Polymers: Concepts, Properties, Uses and Sustainability

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Lecture - 01
Why Are Polymers So Common?

Hello, welcome to this introductory course on polymers. In the first week of the course, we will start learning what are these polymers and what are their unique features? And let us begin by this first lecture on thinking about why are these polymers so common? Why do we see so many plastic objects around us?

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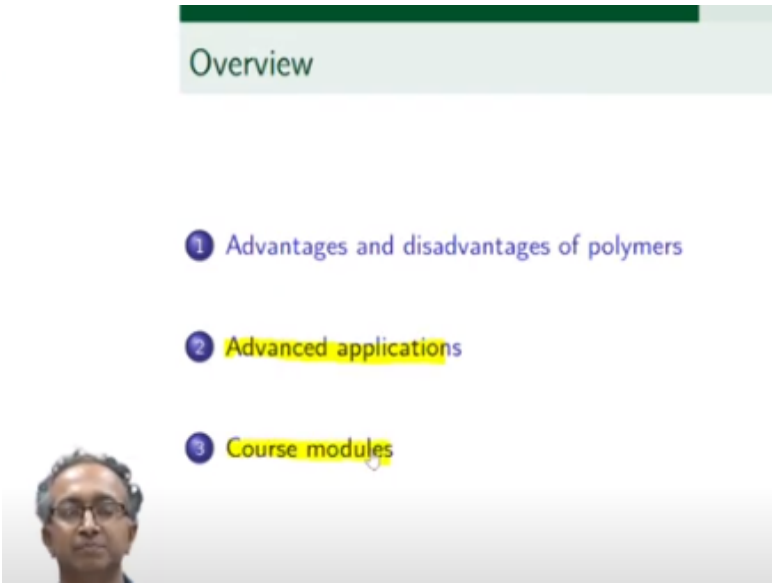

So this central question we will try to answer through this outline. First we will try to look at some of the advantages and disadvantages of polymers. The advantages are the ones which make the polymers so common around us. Disadvantages are certainly there, but looks like we are able to overcome many of these disadvantages and therefore use these polymers. So but we need to still be aware of these disadvantages, especially given so much news about many of these polymers being part of waste and how to handle waste. So this is something which we have to really be aware of. Secondly, we also see that many of these polymers are being used in day to day application as well as an advanced application. So what makes these polymers suitable for these advanced applications?

And so we will begin the with these two advantages, disadvantages and looking at advanced applications and end the lecture by looking at what are the course modules and how we will learn many of the concepts associated with polymers in this course.

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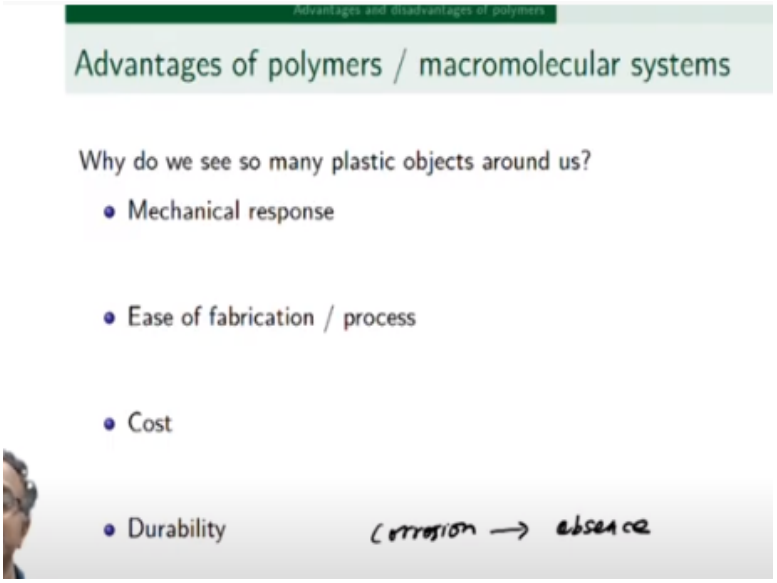

So let us begin with the first question as to why do we see so many plastic objects around us. We start in the morning to traveling to working in either industries or in offices, everywhere we have polymers, rubbers, plastics FRP all these objects around us. So what is it that makes the use of polymers so ubiquitous, so overall dominance? And what do you think are the reasons for such a dominant usage of these polymers.

We should also remember that polymers are as class of materials have come out in only last 100-150 years. So in a short period of a century or little over a century, they have become so dominant in terms of usage. And so if you start thinking about it now, what makes it so unique, what makes polymers so useful is the first thing that you could see is the range of properties that it shows.

So for example, if you look at mechanical response. What you can see is, if you want a flexible material, you can use a polymer. You want to use a rigid material, you can use a polymer. So you can get polymers and plastics by changing their chemistry, their structure, you can get a variety of properties. So we can use polymers for a rubber gasket or we could use it also for a fender in a car, which is a very mechanically intensive application.

In fact, it is trying to absorb energy during let us say, when car has an accident. So very different kind of mechanical properties can be obtained and this is true even for optical or electrical or any other sets of properties. So one key advantages of, key sets of advantages for these polymers are in terms of the range of properties that you can get from them.

What is another advantage that you can think of? One of the key reasons that we see so many complex shaped objects around us which are made out of polymers or plastics is the reason that very easy to fabricate. In fact, the cycle time for fabrication or cycle time to make one plastic object can be very low. Can you guess, as to what could be the timescale? It could be off the order of one second or even less, or at times, maybe a minute.

So you can see that in a minute you can make hundred objects. Is that not a remarkable capability? The reason it is easy to make these polymers into such complex shapes in a very short amount of time, is based on this property that you can have them liquid like and then you can make them solid like and all of this can be done at temperatures and pressures which are not very high. So ease of fabrication is a very key aspect of having these polymers made into several complex shapes, which also eliminates assembly of parts. Otherwise, you have to make 10 different parts and assemble into a complex product. In this case, we can see that a toy which has different materials, which has slightly different colors, all of this can be done using a molding operation and it can be done in very low amount of time.

Cost is also another feature, because of ease of fabrication and because of the speed at which we can make these objects, very high volume production is possible and that brings down the cost. Another important feature of cost being low is the raw material that is used for these plastics. In fact this also is an issue related to sustainability of polymers. We use mostly nonrenewable raw materials which are coming from petroleum. And since petroleum one of the key sets of products there are aviation fuel or petrol and diesel, these byproducts are inexpensive. And these byproducts are what gets used for making plastic. And therefore, raw materials for plastic manufacturing are extremely inexpensive and therefore, plastic themselves also end up being very low cost. And this could be raised as an issue that why are you supplying raw

materials at such low cost to make plastics so cheap, and that is why they are so commonly available and they are causing all the problems associated with its waste. So this is something we have to also think of in terms of plastic usage. And of course, the other thing related to is durability. Corrosion for example, is not there. So absence of corrosion. And so some many of the applications, which require less service life of few days or a few years, we can use these polymeric materials very easily. And therefore, you can see that a chair, which earlier used to be made of different materials now is made out of polymers, because it is sufficiently durable for the service life that is expected out of it. Now you can ask the reverse question also as to what are the disadvantages with polymers?

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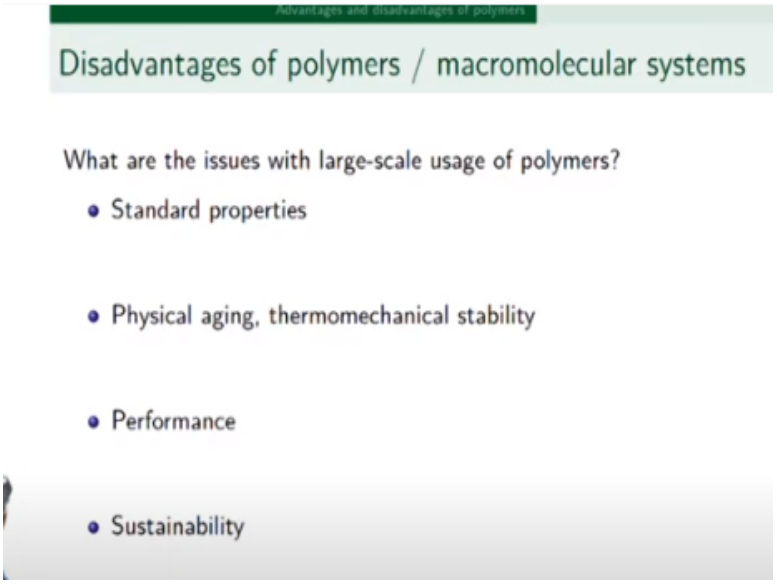

Why do you think such large scale polymer usage is problematic or what are the challenges associated with large scale use of polymers? And one key challenge in fact is the fact that how do we choose which polymer for which application is not as easy. We will see that one of the main things related to polymers is its macromolecular nature. The fact that it is a very giant molecule. And associated with this giant molecule nature, is the fact that variability in property. In fact, I said that as an advantage also. So therefore, if you want to design something with a plastic material, it is a little more challenging to do that, because standardized properties are not easy. Just by saying polyethylene is not sufficient, there are so many features of polyethylenes in terms of molecular structure, molecular weight, in terms of the distribution of molecular weight.

So all these features are possible to be varied. And that is why you can get polyethylene which is rigid, polyethylene which is flexible and therefore it is difficult to get standardized properties. You unlike other alloy materials, or ceramic materials, where standard properties as soon as you know the phases of the material and the composition of the material you can go to a standard handbook and get its properties. In case of polymers, the variability in properties is very high. So therefore, there is always trial and error associated with a given material for a given application. So that is a challenge.

The long term stability of these polymers is also an issue. So we know for example, that a bucket will break after some time and especially if we keep it in the sun, then it tends to break earlier. So in applications such as bucket which are not as safety oriented, it is maybe fine, but what if you want to use it in an aircraft? So if aging and the degradation of properties is not well understood, then application of polymers would be difficult. And we for a material to be used for a given application, engineers need to guarantee the service life. So with prediction of properties, life service life of a polymeric material is more challenging.

And one issue related to polymers is just plain performance. I mean steel in the end will have the modulus and strength that steel has and most of the polymers will not have that. And so polymers have a certain range of properties and they can be used in wherever those properties are required. We can optimize, we can improve those properties, we can try to make them better. But in the end, there is a limitation related to the physical, chemical nature of polymers and its properties. For example, polymers we know are insulators. Now if we want conducting polymers, then is it possible? Of course, we know now that conducting polymers are also there, but again conductivity of a conducting polymers is not going to be same as copper conductor. And so clearly there is an issue related to performance depending on the nature of the material itself. And of course, the last aspect and increasingly it has become very important for us polymer scientist, when we interface with society to answer this question related to sustainable use of polymers.

And as I highlighted earlier, we not only have to worry about sustainable use of polymers and worry about its waste utilization, we also have to worry about nonrenewable use of raw materials in making polymers. So in general, one of the

disadvantages associated with polymers use is the question mark related to its sustainability.

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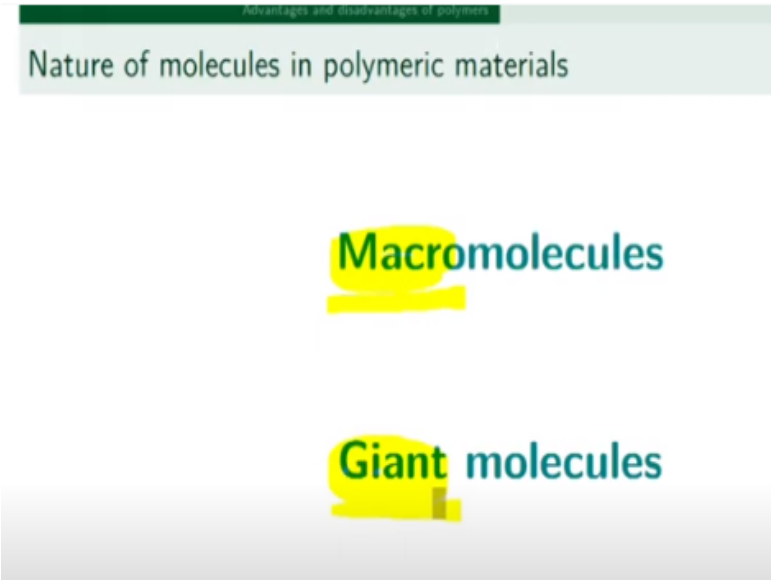

And so some of the concepts that I have already talked about are all related to the polymer molecules being macromolecules or giant molecules. And this is something which we will keep on highlighting in this course. Many of the advantages and disadvantages such as variable mechanical properties or the fact that they do not degrade so easily using biodegradation is not possible.

Many of these are associated with the macro nature or the giant nature of these macromolecules. So given the current scenario, the question is, are polymers therefore, being looked at only for objects around us? And the answer is definitely no. There are very advanced applications for which polymers has been used.

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For example, plastic electronics. When we think of a chip for an integrated circuit or electronics, we think of silicon. But these days, it is possible to use polymers to make a transistor or any other device that is used in semiconductor processing.

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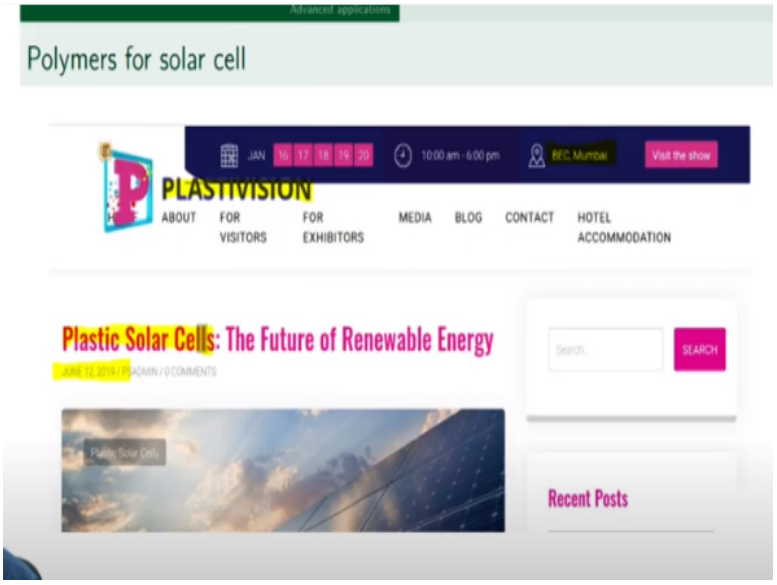

In fact, if you look at this announcement for exposition and a conference related to plastics called ‘plastivision’ and held in Mumbai. And this is not so long ago, just a year ago, we can see that what is being highlighted is solar cell made out of plastics. And mind you this is not plastic cover for a solar cell which is based on inorganic materials. This is where each and every component within a solar cell is being made out of polymers and that is why they are called plastic solar cells. So you can get conducting, semiconducting and insulating properties out of polymers. And therefore, you can think of them as electronic materials also.

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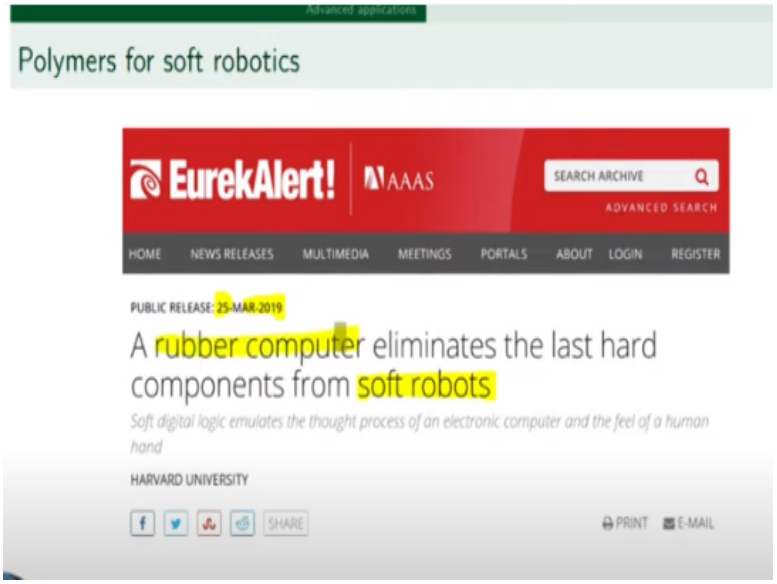

What about little closer to us. We are made of materials which are extremely versatile. We have soft materials, we have hard materials, we have flexibility, we have rigidity when I want to push something. I can generate force, I can sense robotics, right. And generally whenever we think of robotics, we think of very rigid objects and ah oh ah. We think of robots as very mechanical objects. Now if we can make robotics using soft materials like polymers, you can have very flexible to very rigid materials just like what is there in our body. So for example, this story, which is again last year story talks about that a soft robotic, even the computational part, the electronics part in a soft robot can be made out of polymers. So you can make a robot with polymeric materials. So soft robotics is a very new field, where polymers are being used for robotic applications.

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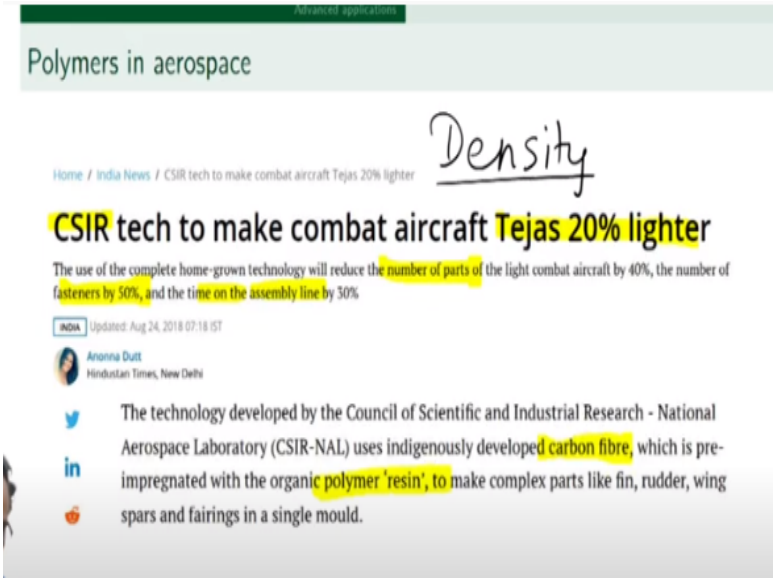

And of course, one key area where polymers get used all the time is aerospace. Do you, can you think of why is this the case? And there is one big reason that you can note down. Density of the material. Whenever you are making materials fly, you want them to be as light as possible. And in fact, the specific properties, which means properties per unit weight, polymers are extremely excellent materials of choice. So therefore, in aerospace, polymer use is increasing and it is going to become more and more because they offer such a unique advantage in terms of very low density. And this story, for example, is from our own CSIR Center for Scientific and Industrial Research, which talks about a fighter jet that has been indigenously developed. And in fact, the idea is to make it even lighter. Because once you make it lighter, you have to carry less fuel and it becomes even more efficient. And of course, this can only be done because we can reduce the number of parts as I said ease of fabrication with polymeric materials. If we do not join then fasteners are not there, joints are not there, mechanical properties are weakest at the joints. So that is prevented.

And then you can also reduce the time on assembly. So this is all the unique advantages of polymers that can make a fighter aircraft economical as well as efficient. And of course, background of all of this is a polymeric resin. Of course, in this case is being used along with a very strong fiber. But the key is the fiber cannot be used in isolation until a polymer resin is used along with it.

So these are called composite materials. So this is an example, where you can see that the unique advantages of polymers will always make them a very strong contender for application.

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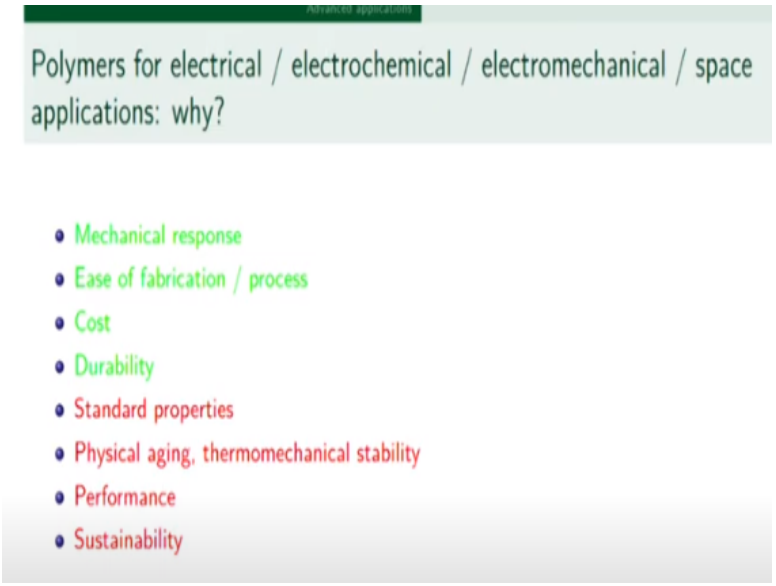

So given these day-to-day applications, as well as advanced applications, the overall point is the following that there are many advantages of polymers and then there are significant disadvantages also. And we have to keep all these in mind while using these polymers for both these sets of applications, day-to-day as well as advanced applications.

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So keeping this in mind, this course will have four broad sets of lectures. In one set of lectures, we will look at the concepts. We will try to learn the basic framework of how

to analyze polymers, how to understand what is meant by crystallinity in polymers and things like that. So it is the concepts associated with polymers.

And we have to also focus on properties, why are there are interesting optical, mechanical, electrical properties of these polymers. And as engineers and scientists, we of course need to see where the application is already or where is the future application. And finally, as I have highlighted throughout this introductory class that as polymer scientists and engineers, we cannot get away from the question of sustainability of these polymeric materials.

And here actually there is one very big sort of hint that is around us or a very big clue around us. If we look at life, whether it is animal or plant world, it is based on polymers. So if biological world places so much faith in polymers and polymers are so ubiquitous, they are also how can we not design polymers and use polymers in a very similar way which is sustainable like nature.

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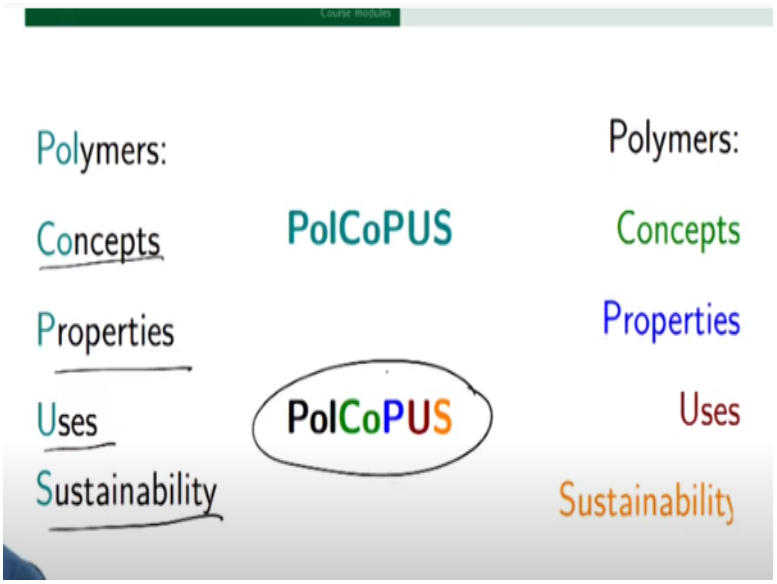

So with this thought, we will finish with this introductory lecture, where we looked at what are the advantages and disadvantages associated with polymers. And throughout this course, we are going to look at the concepts, properties, uses and stability of these materials. Thank you.