Physico - Chemical, Mechanical and Electrical Properties of Polymers

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Lecture – 34
Blends / Composites in Recycling

Hello, welcome again, we are going to focus in this week as well as next week on properties of polymers. Having looked at a single macromolecule and its behaviour, and then all the key features associated with macromolecules, in terms of its last foundation or in terms of its crystallization behaviour, also mixing of different types of polymeric systems to get blends and composites. We have seen a wide-ranging gamut of interesting concepts and tools available for us, so that we can manipulate the properties and so, in this week, we will look at what are all the different properties from mechanical, electrical properties, which are relevant from an application point of view. Given that we have discussed polymeric systems of different kind, in this lecture, we will look at you know, whether they form natural ways in which we can achieve more effective recycling.

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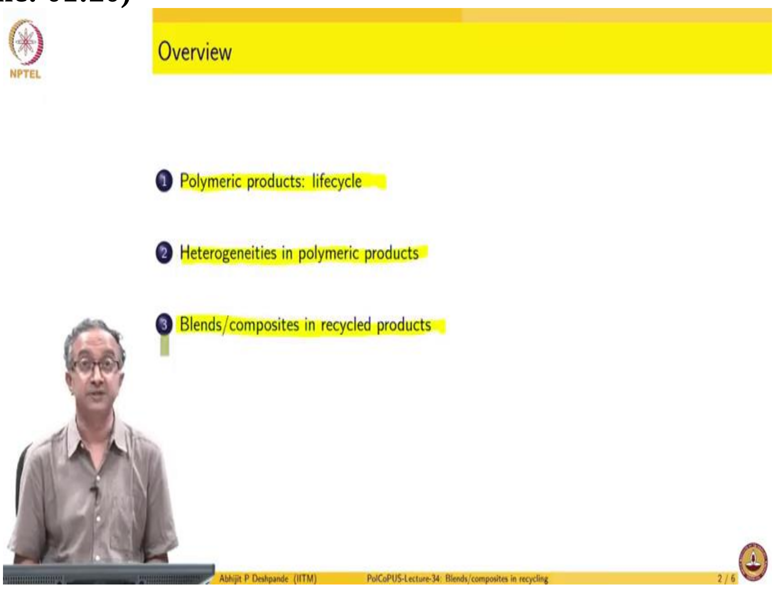

So, that we continue to focus on the overall sustainability aspects of these polymeric materials. And we will do this by first quickly looking at polymeric product and its life cycle and then highlight that post lifecycle handling of polymeric product is challenging because of the heterogeneities which are associated with this polymer product. And, therefore, how blends and composites arise naturally in recycled products, which is an advantage but at the same time, it is a challenge for engineers and scientists to obtain the precise type of interactions between these components which are being added with each other polymer 1 with polymer 2 or polymer 1 with filler one and how do we achieve the correct microstructure and overall compatibility between different components so, that we achieve a targeted performance.

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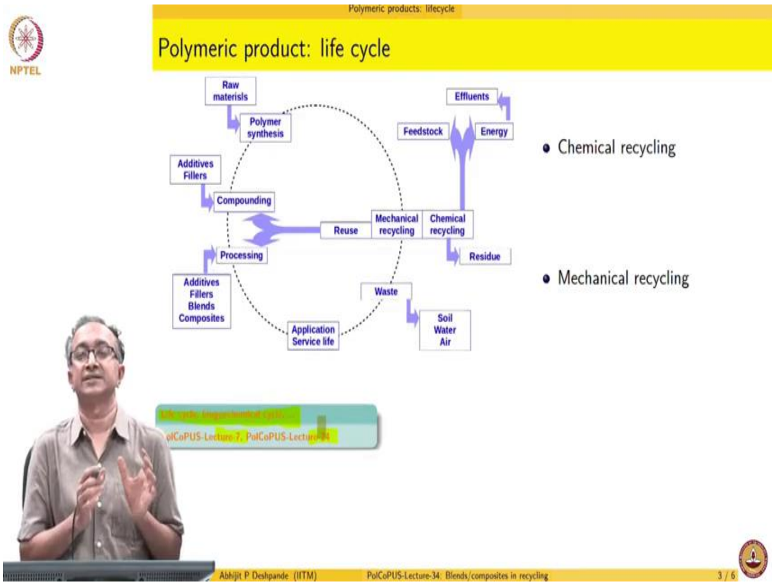

So, if you look at the overall lifecycle of a product and we have talked about the biogeochemical cycles and how from raw material, there is always a cycle going back to the raw material itself, if you look at polymer product, raw materials, which comes from petroleum, we have the polymer synthesis. And then from polymer synthesis, we generally polymer is compounded with some additives and fillers, so, that this is ready to be processed.

So, compounding is an operation or a set of operations in which we get a polymer in a granule or a fibre or any form which is it can be then processed by a fabricator who is going to be interested in using the plastic or polymeric product for a specific application. So, post compounding of course, then it goes to processing, where again, we may add different additives and fillers to use the polymer by itself or it blends and composites.

And then, so, having done these set of operations, in which we synthesize the polymer we compound it, and we process it, we finally, send it for an application. In case of single use plastic this application window is just a single use in many other cases, the service life maybe years together. So, depends on whatever is the application the service life may be large or small and post the service life then what we have is several options.

So, since the service life is over, it can become a waste material. Of course, in our lecture, we saw that reuse is a definite possibility which therefore, can reduce the amount of material which is going to waste and this waste material has a potential to interact with soil ,water and air. And this also we saw that how different states in environment are of relevance as far as polymeric materials are concerned, but having exhausted the possibilities of reuse, then we are forced with looking at how to look at this waste not going into soil water in here.

But, again coming back as part of the cycle. So, we have the options of reuse or mechanical recycling or chemical recycling. And so, all these 3 can lead to certain amount of usage. When we say chemical recycling, we can basically combust and incinerate and get some energy out, or we could break down the macromolecules into smaller molecules and get some feedstock and this again can be actually brought back.

So, therefore, some amount of cycle closing can be done. However, each of these processes will lead to effluence. And so, if you look at this overall polymeric product cycle, there is a very complicated closing of the cycle in case of polymers and this is what we need to achieve, if we have to think overall in terms of sustainability. So, the two predominant methods of recycling, chemical recycling which can lead to feedstock energy or mechanical recycling, which basically takes it back again to the compounding and processing stage, so, that we again can get a new polymer polymeric product and so, both mechanical and chemical recycling are options generally mechanical recycling is preferred from a point of view where then we are not changing the macromolecular nature by depolymerizing we are just reusing. But how many times can we do mechanical recycling is also a question because, once we start processing and compounding the material and once it has been used in application, the macromolecules will not be the same as what they were synthesized.

So, because of the aging processes, because of the degradation processes, because of the interaction with all the other environment and other chemicals and temperature and pressure and all the conditions environmental conditions, basically macromolecule nature will change.
So, how good a polymer is for mechanical recycling has to be also ascertain before we take up the mechanical recycling.

So, all these are very important issues to be dealt with and we have seen that this life cycle bio geochemical cycle, we have in lecture 7 and 24 discuss these concepts which are very important for sustainability of overall polymeric system.

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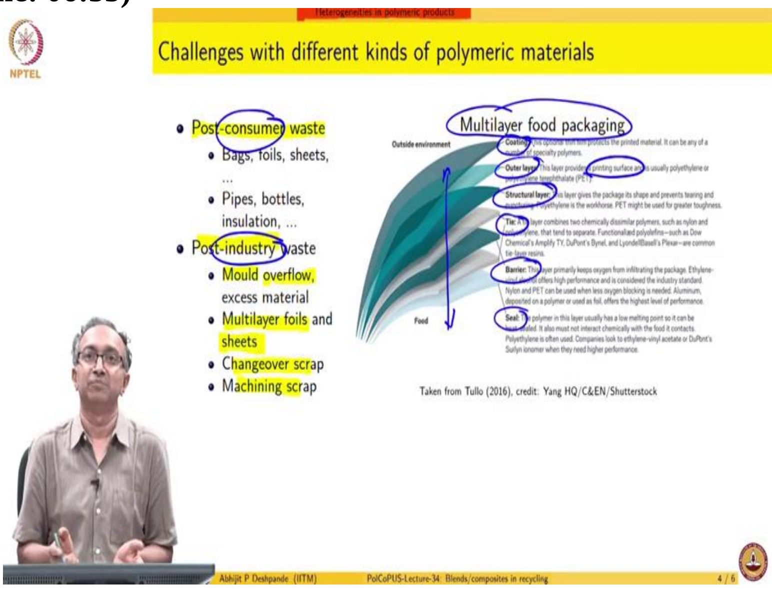

Now, mechanical recycling maybe advantageous from many points of view, but what is the challenge and the amount of heterogeneity is that are there in polymer product is astounding, and we have, we could think of waste in terms of let us say, just a consumer waste or waste which is coming from industry itself, because these polymers are fabricated, processed in an industry itself, you can have moulds, some overflow happening, some packaging which is used in industry.

When you change from one polymer to the other polymer in a mould, there is a changeover scrap when we machine it, we cut the shape, there can be scrap. So, there is possibility of industrial waste as well as consumer waste and this to again highlight the heterogeneity which is present, let us look at what is involved in a multilayer food packaging, look at the number of layers which are there, in terms of consuming food item.

We will just open the foil and then consume it and then throw it and it is a single use material but look at the intricacies of this kind of material system. So, this has tow aspects one is the engineering and science of making such as it is quite interesting and extremely innovative process by which we have come up with such a multilayer packaging. Again, it is easy to say that why do not we just put multilayer but can be process it, can be fabricated it, will the multiple polymers which are being used Can I get the control thicknesses of it?

So, therefore, there is a material science of how to choose these different layers, then there is a engineering fabrication of how to get these layers in a correct way. So, very fascinating subject, and just look at the design of it. So, outer coating is just to protect whatever has been printed, because quite often the printing and the appearance of the packaging will influence the consumer’s behaviour.

The outer layer has to be there because printing has to be there because not all polymeric surfaces can be printing be more effective. So, we need a surface which is printing then we have a mainly structural layer. Structural layer which gives the mechanical stability then we have a barrier layer because structural layer may not be very effective in terms of stopping oxygen, carbon dioxide or UV radiation. So, we need some barrier film also.

And to have both of these together, there may be a tie cell which is a compatible film between the two. And then finally, to ensure that the packing is closely tied on to the overall size of the food material which is being sold. We may have a biaxially oriented or film which is basically a heat seal so you can see that there are several layers in a very thin plastic material, and this is what we have to recycle. So, now you can see.

So, from a point of view of science and engineering to get this film very nice, extremely innovative, very important in terms of getting to know the science behind how diffusion happens, how different cells interact with each other interfacial science very interesting that we can get such a film reproducibly and effectively, but now, when we think of the sustainability aspect that now one has to recycle this, how can we do that. So, therefore, in this case, we already have a material which has multiple polymers in it.

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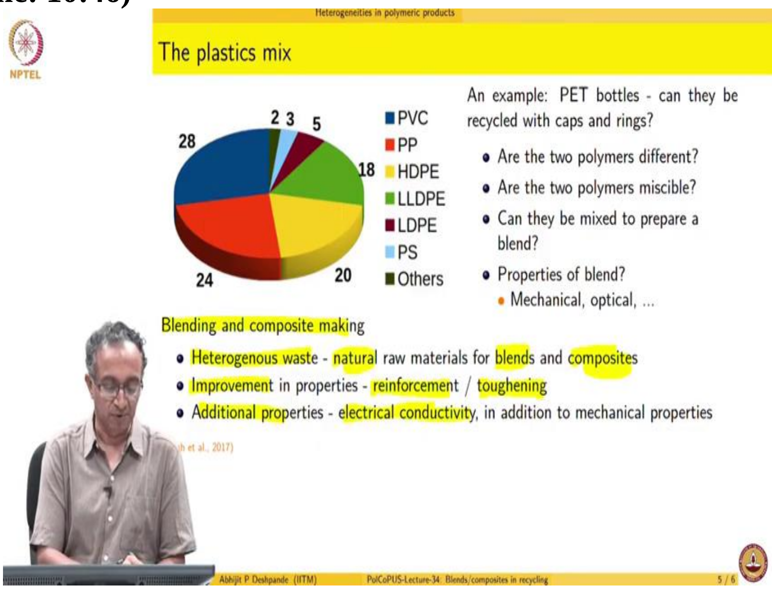

And so, if we want to really recycle such a thing, blend will be a natural choice, but can I not just mix it all up and then use it as a blank just to give you again another idea of you know, what is the different types of plastics and this is based on Indian data, and you can see that polyethylene and polypropylene and PVC and polystyrene form large amounts and so, if we have to really recycle, blending some of these together, maybe an advantage in terms of getting a certain set of properties.

One example is PET bottle, this is actually one of the products which is recycled quite effectively, because it is collection and sorting is quite easy. But there is a challenge, we have the caps and the ring, which is usually different colour than the transparent PET bottle that we have. Now, that is polypropylene. Now, can we recycle this? So, actually quite often what is done now is manually the caps and the rings which is next to the cap have to be separated.

So, that PET bottle alone goes for recycling. Now, that involves cost. So, therefore, can we do it in another way where we do not need to separate and just put PET polypropylene together and so form a blend, but then the key question will be like based on what we have discussed in our blend lectures, PET PP miscible. No, they are not then what will be the domain size of PP.

How will it be distributed and based on its distribution and microstructure, what will be the mechanical properties of the final part? Now, one of the important things for PET bottle as a water bottle or any other soda or cold drinks bottle is the transparency, will the transparency remain of course not. So, then what applications can be useful. So, therefore, once we start using these heterogeneous plastics mix and we want to recycle them, there are several questions that arise.

You know, how different are the polymers that are being targeted to be recycled? Are they miscible? Can they be mixed at all to prepare a blend? What are the properties of that blend? Whether it is mechanically robust enough ? Whether optical transparency is required? Then this cannot be done? So, therefore, these are all challenging options as far as recycling of polymers goes, and generally blending and composite making seems to be an easy way because already there is heterogeneous material systems can we not all mix it up?

And so, some of this is being exploited in several applications. For example, if you just look at plastic wood, you will see that several people are using waste plastics to actually look at generating wooden type of structures for interior applications all exterior applications. So, generally, blending and composite may be preferable because waste itself is heterogeneous. And therefore, they become a natural raw material for making blends and composites.

It is possible that by blending and composites, we will achieve maybe toughened materials or reinforced materials and therefore some improvement in properties. Sometimes by adding these things, maybe we will achieve something which was not there. So, we may get a conducting composite. So, in addition to just looking at mechanical performance, we may get an additional criterion for choosing the material over some other materials.

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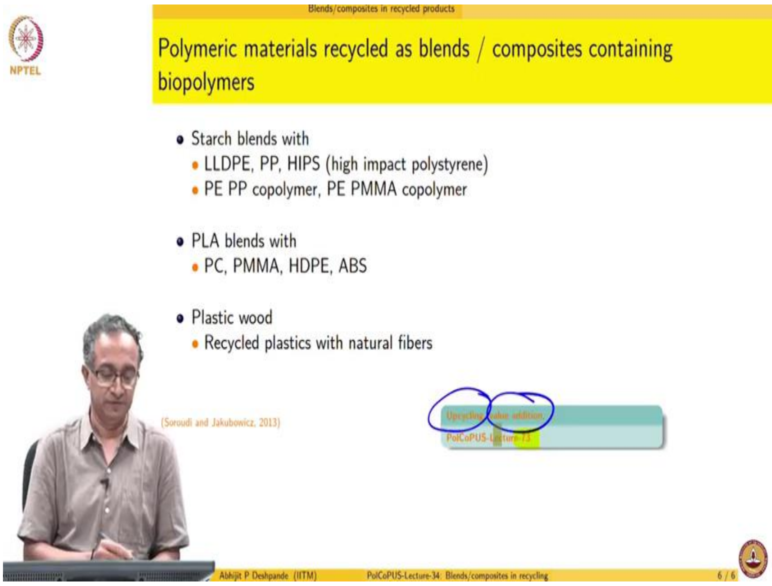

So, in general, because of the heterogeneity of the systems blending and composite making does seem to make sense. And so, just to close this lecture, we will look at some examples of where blending is being done by adding a bio polymer itself. And since this bio polymer is biodegradable or compostable, so therefore, we are now replacing the amount of overall non - renewable mix in the overall product.

So, for example, there are many products where starch has been blended with polyethylene, polypropylene or polystyrene so that we incorporate biopolymer in a commercial product, it is also been in fact incorporated with the copolymer itself? So, we have a polyethylene polypropylene copolymer, mixed with a starch, so, it is a blend and a copolymer together. Similarly, poly lactic acid, which is a biodegradable polymer, is also blended with several polymers.

So, in this case, what we are trying to do is to take a bio polymer and take other sets of polymeric materials and mix them together. So, the recycled product has less of the polymeric material, which is may not be part of the overall closed cycle or the circular economy. However, biopolymers because of the renewable resources as we have seen earlier can be part of a circular economy.

So, therefore, we are reducing the percentage of the non-renewable component in our final products, there are challenges because; blending with starch does it lead to the required properties. One other key thing that we have to remember from an overall sustainability point of view is the lifecycle cost associated with each of these. So, we have seen that there is energy cost or footprint associated with the raw material itself and also there is a footprint associated with processing.

So, starch and poly lactic acid may have less footprint from a material point of view, but if you are trying to make these blends, what is the processing footprint, what is the fabrication footprint and so, many of these are extremely challenging topics for us to contend with and arrive at better and better and more sustainable answers for polymers and polymeric products to be as sustainable as possible.

And so, as I mentioned, plastic wood is also an idea where recycled plastics are being used for furniture and for exterior applications, such as fencing and transport sector applications, where natural fibers are being used with recycled plastics. So, one of the other things that comes to mind when we think of these recycling is that can we not improve the performance while doing recycling?

Because generally the idea of recycling is that the PET bottle which was used for water bottle, which is a an application, where food grade is required, the specific stability of PET bottle is required into something which is less liquid like a bucket or like a soap case or an a product which is which has less cost. And so therefore, it is recycled at the same time, it is actually come down in its value, but can we do an upcycling?

So, while we are anyway recycling the material can we not manipulate the materials in such a way that we upcycle the material. So, this is something by value addition and upcycling, then we will not have this issue of recycling always implying lower cost and lower performance from the part and so, this is something which is very important, because if we have all the options available in terms of recycling, upcycle, down cycle, cycling recycling at the same level, then we will have again similar to what overall biogeochemical cycle is where cellulose for example gets recycled in multiple ways. In biogeochemical cycle, while similar flexibility we should have with respect to polymeric materials being sustainable. So, we will discuss some of this in lecture number 73, which is related to the upcycling of many of these polymeric materials.

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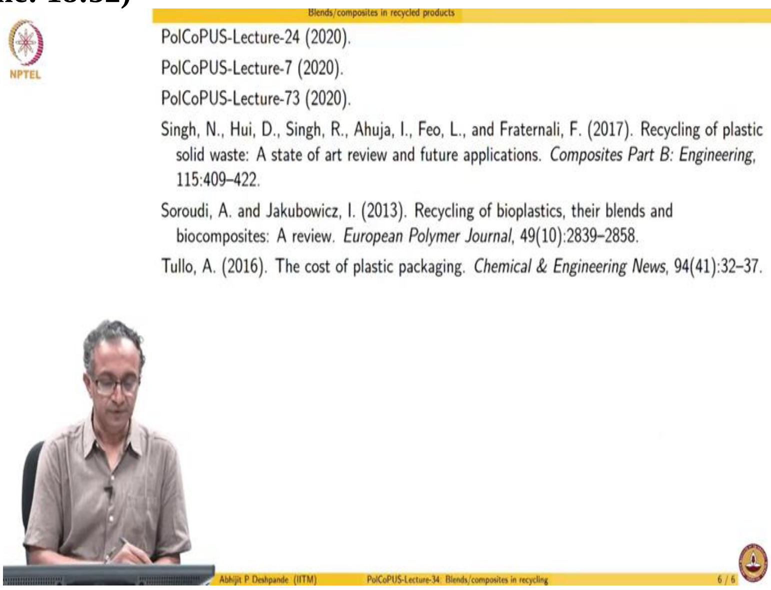

So, with this, we will close this lecture. Thank you.