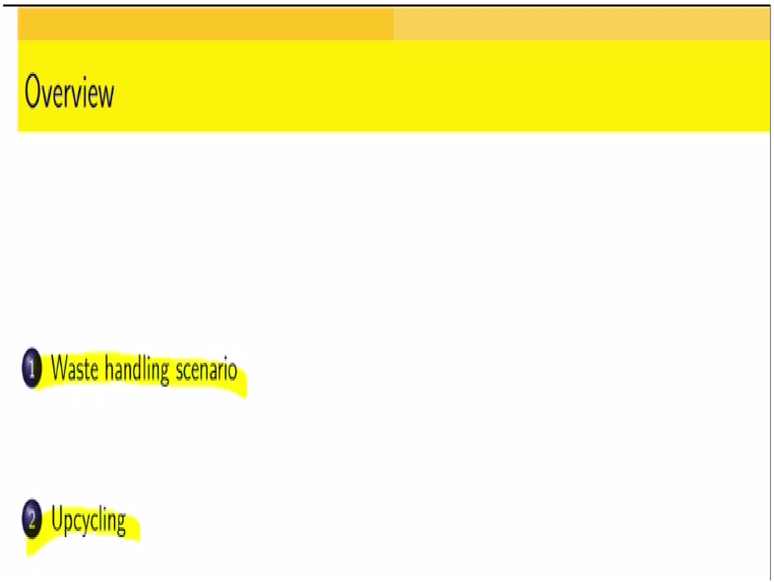
Polymers Processing and Recycling Techniques
Prof. Abhijit P Deshpande
Department of Chemical Engineering
Indian Institute of Technology - Madras

Lecture – 73
PolCoPUS: Recycle, Up-down Cycling

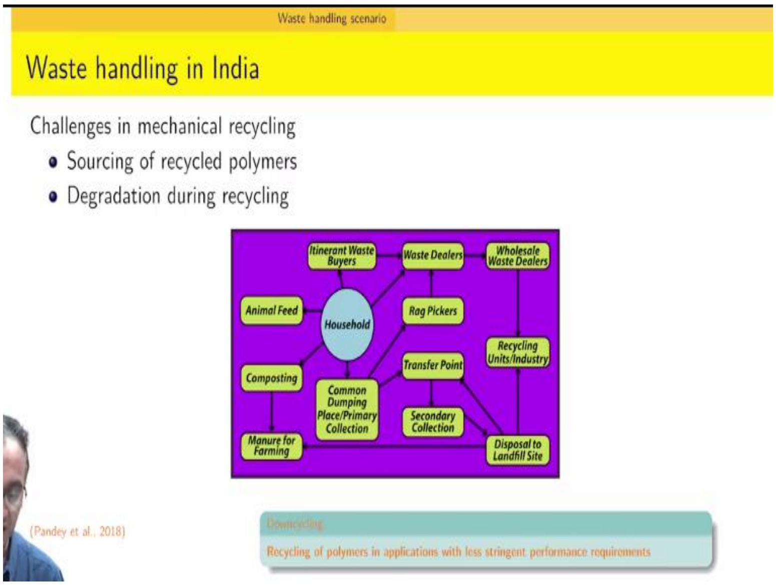
Hello, welcome to the course on polymers and as we continue discussing the polymer processing and recycling techniques, let us look at the issues associated with the recycling and the upcycling, which is promising and what are the challenges associated with it, and all of this we are trying to do because we are interested in the overall sustainability of polymer materials.

(Refer Slide Time: 00:37)



So we will start with looking at waste handling scenarios given that polymers are part of the overall waste and so the waste handling scenario influences what is the availability of many of the polymers for recycling and then the challenges associated with upcycling so that we get a whole range of operations and products in which polymers could be used.

(Refer Slide Time: 01:03)



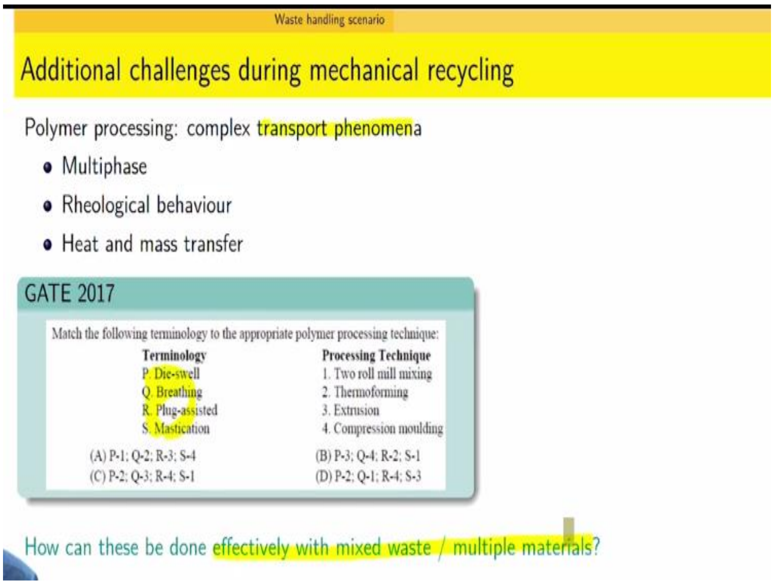
So let us start looking at in terms of waste as a whole and because polymers and plastic are part of this overall waste and so how waste is handled determines also how the polymers are collected, distributed and how are they available for recycling operation. So, for example there are various stakeholders in this process and how polymers get exchange between these different stakeholders and more importantly what kind of other substances do they come in contact with.

So, there are a collection centers like secondary collections. There are common dumping or primary collection centers. There are people who buy waste. There are people who make a living out of collecting it from very scattered set of resources. Waste generally is given for composting and making manure and some of the plastic can go there and again it can come back into the soil and water streams.

And so there are of course recycling units which are trying to take the material and recycle and so from waste dealers, which they take it from either households or from rag pickers or waste buyers, and then eventually it ends up being to the recycling industry. So you can see it is a complex web of different stakeholders and polymers get transferred from one to the other and also in process may see several different environments.

And when it comes finally to recycle unit, the requirements on sorting separation, the requirements on cleaning consolidation may be much higher than if we could collect the plastic material as it is. And therefore, we all saw an example also earlier where the closed loop recycling, which is within the same premises is far more effective compared to open loop and so in open loop recycling, generally what ends up happening is downcycling where the recycling of polymers is application with the less stringent requirements.

(Refer Slide Time: 03:18)



However, our focus will remain on upcycling and upcycling is important because there are a great number of challenges when we look at the polymer processing from the point of view of recycling these materials. So, there are additional challenges. For example, the complex transport phenomenon which happen due to multiple phases being involved, the rheology itself is quite complicated whenever we have the recycling materials and of course the heat and mass transfer.

And over and above these basic complications associated with a polymer processing operation, each and every polymer processing operation involves certain manipulation to ensure that we control it. So over and above these polymer processing operation related issues, which are due to polymers being themselves complex materials, each and every processing operation also involves certain finer aspects.

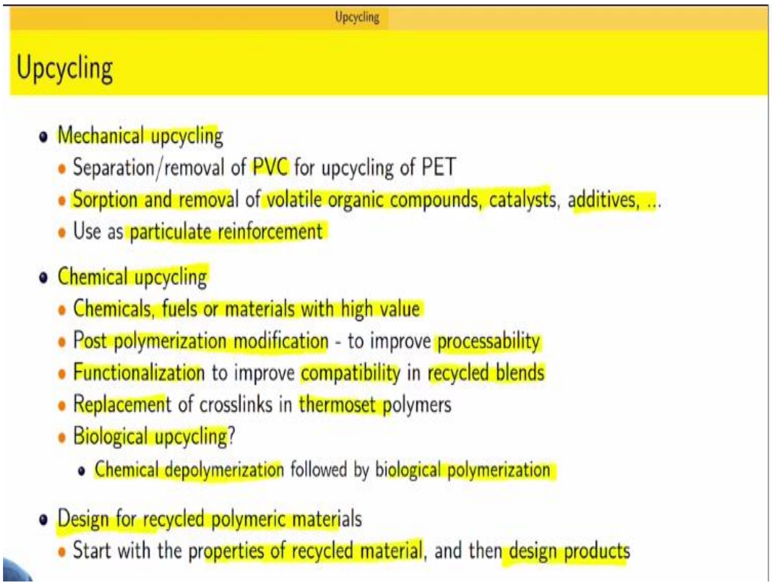
For example, in extrusion when the material extrudes out, there is a swelling of the extra extrudates and so if we are extruding a fiber, then the fiber size is much larger than the die size. Now, the question is if I do recycle the material due to the complicated multiphase and rheological behavior of such a material, what will be the extrudes swell for a recycle polymer?

Having done processed the virgin polymers and pure polymers for decades, we have acquired a very good understanding of how to predict a die swell or how to design a die for a given final shape. Now, once we start recycling with compositions of varying and different versions of recycled plastics in different batches, can we do this control effectively? So that is what you need to really consider while we are looking at the recycling of polymeric materials.

For example, breathing which is an act of making sure that voids or volatiles are taken away from the polymer part so that they are not left behind is also involved in a processing operation. You could also manipulate the molar mass during an operation. So you can do some of the search and try to see what the answer is while we continue looking at the question that many of these recycling techniques will involve the waste plastics.

And in addition to managing transport phenomena in these waste plastic materials while recycling, how do we manage additional operations, additional features to get the final part which is very controlled?

(Refer Slide Time: 06:32)



So upcycling is a very good idea and a lot of work is going on now to try to make sure that options for upcycling increase and this can be done in terms of mechanical upcycling. So, for example, polyethylene terephthalate can be used in better applications or at least the same application if you make sure that PVC is completely removed from any waste recycled PET. Similarly, some of the volatile organic compounds, catalyst and additives can also be desorbed and removed.

One other option is to grind the recycled plastic material and then use it as a particular reinforcement in a higher application. So, this naturally becomes an upcycling because the waste plastic now in a particulate form is being used as a filler and reinforcement in a much better application. This is not always feasible, but there is always a search on for looking at these kinds of applications.

We can do the upcycling by chemical methods also by which we mean we involve rather than just melting and reprocessing or grinding and reprocessing, we can think of dissolving, reacting, certain other sets of processes by use of solvents and catalysts and other entities. So that is why it is called chemical upcycling and one is to basically upcycle it in a set of materials which are high value. So it could be a small molecule, which is high value.

It could be fuel in case the petrol prices are very high, can we not produce petrol from polymer and periodically you will hear this in news also that there are people who are working on pilot plants and some small units which are associated on this concept. Another important possibility is once the polymer is formed or post polymerization, can something not be done in terms of modification, can we not functionalize, can we not extend the chain, can we not do a small graft?

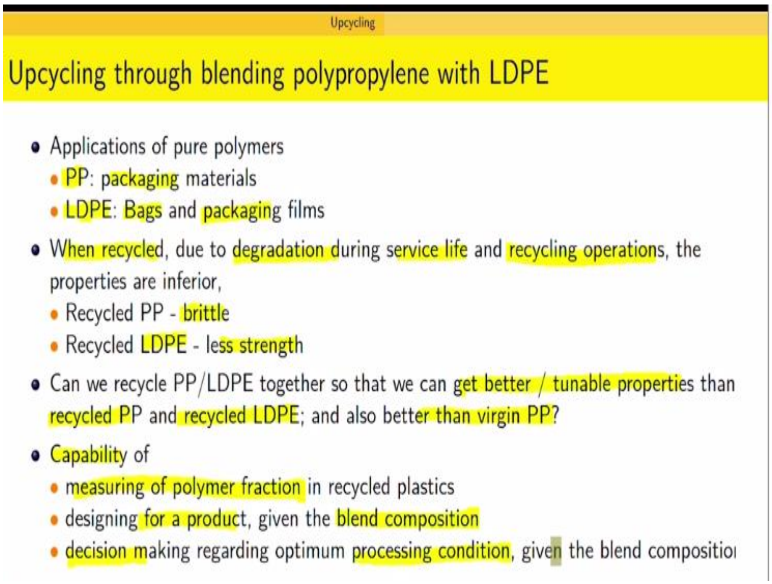
Can we not basically do a chemical modification so that processability is improved? And if processability is improved, then we do not have to apply high temperature, high pressure and then degradation and other negative associated phenomena with mechanical recycling can be reduced and therefore upcycling again can be achieved. Of course, chemical functionalization to improve compatibility is very important for recycled blends.

Can we also think in terms of replacement of crosslinks, can we not remove the crosslinks and then add certain other crosslinks so that again thermoset polymers also become recyclable. Can we also think in terms of biological upcycling? So we can do a depolymerization, but following a biological process of polymerization, so that again we get a polymer which is very high properties or with different level of purity so that it can be used again in wide ranging applications.

So this is related to basically how to do conversion of materials. We could also think in terms of that, given the waste plastic mix that we have and given the recycling operation that is used, we will get a certain property. Now, instead of going with the older designs and saying that oh this property is not matching, can I not design the product itself in a novel way so that with those inferior properties also I can use the material.

So this is something which is design for recycling. So rather than saying design which is for virgin material and then try to adopt the recycled material for those applications, we start with base case of recycled polymeric materials and think of designing products. So designing of products is based on properties of the recycled material itself and again this is something which has been thought of in the last few years and some products are coming out which are done this way.

(Refer Slide Time: 10:52)



Now, we will leave this topic by looking at the upcycling for a very specific example of let us say polypropylene and LDPE. So both of these are widely used materials. Polypropylene is used as a packaging material and LDPE is used also as a bag and packaging material. But when you recycle them, there is always degradation which is during service life as well as during recycling operations.

So polypropylene is brittle when we recycle and LDPE has much less strength when we recycle it. Now, instead of recycling them separately and ending up downcycling both of them, can we mix and make a blend of both of them so that we can get better tunable properties and of course these properties ought to be better than recycled and recycled LDPE, but also better than virgin polypropylene itself because among polypropylene and LDPE, polypropylene is the more costlier polymer.

So if you get properties which are better than polypropylene, then again what we can do is use this blend in an application where stringent property requirements are there more than the polypropylene itself. So even where polypropylene could not be used, now this blend material can be used and that is the meaning of upcycling. But of course, to achieve this, we need a lot of work in terms of getting to know what is the exact polymer fraction which is coming in so that we can design a proper composition.

Based on that composition, what is a product that can be used and then given a target product and a given blend composition, decision making regarding what should be the condition used for a given blend composition. So lot of these are still R and D issues, but you can see the direction in which we can exploit the knowledge of macromolecular systems from a fundamental point of view in terms of miscibility, rheology, compatibility, interfacial science, all of that can be combined to come up with a product and eventual upcycling of these polymeric materials.

(Refer Slide Time: 13:09)

In terms of the issues such as die swell and breathing and other key features associated with each and every processing operation and the challenge that I mentioned, that can these be effectively done for recycled materials, I hope you have been able to get the answer that breathing, for example, is involved in compression moulding where closing and opening is done to allow the voids to escape and mastication is basically control of the molar mass so that the flowability of rubber lattices can be improved. So with this, we will close this lecture. Thank you.