 percent acid group remains polyvinyl alcohol. Polyhema, if you you can remember the formula of polymethylmethacrylate polymethylmethacrylate, they are methyl acrylate. In place of methylacrylate, if you take hydroxymethyl acrylate you will get polyhema. You can write down the strcture in place of methyl acrylate, you have to write hydroxymethyl acrylate. Poly n isopropylacrylamide, this is a modern polymer, known as smart polymers, known as stimuli responsive polymer, known as thermo responsive polymer. Poly n isopropylacrylamide, you know that you see, what is acrylamide, polyacrylamide P Am acrylic acid CONH 2 polyacrylamide. So, here also, you write down this formula n isopropyl means, to this give one isopropyl group, 1 H remains.

So, this is actually poly n-isopropylacrylamide, is a thermoresponsive polymer, it undergo face transformation. From it can shrink or swell by change of one degree temperature. It is so thermoresponsive; and this polymer finds extensive use in bio medical engineering field drug delivery. Pulsatile drug delivery, targeted drug delivery, with the change in temperature, for making artificial pancreas out of this polymer; artificial pancakes or control drug delivery devices using this poly n-isopropylacrylamide. Then these are one category of polymers, in this synthetic class, there are other polymers too available possible to synthesize.

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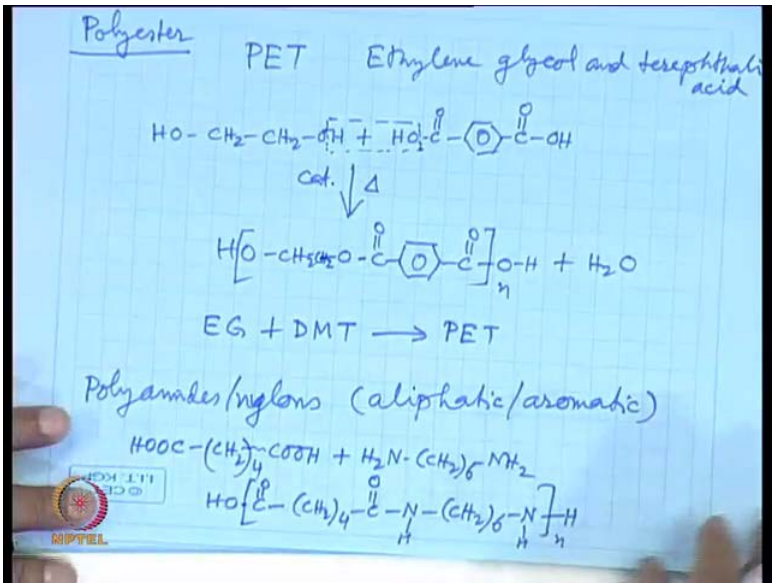

So polyester, your accounted with polyester because the government (( )) varying that is made of polyester fiber. Mineral water bottle, beverage bottles made of polyester, films made of polyester. You are accounted with a polymer PET, PET is a polymer used for making bottles, pens, say overhead transform sapience, their known as miler flame miler flame that is made of polyethylene terephthalate PET. What is polyethylene terephthalate, it is the reaction product of ethylene glycol and terephthalic acid terephthalic acid, what is ethylene glycol, this is ethylene glycol, what is terephthalic acid terephthalic acid.

So, these two this is an alcohol and acid you know, when an alcohol reacts with an acid the product is an ester with the elimination of a small molecule as bi product. Here also if you take a catalyst and apply heat you will get, this unit is repeated along the back bone chain, one more CH is to be there. This polymer can also made by, made from by the reaction of ethylene glycol and dimethyl eretil it by ester inter change reaction. We can take ethylene glycol EG and DMT, dimethyl eretil it will get same pet polymer, this a polyester.

You can have this is a saturated polyester you can have unsaturated polyester too. If you react maleic anhydride with glycerin glycol or another alcohol will find unsaturated polyester. Today unsaturated polyester finds a large consumption in laminating industries, in composite industries and then polylactic acid, polylactate, polylactides,

polyglycolic acids, co polymers of polylactic acid, polyglycolic acid, polylactide co glycolide, polycarbonates, polyamides, Polycarbonates.

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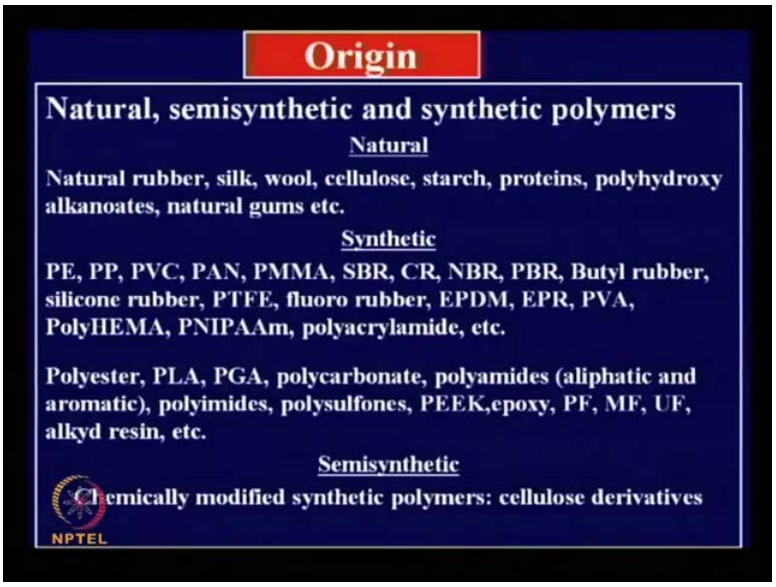

This polycarbonate is a polymer, it is a transparent polymer, color less transparent polymer or you can make it colored also. It is strong; it is rest into delivery temperature, so these are used for making baby feeding bottles, which can be sterilized, polyamides different types of nylons are possible. As you are seen here polyamides nylons or nylons can be both aliphatic and aromatic depending on what reactance you have selected.

You can have aliphatic nylons like nylon 6, nylon 6 6, nylon 6 1 0, nylon 1 1, nylon 1 2, say nylon 6 6 is made from hexamethylenediamine and adibig acid. So, that this is adiabatic adibig acid and hexamethylenediamine reacts. This is nylon 6 6, why nylon 6 6 from the acid side there are 6 carbon 4, 5, 6 from the diamine side, there are 6 methylene groups, so that is why it is called nylon 6 6.

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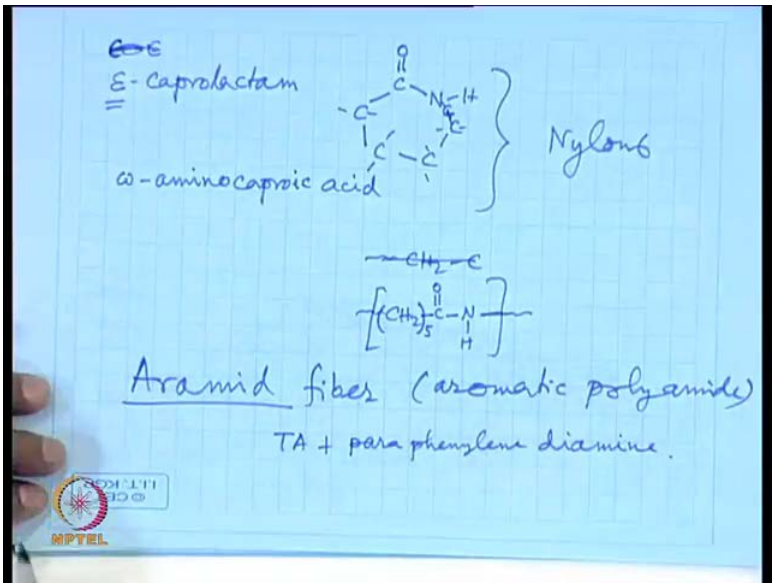

You can get nylon 6 from aprolactam epsilon with in compound, there will one more c one more c, nylon 6 caprolactam recompound, caprolactam nylon 6 or you can have the same nylon 6 from omega aminocaproic acid, jophichen compound both lead to nylon 6., formulize nylon 6.

(( )) yes, Now in clature epsilon caprolactam, this compound is known as this ring compound is known as epsilon caprolactam. Look at the eyepatch common cloture. Aromatic polyimides polyimides say aromid polymer, aromid fiber is aromatic polyimide. What is that? That is made from tri thelege acid and phenylenediamine.

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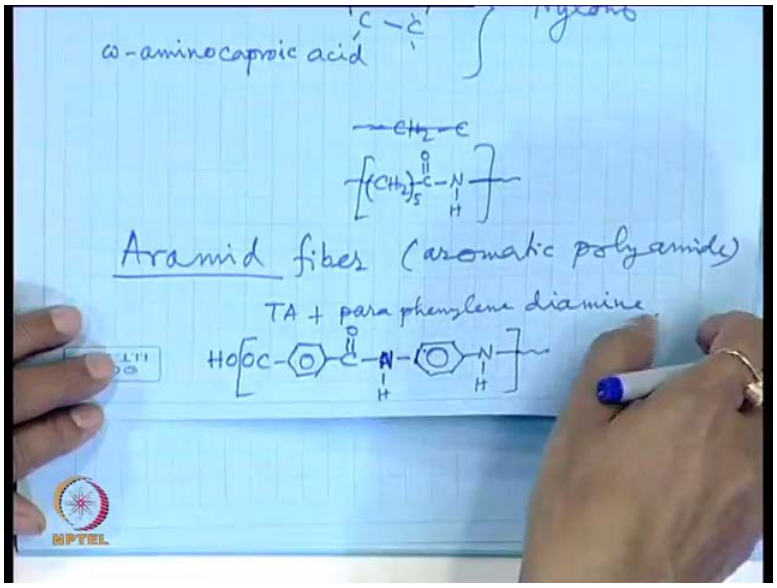

What is tri thelege acid? You have seen earlier I am writing this way paraphenylene mighty, tri thelege acid mighty, on C O N H group has come. So, this is the function group of amide amide function group C O N H is aromatic polyamide. You can have you can take meta substitution as your meta isomer also, then it can lead to a hiver and that is and you can get film or other plastic, but these are high temperature poly polyamides, aromatic polyamides and polyimides. These are polyamides; polyimides are further stronger polymers thermo hit registrant polymers, thermo stable polymers polyimides.

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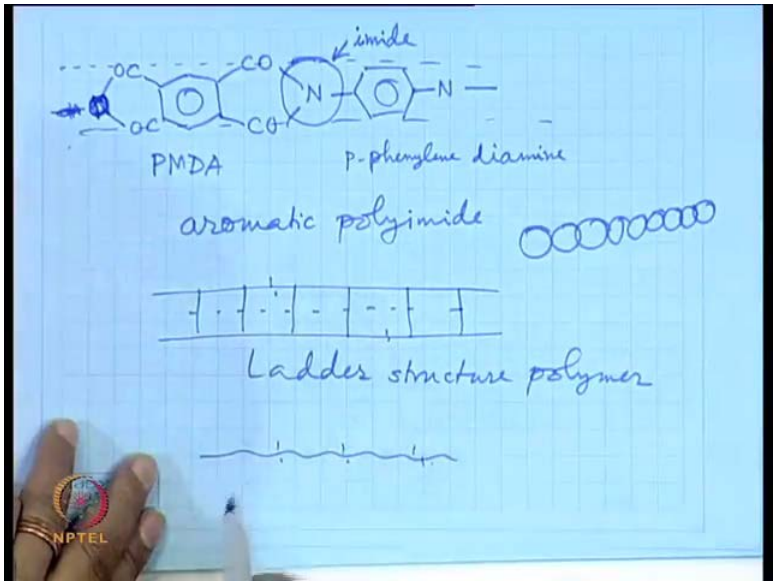

Say, actually this is pyromellitic dien dien adrit PMDA, pyromellitic dien adrit. When reacted with paraphenylene diamine, we get an aromatic polyimide. This is the imide functional group. (( )) here here no actually here nitrogen will come, so i should not show any bound here keep like this an nitrate oxygen keep here oxygen then of course, you have to write one more unit to show this thing one more unit this side. So, this is the imide linkage all the three valencies of nitrogen (( )). That way we can get different types of polyimides.

Aromatic polyimide polymers, there further thermalist able polymer and it leads to a double strand polymer like this. If imagine this way it is called a multi strain polymer or double strain polymer. So, if you find you consider this as a like these like these so, this is a chain carbon chain, this another carbon chain here, this two chains are linked inter linked like this.

(( )) Now, linker molecule means you see is a final lean, this is a imide drem, final drem followed by imide drem followed by final drem followed by imide drem followed by final drem. So, it is look like this ring.

Multitran polymer or double stitran polymer, in case of polythreal what we have seen a single strand that is why that is flexible, but these polymers are very rigid, stable to very high temperature, because of this thing. Because in case of this polymer, if thermal energy is applied to this polymer it can break any where, the carbon back bone chain. But here if it causes breaking at any point here, probabilities like this till then this stricture will be maintained, because these are interlinked with these chain is linked with to this chain by these interlinking bounds, ring stricture.

The probabilities very less that these will be and all these interlinks will also be broken, rings will also be paralyzed, that possibilities remote. That is why this is considered as a or in fact there shown very high thermal stability. In fact there are known as high performance polymers in spacecraft applications, say this polymer is used for making composite with carbon fiber. Carbon fiber polyimide composite it is mechanically strong, as well as thermally durable, thermally stable.

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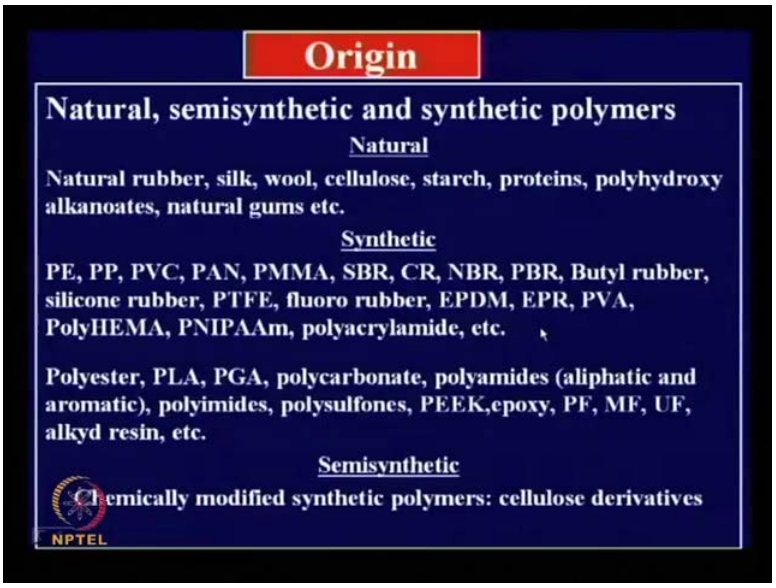

Similarly, polysulfones, polyether ether ketones, you will come across this structures of those polymers then the pork side polymers. Epoch side polymers epoxy polymers, you know araldite, what is araldite, it is a two pack polymer two pack system one pack is the resin polymer and the other pack is the ardinar. Cross linker two pack system, when these two are mixed, it sets to a rigid structure, insolvable infusible structure. Insolvable and infusible form that epoxide polymer, epoxy polymer is used extensively in composite structures. Where glass fiber is used as a glass fiber or carbon fiber or any other fiber is used as a info spent, which is disposed in epoxide rigid matrix. We get epoxy reinforce composites, epoxy fiber (( )) imposed composites.

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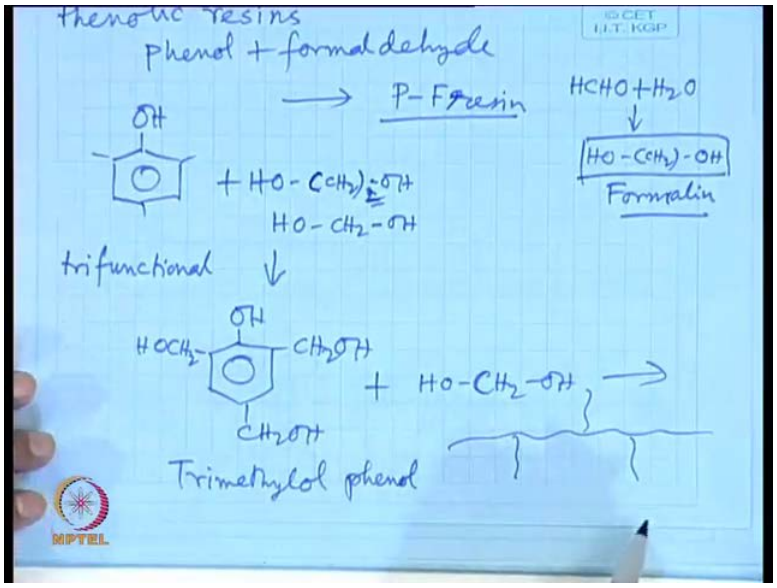

Next comes another important class examples of polymers are phenolic resins; polymer of phenol and formal delyde, this way phenolic resine, P F resins. What is this, you know this is phenol this is phenol. Now, at this point I must mention one thing, for getting a polymer for synthesizing a polymer minimum requirement of functional groups are two. So, if you want to make a polymer you have to select a monomer, which must have two functional groups. Say hydroxy acid, one hydroxy acid can lead to a polyester. Amino acid can lead to a polyamine or diamine having two amine functional groups, can react with a di all having two hydroxyl functional groups.

So, bi functionality is required, that means the functional groups should be minimum number of functional groups should be two, it can be more. Two or more if there are more than two, then there are certain other cases will find later, but I like mention here this phenol.

How many functional sights are there? 1, one of you telling it is 1 and some other is telling as 6. It is trifunctional two artho and one pyra position; these are reactive positions reactive positions in this phenol ring, so trifunctional. So, this trifunctional phenol reacts with fromilid is it mono functional more fromilid no it is bi functional and it is dissolved in water. So, fromilid formalin, in formalin so, find this kind of chemical in it. So, in this react with.. I should not be, should not use a bracket methylene glycol.

Now, when this reacts when this reacts, (( )) You have to go through that (( )) of this phenol ring, there is no scope to discuss all those things. I am going little in depth for your understanding, because this is such a course where I have to cover huge things huge areas and since, in future we not get access to describe all these things. So I am telling just referring these things.

So, this is trimethylol phenol a tri functional these highly reactive again we need further condenceses with formalyde, means a methylene glycol. It leads to a polymer having branches or crosslink structures and ultimately, we get three stages of this phenol family head products. In the stage A, in stage B will get linear P F resin with further formalyde, will get branched P F resin and in stage C in stage C will get branched P F resin.

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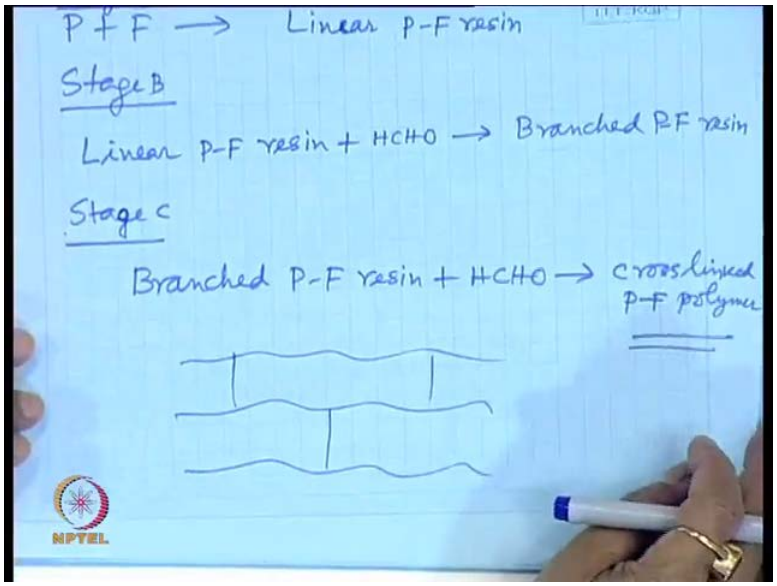

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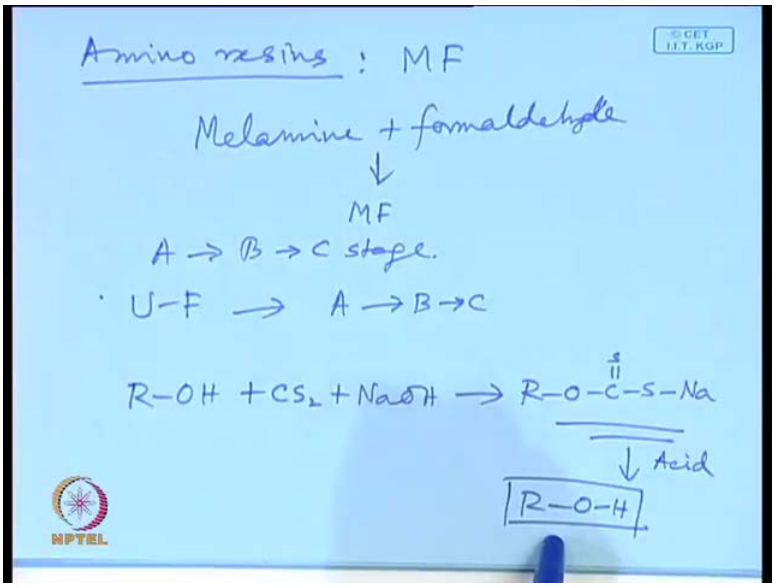

So, this is P F, similarly you can have amino resins, melamine formaldehyde melamine formaldehyde, melamine reacts with formaldehyde you get MF, it also passes through A to B to C. Similarly, area formaldehyde, it also leads to leads from A to B to C stage. So, all these are a leads to a crossed linked polymer structure at the end.

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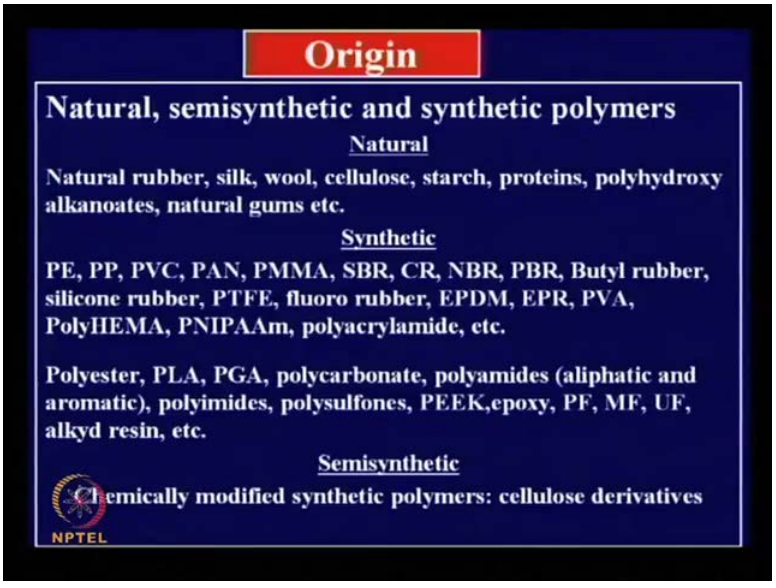

Alkyd resin, is a polymer again is a polyester, it is again the polyester, alkyd resin is a polyester made from chemical and glycerol. Next comes semi synthetic now, you have seen what are synthetic polymers, you have seen what are natural polymers. So, if we do

certain kind of modification, carry out certain kind of chemical modification on natural polymer. We call it semi synthetic polymer say, cellulose is a natural polymer, we can make derivatives of cellulose, we can make nitro derivative of cellulose.

So, say cellulose nitrate, cellulose nitrate is an explosive material you know cellulose nitrate explosive material. But when cellulose nitrate is plasticized with camphor or other plasticizer, it least it leads to a plastic; spect frame, comb, photographic films those are made from cellulose nitrate plastic. So, it is a derivative similarly, viscose rayon viscose rayon regional dead cotton is viscose rayon or cellophane, you have seen cellophane it is nothing but regenerated cotton, sello fan film you have seen in the market you have used also, in various different colors we get thin transparent films in different colors; red, blue, green, yellow etcetera.

That is nothing but cellulose, regenerated cellulose. What is regenerated cellulose? Say cellulose if you consider this cellulose as R-OH having cellulose unit contain hydroxyl groups. When that is reacted with carbon di sulfide in presence of alkali, it actually forms a xanthate, sodium cellulose xanthate. When this sodium cellulose janthet, it actually pord on in acid bath, the cellulose is regenerated. So, this is regenerated cellulose cellophane etcetera. So, this much if you have any queries you can ask me.