Carbon Materials and Manufacturing
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Lecture - 57
Large Scale Industrial Applications of Carbon Materials

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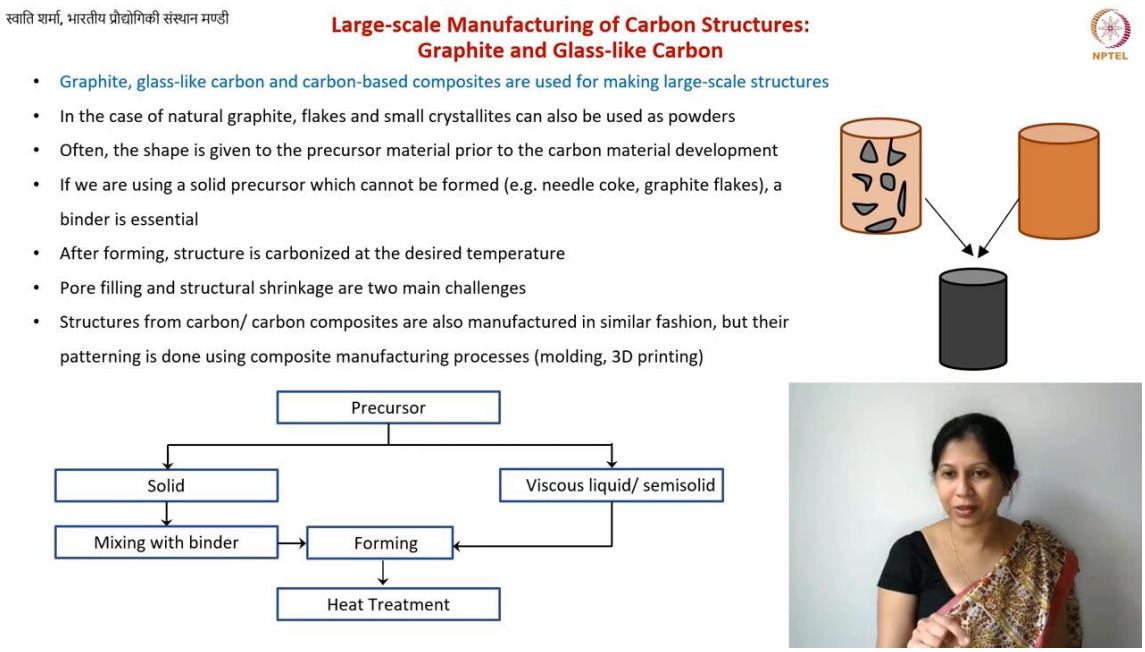

Since we have already talked about the fundamental aspects of all of these carbon materials and all of their properties and what is used for what, now let us still briefly talk about the manufacturability.one important factor is that whenever you are thinking about a certain application, you need to figure out whether or not you will be able to make the kind of devices that you are thinking of. For example, if you think of a certain device that will have excellent properties. If you used single graphene sheets, but you do not have a single graphene sheet; or let us say either you do not have the equipment to produce it, or even though the equipment is there; the method is not optimized for a single layer.

So, either you need to know what are the challenges that you are going to face when it comes to manufacturing. Of course, you can think of all the new fancy applications, also new materials. In fact, I definitely hope that after learning so many things about carbon in this particular course; you will be able to come up with new carbon materials, you will be able to design new carbon materials, carbon-based composites and so on.

So, definitely you should think about all of these things, but at the same time you should know what are the challenges that you are going to face and especially when it comes to manufacturing aspects.by the way, we have talked about the manufacturing of carbon material itself. But now we are talking about; using carbon materials for applications and that kind of manufacturability. So, manufacturing using carbon materials.

First, we will talk about large-scale carbon materials. And maybe in the next lecture, I will discuss micro nanoscale carbon materials. So, first we talk about graphite and glassy carbon. Why are we doing that? Because these are the materials that are used for making large-scale structures. So, I am not talking about powder, I am talking about giving shapes and making something let us say a cylinder or some kind of any shape.

So, primarily for this kind of purpose, we are using graphite definitely. You know about graphite electrodes already. We also use definitely glass-like carbon, we use various structures from lab crucibles to electrodes to everything. So, we do provide a shape, we give a shape, we do forming for glass-like carbon.

What else? Also composites definitely. Composites are used for making even parts of automobile, and airplanes, and whatnot. In that case, definitely, you give them a shape. So, these are the materials we use for making structures.

Let us start with natural graphite. You have flakes because you have natural graphite with very large crystals, but that is very expensive. You are not going to probably use it for just a lab-purpose electrode or something that is very expensive whereas the crystallite size increases. But you will often use flake graphite; flake graphite also can be produced using kish graphite production processes. And also it is naturally found.

Let us say if you are using flake graphite or somehow we produced small crystallites, or we found in the mines and coal seams; you can find these small crystallites of graphite. These kinds of graphites; either we use as powders, or they can be mixed inside a resin. And then you can further carbonize them. And then you can use them for making structures, but they also can be used as powders of course.

So, how do we give the shape? You know this very well probably by now, before most of the large scale materials, whenever we want to give it a shape, we want to do forming. Then what we are doing is, we are rather working with the precursor, with the polymer

itself; with whatever is the initial material. And you know we perform in a way our manufacturing on the polymer or on the precursor, and then heat treat it. So, we do not really make things from graphite let us say.

If you are using powder binder or flake graphite or something like that, in that case, you need a binder; or if you are also trying to get a graphite structure, but you are using certain precursor which is the solid-state, for example, needle coke. You cannot give a shape to needle coke because it is solid-state.

So, in that case you are going to mix this needle coke or flakes of graphite or any type of powdered carbon material or powdered solid-state precursor for your graphite or glass-like carbon for that matter, and then you can already give it a shape using a binder.

If it is solid-state, if it is not solid state, if it is a viscous polymer or a resin itself which typically happens in the case of glass like carbon, then you can directly give it to shape. I mean that itself is like a binder. So, you do not really need. These shapes to be given using typically a molding process, that again we have learnt a lot about it.

3D printing also is used especially if you are making biomedical implants. Or let us say if I want to make a tooth implant using glassy carbon, in that case, the shape of the tooth can be written using a 3D printer. So, these are some of the techniques.

One very important challenge is that you need to take care of the shrinkage. So, two things, pore filling, when you are using something like needle coke and then you know a binder which can be a petroleum pitch or it can be a resin, and then you are heat treating it; that is number 1.

There you need to make sure that your pores are filled. And if you are using just a resin structure itself, in that case, shrinkage becomes very important. These are the couple of challenges that you need to ensure you need to take care of.

Here is a quick chart of whatever I just said. So, you have a precursor, either it is a solid-state precursor or it is a viscous liquid type precursor; typically we are not talking about gaseous hydrocarbon precursors because with the gaseous hydrocarbons you are not going to make a structure.

So, right now we are talking about structures. With gaseous hydrocarbons, you will either get films or coatings, which often happens in the case of diamond-like carbon and of course in the case of pyrolytic graphite. So, then you can get a film or coating, but you are not really holding them and making a structure.

However, if you want to use it, that can also be done; which is often done when we will learn about graphene-based devices. In fact, we mix graphene with a certain binder and then we make whatever shapes are desired. Binders of course can be different.

They can have low viscosity that will also depend on how compatible your manufacturing technique is with the size or the scale of the structure that you want to make. So, if you want to make nanoscale structure, you need different viscosities. And if you want to make large-scale cylinders, you need probably a much more viscous liquid to work with.

But here we are talking about just direct structure forming. So, we have either viscous liquids or semi-solid like materials, or we have solid-state precursors. Then we perform the forming. In the case of viscous liquids, directly; in the case of solid materials we will then mix it with a binder, and then we do the forming. And after all of this, we will always perform the heat treatment. So, this is a very simple schematic.

Here you see that you have some needle coke particles inside a resin, we have seen similar structures through this course. This is just a resin. There is no additive in it. In both cases, you will get a slightly shrunk cylinder. Shrinkage will depend upon various factors that you have. So, this is basically the overall idea.

Carbon-carbon composites, as I said that they are also used for making large-scale structures. We did already learn about their manufacturing and also the challenges related to manufacturing like the drilling process, and you know what kind of deformations take place when we perform machining of carbon-carbon composites.

The idea, however, is also pretty much the same that; remember I am talking about carbon-carbon composite. So, you mix carbon fibres inside a carbon resin matrix, and then you heat treat it. Again, you will have the same challenges like pore filling and structural shrinkage. And also in that case one additional challenge is the adhesion of your fiber and matrix phase.

By the way when you are making biomedical implants; let us say you are making a bone implant, in that case, you could also use 3D printing in that case, like I was saying for tooth implant; also for other biomedical implants, you can use 3D printing. Because, their cost is not so important, precision is very important. So, in that case, you can go for more sophisticated manufacturing techniques.

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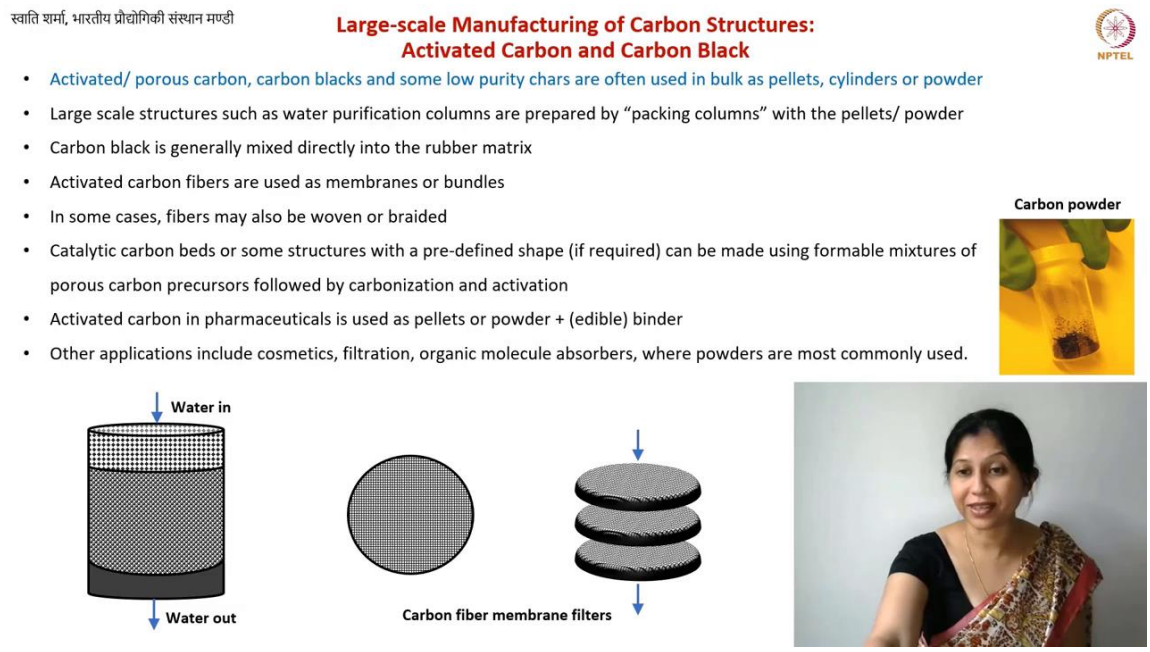

Now we come to the activated carbon and carbon black. Again, we are still talking about large-scale materials, and not yet talking about micro nanoscale materials or devices. Activated carbons, porous carbon; porous carbons basically the carbons that are just porous, but they do not have any specific surface functional groups that we induce by the activation process, and then we call them activated carbons.

So, I have included both activated and porous carbons and carbon black. So, these are also large-scale industrial carbon materials. So, I am not talking about exceptions, but in general, they are not used for making structures; I mean using the fabrication process. So, you basically have them in the form of either powder or pellets or cylinders which is rather more common.

These are the forms in which you can buy these materials in several kilograms in that kind of quantities even in hundreds of kilograms for certain applications. And then you can pack columns. So, you will not add a resin and do the heat treatment in this particular

case. If you want to make a certain structure that is more of a physical packing rather than further heat treatment. So, these materials are available in the form of powders or pellets.

And also, some other char like materials, for example, waste-derived carbon. So, all of these materials are available as pellets. What is the most important application of activated carbon? Water filtration columns.in that case, you will pack a column. So, here I have shown this water filtration column. Actually all three levels are activated made of activated carbons, but the idea is that you will reduce the size.

First, you want to remove the larger impurities from your water, and then you want to make sure that they are also electrochemical, sometimes the heavy metal ions are removed. And then later on you can also reduce the particle size. There may be different strategies. This is just one way of doing it. You can also have electrochemically induced removal of impurities and so on.

What I am trying to tell you here is that you will not really perform further heat treatment when it comes to these kinds of carbon materials as I mentioned here. Similarly, for carbon black, you will generally mix it into your rubber matrix in the form of a powder or pallets, so that is directly used again without any further processing. You also can use activated carbon or at least activated carbon fiber membranes.

So, membranes basically are these woven kinds of structures as you can see then you can have them in circular shape. You can have any shapes for that matter. You can also stack multiple membranes and you can also use that for not just large-scale water filtration, but also for example, filtering out some lab-scale chemicals. So, you can use it for multiple purposes.

Again you can also have electrochemical properties and can be used in combination with the surface properties. Activated carbon fibers can also be used as bundles, and then again you can use them for various applications. Catalytic activity; so activated carbons are also often used as catalytic beds.

In that case, you probably need a surface or sometimes also it is done using columns. So, column you can pass; let us say I want to pass some gas through it and then I want to then perform certain activity or certain catalytic activity on that gas.

So, what I can use? I can use a column or tube-like structure where I filled activated carbon. And from one side to another side, we can pass the gas or even liquid through it, so that is also one option. But if you want a bed-like structure, in that case, you may have to just take the activated carbon and make a solid bed.

You will not really you may require some binder for making the bed, but you would typically avoid any binders with activated carbons because that causes the loss of their surface properties.

We performed the activation. We made sure that we have a lot of good chemical functional groups on the surface. And now, we if you put binder on top of it, so that is something we want to avoid. So, these materials are generally directly used for various applications.

You would have also heard of charcoal tablets because they have good absorbance. So, also in your stomach if there is something that is causing food poisoning; they can absorb a lot of things. So, charcoal is also used in pharmaceuticals. They call it charcoal, but this is highly purified activated carbon, in that case you can also again use a powder with certain binders, but these binders are edible. So, you can eat them. And for many other tablets and capsules, these binders are used anyway. So, similar binders can also be used with activated carbon powders.

This is the picture of carbon powder not necessarily activated carbon powder, but this is how carbon powders look like. They are extremely light that is one interesting thing about them.

So, what are the other applications of activated carbons and carbon black; you can figure it out for yourself. But cosmetics and then different types of filters and odour smell absorbers or organic molecule absorbers, and all of these applications typically would use powder form of activated carbons.