Science and Technology of Polymers

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Lecture - 36

Multi Component Polymeric Materials (Contd.)

In the last lecture I discussed about the classification of definitions as well as the classification of polymer blends with some examples.

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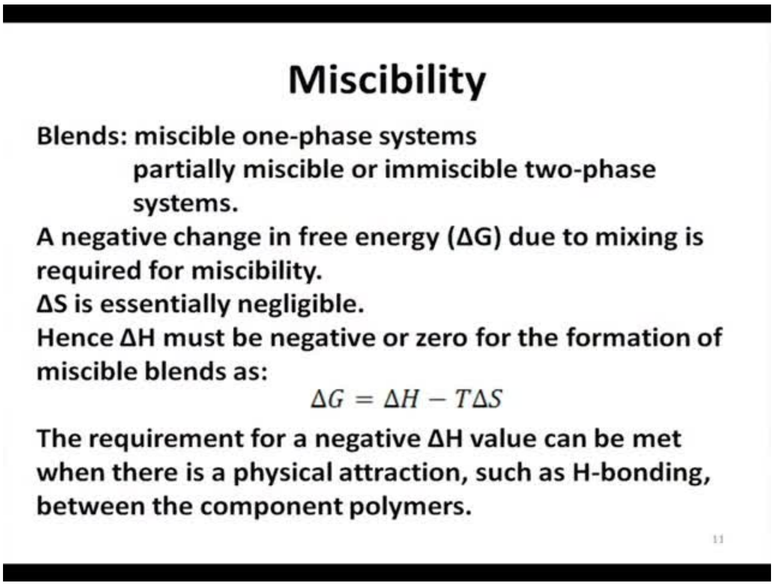

Miscibility

Blends: miscible one-phase systems
partially miscible or immiscible two-phase systems.
A negative change in free energy (ΔG) due to mixing is required for miscibility.
ΔS is essentially negligible.
Hence ΔH must be negative or zero for the formation of miscible blends as:

$$\Delta G = \Delta H - T\Delta S$$

The requirement for a negative ΔH value can be met when there is a physical attraction, such as H-bonding, between the component polymers.

Now, let us a little discuss on the miscibility aspects of, miscibility criteria of the component polymers to form a successful blend. The miscible blends can be, say miscible one phase system, it can be partially miscible system or immiscible two phase system, so partially immiscible two phase system or immiscible two phase system. Now, when these two components are mixed, we must considered this thermodynamic parameter, this delta G, free energy of mixing when the two component polymers are mixed, this delta G or thermo Gibbs energy mixing should be negative.

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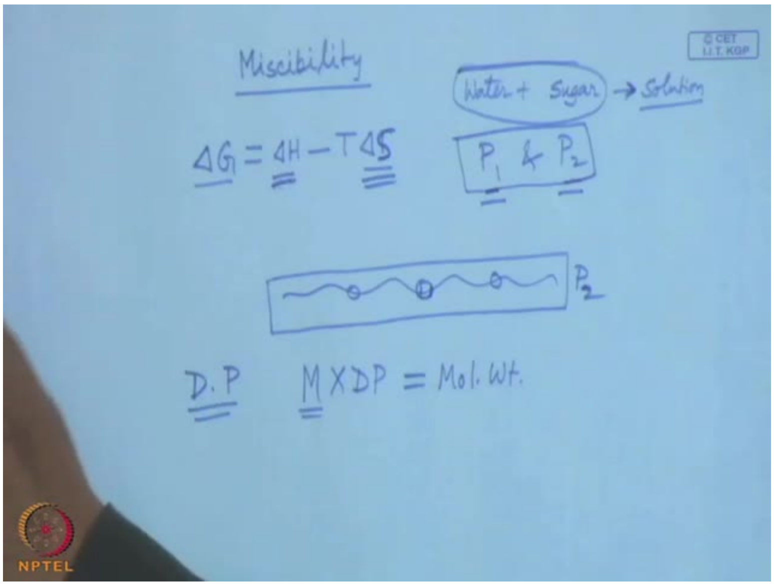

Now, in that case, we must consider this equation, a famous equation delta G is equal to delta H minus T delta S minus T delta S, where it is a phenyl mixing is an enthalpy change this is the entropy of mixing. This heat of mixing or in this entropy of mixing and T is absolute temperature. Now, here delta S is essentially negligible. Why? Because the component polymers are having P 1 and P 2 are having very high molecular weight. If you compare the miscible solution of this P 2 in P 1, say P 2 may be solute, P 1 may be the solvent, and in in this system both the components P 2 and P 1 are of very high molecular weight.

If we compare this system, with simple solution of sugar in water, when you put sugar in water this sugar dissolves in water, and we get a uniform solution, solution of sugar in water. Now, this sugar molecule is very, this size of the sugar molecule is very small, and size of the water molecule is also very small. Since, these two smaller units are mixed together having their close solubility parameter there are miscible, and they enter into solution have formed a uniform distribution of sugar molecules in water phase.

So, if we go details we can explain this phenomena of solubility, solution or dissolution phenomena with the help of liquid lattice model we can understand. Now, the picture is little different in case of polymer here, the in case of your simple solution the entropy of mixing of the sugar and water is quite high, because of their discrete molecular nature.

Here, the entropy of this polymers will be very less, almost negligible because of the high molecular nature. Now, a particular segment suppose this is a polymer chain, a small segment may be little mobile, but the mobility of the polymer molecule as a whole is not possible. Say for example, this P 2 mobility of P 2 in P 1 is not feasible that way. So, the entropy of mixing of P 1 and P 2 is negligible. Hence, the delta H must be, this delta H must be negative or 0 in order to make delta G negative.

So, delta H is very small, so in order to make this delta G is negative the delta H must be made very small or 0 or negative or 0 for the formation of miscible blends. Now, requirement for a negative delta H value can be met when there is a physical interaction, physical attraction between the component polymers, suppose hydrogen bonding. Now, there can, there are various models of this.

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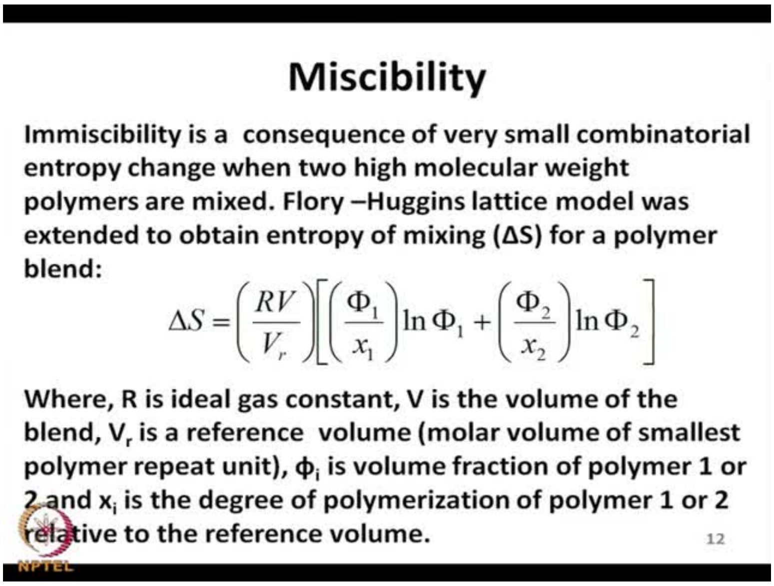

Miscibility

Immiscibility is a consequence of very small combinatorial entropy change when two high molecular weight polymers are mixed. Flory –Huggins lattice model was extended to obtain entropy of mixing (ΔS) for a polymer blend:

$$\Delta S = \left(\frac{RV}{V_r}\right)\left[\left(\frac{\Phi_1}{x_1}\right)\ln\Phi_1 + \left(\frac{\Phi_2}{x_2}\right)\ln\Phi_2\right]$$

Where, R is ideal gas constant, V is the volume of the blend, V_r is a reference volume (molar volume of smallest polymer repeat unit), ϕ_i is volume fraction of polymer 1 or 2 and x_i is the degree of polymerization of polymer 1 or 2 relative to the reference volume.

To explain the immiscibility or miscibility of the component polymers and this immiscibility is a consequence of very small combinatorial entropy change when two high molecular weight polymers are mixed. Now, the if you use this Flory- Huggins lattice model for, to in order to obtain entropy of mixing delta S for a blend of two polymers P 1 and P2.We can use this equation delta S equal to R V by V r into phi 1 by x 1 into ln phi 1 plus phi 2 by x 2 into ln phi 2 where R is ideal gas constant, V is the volume of the total volume of the blend of the component polymers P 1 and P 2.

And, V r is a reference volume of this smallest repeated unit of the two component polymers, of the molar volume of smallest repeated unit of the two component polymers. And phi i or phi 1 or phi 2 are the volume fractions of the two component polymers phi 1 is a volume fraction of P 1 phi 2 is the volume fraction of P 2 and x 1 or x 2 are the degree of polymerization DP that which is related to molecular weight DP. DP is related to the molecular weight of the polymer DP into n that means degree of polymerization.

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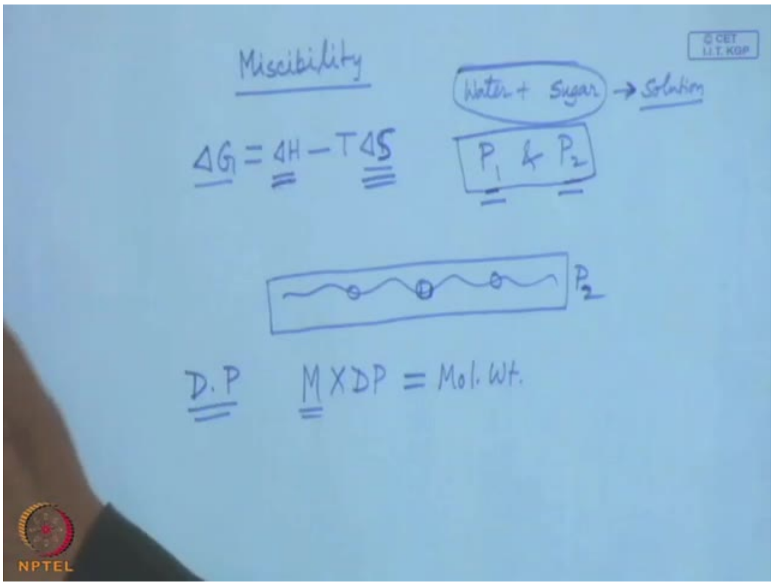

If, it multiplied by the number of small units that can be get the molecular weight of one of the molly unit into DP weight of the monomer unit into DP degree of polymerization we get the molecular weight of the polymer molecular weight of the polymer. So, in that case this x 1 is a degree of poly polymerization of the component polymer and next with the degree of polymerization of the component polymer two and they represent their are corresponding molecular weights. So, we can utilize this model in order to calculate this entropy of mixing of the two component polymers.

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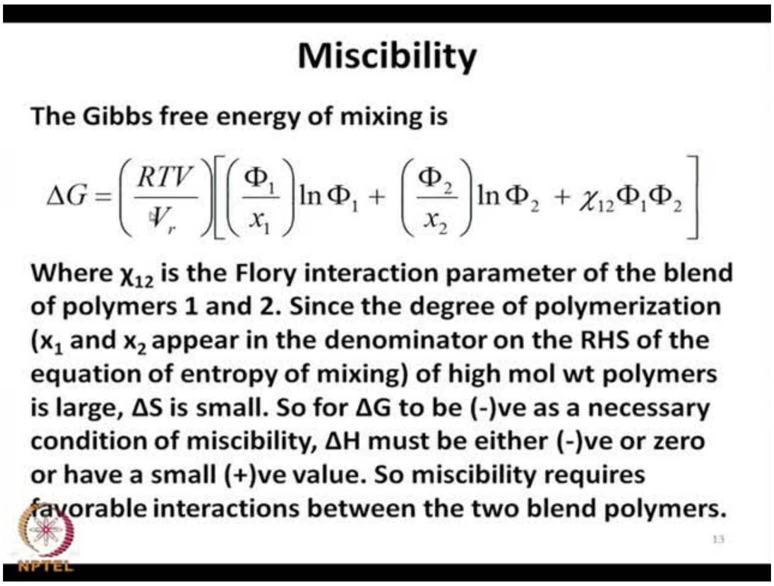

Miscibility

The Gibbs free energy of mixing is

$$\Delta G = \left(\frac{RTV}{V_r}\right)\left[\left(\frac{\Phi_1}{x_1}\right)\ln\Phi_1 + \left(\frac{\Phi_2}{x_2}\right)\ln\Phi_2 + \chi_{12}\Phi_1\Phi_2\right]$$

Where χ_{12} is the Flory interaction parameter of the blend of polymers 1 and 2. Since the degree of polymerization (x_1 and x_2 appear in the denominator on the RHS of the equation of entropy of mixing) of high mol wt polymers is large, ΔS is small. So for ΔG to be (-)ve as a necessary condition of miscibility, ΔH must be either (-)ve or zero or have a small (+)ve value. So miscibility requires favorable interactions between the two blend polymers.

And, this Gibbs Free Energy of Mixing is given by this relation delta G is equal to RTV by V r into phi1 by x 1 l n phi1 plus phi 2 by x 2 l n phi 2 plus an interaction parameter has been introduced in the third term aki. One two interaction between the component polymer one, and the component polymer two, these volume fraction of the product of volume fraction of the two polymers phi 1 and phi 2 this interaction parameter is nothing but the interaction of one polymer molecule with the another polymer molecule in the blend interaction can be of different nature or a sum of different types of interactions between the two component polymers.

That can be through some chemical reaction of the two component two functional groups of the two different polymers or that can be hydrogen bonding that can be entanglement between the segments of the two polymer chains. Or there can be hundred walls interaction or secondary interactions arranging out of the (( )) dispersion force. So, this interaction parameter which is again related to the solubility parameter of the two component polymers this is very much important and with the help of these parameters one can calculate the Gibbs Free Energy of Mixings.

Since the degree of polymerization x 1 and x 2 of two component polymers appear in the denominator the right hand side of the equation of entropy of mixing this this one entropy of mixing will be of high molecular rate polymers is very large, and therefore the delta S is very small, so that means this x 1 and x 2 comes in the denominator. So, the delta S delta delta S the component becomes very small. So, in order to get delta G to be negative as a necessary condition of miscibility, then there is no other option, but to have this delta G negative or 0 this delta G to be negative or 0 or very small positive value.

If even if it is positive that is very small, so the, this this term becomes bigger, so ultimately it becomes negative and delta G will become negative. So, miscibility requires favorable interactions between the two polymer blends, so that is actually known from this equation where this interaction parameter is included.

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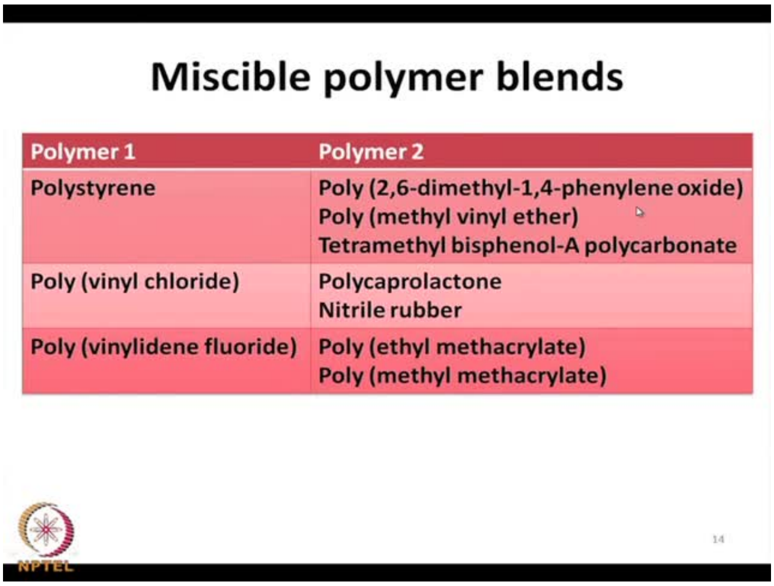

Miscible polymer blends

Polymer 1	Polymer 2
Polystyrene	Poly (2,6-dimethyl-1,4-phenylene oxide) Poly (methyl vinyl ether) Tetramethyl bisphenol-A polycarbonate
Poly (vinyl chloride)	Polycaprolactone Nitrile rubber
Poly (vinylidene fluoride)	Poly (ethyl methacrylate) Poly (methyl methacrylate)

Let us look into after having this miscibility criteria let us see the successful polymer blends say polymer blend of polymer one with polymer two say if the polymer one is polystyrene then what could be the second component polymers that can be say one example can be poly 2, 6 dimethyl 1, 4 phenylene oxide. So, polystyrene with this polymer can have a good blend polystyrene with poly methyl vinyl ether can be a different blend new blend of polymers of polymer blend polystyrene with tetramethyl bisphenol a polycarbonate again a new polymer blend.

If you want to develop some polyvinyl see polarity in a polymer come a blend in a polymer product we can take polyvinyl chloride as one of the components. Now, we can mix polyvinyl chloride PVC with polycaprolactone that is a biological polymer or biologe that is your biodegradable polymer. So, we can mix polyvinyl chloride with poly carbonate or we can take the poly PVC PVC as the, as the matrix in which we can include little amount of the polycaprolactone, then we can mix or we can have mixer blend PVC with nitrile rubber.

Now, PVC nitrile rubber blend is a very successful blend for electrical insulation electrical cables electric cables, cables nitrile rubber PVC blend, so nitrile PVC blend very good for electrical electric cable, application electric cable for heavy duty electric cable for high voltage electric cable undergone high voltage electric cable this after polyethylene insulation.

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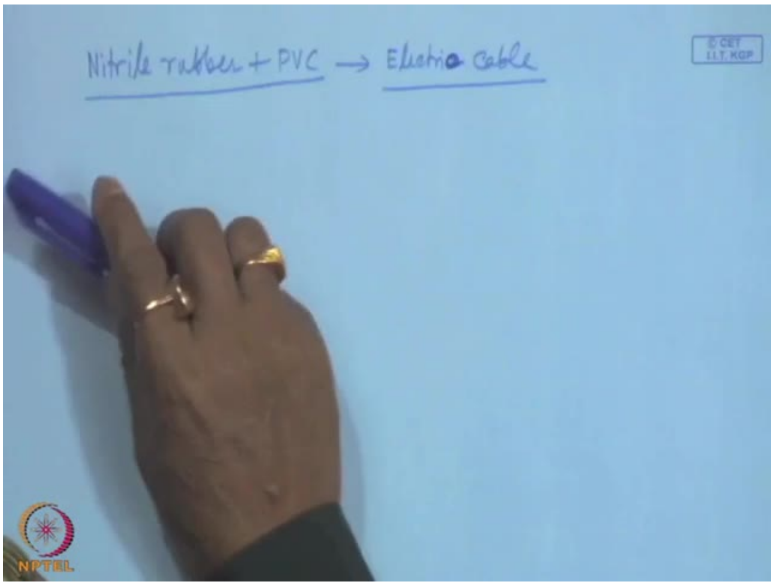

Nitrile rubber + PVC → Electric cable

This nitrile PVC blend is used as a shear material shearing material or PVC is used to quote conductors for domestic wearing then polyvinyl chloride is a chlorinated polymer that can also be blended with poly ethyl methaycrylate or that can be blended with poly methyl methacrylate. Now, this they are blending capability their miscibility can be understood if their chemical structures are written if their looking into their chemical structure one can understand their miscibility of this these component polymers mentioned in this table.

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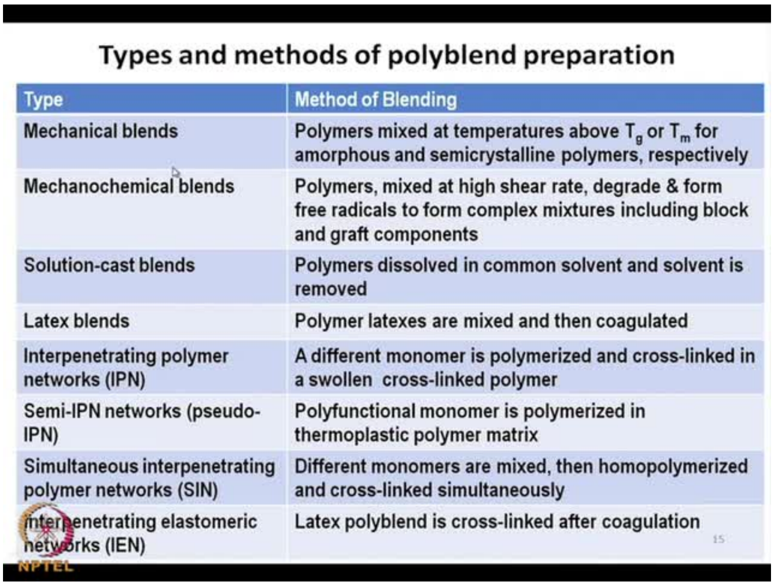

Types and methods of polyblend preparation

Type	Method of Blending
Mechanical blends	Polymers mixed at temperatures above T_g or T_m for amorphous and semicrystalline polymers, respectively
Mechanochemical blends	Polymers, mixed at high shear rate, degrade & form free radicals to form complex mixtures including block and graft components
Solution-cast blends	Polymers dissolved in common solvent and solvent is removed
Latex blends	Polymer latexes are mixed and then coagulated
Interpenetrating polymer networks (IPN)	A different monomer is polymerized and cross-linked in a swollen cross-linked polymer
Semi-IPN networks (pseudo-IPN)	Polyfunctional monomer is polymerized in thermoplastic polymer matrix
Simultaneous interpenetrating polymer networks (SIN)	Different monomers are mixed, then homopolymerized and cross-linked simultaneously
Interpenetrating elastomeric networks (IEN)	Latex polyblend is cross-linked after coagulation

Now, let us look into different types of blends and methods of their preparation, say there can be a type of blend known as mechanical blend such mechanical blend are obtained by mixing of the polymers at temperatures above glass transition. In the component polymers amorphous if the, if two component polymers of amorphous, so those two component polymers can be mechanically mixed in mechanical blenders say like polymer mixer say two row mixer or a internal mixer by heating the polymer above their glass transition.

Above their glass transition the polymer will become very soft and flexible, and then those two component polymers can be amorphous component polymers can be mixed if the polymers are semicrystalline in nature. Then the polymers have to be further heated to higher temperature beyond Tg near to their melting temperature or softening temperature. At that softening temperature the component polymers semicrystalline component polymers can mix easily and it form a blend that is known as mechanical blending.

Now, mechanochemical blending or mechanochemical blend that is another class of polymer blend which is prepared by simultaneous application of mechanical shearing as well as some chemical reaction. So, mechanical shearing and chemical reaction both help mixing of the component polymers, and they are mixed at high shear rate high shear rate it is two component polymers are stirred at a very high shear rate. And the polymers degrade during such shearing mechanical shearing and form generate due to the cleavage of pyrolysis of chemical bonds that forms free radicals those free radicals form complex mixtures of different ingredients developed or produced from the component polymers and that can form block and graft components also.

So, this way by mechanically two polymer components are mixed, and during such mixing at high shear rate what happens chemical bonds are broken. That means the polymer molecules are degraded during such degradation during the breaking of the polymer chemical bonds free radicals are created those free radicals interact with each other to form a new product. And that can be a kind of graft polymer produced by mechanochemical mixing blending or that can be a complex mixer of a block co-polymer graft co-polymer.

Graft components we should not say co-polymer block or graft components then solution cast blending now sometimes there are certain polymers which are really difficult to dissolve in some solvents in that case we can go for mehcano chemical blending, but mechanical blending by mechanical shearing. Now, there are certain polymers which can be dissolved in some suitable solvents, solvents are available in those cases the solvents selected with the proper after proper selection of proper solvent composition the component polymers are dissolved in a common solvent.

They are mixed and after mixing the solvent is removed by evaporation and that can be collected recovered for reuse and the product is a becomes a blend of two component polymers. So, in some cases we can use some solvents for solution blending if it is not allowed then we can go for mechanical blending or mechano chemical blending. Now, there are certain problems with the solution class blends, because this is, this cannot be a an environmental friendly technique. Now basically these are organic solvents these organic solvents.

Basically these are organic solvents, these organic solvents are not environmental friendly. This leads to different hazards health hazards. So, it is better to avoid use of organic solvents, but in case of some, some speciality applications special cases the solution cast blends blending technique can be formed. Then latex blends, now there are certain polymers which are synthesized by emulsion polymerization technique.

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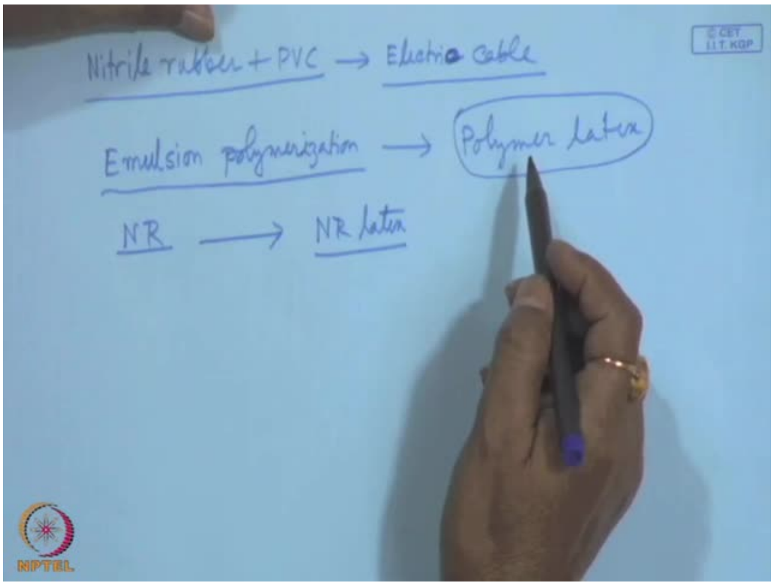

Nitrile rubber + PVC → Electric cable

Emulsion polymerization → Polymer latex

NR → NR latex

Now, emulsion polymerization leads to form a polymer latex ultimately the polymer is obtained in the latex form that means polymer molecules are dispersed in a dispersion medium with which are stabilized by emulsifier molecules, so that is known as polymer latex. Now, this polymer latex can be used directly to make some product or the polymer is coagulated for isolation the emulsion form latex to obtain a dry polymer. Now, this is, this is a case of synthetic polymer latex that means polymer produced by emulsion polymerization technique artificially.

Now, there are some naturally occurring latex say natural rubber natural rubber latex produced by Hebia Brasicilancies tree that is also a latex known as NR latex . So, we can have polymer emulsions or polymer latex either we can isolate the polymer from the latex to form to get dry polymer. And you have seen mixing or blending of dry polymers involve huge machineries in that you needs huge energy consumption as well as involvement of high energy shear mixing we can avoid that, if you go for latex blending that means blending at the latex stage.

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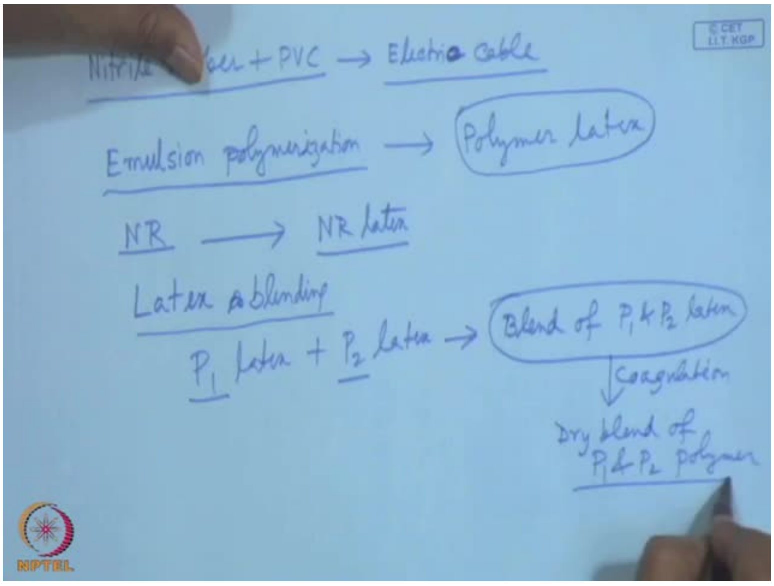

That is we can have a P 1 latex we can mix this P 2 latex with the P 2 latex emulsion of P 1 polymer can be mixed with emulsion of P 2 polymer then after mixing after mixing in the latex stage, then we can have a blend of P 1 and P 2 latex. Then we can go, we can go for coagulation we can coagulate, we can coagulate this blend latex blend we can have a dry blend of P1 and P2 polymer. Then next is interpenetrating polymer network IPN. This is case where a different monomer is polymerized and cross linked in a swollen cross linked polymer.

So, we can have a polymer one which is already cross-linked than that is put in a solvent or in liquid phase of second liquid phase of monomer of the second polymer which will swell the first polymer first cross-link polymer, so we take a cross-linked polymer say polymer P 2 or polymer P1. Any of the two polymer in cross-linked stage we place it in the monomer of the second polymer which will swell this cross linked polymer than after swelling of this cross linked polymer by the monomer of the second polymer this monomer will be polymerized.

So, this polymer of this monomer polymer of this monomer will be grown inside the cross-linked network of the first polymer. So, this way the product which is formed that is known as interpenetrating polymer network there can be a semi-interpenetrating network or we can say a pseudo interpenetrating network polymer. In this case we have to consider a different kind of monomer with functionality is more than two, that is poly functional monomer say for example, glycerol. Glycerol is a tri functional monomer or penta erythretal penta known as penta penta erythretal containing four hydroxyl group.

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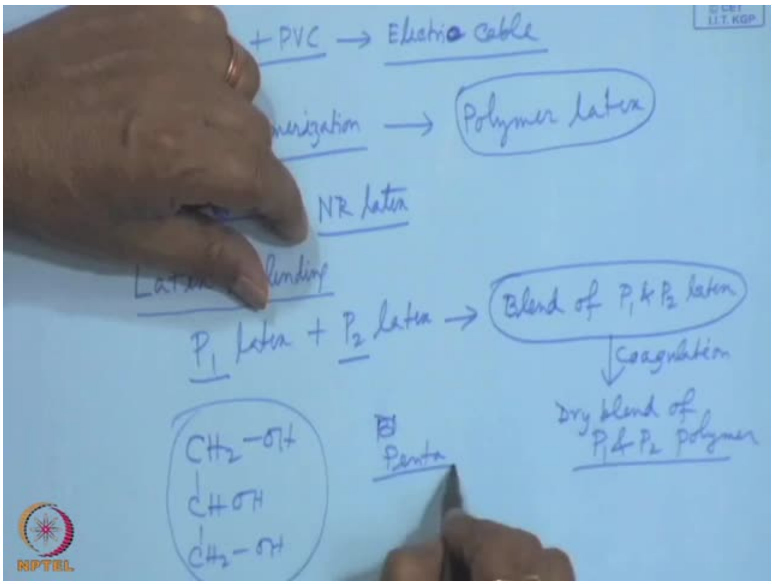

So, such type of functional poly functional or we can take phenol that is a tri functional monomer, so this way we can use poly functional monomer which can be polymerized in a thermoplastic in a second thermoplastic polymer matrix. So, thermoplastic polymer matrix will constitute one network of one polymer in which a second monomer having more than two functional groups is polymerized, and that we lead to again a three dimensional network system in within the thermoplastic matrix that is known as semi-IPN.

Since, it is thermoplastic it is not cross-linked where as is poly functional monomer having functionality more than two that will form a three dimensional cross linked network. So, this is cross linked this is not cross linked, so we call it a semi-IPN network or pseudo IPN network polymer network blend. Simultaneous interpenetrating polymer networks, so different monomers are mixed together then they are homopolymerized and cross-linked simultaneously that leads to simultaneous interpenetrating network system.

Then, interpenetrating elastomeric networks IEN in that case latex polyblend as i-i just described few minutes back that latex polyblend if it is cross-linked after coagulation here this coagulate it is coagulated latex blend is coagulated. Now during coagulation we can mix some cross-linker along with the coagulants along with the coagulating agent, so you have to add coagulating agent and along with coagulating agent.

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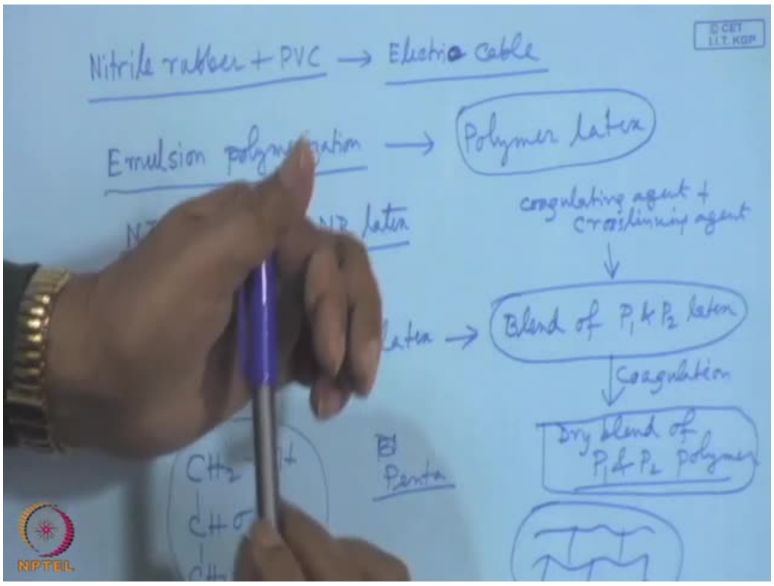

We must add some cross linking agent which will remain dormant even passive during coagulation stage after coagulation of the two component polymers along with this cross-linking agent it is washed and purified. Then it is given a safe and heated in an oven or in an mold fire during heating this cross-linking agent present in this coagulated polymer blend will decompose to form some active ingredients which will form a three dimensional network of the polymer chain appears that means that will leads to a cross linked polymer morphology. So, that kind of kind of system is known as latex inter interpenetrating elastomeric network and it is done from the latex stage itself.

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Equipment used in the preparation of PAB

1. Batch Mixers:
   a) Roll mills
   b) internal mixers
   c) Kinetic mixers

2. Continuous Mixers
   a) Single screw extruders
   b) Twin-screw extruders
   c) Single-shaft intensive mixers
   d) Twin-shaft continuous intensive mixers
   e) Disc extruders
   f) Motionless mixers
   g) Others

Let us look in to the different types of equipments equipment necessary in order to make this polymer alloys and blends. Now, this can be such mix mixing equipment can be of batch type or continuous type. Roll mills say open roll mills, the cross section of open roll mills look like this the cross section view of one roll the cross sectional view of the other roll. The gap between this two roll is known as nip nip gap. Now, this polymer actually row polymer material component polymers are placed over the roll surface.

These two rolls rotate in opposite direction not only that in order to get this shearing action between this gap nip gap in if in the nip gap these two rolls rotate in different cell rpm. That means rpm of, rpm rpm of the first roll can be if can be say suppose eighteen the rpm of the other roll, other roll can be suppose 15. So, what happens? This stationary roll? So, the faster roll rpm this this roll rotates at higher speed than this roll.

So, at any instant of time one roll appears to be stationary to the other roll that provides the shearing action over here, and that shear action breaks down the molecular chains polymers or that generates heat and it makes the polymer soft decreases the viscosity. So, by this principal we get a mixing of this components polymers two roll mill and internal mixing is a variation of this open mill.

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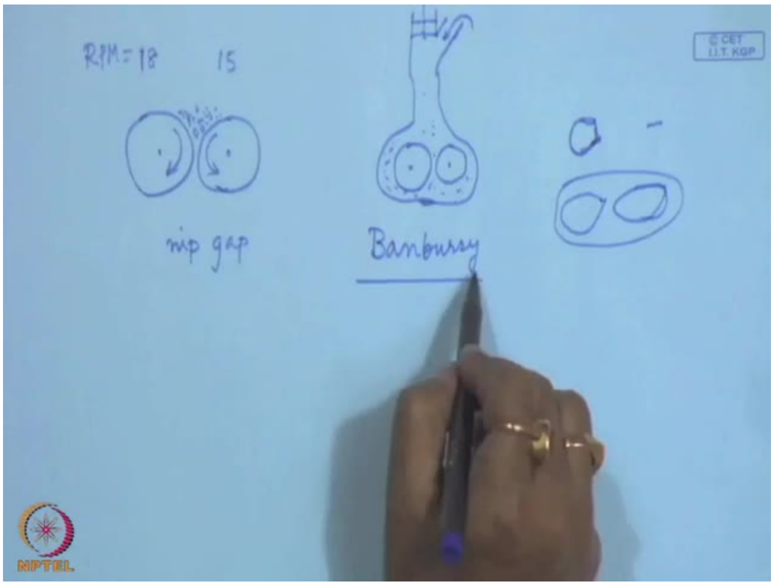

The cross sectional view of this internal mixer, again that is basically enclosed in a chamber, and here also the design of the roll is not circular a wheel a wheeled circular it is a not circular that can be of different design that can be of this design not, not like this camp type .It can be camp type design, camp type design rooted design is different that can be actually modified depending on the necessity of amount of shear necessary over here ,here.

We can get this shear action at the between the gap at the gap of between the two rolls rotors as well as these are wall stationary wall of the chamber where we can have also shearing action now there is some. So, the polymer can be inserted through this hopper and there can be ram which can this ram can be moved up and down this way to, to carry this material from the hopper into this zone. So, this way we get this we can have a facility of polymer mixing in a closed chamber and that can be dumping door at the bottom.

So, after mixing the mixed product can be dumped down from here, so that is known as internal mixer, so there are various type of internal mixers say banburry mixer or there can be many other names. So, internal mixer or kinetic mixers, so these are all batch mixer that means after mixing of one batch again the second batch is to be loaded then it gets helps in mixing so through shear action get this mixing in this batch mixer then we can have a continuously mixer. Now, continuous mixers are well known these are actually basic basically a screw extruders having a single screw or a double screw twin screw and basically this extruder looks like this.

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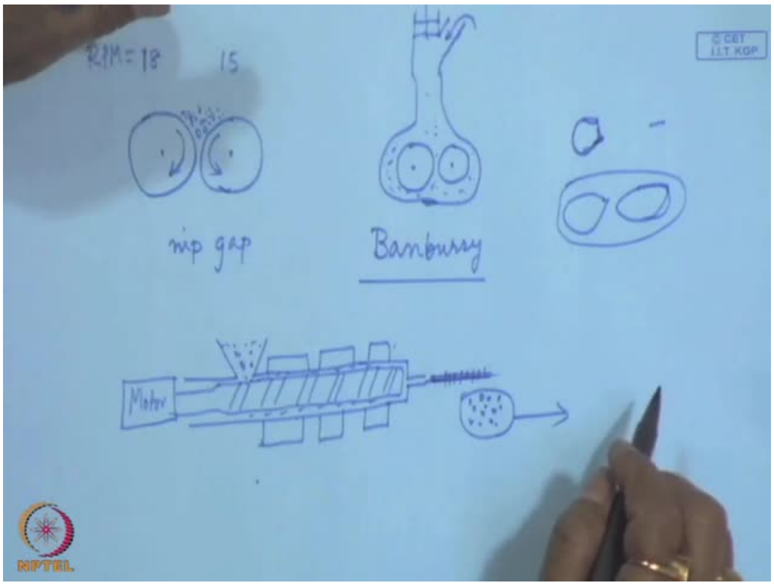

So, this is a screw this is known as the barrel, this barrel is having some heating zones provided with heaters having different heating zones. So, material is actually inserted from the hopper into the extruder and screw flides are there, so this is rotated by a motor. So, motor rotates this screw, and this gives enough shear action between the barrel of the extruder and between the barrel and screw of the extruder and ultimately the this polymer is carried and there is some heating provision all these things.

So, it decreases the viscosity and gives efficient mixing of blending of the component polymers and then ultimately it comes out of the dye, and this is also a technique for manu, manufacturing say pipes, tubes, coating of wires etcetera, etcetera. And also it is used for blending of the component polymers, so this extruder can be a single screw extruder or that can be a twin screw extruder within the same barrel. So, twin screw extruder, extruder is a modi kind, modi kind modification of the open to two roll mill, two roll mill.

So, it is modification of again internal mixer ,internal mixer in a continuous way, so continuously polymer is fed to the screw extruder hoper and continuously this polymer after mixing it comes out, and it can be chopped to form polymer granolas mixed polymer granules . So, in the form of granules or tablets or rods we can have the blended polymer. Then this can be further used for the subsequent processes to make different types of products, say it can be used for index injection molding of prop products it can used for extrusion of pipes or tubes or insulation of coppering of the electrical conductors these things.

So, you can have different type of the screw extruders say single screw extruders twin screw extruders single shaft intensive mixers twin shaft continuous intensive mixers disc extruders motionless mixers others. Since, there is a scope of discussion in, in details of this different types of batch mixers or continuous mixers just a mention is sufficient about the different types of mixers available for making the polymer blends.

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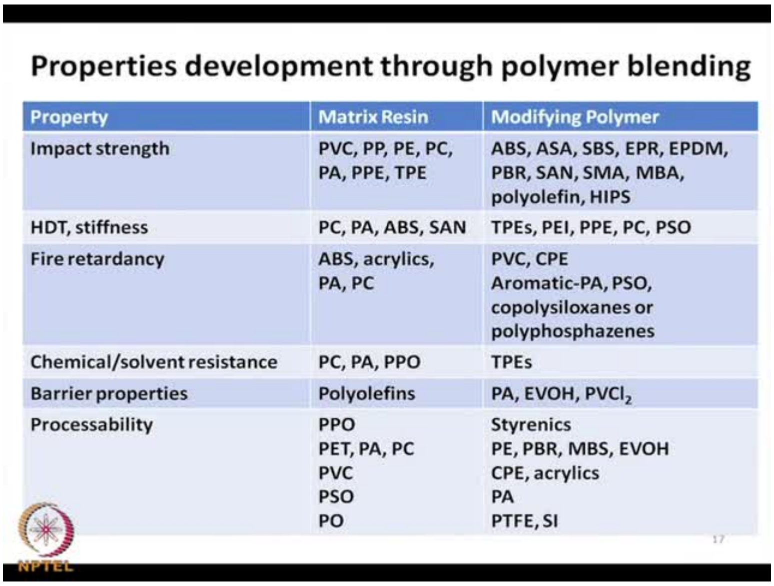

Properties development through polymer blending

Property	Matrix Resin	Modifying Polymer
Impact strength	PVC, PP, PE, PC, PA, PPE, TPE	ABS, ASA, SBS, EPR, EPDM, PBR, SAN, SMA, MBA, polyolefin, HIPS
HDT, stiffness	PC, PA, ABS, SAN	TPEs, PEI, PPE, PC, PSO
Fire retardancy	ABS, acrylics, PA, PC	PVC, CPE Aromatic-PA, PSO, copolysiloxanes or polyphosphazenes
Chemical/solvent resistance	PC, PA, PPO	TPEs
Barrier properties	Polyolefins	PA, EVOH, $PVCl_2$
Processability	PPO PET, PA, PC PVC PSO PO	Styrenics PE, PBR, MBS, EVOH CPE, acrylics PA PTFE, SI

Then, let us look into the properties of polymer blends which are developed after mixing, say you on to improve the impact strength, that means you want to modify the impact strength of a polymer. What to be done say suppose we have a PVC, it is having some impact property polyprophelene polyethylene these are all home polymers. So, we want to modify the impact property of this homo polymer separately these are all example placed together in one place, in one place, so in one place over here. So, if you want to modify the property PVC, so we have to we can make a blend of PVC with any of this polymers depending of the, the impact property which is needed.

One good example can be said polystyrene polystyrene is a brittle polymer, polystyrene is a brittle polymer to include the impact properties of polystyrene. If we can make a blend of polystyrene with little bit of poly buterene say polystyrene is a brittle polymer that means a low impact polymer to the slow impact polymer. if you, if we mix poly buterine rubber little bit say ten percent or twenty percent or thirty percent of poly butylene rubber with polystyrene.

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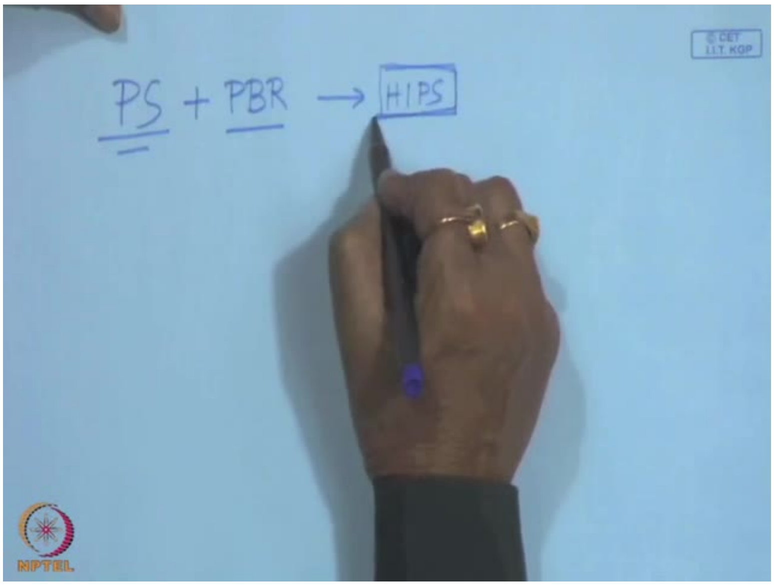

We can get high impact high impact polystyrene, so high impact polystyrene get basically it is made by blending of a little portion of polybuterene or other elastomer with polystyrene we get high blend having input impact strength. So, if we take the this stabilize guide line, so this PVC PP PE PC poly amide poly vinyl ether or thermoplastic elastomers all these things this can be the used for making a polymer blend having high impact strength. And these are considered as modified polymer ABS SBS EPR EPDM polybuterene style lacto nitrate polyolefin high impact polystyrene, so this can be used for blending with this any of this matrix resins to have newer products.

Heat deflection temperature or stiffness now the heat deflection temperature can be that means, it should demand dimensional stable at elevated temperature or in thermal environmental to increase that heat deflection temperature means it should not deflect within the ah during solvents. So, what is the heat duplex and temperature for one particular application means that the polymer should be should maintain its dimension at that elevated temperature. So, that heat deflection temperature polymer can be changed or improved or can be decreased by considering the blend of this polymer matrix resin with these modified polymers stiffness can also can also be increased.

Say these are the matrix resin matrix polymers polycarbonate polyamide acrylyte butel styrene ,styrene acrylate nitrile. So, thermoplastic poly, so thermoplastic astromous can be used polyetheyl amide can be used poly phenyl ethyl can be used polycarbonate again can be used with another polycarbonate PVC or PC polycarbonate with ABS or PC with thermoplastic astromous. Fire retardancy can also be included in one polymer is not retardancy which is not retardancy to fly say ABS acrylics butyle butelin styrene acrylates polyamide poly carbonate these their fire retardancy arise is not good.

So, in order to make them resistant to fire or fire proof or improved fire retardancy then one can mix abs with PVC or one can mix ABS with chlorinated polyethylene or one can mix say ABS with aromatic poly amide or poly sulphone or co polysiloxanes or polyphosphazenes. So, these polymers are used as an additive to improve the fire retardancy property in this matrix resin either of the matrix resins, so this when these polymers are used as additive that they are used in little higher concentration. So, it is better to tell them as modifying polymer instead of additive.

Chemical and solvent resistance now this chemical resistance or solvent resistance in one polymer can be improved by bending say poly carbonate polyamide poly phenyl ethers. So, their solvent resistance can be changed by mixing with thermoplastics elastomars barrier properties say polyolefins barrier properties polyolefins like a polyethylene or polyprophylene can be changed by mixing with polyamide nylons or polyesters or, or ethylene or vinyl alcohol or poly chloride polyvinylchloride.

Say for example, in case of duplexable packaging of liquid products likes a milk or oil milk and oil, so those flexible packaging pouches where this milk is packed or or oil is packed. Now, that that frame should be mechanically strong enough as well as there should be that master good barrier properties that is why such type of milk packaging film or well packaging film those are basically known as laminated films.

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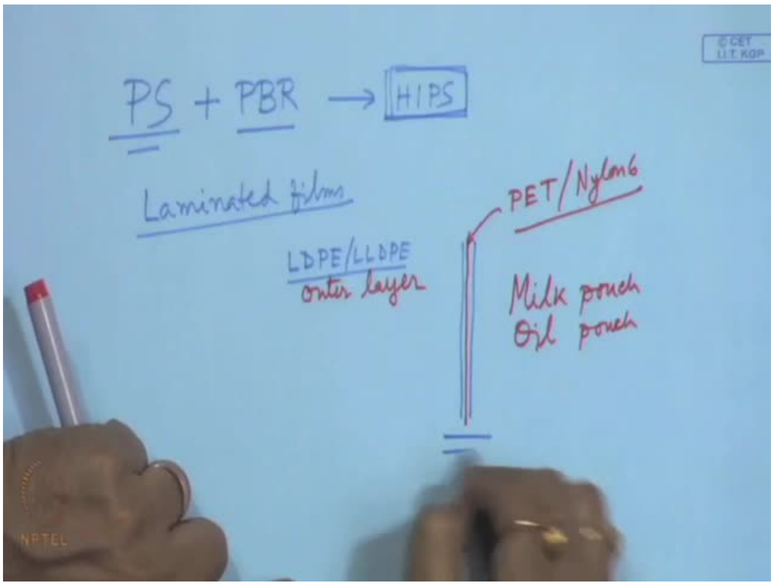

Those laminated films are made of basically a blend of LDPE and LLDPE. Now, this is this LDPE LLDPE blend is used as the outer layers within this two outer layers there is a third film either this third film is either polyethelene teritalate or nylon 6. So, this helps in developing the barrier properties in between this LLD LDPE LLDPE blend.

So, this is a laminated film basically this milk pouch or oil pouch these are laminated films the where the outer layer is made of LDP LLDPE blend and the inner layer is known as the barrier layer known as the polyethylene teritalate and nylon six, so barrier properties are developed in this fashion. Then process ability in order to improve the process ability is not so easy as that all polymer are possible, are process able. So, for example, say polybutyle rubber the process ability of polybutyl rubber is not good.

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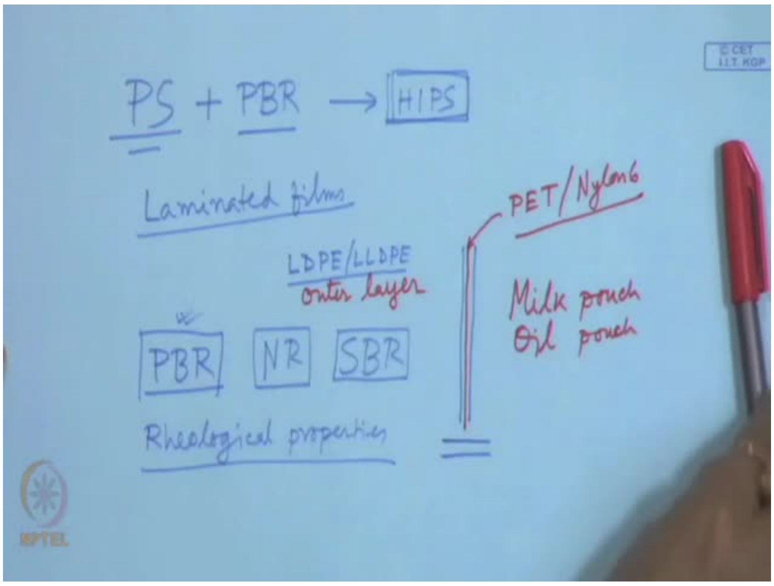

Whereas the process ability of natural rubber is very good process ability of SBR is also very good. So, process ability I mean the compounding of this polymer as well as setting and fabrication of the compounded polybutyl rubber with some other additives that is not good in order to improve the process ability we can use little amount of a natural rubber or SBR with this polybutyl rubber. Similarly, process ability of other thermoplastics polyaliphenes or other polymers say (( )) polymers.

Now, there are rheological properties is that prove here during compounding as well as fabrication that can be altered or modified by mixing with some other polymers. I mean say, it becomes very difficult to mechanically, mechanically mixed two component polymers due to their high viscosity or their degradability then a second polymer can help to develop good process ability that means viscosity or flow characteristics during extrusion or injection molding or film blowing.

So, here say polyphenyl process polyphenyl oxide can be good some quantity of styrene polymer can be blended with polyphenol oxides. Similarly, polyethylene teritalate polyamide polycarbonate their process ability is modified or encamped by use of small quantity of polyethylene or polybutelene rubber or ethylene vinyl alcohol etcetera than PVC with chlorinated polyethylene acrylics polysulphones with polyamide polyolefins with ptfe and other polymers.

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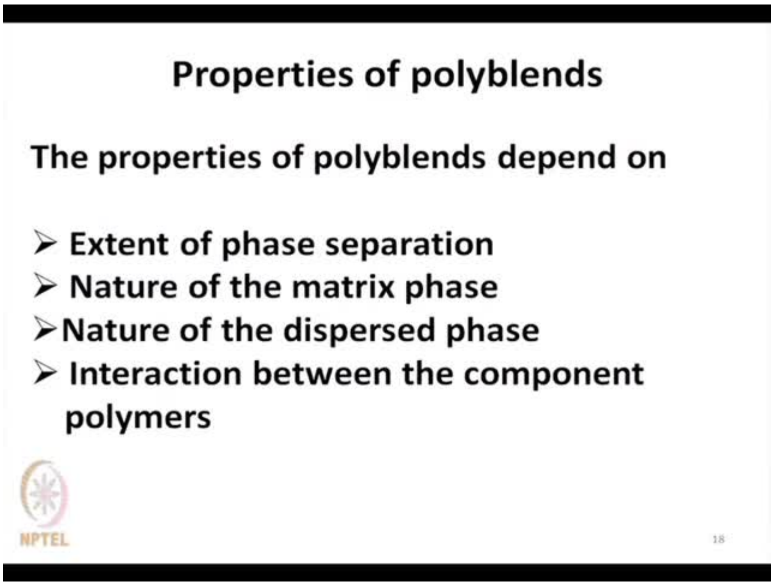

Properties of polyblends

The properties of polyblends depend on

- **Extent of phase separation**
- **Nature of the matrix phase**
- **Nature of the dispersed phase**
- **Interaction between the component polymers**

Then the properties of polyblends ,the properties of polyblends depend on the extent of phase separation as I was discussing about the phase separation aspect nature of the matrix phase nature of the dispersed phase interaction between the component polymers. So, these four different issues are very much important in order to have optimum properties level as well as broad spectrum of the properties.

There should not be separation into different phases, and matrix nature of the matrix phase should be such that the, the become interactive show interface addition between the component polymers should be good. And the we must look into the nature of the dispersed phase, so that it becomes miscible with the matrix phase then interaction between the component polymers.

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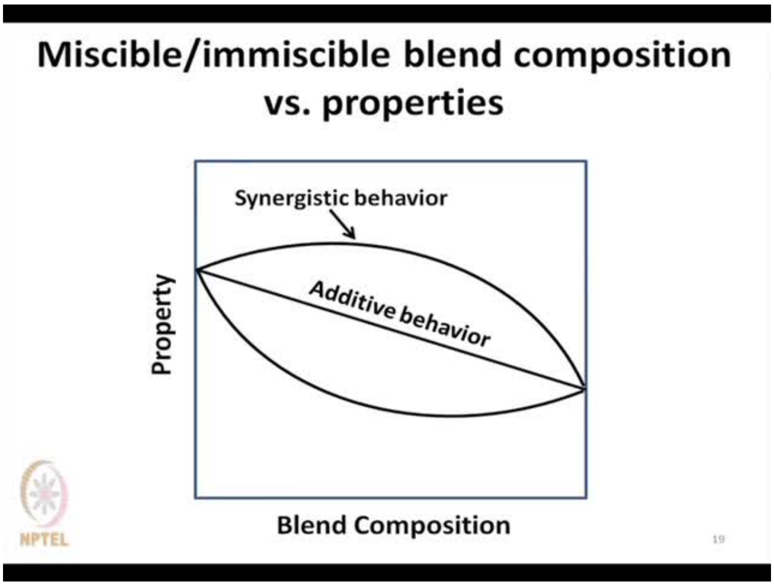

Miscible/immiscible blend composition vs. properties

Now, let us have a look into effect of miscibility immiscibility of blend composition on the properties of that polymer blend now here this is the composition axis, this is the property axis now here this axis, this axis can be for a pure component polymer.

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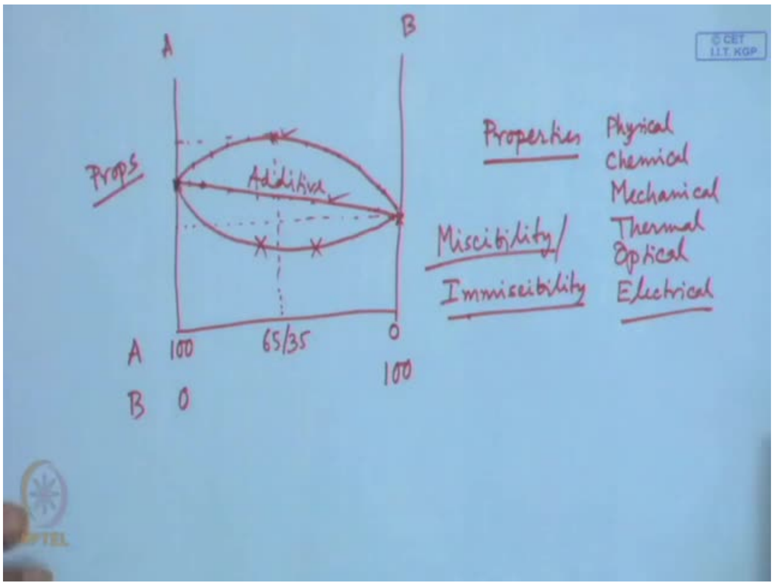

Say component polymer component A component B now this is hundred percent over here this is zero here, it is 0 here it is hundred, so this is the properties axis of pure B this properties axis of pure A. When we mix say 10 percent of B with 80 percent of A similarly, 30 percent of B with 70 percent of a 60 percent 40 percent of B with 60 percent of a 50, 50, 50 and gradually decreasing the amount of A from here to this axis, and increasing amount of B from here to this axis.

We will have a full range of composition, and we can make a infinite number of blends of A and B taking intermediate compositions. And one can evaluate the properties of those properties of those different compositions properties. I mean that can be physical properties, that can be chemical properties that can be mechanical properties that can be thermal properties that can be optical properties, that can be electrical properties, so and so. So, in general these properties can change suppose here lies the property of A, and here lies the property of B, so if we add this two points will get an additive line that means if we gradually mix A with B for B with A.

So, property changes like this, that means if you have more proportion of A less proportion of B. Then we can have a property over here that means it have this line. So, this is known additive. This is actually additive line additive behavior then we can have a synergistic line like this. That means there can be some composition. Say here it is, so here it is suppose say 65 35, for example, 65 35, 65 35 composition can give maximum properties which is neither available from this A nor B.

That is a kind of synergistic behavior that this are the benefit of such polymer blends having intermediate compositions which is neither available with A nor available in B there can be another situation where this properties line remain below the additive line. Thus that is the system may not be useful where as this can be useful or this can be useful at certain compound at any composition helpful, so we can remain at any point where you like or any point where you in the additive case we can diminish.

This way we can get improved properties by blending of the components polymers A and B and we can critically analyze in between for this is intermediate compositions about their miscibility and immiscibility. Immiscibility you can have several situations of miscibility and immiscibility or semi-miscibility or semi-immiscibility behind this parity in between this syllogistic and additives behavior or immiscible will come below this additive line. So, we shall discuss in the next lecture other parts in the next lecture.

Thank you.