Science and Technology of Polymers
Prof. Basudam Adhikari
Materials Science Centre
Indian Institute of Technology, Kharagpur

Lecture - 1
Basic Concepts on Polymers

In this course you must see some basic, basic aspects of non polymers that you have to know, certain basic concepts. Last day I told you in general, some aspect on material science, general materials. I mentioned there are three major members in the family of materials of which the polymer is one of them. Now, I have already defined, what is a polymer.

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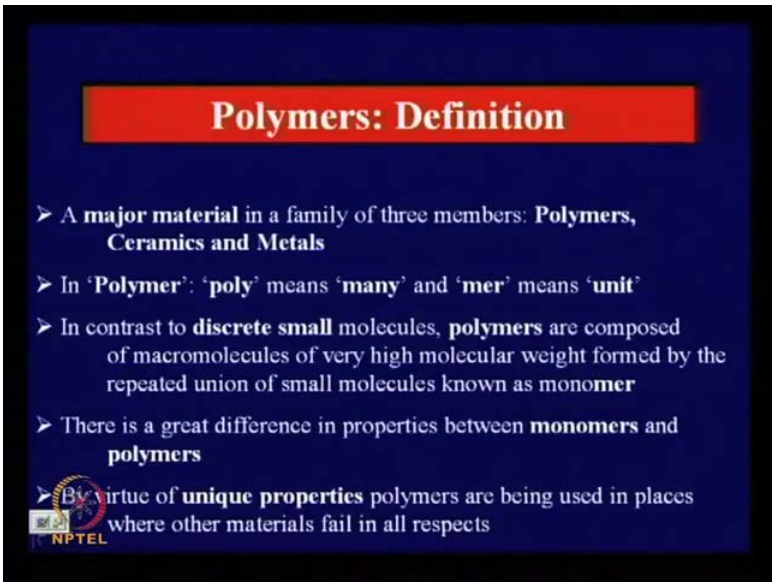

From where you can see polymer in this word, if you divide this word, break this word into two parts poly and many. Poly means many and mer mean units. In contrast to discrete molecules, polymers are composed of macromolecules of very high molecular weight, formed by the repeated union of small molecules known as monomer. By virtue of their very high molecular weight, there is a large difference in properties between monomers and polymers, and that to discrete molecules and polymers. You will gradually come to know, how much is the difference? By virtue of their macaronis, these polymers have shortened unique properties, which have test them top of other materials and we will gradually realize.

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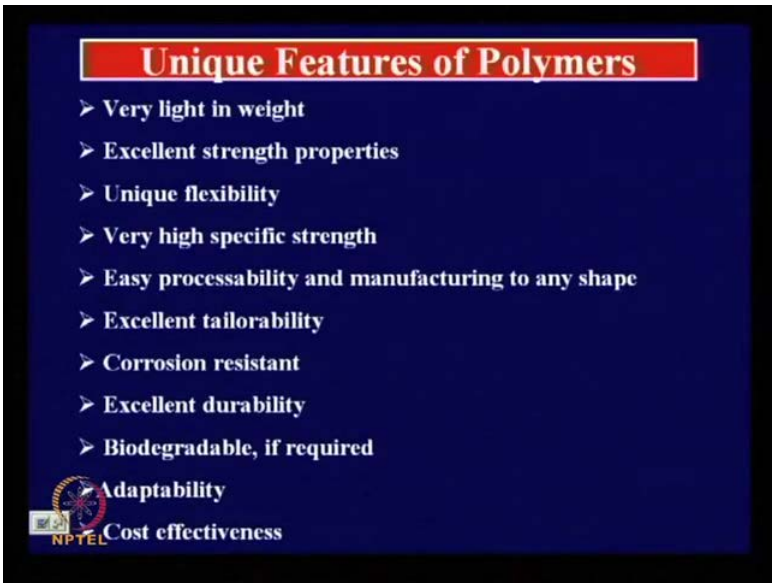

Now, what are these unique features of polymers? Polymer materials over other materials say, metals and ceramics. The first and foremost point is, it is very light material. Say if we want to manufacture some space vehicle or air craft, the load is a, is an important criteria, you know have to save fuel and better flight efficiency we must redeems the weight of the vehicle. If we take metals, you know the specific gravity of metal is very high, so the weight of the vehicle is very high. Sometimes you cannot escape you have to use some material metal, but effort has been given to replace this that metal by polymers.

Talking about ceramics, yes there are certain special cases to be used at alleviated temperature. There ceramics cannot be avoided, ceramics material cannot be avoided still then, polymer materials have been developed in such away, so that these polymers can also provide resistant to very high temperature, we will gradually see those things. So, the most important point is weight, that means the polymers should be light, specific gravity should be very low. In fact these polymer are really very light.

If we look into the specific gravity of polymers, say think of commodity polymers which we use every day. What are commodity polymers? Say think of polyethylene, say carry bag films. Without carry bag films, today we cannot think of anything. We go to market, we ask to some commodity, the shopkeeper gives the material in a thin film packet, so that those are carry bags made of low density polythene. Think of where insulation and

covering, that is made up polyvinyl chloride. Think of certain toils made up polystyrene, lightweight as well as very cheap.

Not only that for packaging materials, packaging in the packaging fields on these polymers also highly used. So, these are the materials knows as commodity polymers and they are very light. For example, the density of polyethylene may lie between say 94 0.94 to 0.98 less than 1, specific gravity is less than 1. To talk about another polymer that is polypropylene, it is a lightest of all this polymers. The density of or a specific gravity polypropylene is around 0.92 to 0.93. So, these show a we can make this materials will lighter and lighter like this and we can remove, replace metals and ceramics in many useful applications.

So, that is a very light in weight, we will gradually see large number of examples of these polymers. I am not going to crowded, crowd this points with the examples of the polymers, will gradually see and time to time I will refer back there. Then excellent strength properties; only the material light weight in material is not sufficient enough, they must bear load, they must have adequate load bearing capacity. They must be mechanically strong, tensile strength, tensile modulus should be very high.

They should not be gristle, they should be top material, it should not break and sometimes we need some elongation properties also. In general we can say these polymers can provide, in fact these are providing very excellent strength properties. Then, unique flexibility. These polymer material are flexible, you can bend a polymer item because it is flexible.

Now, you have to correlated this flexibility with the structure configuration etcetera. How it become flexible? We will gradually see, because it is a that day I was telling, it is a molecular bonding in material. It is the bond, what kind of bond is there? It is bond of flexible. Say carbon carbon bond you know, it is a flexible one. Carbon carbon single bond is a flexibilize can rotating combined it like that. It it can undergo bending, flexing etcetera that is why, that is actually available in this polymers. Very high specific strength, what is specific strength?

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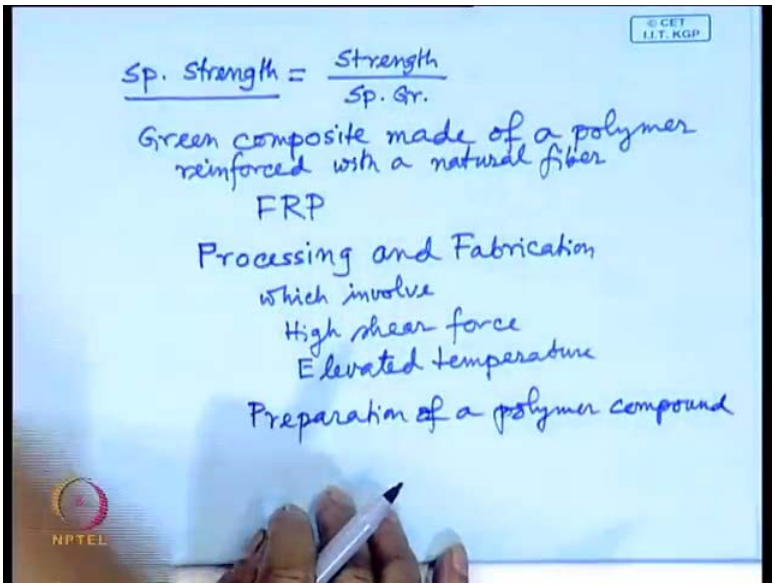

What is specific strength? Specific strength is the, strength ratio of this strength to specific gravity of the material. That means we are having a material, which is strong as well as it is light. Think of steel, tensile strength is very high. Divide that tensile strength or tensile modules or comprising modules by its specific gravity, you will get some value. Now, you take one polymer sample.

Say if in a natural fiber for example, say jute fiber. Its tensile strength suppose 450 megapascal, its density is around 121.121 to 121.122 like that. So, polymers still lower density, so since density is low specific length is very high. So, this is a material material, this is a property, this is a property which is very much essential today, in today's civilization seems civilized applications. We can get very high strength, but light. Today vehicles are, say automobile vehicles are lot of fully green composite. What is green composite?

It made of a polymer reinforced with a natural fiber. So, it may be natural fiber, it may be synthetic fiber, if the fiber is used reinforcement it is passed in a matrix polymer matrix. Now, it known as polymer regime, we will get a product known as FRP fiber reinforced plastic. This is light as well as strong with high impact strength. If a vehicle heats some object or if a vehicle collides with another vehicle, the passenger inside the vehicle will remain safe. If that impact energy can be absorb by the vehicle, that is not possible with metal.

That metal can shatter an just pierce the passenger like a sowed. Whereas if this composite is light as well as it can withstand very high impact properties, it will not break in that passion, so that passenger inside the vehicle will remain safe, even if the accident is very severe. So, this are the advantages, so very high specific strength this property, we should not forget. Then, easy processability and manufacturing to any shape. What do you mean by easy processability? Now, in our country or in worldwide, there are many polymer manufacturing industries.

They manufacture some polymer materials, said be its polyethylene. its polypropylene. its nylon. Polycarbonate, some rubber those are manufactured by chemical reaction, in chemical reactor and we get basic raw polymeric material known as virgin polymeric material. But that virgin polymeric material is not usable and is not useful, until and unless we go through certain processes and include some functional additives inside this polymer, before obtaining a final product. So, the product is a mixture of polymer with functional additives.

Now, in order to get this thing mixture of functional additives with the polymers, we have to pass through some procedures, processes. What are those processes? First off all you have to make a mixture a blend of these polymers with the additives, all right? After making the blend a compound is found, that is called a polymer compound. We will cover in the subsequent lectures those things what is polymer compounding, what are additives, what are functionalize tips, what are their functions, we will cover gradually.

But before that I am just referring in connection with this thing; that need safe needs the formation of a polymer compound known as compounding. Once the polymer compound is formed, then that polymer compound is passed through certain machineries, through the another subsequent stages stages of processing to give a final safe to the product that is known as fabrication. So, we have to go through processing and fabrication steps, which involve high sheer force as well as elevated temperature, you understand? So, those processing machineries are say an internal mixture or a polymer blender or a two roll mill on making the polymer compound or a polymer needier to make a polymer compound.

After the polymer compound is obtained, prepared then that polymer compound is subjected to extrusion, injection molding, calendaring, compression molding,

thermoforming, so various processing techniques are there. We will also mention those things in subsequent lectures, various deferent processing techniques. While going through these processes, these polymers can be easily softened, easily processed. It can, say for example, preparation of a polymer compound. First of all the polymer needs needs to be softened by application object and some sheer force until and unless it is softened, it cannot incorporate the functionalary tips in the form of particle, in the form of fiber and after incorporation and its need to be in disposed.

So, the softening is very easy in case of polymer as compare to metals and ceramics. It is known to you, so that is why it is known as easy processibility. Not only that, there are certain process, your product and devices which can be meet through solution processing technique, because these polymers are easily soluble in suitable solvent. Even there are certain polymers, which goes easily into water, you can have water solvable polymers. For example, polyvinyl alcohol or natural gums, these are solvable in water and some other polymers which are not solve in water, but organic solvents are available in which in dissolve and we get a polymer solution.

Once we get a polymer solution, we can utilize that polymer solution for making a product. Suppose, you want to make a fuel we can utilize that polymer solution inorder to form that film, is it all right? So, we can easily say or we can very well say that is it, these met polymer segments are easy easily processable and it can be products can be easily manufactured of any shape, which is not so easy shafting buying excepting in case of metals and ceramics. That needs sophisticate, sorry that needs very high temperature, huge is to installation of machineries.

For example, you take one example of footwear or even you take the example of this pen or this pen. These are made by injection molding process or you think of a bucket, monks, balls any type of thing where we need larger of need to produce large number of items, in a short period of time. So, we can have one injection molding which is connected to a molding assembly or shaping assembly, where large number of small modes of this pen or bucket all those things are there. So, in one sort of injection, what are injection?

You observe, you know you think of hypodermic syringe, the hypodermic syringe how the medicine or fluid is injected into the body. This depends sibyls is almost same. So, in

one injection you can fill the mold with molten polymer. Then by cooling the mold you can open, after cooling the mold you open the mold you will get many number, I say 32. For example, in one shot we can get 32 items in footwear industries. If you go you will see and that is fully automated, fully automated no man power is there. You just start the process it continuously and one cycle of this manufacture your molding might be say 2 2 3 minutes

Now, you think of the volume production, large number of production of those mold units by in a some molding. So, it is not so easy for any products made of ceramics and metals. That is why we can say these polymers are easily processable and manufacture, manufactureable and we can give any safe as we like. Next important point comes is tailorability.

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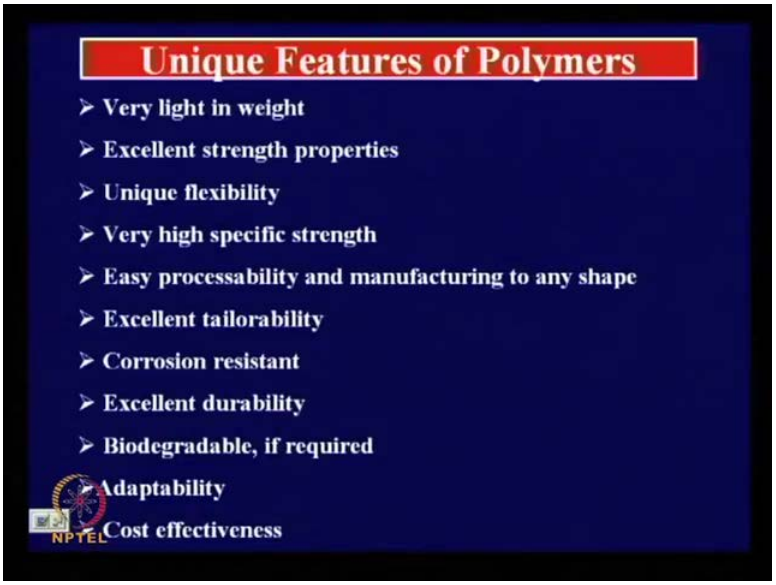

What is tailorability? You know, who is a tailor? The role of a tailor? What a tailor does? What a tailor does? He cuts the clothes according the shape, dimension, you know to fit you, that is called tailorability. Now, why we called this polymer a very good tailoring material? I give you a simple example, I give you a simple example say you have in your hand.

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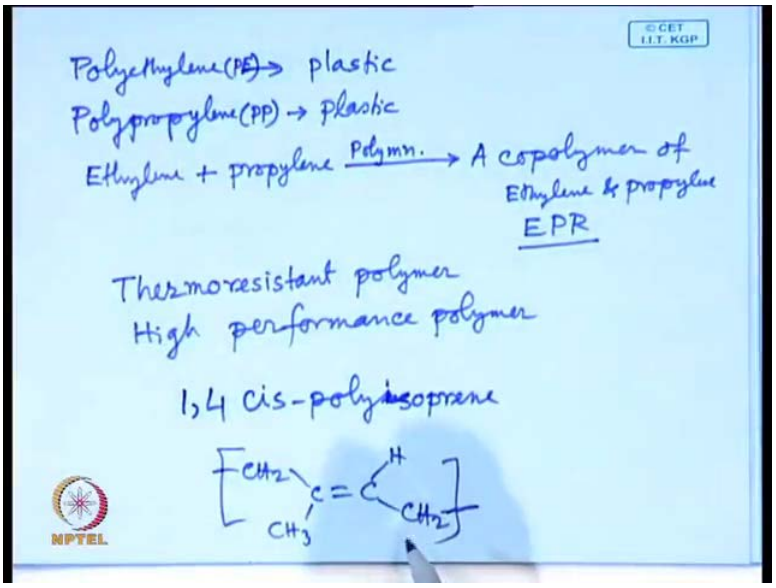

Say polyethylene, a polymer material polyethylene. You want to make a fiber, yes you can do. Polyethylene is hydrophobic in nature, you want to make it hydrophilic, yes you can do by chemical modification. So, by doing physical and chemical modification on a base polymer, you can get another polymer. That means you can develop a new set up profile, properties on the polymer having already existing with existing another set of properties.

So, you are existing material has got a set of properties. Now, you can broaden the properties even you can improve the properties. This is, this kind of properties is not available in alter materials, you can tailor it. So, since I have told you this example of polyethylene, now polyethylene stamped as a plastic material. Polypropylene these also a plastic material. Suppose, you has these two polymers polyethylene polypropylene, you need a rubber, plastic is not like that of rubber, that is a different kind of material having different set of properties.

If you want a rubber, what you have to do? You can say sir we can make a blend of polyethylene or polypropylene. You will get a new product, sure of course, you will get a new product, but that new product will have different set up properties, but that do not be rubber. But you can develop a rubber from these two materials, how? For that you have to go for monotonic stage. You take ethylene allow with propylenes, polymerize together polymerize together by applying suitable conditions of temperature, pressure, catalyst,

will get a new product that is a copolymer of ethylene and propylene known as EPR, ethylene propylene rubber, that is a rubber.

The properties of this EPR is totally deferent from the polyethylene and the polypropylene. So, you got a new material from ethylene polyethylene and polypropylene. So, this is a kind of tailoring technique. There are plenty, there are plenty if you see, if you keep your eyes and ear open you will find that any of the polymers you come across, that can be tailored to have new set up properties or you can broaden the properties. You can broaden the properties means you can have a broad spectrum of properties, as well as you can increase a level of properties both the things you can do.

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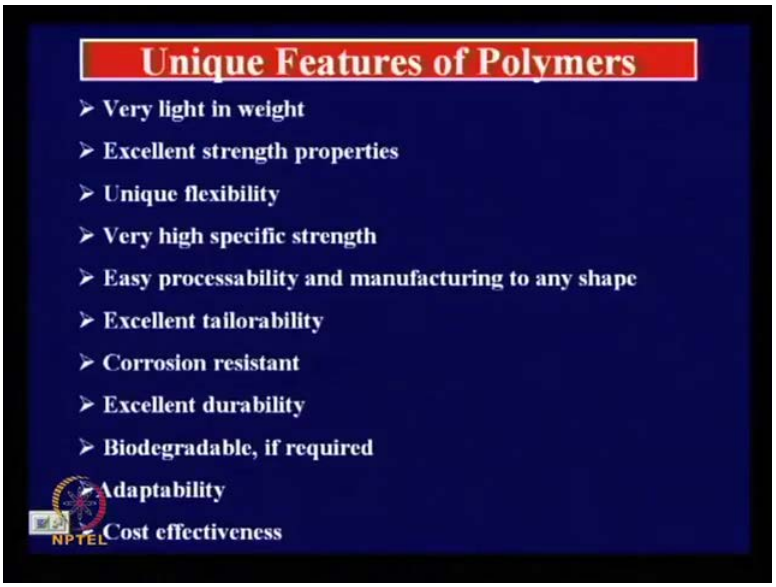

Then, corrosion resistant. We fulfill our demand utilizing the available materials, the metals. Now, metals are not resistant to corrosion you have to prevent corrosion of metals you take the help of polymer by applying a coating by polymer over this thing. So, that this electrolytes cannot get access to the metal surface in order to safe elect chemical reaction, which occur say corrosion process. So, this is not that corrodible, but it degrades also, that is deferent aspect.

The polymer degrades in other through other mechanism, but metal degrades through corrosion. In the excretal durability it is stable, you can have the stability properties to very, towards to very high temperature. Say these are known as thermo resistant polymer. Sometimes we call high performance polymer these thermoresistant polymer or

thermally resistant polymer can be consider as high performance polymer. Then, next point comes the biodegradability. What is this biodegradability? What do you mean by that? What is the necessity of that compatibility?

Student: (( ))

Compatibility? It is not like that

Student: (( ))

Yes, yes now right, give me, let me give you the background. Till 1980's of the last century, scientist were in a motive to develop more and more stable polymers. How much we can make its stable? To what extend you can make it stable? You should not degrade by the environmental agencies like heat, light, mechanical impact, it should be stable for long time. Now, when this conjunction of polymers is gradually increasing day by day, we find that after the use of the polymer when the use of the polymer is over, what we do? We throw it away.

Why? Where to throw? Where to throw? Usually it becomes useless, when it becomes useless we have to throw it. Now, once we throw it to the environment, since this is the synthetic material, made up carbon carbon carbon hydrogen carbon nitrogen bonds, which are almost stable bonds, does not break. So, it gets filed up in the environment, causing dilutions, causing pollution, there is lot of human cry and the entire world various care about this plastics polymers, how to dispose it?

There is a great disposal problem with this polymers, these thing was not thought of till 1980's. It is by the scientist, then people started realizing when this problem started coming, no this is not the proper thing probably. We have to think of some biodegradable polymers, biodegradable materials, after our use we throw it to the environment environment will environment will take care of it disposal. Gradually it will consume without affecting the environment, it will maintain the eco friendliness of the environment. That is not so easy job. For that of course, some biodegradable polymers have been thought of, how? What is this?

What do we mean by biodegradation? That means degradation by bio organisms, micro organisms that means these polymers should be consider as their food, food for the micro

organisms, they can eat away. Say think of this naturally occurring material say wood, produced by nature or wood materials or plant materials, if it is just kept or a exposed to the outdoor environment, it is eaten by a micro organisms say bacteria fungi on this things.

How they they actually degrade? Because you have to go little insight, you have to go little insight into the chemical structure, chemical formula, function of groups, actually those are attacked by these micros. Produce the certain engines, those engines catalyze this process, this way we get the biodegradation. We get the this materially condiment by the nature. So, that is if required we can introduced mimicking the nature, such type of function of groups in the polymer.

So, the polymer will biodegradable as well as is it is strong as well as at it is stable and flexible flexible as well as it is light. So, maintaining all those properties after our use, if this can we taken care of by the nature and there is nothing parallel to it. So, we can think of this biodegradable polymers, adaptability is… So these are related to relevant things or a it should be easily adopted by the environment. You think of the car, today you see many of other using car in India. It was not the situation 10 years back. Then after 5 years, the new model has come.

So, I like to sale it off or dispose it off, after that I will buy the new model. Where this will be disposed? You will take it, you will say, no sir I will not take your car because that is old. I will go for a modern recent model isn't it? Then why to throw it, but to dump? The people, the human being, they do not have space to live. They are living in two tier, three tier, now in your hostel, how your living? In one room instead of one person, two persons three persons are living. So, there is no space to this space for living space for humans, then where is the space for keeping all these vehicles.

So, the necessity of biodegradable comes. So, who will thing the responsibilities lying on you? Our days are over, our days are over we are dying, but you are the persons on which we like to transfer the responsibility to think of biodegradable materials, that to biodegradable polymers which will be strong as well as stable as well as durable as well as easily processable, tailorable all these things. So, this is biodegradability, biodegradable polymers, this is a suppose to common a very bigger way.

Student: (( ))

Tailorability means, it is a means of or of modifying the existing polymer to suit our application or to develop certain properties, so that I can get it. Suppose, I need a frame resistant fire resistant polymer; I do not have, I do not have that polymer. So, but I need this fire reties properties. I can develop it, how? You halogenated the surface or you add some fire resistant, frame resistant and edit it, yes. You will get a product which is fire resistant, that is a tailorability.

As I told this ethylene propylene copolymer these are rubber in material. I do not have a rubber. You think of if, you go back to history, I am I am not very good in history. Somehow I passed in my school examination history, but during second world war time, what happened? To germany, in a United states of America, they stopped supply of natural rubber to Germany. What they will do? They need rubber, they need rubber for your making tiers. When this was stopped, they did not just a remain idle. Within a year time they develop synthetic rubber industries, industries.

They develop synthetic rubber because it was not there. See, it actually came within 40 45, 1945, that time that is a tailorability. Natural rubber, you do not have natural rubber, do not worry. Supply stop, do not worry, defense people is here, they know. If something is not available, fine let me think off, I have to get off this problem. How to get out of this problem? Now, you are human being, you can think off you can get out of the problem. That is tailorability, you have to tailor. So, have if ethylene propylene,e copolymerize you will get a material that is a rubbery material. We have polystyrene, we have styrene,e we have butylenes, okay?

So many copolymers styrene and butylenes that is a rubbery material, rubber and that is a sub seat of natural rubber. Also natural rubber the chemical constituent natural rubber you will see, that is 1, 4 sorry, isoprene 1, 4 cispolyisoprene. These a chemical constituent of natural rubber 1, 4 cispolyisoprene. Synthesized by nature, but this can synthetically made in industries in polymeresion reactive. So, these a tailorability, clear? Cost effectiveness, cheap material, we can get 1 kg of this plastic.

Say a polymer, say for example, in 60 to 70 rupees, earlier it was less than 40 rupees because of inflation today it is 70, 75 like this. Cheap material, you can say sir metals can be available, even less then 70 rupees, fine. What you think of a product, you can

make how many pieces out of 1 kg polymer and out of 1 kg ceramics or 1 kg metal? You will get more number of items from this polymer, so it is cost effective.

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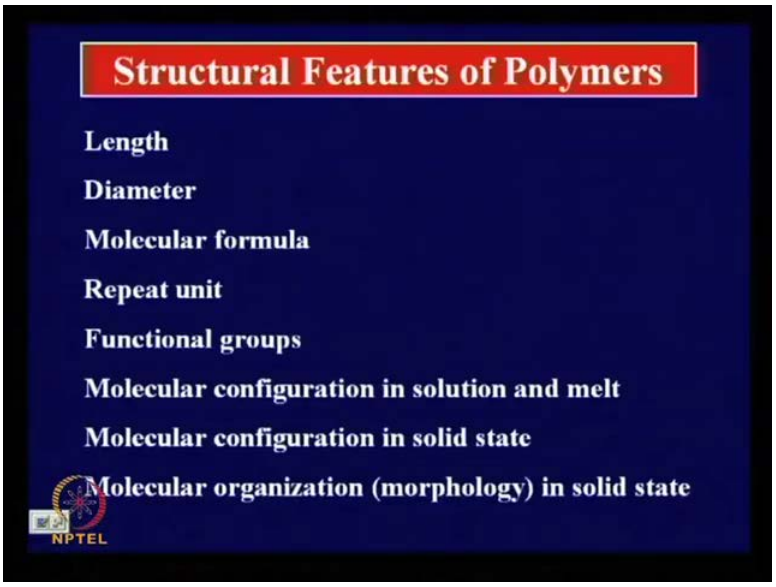

Then, noted to know this handsome technology of polymers. Gradually we will go deeper and deeper this way, we have to know this structural features of polymers. Because you are the scientist. Today there are some existing polymers, but we should not satisfied with existing polymers, you have to develop newer and newer polymers. (( )) you have read yesterday's telegraph newspaper, have you read, yes?

There is a report professor C N R Rao, he is a national scientist, emanative scientist at Bangalore. He said that there are two forms of carbon, two forms carbon to diamond and nano carbon like that. That can deposit at on polyvinyl alcohol on deposition of these polyvinyl alcohol, very small with a small dimension. Few billionth of a meter, so that forms a composite, nano composite, strong, he's claiming strong and tough.

Student: (( ))

500 kb he is telling, he is claiming.

Student: (( ))

So, you have to know this structure you have to know the chemical formula, you have to know the structure, you have to know the molecule, you have to, you have to recognize

the molecule. So, the structure feature says, if you look into this point length of the polymer molecule. Length means length of the polymer molecule, diameter of the polymer molecule. You think of, imagine some isolated polymer molecule. Say polyethylene, like a stream or a thread, a lying length structured configuration. How long it is? What is a diameter? Then length to diameter ratio, l by the ratio. You can calculate the length of a polymer molecule, just I am giving you some input. You take the bond distance between carbon and carbon, this is 1.54 Armstrong and the bond angle.

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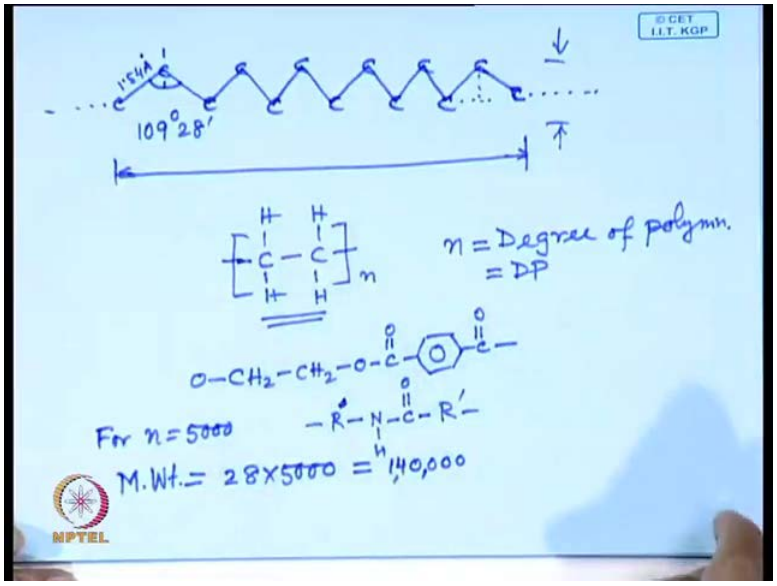

Suppose, a fully extended polyethylene molecule look like this. There is one C, there is one C, one C C C C like this. This is the basics of, basic aspect of polymer molecule, isolated polymer molecule. So, it continuous, it continuous and hydrogen's are there. I am not saying the hydrogen's. Now, what is these angles? You know 109. So, if you bond length 1.54 Armstrong and this angle, you can find out the length between one end to the other end.

Can one calculate, if you know and how many the c c units are there? You can calculate. Suppose, there are 1000 units c c units are there, you can calculate. So, you take this as a home task for calculation of in this length of this polymer chain. Then, these dimension you can also calculate the simple geometry. By simple geometry you can you also calculate, so this is a diameter of a polymer molecular, this is a length of polymer molecule.

Now, this length and diameter of a polymer molecule extracts havoc influence on the properties of a product made of that polymer, clear? Then you have to know the molecular formula. What is the molecular formula, chemical formula? From the chemical formula, we could know that it contents carbon, hydrogen or nitrogen or oxygen or sulphur or phosperous like this. Say if you think of ethylene, polyethylene, it contains carbon and hydrogen. So, you can say very easily that it is a hydrocarbon material, it is hydrocarbon material.

If we think of another polymer say like this, having carbon hydrogen oxygen. The polymer I am not writing the full molecule, these R sorry, R and R prime, R and R prime contents carbon hydrogen. This contains nitrogen link to carbon, nitrogen link to carbon on oxygen is attach to this carbon by double bond and one hydrogen is there. So, you can know what are the items present? We know the from the periodic table, where they are placed? We can know the deference in electro negativity of the atoms and that has influence on the properties of the molecule. So, molecule formula you know.

Then, repeat unit, what is repeat unit? I do in the definition of the polymer, I showed that this unit is repeated many number of times, n number of times along the molecule chain, along the backbone of the molecule. That is known as repeat unit. This n is known as degree of polymerization or DP degree of polymerization. So, if I know the value of n then I can easily calculate the molecular rate of this polymer.

Suppose, for n is equal to say 5000. From the mass of this atom of carbon and hydrogen you can write it is 28 into 5000, so this is 1,00,000 or 140 kilo Dalton molecular rate. So, this is the repeat unit, it is repeating along the backbone chain, repeat unit. Then, functional group. Now, there is no functional group like that as we know. Functional group you mean, say a carboxyl group.

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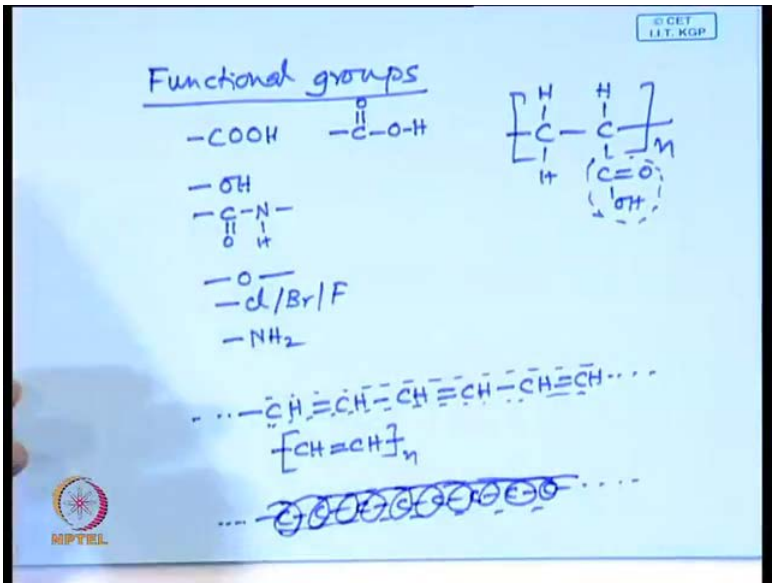

I mean say, a group like this or you can right this way, attach to a polymer background chain. Now, a there you show that it can have, this is the function group, carboxyl group betters the polymer. Now, other functional groups might be O H, other functional groups might be, other functional group might be ether, other functional group might be halogen, other functional group might be this, so and so forth. So, these are functional group. You must know this function groups. Functional group means definitely they have certain functions to play.

Remaining pressure in the polymer molecule mind that molecule is used for making a product, that product in that product these function groups will play certain roles. This is one kind of thing. Another thing you see, say what is this molecule? Polyacetylene now this is a phi electro bound, that means enter chain will have a cloud delocalized phi electron cloud, which is extended along on the chain. So, it can have some phi extended phi electron structure, there is also one kind of functional ability.

That means these molecules in the center, there is carbon chain carbon skeleton like this continuous. Surrounding this carbon skeleton like a thread it can have a cylinder of like a solid anoint. That means this is phi electron cloud, phi electron sound this thing. So, that means this carbon skeleton remains within the center of this electron cylinder. It will behave like a conductor, it is behave like a conductor, conducting polymer. It is commonly very big way in semi conductive industries because it is processable.

So, this one example of polyacetylene, you can know polyaniline, polypyrrole, polyethylene like this. So, these are the thing. Then, so function of groups. Function of group means definitely those groups have certain functions to play. That is a function groups, then molecular configuration is solution and melt.

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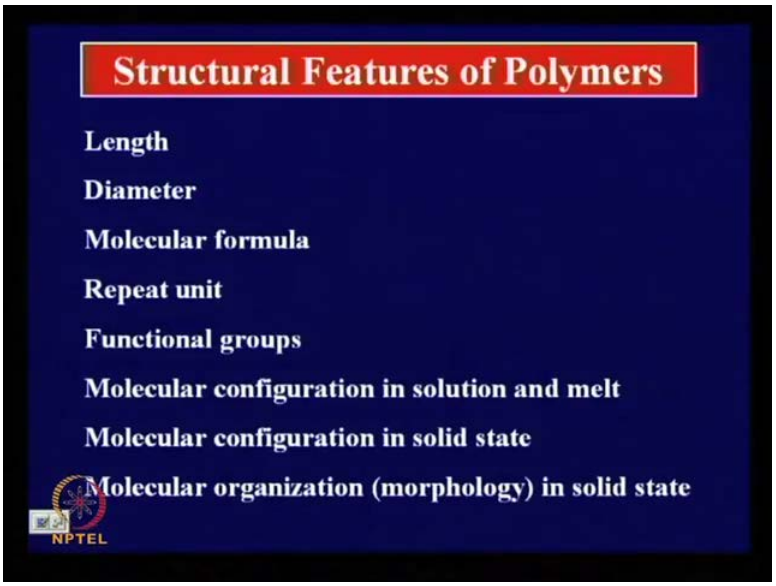

Molecular configuration and melt, I mean that you have to know the science. You have to think of an isolated molecule. Suppose, if you remain in one room, in a big room, if you live in a big room, you are behavior, activities, will be of one kind. If you are put along with few tigers, your behavior will be another kind. If you are kept in one room with very good friends another kind or odd friends will be another kind. So, that means your surroundings. So, that surroundings how it there is configuration? That means they geometric configuration or to do with geometry. Now, think of a movie housem very serious movie is going on.

You have just watching at serious movie, you are sitting very attention position, you forgot that there are many people in the audience, your auditorium as watching that movie. That is one kind of configuration. Now, if you like that movie, then you will try to stretch your legs and hands and something like that. Sometimes you sit the this way that way and was stand this way and you will probably those, you may not like that film but, you are person sitting in a backside he might be liking that film, so you got

disturbing him. So, he will curse on you, what you are doing? Please get out of this auditorium, like that.

So, the configuration, so this kind of molecular configuration, how it they geometric disposition of the molecular is segments etcetera etcetera. In solution and melt kinetic energy, kinetic situation, dynamic situation. Then, when it is frozen, it become solid so, configuration in the solid state. What do the configuration of solid states? Now, if a material just frozen from its solution or melt, what happens? It will be set in the position, but if it is annealed or slowly it is allowed to configure, then the organization of the molecular will be of different kind. Molecular organization, morphology in solid state, you can have amorphous morphology, you can have crestline morphology like that.

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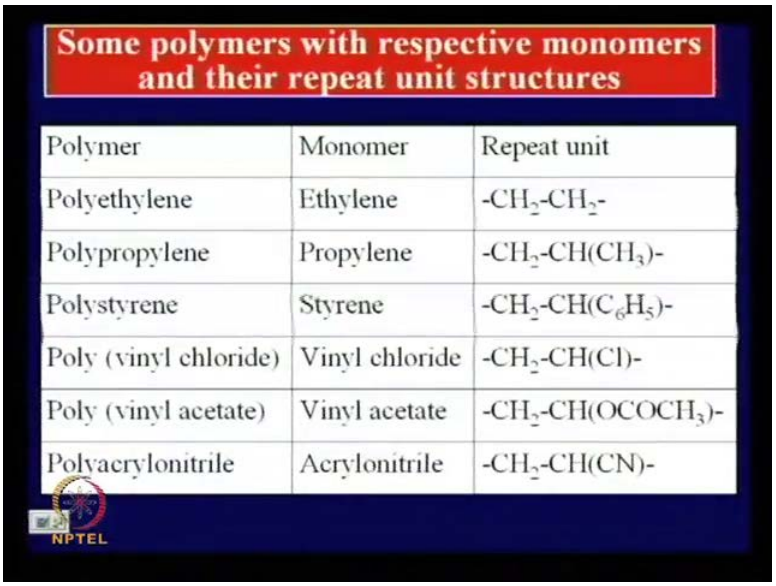

There are few examples, there are polymers, these are few only. We will come across large number of examples and the easy or a remember the formula, repeat unit formula of these polymers, you start with this ethylene molecule.

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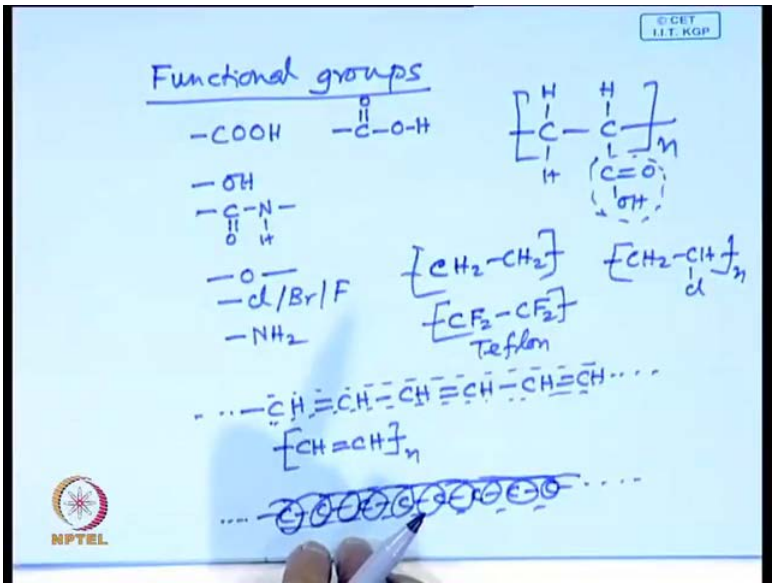

Ethylene molecule, note this not a ethylene molecule it is a derivative, ethylene molecule start with ethylene molecule C H 2 C H 2. We can substitute 1 hydrogen atom by one functional group, 2 hydrogen atom by two functional groups or the same functional groups or all the functional groups all the hydrogen atoms by different function of groups. Say you can graduate graduate you can get easily a polymer. What is this? These Teflon, tetra poly tetra polyethylene teflon.

So, it is easy to remember polyvinyl chloride by this polyvinyl chloride. It is easy to remember, so you have to make practice. Look at the formulas; you see there is nothing to discuss this thing. Actually I could not I did not have time to give proper arrangement of this groups, through certain software. That can be… but I will show you here, and l by d ratio of a polymer molecule is very high. So, today I shall not start this one, next I shall start. From next day onwards I will try to go little faster.

Thank you, very much.