Science and Technology of Polymers
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Lecture - 39
Engineering and Speciality Polymers

Today we shall discuss about a new topic, engineering and specialty polymers. There are different categories of polymers, polymer materials, from which products are made. We are very much accounted with the commodity polymers or general purpose polymers, which find high volume application, high volume consumption; and which are cheaper, as compare to the other engineering and specialty polymers, not only that these general purpose commodity polymers are used for general purpose use. That means, where no special need for high temperature resistance, or resistance to harsh environments chemicals and solvents, these are called general purpose polymers.

Whereas, engineering and specialty polymers are of, are known as high performance polymers, which are supposed to function at elevated temperature and they are suppose to have excellent solvent resistance, chemical resistance and they can with stand so harsh and environments of temperature and gases. Not only that their mechanical properties are quite high as compare to the general purpose polymers.

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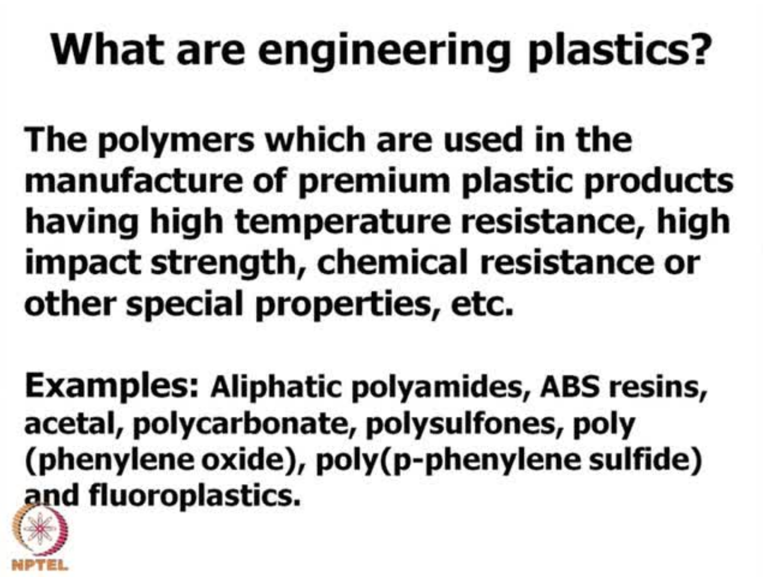

What are engineering plastics?

The polymers which are used in the manufacture of premium plastic products having high temperature resistance, high impact strength, chemical resistance or other special properties, etc.

Examples: Aliphatic polyamides, ABS resins, acetal, polycarbonate, polysulfones, poly (phenylene oxide), poly(p-phenylene sulfide) and fluoroplastics.

Now, what are engineering plastics or engineering polymers. The polymers, which are used for the manufacture of premium plastic products or polymeric products having high temperature resistance, they must have high impact strength, they must have high resistance to chemicals and solvents, or they should provide other special properties like flame retardant c or fire retardant c or high abrasion resistance or they must be resistant to extreme temperature and environments, including this a cryogenic temperatures etcetera etcetera

To speak about the examples, we can till the names of polyamides say nylons. Nylons may be of two type’s aliphatic nylons or aromatic nylons, then ABS resins acrylonitrile butadiene, styrene resins, or acetal resins, polycarbonates, polysulfones, poly phenylene oxide, poly para phenylene sulfide, fluoropolymers or fluoroplastics, photoresistant polymers so and so.

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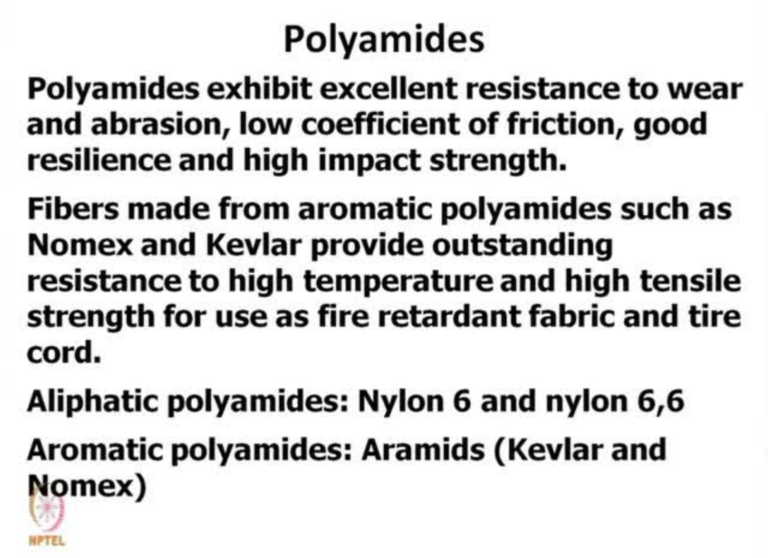

Polyamides

Polyamides exhibit excellent resistance to wear and abrasion, low coefficient of friction, good resilience and high impact strength.

Fibers made from aromatic polyamides such as Nomex and Kevlar provide outstanding resistance to high temperature and high tensile strength for use as fire retardant fabric and tire cord.

Aliphatic polyamides: Nylon 6 and nylon 6,6

Aromatic polyamides: Aramids (Kevlar and Nomex)

Now, let us start with the discussion on polyamides. Polyamides exhibit excellent resistance to wear and abrasion they show low, very low coefficient of friction they provide good resilience and high impact strength. Fibers can be made from such polymers particularly say polyamides for example, nomex I told in I have told in other lectures, this nomex is one aromatic polyamide.

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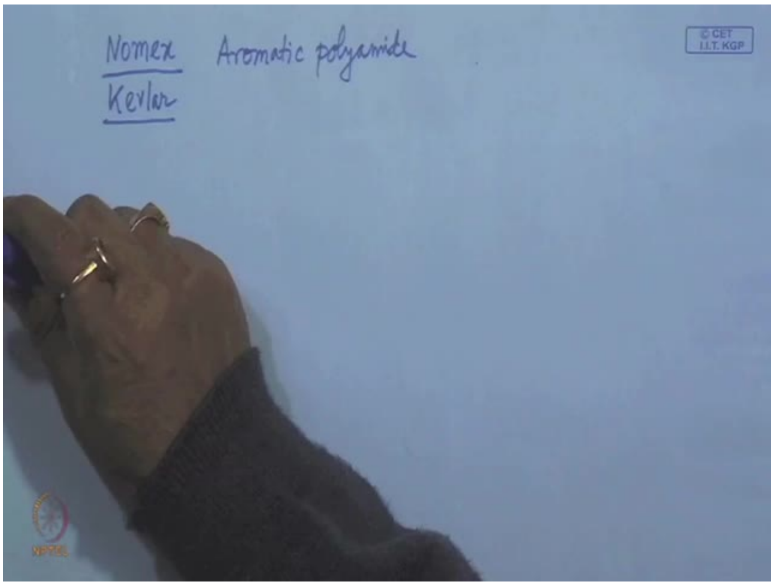

Aromatic polyamide and Kevler, this also aromatic polyamide, only the linkage in the final link of ring of the amine part differs, say one is earth linkage and the other is meta linkage and the other is para linkage. Such, aromatic polyamides as compare to aliphatic polyamides, offer outstanding resistance to high temperature and the offer very high tensile strength for use as fire retardant, fabric say not only that fire retardant fabric that can be use full for will be use full as protective armor or weights, which is resistance to bullet piercing. That means, bullet proof jackets or bullet proof armors can be made from high performance aromatic polyamides.

Not only that for some heavy duty automobile tires, the cord used in the tire that is also made of this aramid fiber or kevlar fiber. Aromatic polyamide fiber, which actually replaces, sometimes steel fiber or polyester fibers. Now, out of these aliphatic polyamides we know about nylon 6 and nylon 66 and aromatic polyamides, I have already mentioned these are known as aramids, aramids these are aramids can be kevlar either kevlar or nomex.

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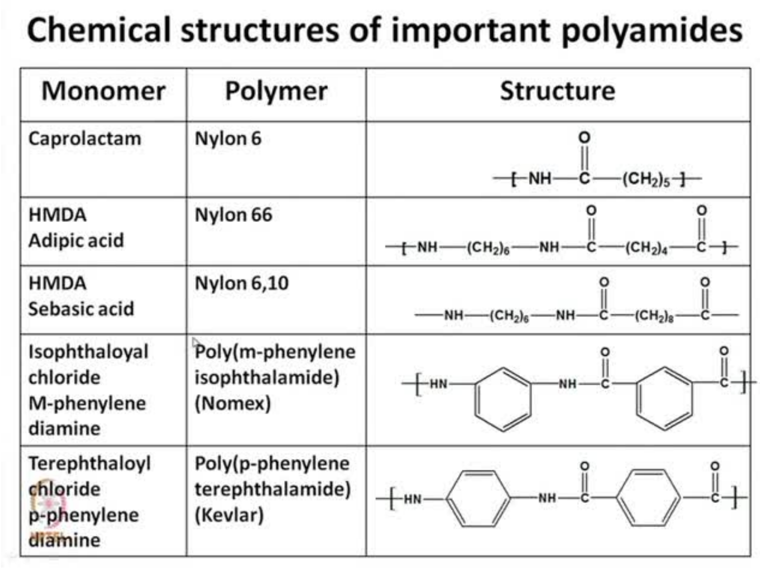

Chemical structures of important polyamides

Monomer	Polymer	Structure
Caprolactam	Nylon 6	$-[NH-\overset{\overset{O}{\|}}{C}-(CH_2)_5]-$
HMDA Adipic acid	Nylon 66	$-[NH-(CH_2)_6-NH-\overset{\overset{O}{\|}}{C}-(CH_2)_4-\overset{\overset{O}{\|}}{C}]-$
HMDA Sebasic acid	Nylon 6,10	$-NH-(CH_2)_6-NH-\overset{\overset{O}{\|}}{C}-(CH_2)_8-\overset{\overset{O}{\|}}{C}-$
Isophthaloyal chloride M-phenylene diamine	Poly(m-phenylene isophthalamide) (Nomex)	
Terephthaloyl chloride p-phenylene diamine	Poly(p-phenylene terephthalamide) (Kevlar)	

Now, let us look into structures of chemical formula and their structures of some important polyamide. So, nylon 6, this nylon 6 is a fiber grade polymer, which is made from caprolactam it is a ring compound, this ring compound can be polymerized to nylon 6 by ring opening polymerization its formula is N H C O C H 2 whole 5. This is the repeat unit of the nylon 6 polymer for preparing nylon 66 this caprolactam is not suitable here hexamethylenediamine as the anime part and adipic acid. As the acid part or condensed through nylon salt formation to produce nylon 66 polymer by melt polycondensation at high temperature say around 265 to 277 degree celsius.

Here this nomenclature nylon 66 that numerical figures 6 and 6 comes from the number of carbonate atoms, in the amine part and the number of carbonate atoms in the acid part. Here in the amine part 6 methylene units are there in each methylene unit, there is 1 carbon and in acid part there are 4 methylene units, each methylene unit contain 1 carbon and 2 carbons are present in the acid groups.

So, this way it founds the nylon 66 and it is actually this nomenclature is given as nylon 66. Similarly, one can have nylon 6, 1 0 in this case 6, 1 0 same diamine hexamethylenediamine HMDA is used and in the acid part is state of adipic acid this sebasic acid is used which contains, 8 methylene units and 2 carboxyl group through this way you get nylon 6, 1 0.

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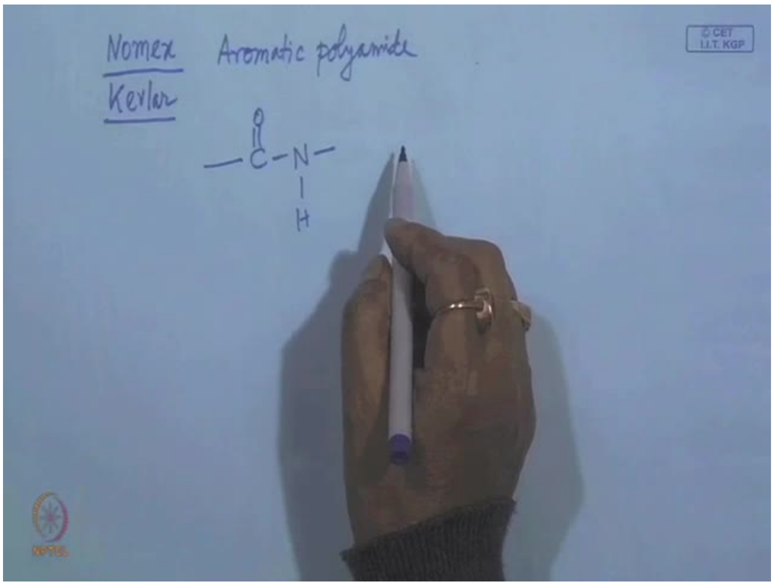

As I mention the name of nomex, which is aromatic polyamide basically such elliptic or aromatic polyamides both contain amide linkage. This C O N H, this C O N H is the amide linkage C O N H is the amide linkage, if this kind of linkage is present in a polymer that we call as polyamide. Now, in this linkage is connected to aliphatic units, we call it aliphatic polyamide and if it is link to sum aromatic groups, aromatic rings, penile rings etcetera we call it aromatic polyamide.

In case of nomex, as I just told that nomex contains this phenylenediamine and this amine groups are linked at the meta position or 1, 3 position. As well as this isophthaloyal chloride, isophthaloyal chloride this is made from isophthaloyal chloride or isophthalic acid, it is isophthaloyal chloride is more reactive to isophthalic acid. So, isophthaloyal chloride is use for condensing with this meta phenylene diamine, and it forms this amide linkage and it forms this aromatic polyamide nomex.

Now, terephthaloyl chloride and peraphenylene diamine terephthaloyl chloride on in place of isophthaloyal chloride. Here in case of isophthaloyal chloride it was the metal linkage here as in case of terephthaloyl metal linkage. In case of terephthaloyl chloride it is para linkage. So, this link para linkage or mata linkage or para para linkage, mata mata linkage that causes large change in their stricture, as well as in their properties. So, this is also a fibergrate sometimes this is used for making film nomex is use for making film. Whereas kevlar is always used for fiber which is made from para para linkage of diamines and the diacid or diacide chlorides. So, this is terephthaloyl chloride is the diacid chloride and peraphenylene diamine is the diamine.

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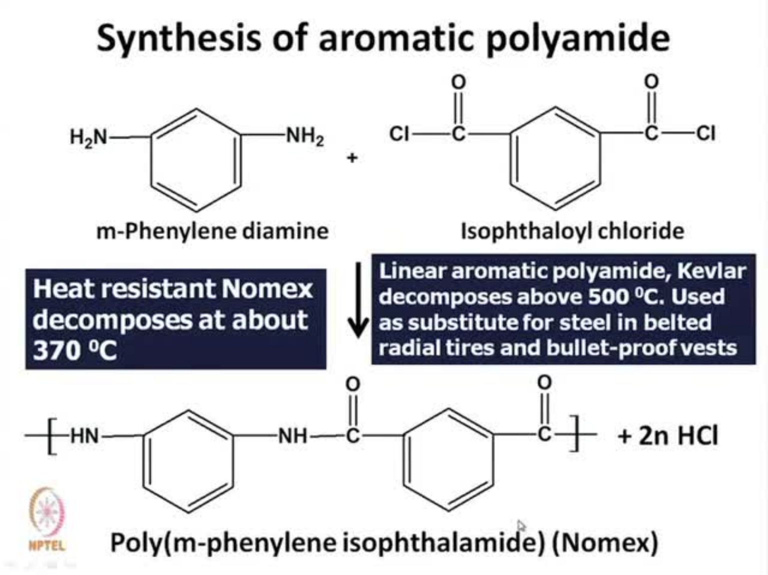

Synthesis of aromatic polyamide

m-Phenylene diamine

Isophthaloyl chloride

Heat resistant Nomex decomposes at about 370 ⁰C

Linear aromatic polyamide, Kevlar decomposes above 500 ⁰C. Used as substitute for steel in belted radial tires and bullet-proof vests

Poly(m-phenylene isophthalamide) (Nomex)

Now, these are aromatic polyamides are senomyx is synthesized by reacting meta phenylene diamine, this is the formula of meta phenylene diamine, this is the formula of isophthaloyl chloride. So, they react to form this poly meta phenylene isophthalamide poly meta phenylene isophthalamide or nomex. This is the structure or formula of this nomex or poly poly meta phenylene isophthalamide.

Now, this nomex is heat is resistant to heat at high temperature, thermal resistance thermal stability is very good, but it decomposes or start decomposition at about 370 degree celsius. So, this polymer can be safely used up to say 215 or 200 degree environment, without any decomposition or without any loss in their strength properties. Now, this a linear aromatic polyamide kevlar on the contrary decomposes above 500 degree celsius.

Just you compare their decomposition temperature or thermal stability, taking this decomposition temperature having the meta linkage, this nomex decomposes. Such decomposition at 370 degree, whereas the aromatic polyamide kevlar this starts decomposition above 500 degree celsius. This is due to the molecular alignment, molecular organization if you go back to the previous slide, here you see para para linkage has the molecular more than than that is found in nomex, due to the presence of this meta linkage.

So, the thermal stability is obvious from the configuration of the polymer molecules, or the linkage of the amine and acid parts at the meta position for nomex at the para position for the kevlar. Now, this is such this kevlar polymer is used as substitute for steel. As I mention the used as a substitute for steel in belted radial tires, radial automobile radial tires and bullet proof vests. This is a that is they that is why, this is called a high performance specialty polymer.

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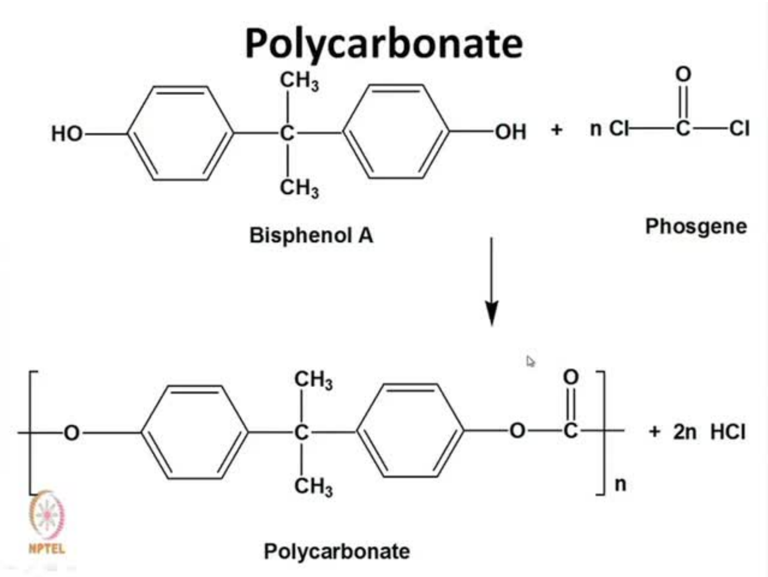

Polycarbonate

So, this all about I have told about the aromatic polyamide or aromatic nylons and aliphatic nylons, you know and polycarbonate.

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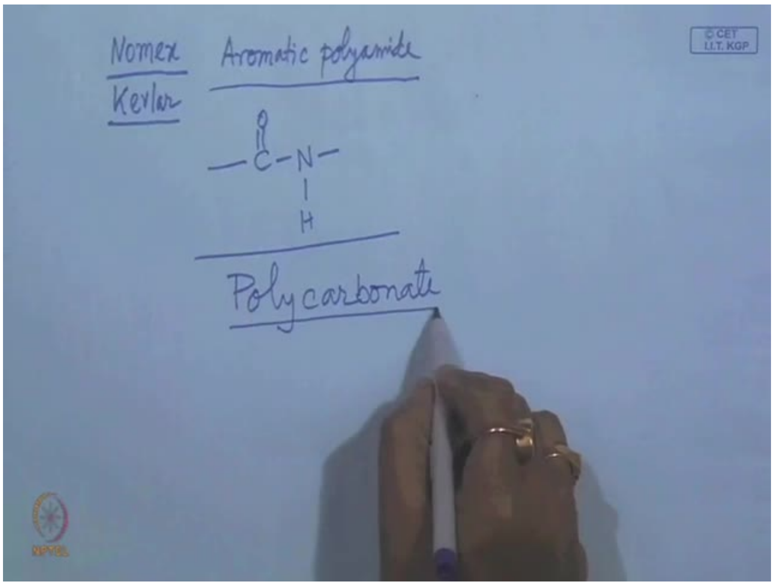

Next, polymer is polycarbonate, polycarbonate the carbonate means it contains C O 3 group, C O 3 group this carbonate group is present in the polymer along with the phenyle links. Now, this is basically the general polycarbonate is made from bisphenol A. This is the formula of bisphenol A is a phenolic group is a phenolic group 2, phenolic groups is present in this bisphenol A and this is the frozen C O C L 2.

Now, this bisphenol A is highly reactive to frozen or frozen is highly reactive to bisphenol A after reacting the form a polymer that is known as polycarbonate. Here you see this carbonate linkage C O O, this carbonate linkage this both side of this carbon 2 atom there one is here and one is here. This is the, we how to show the repeat unit of this polycarbonate.

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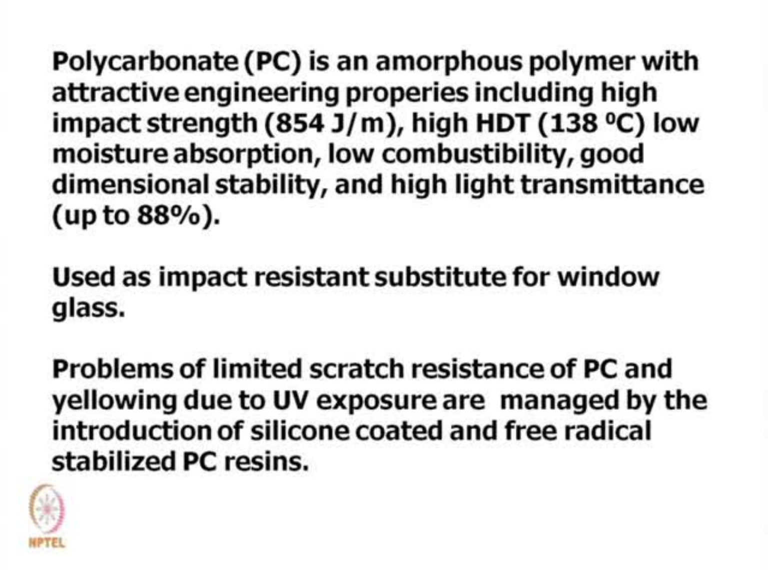

Polycarbonate (PC) is an amorphous polymer with attractive engineering properies including high impact strength (854 J/m), high HDT (138 °C) low moisture absorption, low combustibility, good dimensional stability, and high light transmittance (up to 88%).

Used as impact resistant substitute for window glass.

Problems of limited scratch resistance of PC and yellowing due to UV exposure are managed by the introduction of silicone coated and free radical stabilized PC resins.

Now, this polycarbonate is an amorphous polymer having very attractive engineering properties including high impact strength, high heat deflection temperature, they have low moisture absorption, low combustibility, good dimensional stability and high light transmittance, transmittance.

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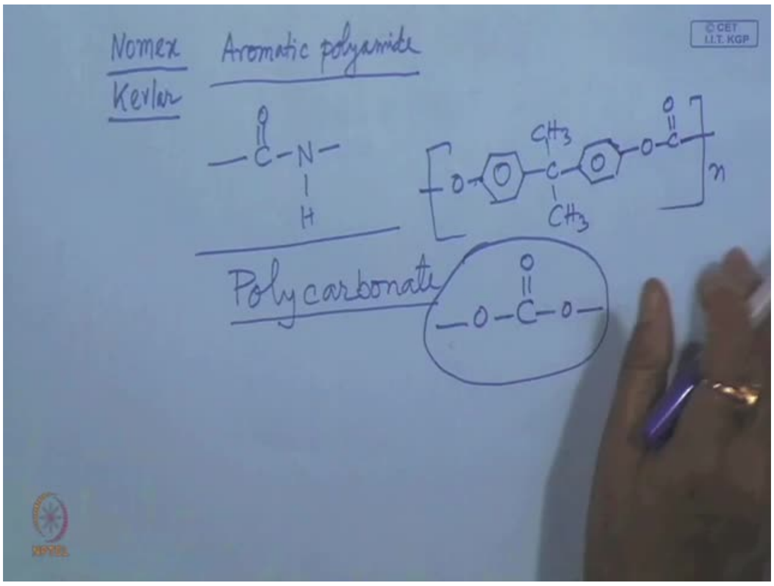

Now, this polycarbonate is an engineering plastic, this because of the presence of such phenyl ring in the polymer chain and high polarity due to the presence of oxygen linkage C O O carbonate linkage. This carbonate linkage, carbonate function group in the polymer chain, this group this is polar and the presence of this phenyl rings that makes so strong impact property is also very good and heat distortion temperature. Means at it is the heat distortion, temperature tells about the dimensional stability of the product at elevated temperature or under pressure under load.

So, it should not be deformed at high temperature. So, here the temperature it can withstand up to say 130 degree celsius without any deformation, or without any deflection or distortion. And by virtue of the presence of this phenyl rings, although the carbonate group is present over there, it shows excellent moisture resistance characteristics, moisture absorption characteristic. It does not allow moisture to penetrate in the bulk of the product meta polycarbonate.

And because of the presence of this phenyl rings, although it methyl groups are 3 phenyl ring and this C O O 3 groups, it shows excellent resistance to combustibility; or it one can say, it is a (( )) polymer not only that, it has a good light transmittance, light transmission property say, it can transmit U V light visible light up to 88 percent. That is why this polycarbonate is used for as automobile head lights covers, as well as window glass or some. Since, it can with stand very high temperature, it can be used as baby feeding bottle, which is sterilizable at autoclave temperature. So, and now this is to talk about the application used as polycarbonate used as the high impact resistance, substitute for window glass.

The problems of limited scratch resistance of polycarbonate. Now, this polycarbonate has one limitation or one problem with this scratch resistance is not good, not only that the it is this polycarbonate starts yellowing, when it exposure to U V light if there is high percentage of U V light in the sun, sun light there are certain reasons where U V percentage is more. So, in that area this polycarbonate starts yellowing. That means, yellow color is developed in the polymer, although it is transmit transmission property is good.

Now, these can be managed by some coating of silicon polymer, as well as coating with that coating may contain some fluidical stabilizer. So, silicon fluidical generating compounds, in silicon that composition can be used as a coating over polycarbonate items, which will release free radical on exposure to U V light and that stabilizes that decomposition of polycarbonate to develop such yellow color.

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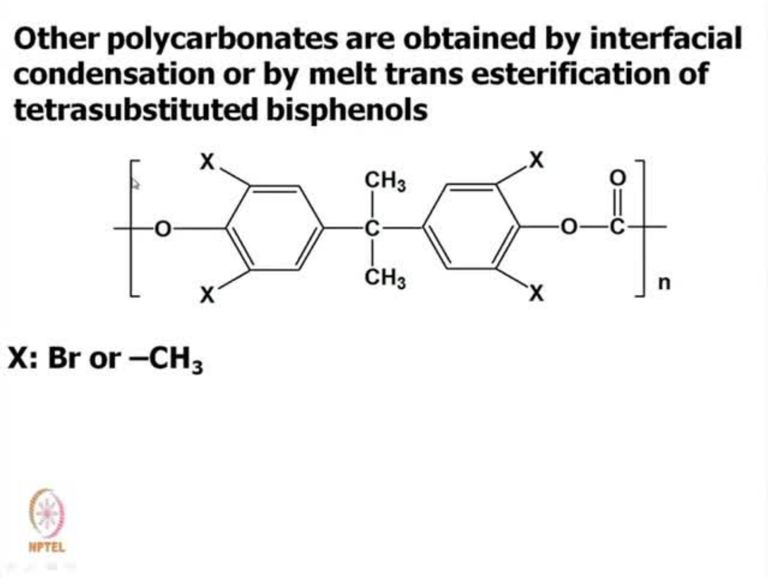

Other polycarbonates are obtained by interfacial condensation or by melt trans esterification of tetrasubstituted bisphenols

X: Br or $-CH_3$

Now, there can be other polycarbonates as derivatives say bisphenol A derivatives some groups can be functional groups can be attached to the phenyl ring of this phenol a and the product will be polycarbonate but, that is different from that is normal bisphenol carbonate. So, such type of polycarbonates can be prepared by interfacial poly condensation or by melt trans esterification of tetrasubstituted bisphenols.

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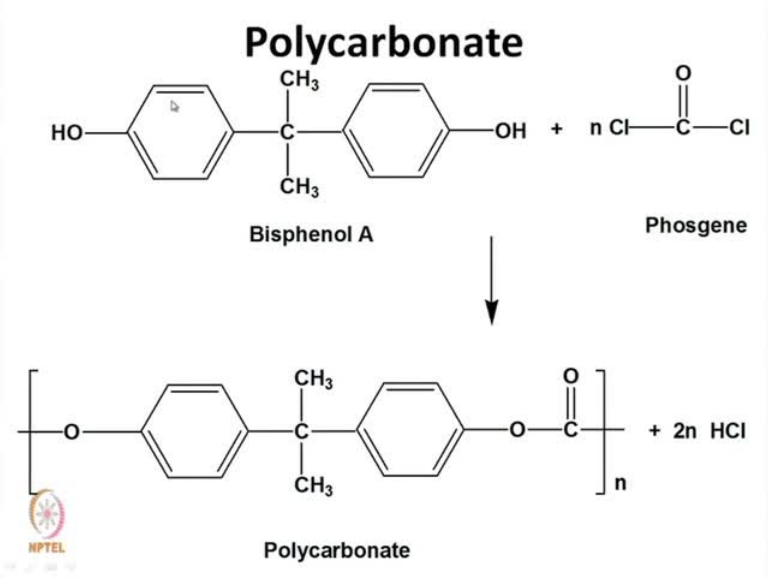

Polycarbonate

As you, as you have seen in this case if there are functional groups attached at this linkage at this point at these two points, are as well as at this point at this point. That means, I mean to say.

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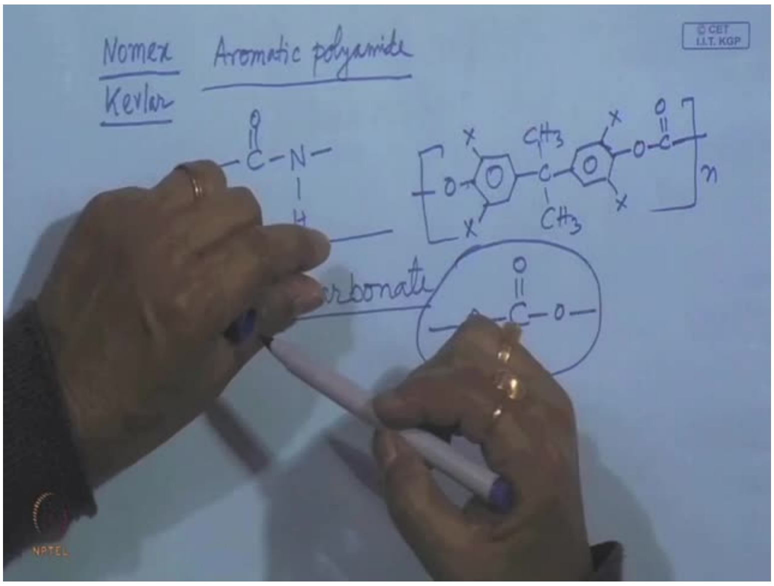

Here is one functional group here one functional group x, x, x, x. So, such type of bisphenol A can be interfacially polymerized poly condense polycondensation reacts interfacial poly polycondensation reaction can be converted to tetrasubstituted. This is 1, 2, 3, 4 tetrasubstituted bispheonls, bisphenols and bisphenol poly polycarbonate that undergo sum trans justification reaction. So, here x might be some halogen groups, halogen atoms say it can be in major cases it is bromine or sometimes it can be even methyl group. So, polycarbonates can be of different grades depending on the presence, or absence of substitution on the phenyl ring of the bisphenol A component, we can have different grades of poly carbonate.

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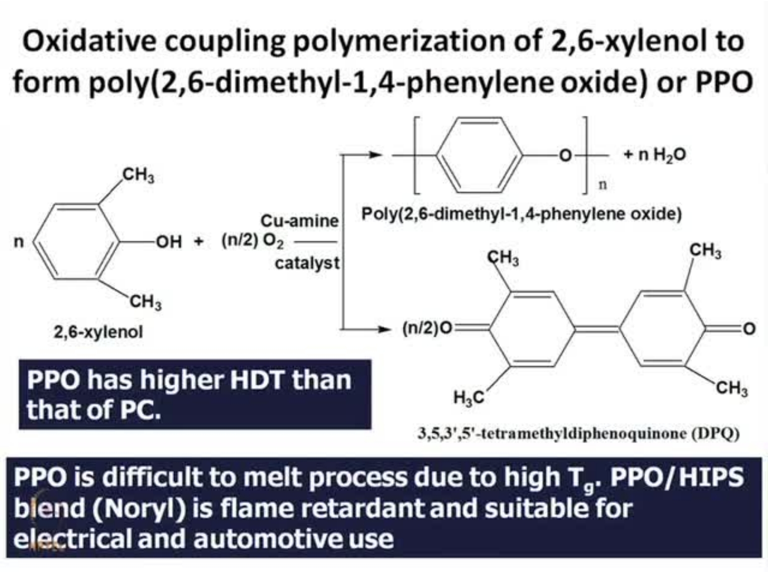

Oxidative coupling polymerization of 2,6-xylenol to form poly(2,6-dimethyl-1,4-phenylene oxide) or PPO

PPO has higher HDT than that of PC.

PPO is difficult to melt process due to high T_g. PPO/HIPS blend (Noryl) is flame retardant and suitable for electrical and automotive use

Now let us see, other polymer let as pass from to other polymers from poly carbonate say polyphenylene oxide, this is another specialty polymer or high performance polymer polyphenylene oxide. Polyphenylene oxide means, that it contains phenyl ring as well as oxygen. So, that is known as polyphenylene oxide. The formula of 1 polyphenylene oxide is this phenyl ring and oxygen. That means, this is the repeat unit this can be repeated along the backbone chain. So, basically one can say this is a polyether, polyether type of polymer and oxygen is linked to phenyl rings.

So, this phenyl ring acts to the rigidity of the polymer molecule and due to the presence of such rigid phenyl ring, it shows high performance characteristics like high thermal stability as well as other good mechanical properties at due to the para linkage, the tensile or mechanical properties would be better. So, the name of this polymer is poly 2, 6 dimethyl 1, 4 phenylene oxide, it is prepared by reaction of 2, 6 xylenol. This is 2, 6 with oxidative coupling polymerization of oxidative coupling polymerization of 2, 6 xylenol in presence of copper amine as catalyst this polymer is formed.

Now, while this polymer is form this polyphylene oxide PPO is reduced along with this some by product 3, 5. 3, 5 prime 5 prime tetramethyldiphenoquinone DPQ. So, this tetra methyldiphenoquinone is from resin by product along with this mean PPO, it should be removed or the products with purified by removing this TPQ from the main product.

Now, this polyphylene oxide shows higher heat distortion temperature than that of poly carbonate. So, here is a difference between polyphenylene oxide and poly carbonate this poly carbonate contains 1 carbonate group after a phenyl ring at here it is only oxygen and because of the distance between the 2 phenyl rings. That means, the only 1 oxygen atom is present between 2 phenyl rings, the rigidity of the polymer is high that is why the heat distortion temperature is higher than that of poly carbonate.

But although the heat distortion temperature is high, but such type of polymers is polyphenylene oxide is difficult to melt process because the melting temperature is higher and they have high, very high last legion temperature T g. So, to invert to work come some difficulty of melt processing because processing, processability is another criteria a polymer can be have high performance characteristic, it can be very strong, it can be very stable at elevated temperature, but it should be converted to a product.

That means, it should be compounded with additives then it should be fabricated or saved with the help of using machineries, like compression molding or transfer molding or even extortion or injection molding all these things, but those actually involve this melt processing of the polymer. That means, the polymer should melt at high temperature, and it should reduce the lower the viscosity by melting and then it should be should have adequate flow characteristics, geological characteristics then only it can be formed to give a required dimensional shape, and dimensional of the product.

Since,PPO is lacking in this property, it is blended with another polymer or auxiliary polymer. That is high impact polystyrene, high impact poly styrene has good impact resistance property, but it melts at lower temperature than PPO. If a certain proportion of high impact polystyrene is blended with polyphenylene oxide, that blend can be easily processed and that blend is available in the market, as a commercial in a commercial product brand name is noryl.

This noryl polyphenylene oxide high impact polystyrene blend, noryl is strong as well as it show some flame retardant properties because of the presence of large number of phenyl rings along the back bone chain. So, flame retardant polymer blend composition with high performance properties like thermal resistant’s etcetera, can be prepared by blending high impact polystyrene with polyphenylene oxide and that polymer is suitable for electrical as well as automotive applications.

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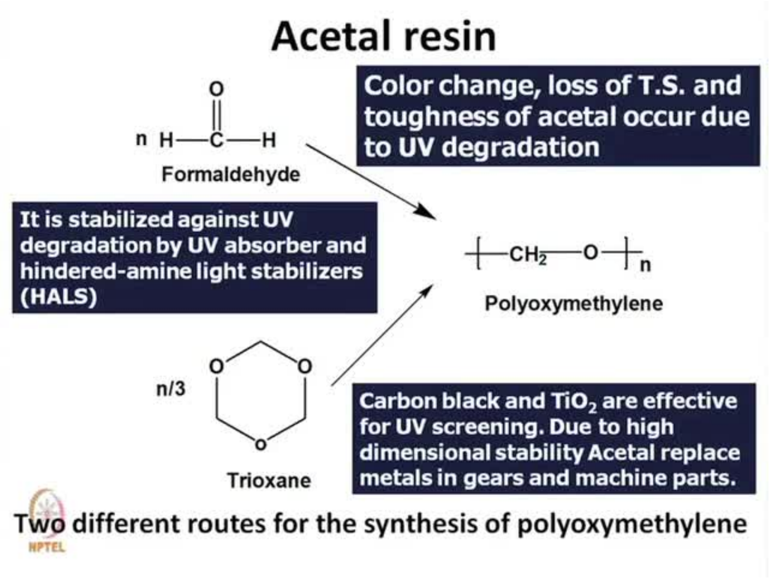

Acetal resin

Color change, loss of T.S. and toughness of acetal occur due to UV degradation

It is stabilized against UV degradation by UV absorber and hindered-amine light stabilizers (HALS)

Carbon black and TiO_2 are effective for UV screening. Due to high dimensional stability Acetal replace metals in gears and machine parts.

Two different routes for the synthesis of polyoxymethylene

Next, let us see acetal resin this is the this is a kind of premier resin, we can say it was consolized and somebody has rejected this presence of acetal resin in Halley's comet. I Halley’s comet this acetal resin is there acetal polymer is there, basically this acetal resin is called polymethylene oxide or polyoxymethylene CH2O, it is actually a polymer of formaldehyde or trioxane. This formaldehyde you know is formula of formalidehyde is very simple H C H O, it can be polymerized to form polymethylene oxide and it can also we prepared from trioxiane two different routes are there, formalidehyde route or the trioxane route for the synthesize polyoxymethylene.

Now, this polyoxymethylene can is stabilized against U V degradation by U V absorber and hindered amine light stabilizers. So, if hindered amine lights stabilizers is blended with this polyoxymethylene or other, if it absorber absorbing compound as additive then this polyoxymethylene is excellent composition, polyoxymethylene with U V absorber is an excellent composition, which is which can prevent the product from degradation from U V exposure.

Now, there is a change of color due to the due to the exposure to visible light or the sun light, that happens due to U V absorption. And as a result on absorption of U V it degrades and with an attendant loss of tensile strength, as well as toughness also is reduced due to the U V absorption. So, U V absorption, U V absorbing compounds or U V stabilizer or hindered amine type of compound hindered amine means, amine derivative with long hydro carbon chain that is such type that is known as hals hindered amine light stabilizer can reduce, the degradation of such polyoxmethylene from U V light. Sometimes it has been found that carbon black is a very good U V absorber, as well as titanium dioxide filler. So, carbon black is smaller quantity of carbon black, as well as titanium oxide if there blended or mixed or compounded with this polyoxymethylene, that becomes very highly effective for U V screening, U V that we this titanium oxide or carbon black will absorb the U V and reduce it will prevent, it will protect the polymer form the degradation.

Due to the if this U V can be U V absorption or u v protection, protection from U V can be done then, it is excellent polymer because it shows very high dimension stability because although there is no aromatic linkage present over here, but it shows very high dimensional stability and sometimes there tensile strength, and impact tensile strength and modules an impact resistance is so high. Impact property is so high that such acetal resin when filled with carbon black and titanium oxide, can replace some times metals in gears. That means, this polyacetal gears can be used in palace of metals or some missing part can also be made in place of steel. So, this polyoxymethylene is a very good polymer for mechanical or engineering application like gears and machine parts.

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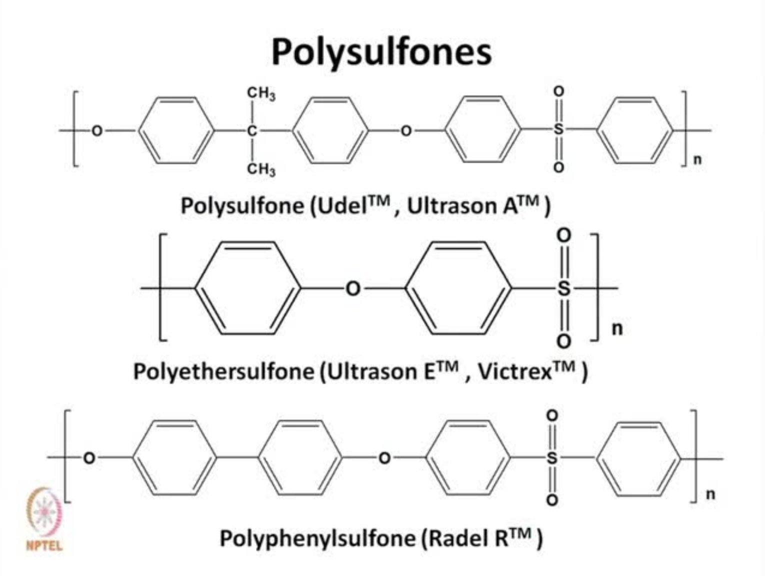

Polysulfones

Polysulfone (Udel™, Ultrason A™)

Polyethersulfone (Ultrason E™, Victrex™)

Polyphenylsulfone (Radel R™)

Next is polysulfone we have seen polyphenylene oxide, we have seen polyamides aromatic polyamides, we have seen polyphenylene oxide, we have seen polycarbonates, we have seen acetal resins. Now, let us see polysulfones.

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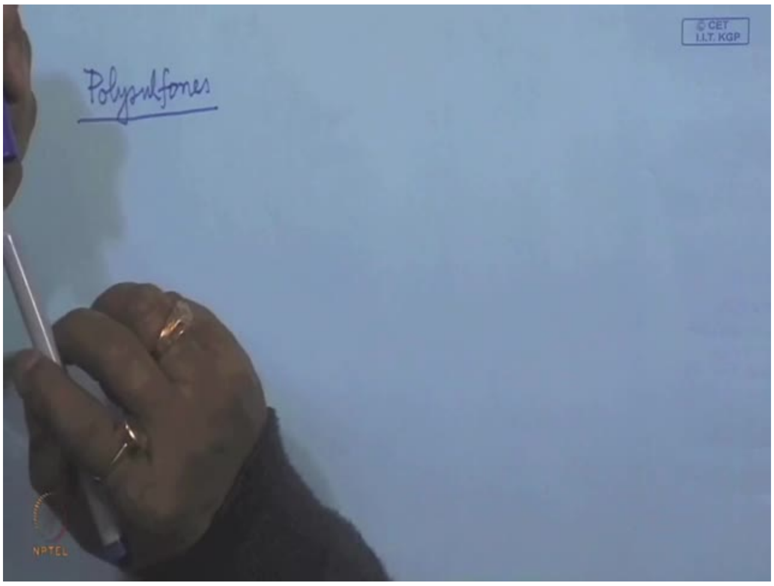

This polysulfone is again another engineering polymer. Polysulfone means, it contains sulfur in the polymer just look at the formula of this polysulfone. Here this due to the presence of this sulfur with 2 oxygen, this is a sulfone group, this is the 2 sulfone group. Now, this sulfone group containing reactant can be used that is di amino di this is a polymer containing sulfone group having 2 phenyl rings at the other both side of the sulfone group, and this is bisphenol A, this is bisphenol A. So, bisphenol A and this monomer can be used for making polysulfone.

This polysulfone is commercially available with the brand name trade name Udel or ultrason udel or ultrason. Similarly, you can have polyethersulfone, polyethersulfone. This polyethersulfone say ultrason E t m or vectrex A t m. So, this contains only this type of for formula or linkage having phenyl rings and sulfone groups just here, one thing to be noted between if we compare this polymer with this polymer between two sulfone functional group, there are many phenyl rings.

We had here 3 4 phenyl rings are there. Here after 2 phenyl rings 1 sulfone is coming along with the presence of this ether linkage, this is a ether linkage through linkage through oxygen. There is another polysulfone is called polyphenylene, polyphenylsulfone radel R, radel radel R. So, this is the formula of polyphenylsulfone.

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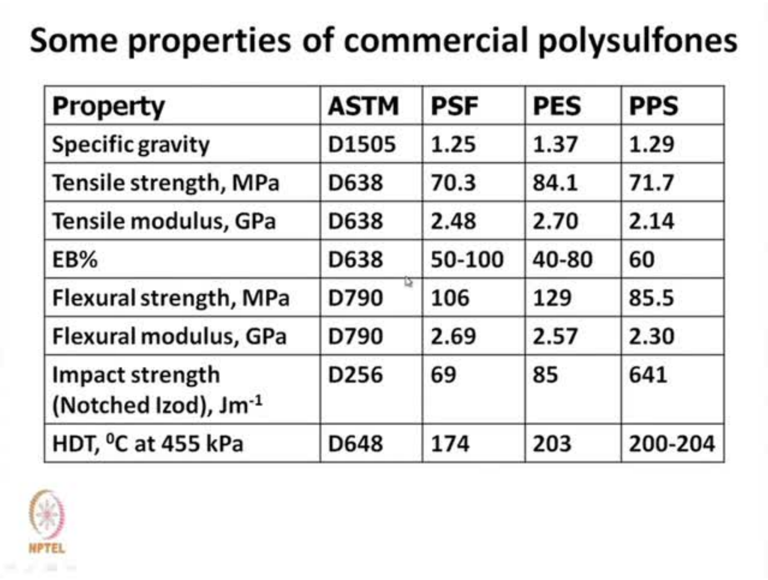

Some properties of commercial polysulfones

Property	ASTM	PSF	PES	PPS
Specific gravity	D1505	1.25	1.37	1.29
Tensile strength, MPa	D638	70.3	84.1	71.7
Tensile modulus, GPa	D638	2.48	2.70	2.14
EB%	D638	50-100	40-80	60
Flexural strength, MPa	D790	106	129	85.5
Flexural modulus, GPa	D790	2.69	2.57	2.30
Impact strength (Notched Izod), Jm^{-1}	D256	69	85	641
HDT, ^0C at 455 kPa	D648	174	203	200-204

Now, let us look into a comparative situation of this comparative properties of different polysulfones. One is PSF, one is PES another is poly PPS. This PSF is polysulfone and PES polyethersulfone and PPS is polyphenylsulfone. So, polysulfone polyethersulfone polyphenyl, poly polyphenylsulfone, polyphenylsulfone. So, in these three polymers number of phenyl rings as well as the number of oxygen linkage, ethyl linkage in there, in the repeat unit of the polymer differs the and let us see their change in properties look at this specific gravity, specific gravity where is from 1.25 to 1.37.

Tensile strength in case of this polyethersulfone, tensile strength is highest among this three, this is 84 magapascal and tensile modules obviously, tensile module is also high highest for this polyethersulfone, and elongation with break is at the lower range of for this polyethersulfone. Flexural strength is excellent 129 as compare to 106 and 85.5 for PSA and PPS respectively. Flexural modulus again it is high then impact strength, it is the impact strength it is a here something wrong it will be 64.1 instead of 641, it is 64.1 not 641 and it is 85 highest impact strength for this polyethersulfone. And heat distortion temperature is almost comparable for this two polyethersulfone and polyphenylene sulfone, polyphenylene sulfone and it is lowest for this polysulfone only.

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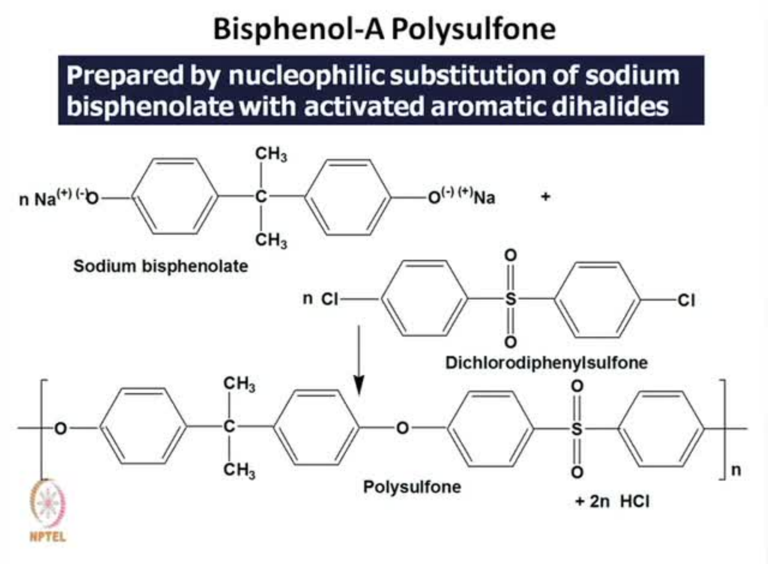

Bisphenol-A Polysulfone

Prepared by nucleophilic substitution of sodium bisphenolate with activated aromatic dihalides

Now, we can have this different types of sulfone as I told now let us look into one kind of sulfone that is bisphenol A sulfone containing bisphenol A in the polysulfone mighty or in the repeating unit. Now that is prepared or synthesized by reacting sodium bisphenolate, sodium eyen of bisphenol sodium salt of bisphenol known as sodium bisphenolate. So, this is reacted with sodium hydroxide bisphenol is reacted this sodium hydroxide to form this sodium bisphenolate. Now, that is reacted with dichlorodiphenylsulfone.

This dichlorodiphenylsulfone that condenses through this chlorine atom of this dichlorodiphenylsulfone, and some sodium chloride molecule is aviated out and by such an elimination. This linkage occurs at this oxygen, this phenyl ring and this phenyl ring phenyl ring gets linked through this oxygen and to form, this poly bisphenol A polysulfone. And in this tape, since HCL is there or some acid accept some acid is used. So, HCL is produce over here.

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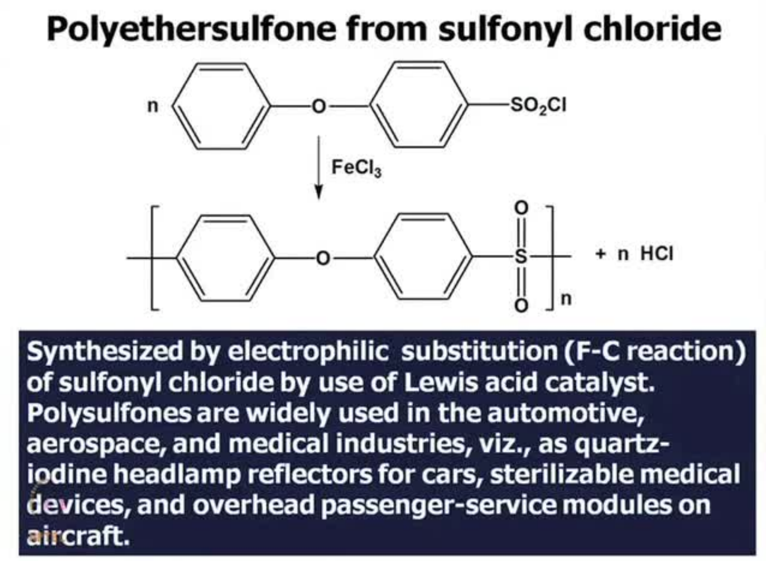

Polyethersulfone from sulfonyl chloride

Synthesized by electrophilic substitution (F-C reaction) of sulfonyl chloride by use of Lewis acid catalyst. Polysulfones are widely used in the automotive, aerospace, and medical industries, viz., as quartz-iodine headlamp reflectors for cars, sterilizable medical devices, and overhead passenger-service modules on aircraft.

Polyehersulfone can be prepared from by the reaction of a Friedel crafts reaction of sulfonyl chloride. Now, it is synthesized by electrophilic substitution through Friedel crafts reaction. This is the Lewis acid catalyst, ferric chloride and this is used for condensing, this sulfonyl chloride and such polysulfone, such polysulfone is widely used in the automotive industry for different automotive parts because it shows, very excellent high temperature resistance and excellent mechanical properties as well.

As it is also used in the aerospace and the aircraft or aerospace structures and is also used in medical industries, like some biomedical components are prepared or used of by biomedical components are made from this polyether sulfone. Say for example, this is quartz, as quartz iodine headlamp reflectors for cars sterilizable. Sterilizable medical devices and over head passengers service modules on aircraft.

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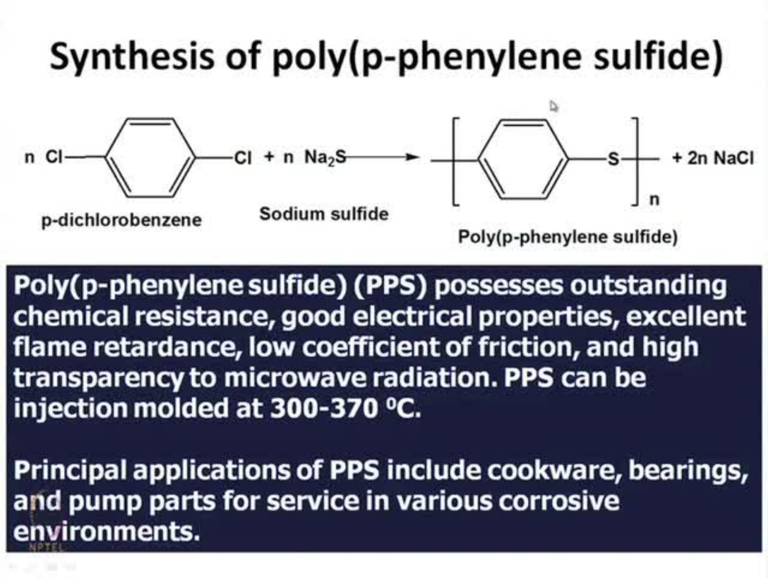

Synthesis of poly(p-phenylene sulfide)

Poly(p-phenylene sulfide) (PPS) possesses outstanding chemical resistance, good electrical properties, excellent flame retardance, low coefficient of friction, and high transparency to microwave radiation. PPS can be injection molded at 300-370 °C.

Principal applications of PPS include cookware, bearings, and pump parts for service in various corrosive environments.

Polyphenylene sulfide can be synthesized by reacting paradichlorobenzene with sodium sulfide, sodium sulfide. Sodium sulfide condensed with this polymer with this paradichlorobenzene monomer and form poly paraphenylene sulfide. This poly paraphenylene sulfide PPS possesses outstanding chemical resistance although sulfur is resent over here, it is resistant to very corrosive chemicals, reactive chemicals. So, resistant to chemicals and shows good electrical properties, excellent flame retardancy characteristics, low coefficient of frictions and high transparency to microwave radiation. And this is due to this or flame resistance properties, flame retardancy properties comes from the less amount of hydrogen present in the polymer.

Here the formula of the polymer, empirical formula of the polymer would be say 6 carbons and only 4 hydrogen’s and 1 sulfur, there is no more hydrogen or oxygen these are present. So, this polymer is not combustible since, amount of hydrogen is less there it forms char, if char formation occurs on at the flame temperature or when it comes in contact with flame or if there is any fire, if this polymer is present it forms char a charring effect. So, this flame retardancy effect is observed in case of polyphenole, polyphenylene sulfide.

This so far as the processability fabrication of this polymer is concerned, this polyphenylene sulfide can be melted at 300 to around 370 degree celsius temperature and it can be injection molded in this range of 300 to 370 degree celsius temperature. Major applications of this polyphenylene sulfide include cookware different types cooking ware can be made from this polyphenylene sulfide. We are accounted with some cookware, cooking wares there that is teflon coated metallic cookwares, but this polymer can be directly used for making that cookwares. Since, at it can withstand very high temperature.

Apart from cookware, this polymer is used for used in mechanic as mechanical parts, as bearings or gears mechanical gears or mechanical bearings. And some pump parts of some this pump parts can be made from this polymer for service in various corrosive environments. So, in terms of pump pumping of corrosive chemicals, corrosive liquids, the seals and gaskets or bearings or bearings in the pipe line, or the propeller of the pump those are actually made off this polyphenylene sulfide polymer.

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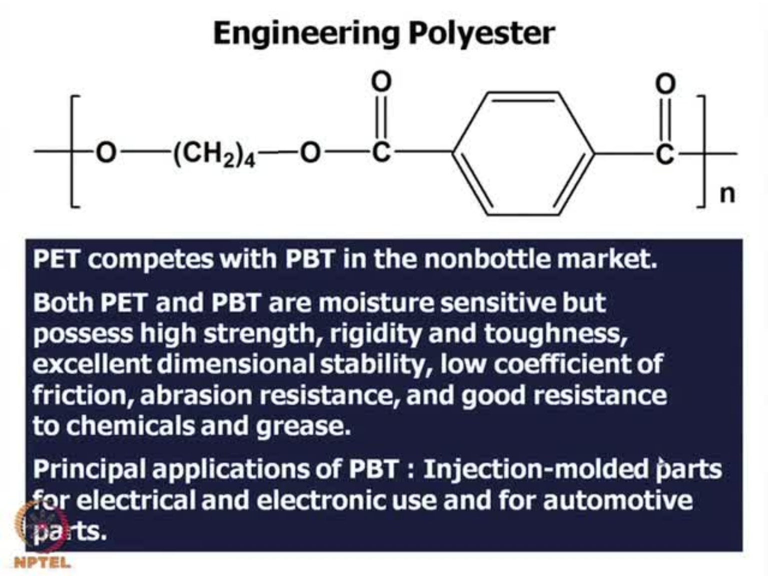

Engineering Polyester

PET competes with PBT in the nonbottle market.

Both PET and PBT are moisture sensitive but possess high strength, rigidity and toughness, excellent dimensional stability, low coefficient of friction, abrasion resistance, and good resistance to chemicals and grease.

Principal applications of PBT : Injection-molded parts for electrical and electronic use and for automotive parts.

Now, let us look into the polyester.

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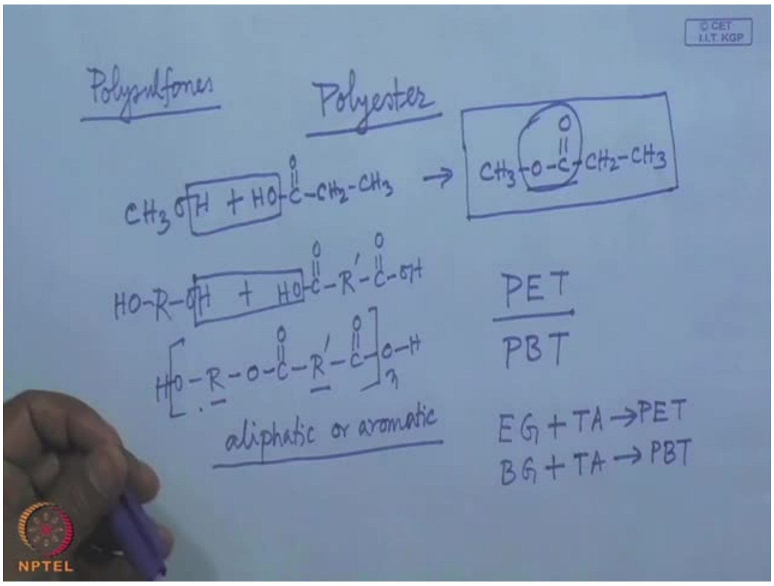

Now, what is polyester? This polyester is ester group is formed by the reaction of some alcohol group with some acid group. So, this acid group and alcohol group condensed to form ester, this is the ester function C O O ester group. This is an ester, this is a simple loom molecular with ester, it is not a polymer. Now, this principle of esterification has been extended to form to synthesized polyester by reacting a diol having two alcohol groups with a di-acid. Here also this condensation occurs between this acid and alcohol two form, this ester linkage. This is repeat unit; this is the ester. Now, this R and R prime can be either aliphatic or aromatic.

Depending on the nature of groups, we get aliphatic polyester if it is aromatic R and R prime is aromatic, we get aromatic polyester. Now, one well known polyester is PET polyethylene terephthalate. There can be another polyester, polybutylene terephthalate. Now, this alcohol part can be ethylene glycol or butylene glycol; if this ethylene glycol is condensed with terephthalic acid TA terephthalic acid, we get PET and this butylene glycol is condensed with terephthalic acid, we get poly butylene glycol PBT, but the properties of these two different polyesters are not same, you just have a look into the formula of this polyester.

This polybutylene butylene glycol is condensed with terephthalic acid to form this PBT. This is PBT formula and if there is 2 methylene units, it will be fluid. Now, PBT is suppose to be more flexible, PBT is suppose to be this polymer is suppose to be more flexible than polyethylene terephthalate. Polyethylene terephthalate can be available in the form of film, it can be available in the form of fiber, it can be used for making molded plastic products. Say paper bottles or drinking water bottles are made of PET polymer polyethylene terephthalate polybutylene, but PBT is flexible. Now, let us look into their properties correlating with their formula and structure, both PET and PBT are moisture sensitive because of the presence of this ester linkage, but they causes high strength.

They are rigid due to the presence of phenyl ring, and this polymer becomes tuff toughness property is good, because of the presence of this methylene in its which is flexible flexibility apart by this methylene rings, and rigidity is offered by this phenyl ring through this flexibility and rigidity are compromised, or adjusted in such a way so that one can achieve very high strength as well as high toughness. And this O excellent dimensional stability, low coefficient of friction and this O resistant's to abrasion mechanical abrasion, as well as a good resistance to chemicals and grease.

Now, synthetic garments fabrics majority of the today's synthetic garments are made from this PET fiber, polyethylene fiber PET polyester polyethylene terephthalate fiber, that is synthetic polyester and when that is also blended, or mixed with some trams cotton. So, cotton polyester blended fabric is available in the market and we are basically, very using such type of garments. Principle application of PBT is that can produce injection molded parts for application, in the field of electrical and electronic gadgets as well as for automotive parts.

So, that can be a computation between PET and PBT. Now, one can have purely aliphatic polyester. This ethylene glycol or butylene glycol, here it is condensed with aromatic aromatic diacid that is terephthalate acid. Now, this can also made from isophthalic acid. Now, if we replace this terephthalate acid with isophthalic acid having linkage at the meta position, we get a polymer and that would not be fiber grade polymer that can be used for making some molded plastic items. Apart from that this acid part can also be replaced with aliphatic; this aromatic acid part can be replaced by aliphatic diester that is say adipic acid.

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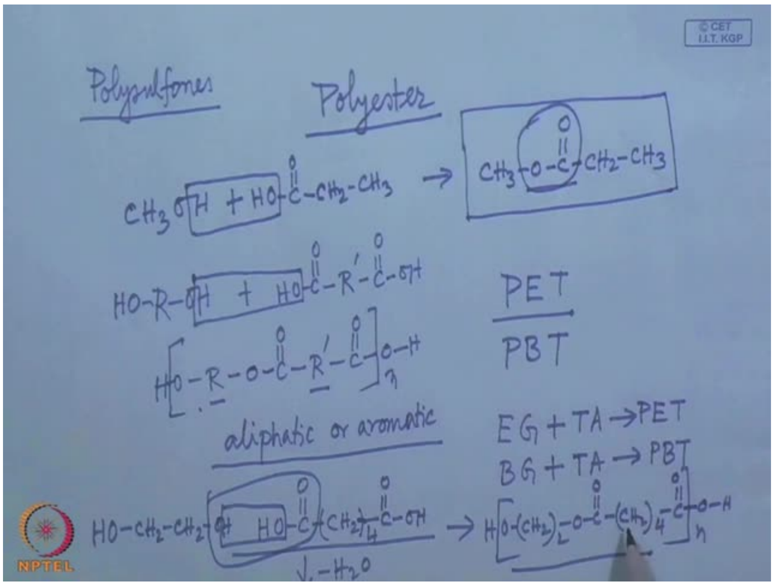

Adipic acid is 4 methylene units are linked to 2 carboxyl groups, this adipic acid. So, in place of this phenyl ring 4 methylene units have come and we can get this polymer, if we react with ethylene glycol. So, it will form a polyester having this ester linkage C O O. This H O H will go out as final H 2 O and will get a polymer. This is the repeat unit of aliphatic, purely aliphatic polyester condense with adipic acid and ethylene glycol. Now, it is its property is much inferior to that of either PET or PBT, but it can also be used as a fiber grade polymer, it will be highly flexible, but its strength will be inferior to that of polyethylene terephthalate or polybutadiene terephthalate.

Thank you.