PolCoPUS
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Lecture No -55
Biomimetic polymers

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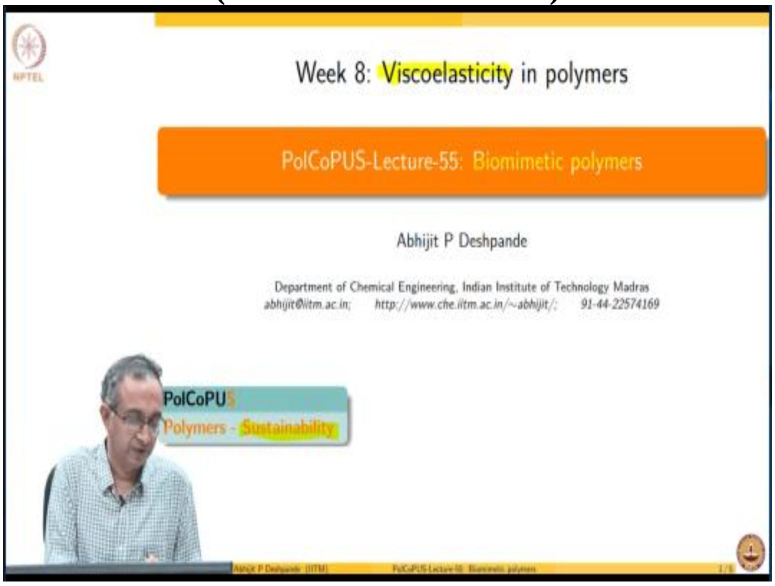

Hello. Let us continue our journey in this course on polymers. And in this lecture let us look at examples of biomimetic features to arrive at ideas related to polymeric materials. So, in this week we are largely focusing on viscoelasticity in polymers and we have seen that how viscoelasticity of polymers is an important determinant of its overall applications its understanding that we have. And so, given that we know a lot about polymers and their viscoelastic response.

Can we get inspiration or can we copy from natural systems and arrive at material systems which are far more sustainable than synthetic polymers. So, therefore focus is from the point of view of learning from bio biology and therefore looks at biomimetic polymers.

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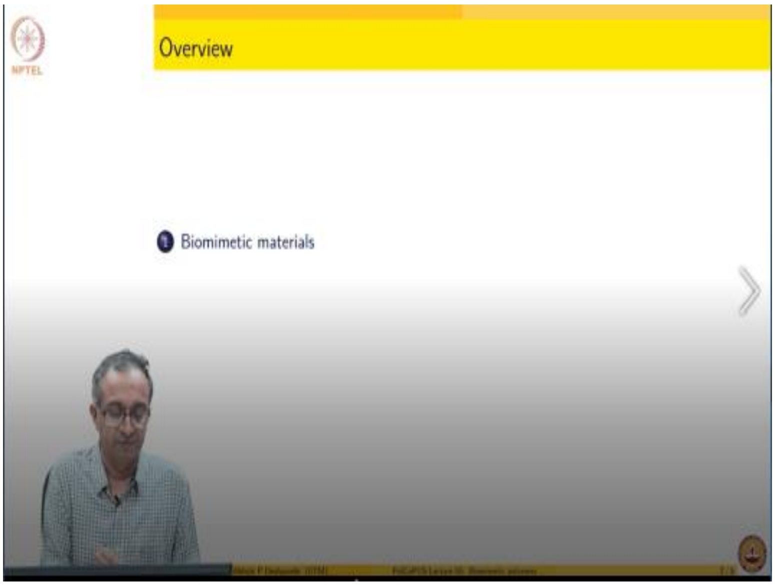

And so, the emphasis is on biomimetic materials as opposed to biomimetic devices

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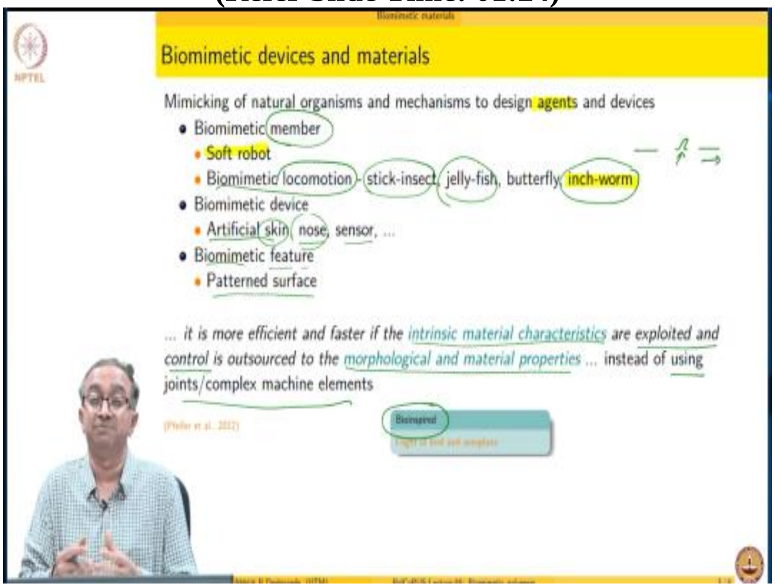

So, when we say it is a biomimetic device it could be for example an agent itself. So, for example a soft robot is an agent, we can say that it is mimicking a let us say a load carrying animal or it is mimicking an insect. So, that is basically the overall robot itself mimics a certain agent and it has a certain agency it performs some function.

It could also be for example that it is something which can move. And inchworm is basically a species which moves by pulling one part of its body forming a loop and then pushing another body and that is how it moves. So, there is a very specific mechanism by which inchworm moves. So, can I not get let us say a thin rod of material which initially is flat like this then it becomes like this and then it moves like this.

So, then what we are doing is we are now getting a device which is capable of moving when applied in electric field or when pH is change or some condition due to which it undergoes these shape changes. And the effect of these shape changes is that it moves. And so, it is mimicking an inch-worm while moving. And therefore, we will say what we have done is arrived at a biomimetic device which mimics the locomotion that is exhibited by an inch worm.

And so, such biomimetic things can be there for stick insect or jelly fish or butterfly and so on. We can also have a device specifically which is a far more specific thing it is just a sensor which let us say measures pH or it is a sensor which measures humidity or like artificial nose it can measure four or five different smells or four five different compounds which are important from smell point of view.

And the skin for example so; it can measure the touch or mechanical loading of different kinds. So therefore, these are all biomimetic devices which are mimicking skin property mimicking a nose or so on. Now we could also have a biomimetic feature in the device or in the member or in a material. We could just have a surface. And here for example lotus leaf is a very common way in which people talk about surfaces.

And can we mimic whatever may be the patterns there on a lotus leaf to in a synthetic material. And get similar properties to lotus leaf. So, that is again saying that I will mimic a pattern surface it is a specific feature in a material. But all of these are talking about the biomimetic phenomena in either a member on a device for this course purposes what we will confine our attention is to biomimetic polymers.

And why should we do that it is because when we make a device or when we make an overall agent we have combination of several we have joints, we have things so. For example, something which moves will have to have different components and they are joined together and each component may be rigid. Especially if you make it out of metals and ceramics and other materials but if we want to utilize the wide range of modulus and flexibility which is exhibited by polymer.

Again, what we may have to do is put a flexible polymer then put a rigid polymer and all that. So again, we will have to combine and join several materials. But can I not transfer some of these in terms of the control by changing the morphology and material properties the intrinsic material characteristics itself. So, instead of joints and complex machine elements doing a job can I not do it based on a material itself and it is changing.

So, for example, if I make a rod like this and can I not have the morphology in such a way that lets say if I change the temperature the morphology will change here and it will deform. And then I get basically the action which is there due to a joint. So, what we are trying to do now is develop a polymer which itself can change based on the conditions changing. And the question that we are trying to ask is can we learn anything from biological polymers in this.

The other word which is quite commonly used is bio inspired and in biomimetic we are trying to copy certain feature it could be an agent it could be device it could be a polymer. So, we take look at biological system and then we try to say we will mimic that in our agent or our material system. The other could be bio inspired for example flight. So, flight of an aircraft is a bio inspired in the sense that birds fly and therefore aircraft fly something a machine which can fly also was the idea of the aircraft.

But the two are very different. So, it is bio inspired that one should have be able to fly but it is not the control systems and the design of an aircraft is very different compared to how a bird is designed. On the other hand, we could make a biomimetic device which flies which is like bird. So, that will be a very different. So, that is biomimetism as opposed to bio inspiration.

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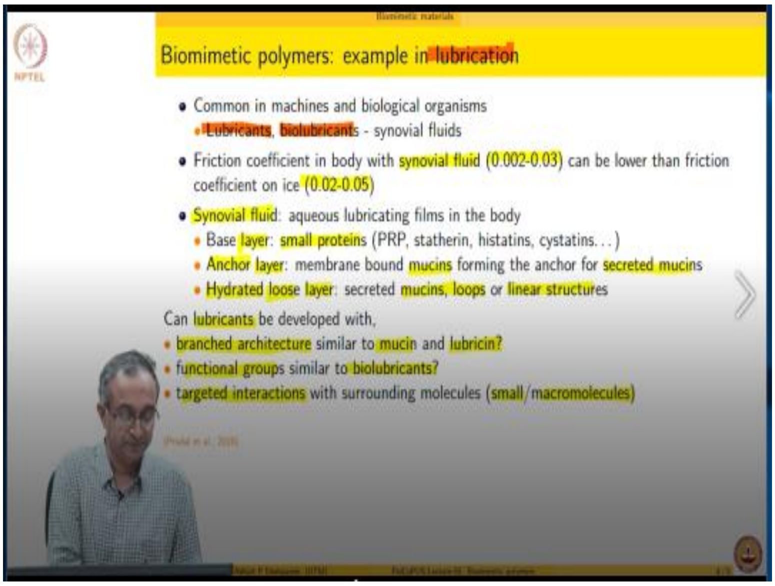

So, biomimetic polymer I will just give an example from lubrication. And again biomimetic polymers are not very common. There is lot of research still going on in trying to learn from biology and evolve polymeric systems which will do the job the way biomimetic polymers the way they do in biology. And one example is in lubrication because lubrication is there in all our joints. And generally so we have lubricants in machines because there are complex mechanisms.

And different machine parts move with respect to each other and lubrication and greases will have to be provided. Similarly, we have biolubricants which are also called synovial fluids and they are there in all our joints. So, can we learn looking at synovial fluids and then try to do something related to lubricants which are used in machines. So, then that is what is biomimetic polymer. So, just to give you an idea why would one want to do this is look at the friction coefficient of a synovial fluid. It is in fact lower than ice.

Because many more often than not we see people slipping on ice or ice being very thin. And it is in fact also there in languages saying that you are on thin ice which means you are on slippery slope and things like that so. Generally, friction on ice is supposed to be very low but the synovial fluid has friction coefficient even lower than that. And what is the synovial fluid it is basically actually complex biological systems in which there are layers.

So, there are 3 layers there is a base layer there is an anchor layer and then there is a loose layer. And each of them contains different components and what I have noted down here are just the broad components. A biological system of course is much more complicated and contains many other components. Also, small molecules, salts so ionic environment macromolecular flexibility all combine together to make this functional.

And so, there are small proteins in the base layer. Then there are mucins which is the key determinant of the synovial fluid properties. And so, mucins are there in both of these layers and they form these loops or linear structures and that is what determines the overall lubricating properties of synovial fluid. So, when we are thinking in terms of biomimetic polymers can we look at mucin and can we say that does this give us any idea about design of macromolecular systems.

So, for example it is known that lubricin and mucin which are commonly observed polymers in synovial fluid. They are all branched. So, then branched architecture; may be a very good property to have in terms of macromolecular systems if we are searching for new bio lubricants. So, can we get the lubricants which have branched architecture. Can we get functional groups which are similar to bio lubricants or can we get targeted interactions based on these functional groups.

Which can then; react with other macromolecules or other small molecules which are surrounding. So, this is biomimetic thinking and of course all of this is still in the research domain. But this is an important direction in which again sustainability can be thought about. Because we know that the synovial fluids and other macromolecular systems which are involved in such biological systems are sustainable from the point of view of circular.

They being incorporated into biogeochemical cycles. There is bio degradation pathways available for them the raw materials for them are coming from renewable sources and so on. So, therefore biomimetism can also be one way of solving the sustainability issues related to macromolecular systems.

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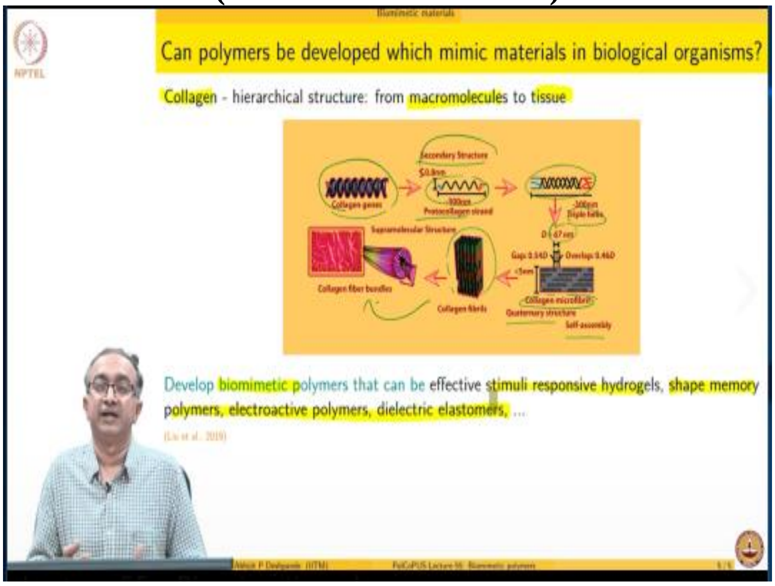

The other challenge that; I want to leave you with and again as I have been mentioning twice in this lecture already that these are all still research questions. And a lot of us have to do work in this area for biomimetic polymers to become much more common. Look at another polymer which is Collagen which is part of our tissue. Can we look at how collagen does assembly and come up with this tissue as a structure.

And tissue is what gives strength to our body. And tissue mediates the interaction between different parts one side subjected tissue to the other side of the tissue how interactions happen through molecular exchange through deformation. All of that is determined based on tissue so it has a very important role. So, collagen as a macromolecule is there and then it is important component of tissue.

So, how does this scale different length scales in the end through molecular interactions through assembly how do we get this from macromolecule to tissue. So, just to highlight that what we can look at is basically the genes of collagen through which we form the secondary structure and basically the helical structure of a collagen strand which is called the proto collagen strand. And each of them have different lengths.

So, this is very small and then there is an assembly in terms of helix which gives us the triple helix. And that has a diameter of around 60, 70 nanometers. And these actually form into microfiber. So, these triple helix stack with each other and then form microfibril. This is basically part of the quaternary structure and this happens through self assembly while tissue is being generated. And these fibrils then again stack up and the microfibrils to give you fabrics.

And these fibrils stack up to give you the bundles. And, these bundles inter mesh each other to get finally the tissue. So, can we mimic some of these properties to get a structural material like tissue. And can we start looking and getting inspired from collagen. Of course, one easy answer in this is to just use collagen directly. But is it possible for us to manipulate produce manufacture collagen in such quantities which our body is able to do.

Or in the can we devise a polymer which is mimicking collagen and then hopefully it can mimic also the tissue generation that collagen does. And so, in general in macromolecular research scientists are grappling with this idea of trying to take biomimetic polymers and then see whether they can do many of these things which are already being done in biology. So, can they play the role of a hydrogel or a shape memory polymer so that sensors actuators members and active components can be formed from these polymers.

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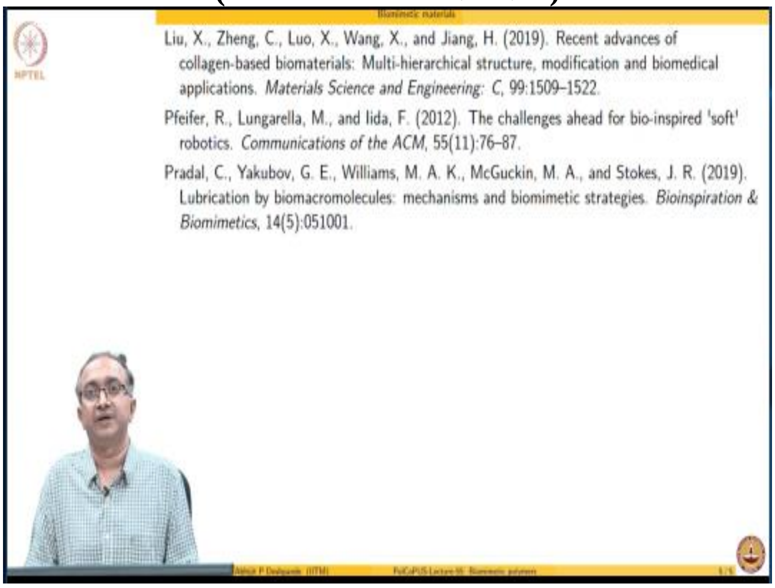

So, with this thought we will close this lecture biomimetic polymers is still a promise which still has to be looked at before we can see many applications from it. But from a sustainability point of view it is probably a very good direction to take in terms of looking at new sets of polymers. Thank you.