Electrochemical Energy Storage
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Module - 08
Advanced materials and technologies for supercapacitors
Lecture - 40
Current Collectors, Separators etc. and their Effect on Performance

Welcome to my course Electrochemical Energy Storage and this is module number 8, where we are talking about Advanced materials and technologies for supercapacitors. This is lecture number 40, the last lecture of this module, where I will introduce the details of the Current Collectors and Separators, the construction of the super capacitors, what are their effect in their performance of the electrochemical performance of the supercapacitors.

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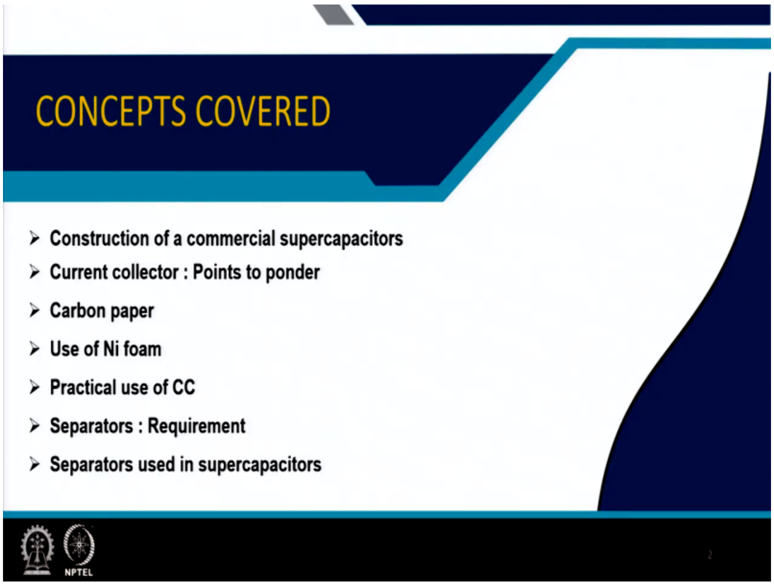

Now, if you I mean the concept that I want to cover in this lecture that is the first the construction of a commercial supercapacitor, how does it look like. And then, in current collectors, what are the important points that you should consider and there are different types of current collector that we will introduce and practical super capacitor, what are the current collectors that is used and then, the separator is another important part of the super capacitors and what are the super, what are the separators that is used in the super capacitors.

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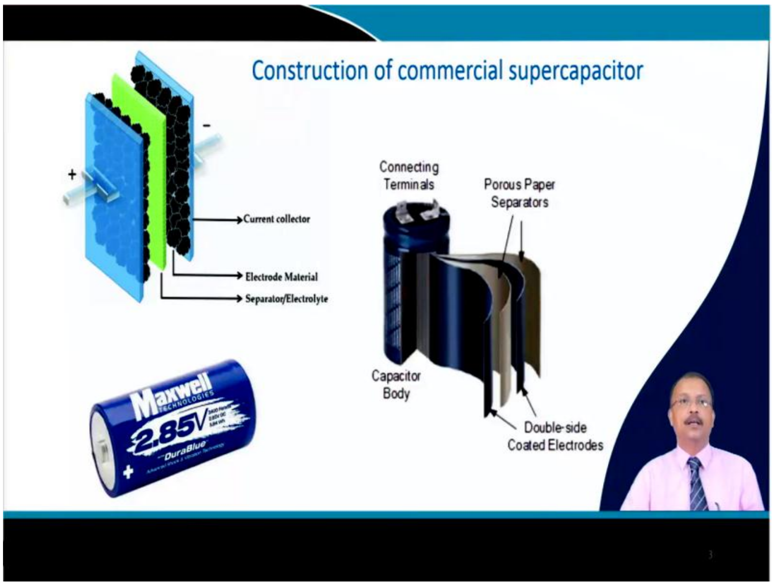

So, if you see the construction, this is the basic construction. So, you should have a current collector and then, you have a coating of either EDLC or a pseudo capacitative material and then, you have a basically a separator which is soaked in electrolyte. And then, you have another electrode and then, you have some kind of contact made so that it is connected to the external circuitry.

So, this kind of thing basically in case of a cylindrical super capacitor is something similar to the type of construction which already I talked about while cylindrical lithium ion cell, I described. So, as you can see that usually they are double sided coated in order to increase the capacity and then, there is a porous paper separator is used.

That is also one of the type of separator that is used and then, you will have to connect it individually, take the connection of all the positive and negative electrode material and then, bring it, attach it to the connecting terminal. And once you close it, so you will see that this kind of supercapacitor; it looks like that. And just note at the capacity 3400 farad and operates at 2.85 volt DC and the energy is a bit low; 3.84 whatever.

I would like you to calculate what is the similar type of energy that you see in a commercial lithium ion cell. So, you can calculate it back, you know what is the voltage and what is the capacity that one get from this kind of cylindrical cell. So, can I mean estimate the energy and compare the capacity, charge capacitance of the super capacitor and battery just to get an idea.

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So, in case of a super capacitor, mostly pseudo capacitive transition metal oxide that is used and as I have told you that they have poor electrical conductivity except RuO 2, they are metal like conductivity. So, the surface redox reaction only take place within a very small thin layer. So, therefore, this layer is pretty thin.

So, this is basically a nanostructured material that you know that is quite effective. Porous material is also effective and in case of EDLC, we talked about physical way of making this porosity or chemical way of making this porosity. So, the fabrication of this nanostructured pseudo capacitive material that is done in order to increase the specific surface area.

So, once the specific surface area is increased and the diffusion length is less, because a charge transfer reaction is involved. So, it shortens the path of diffusion and also, electron conduction. So, that is quite effective and another architecture which is commercially is not adapted yet I guess. That is the loading the super capacitive material onto a conductive nano-architectured current collector which already is having large specific surface area.

So, the charge transport is quite efficient and many things are used; carbon foam is one of them. One can also use a porous carbon paper and nickel foam is another thing and aligned carbon nano fibers, so they are quite effective as far as the double layer kind of super capacitors. So, this will offer you quite reasonably good high performance I should say, ultra-capacitor one can actually make out of this structured conductive material as a current collector.

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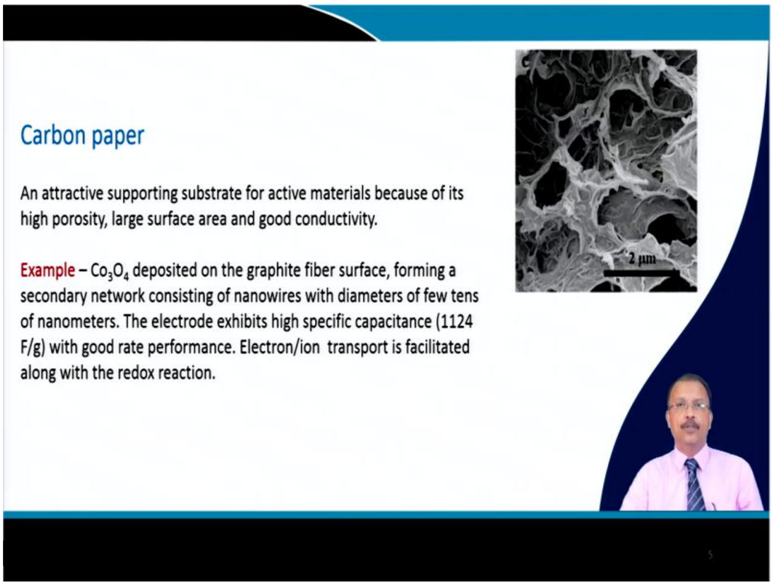

So, if you consider this carbon paper, so that is a supportive substance for the active material. So, it has very high porosity and surface area is also large, conductivity is good. So, one example is that a graphite fiber surface, then this pseudo capacitor that is decide I mean deposited. So, it forms basically a secondary network that consist of the nanowires of this material with a few 10s of nanometer.

And this type of electrode they exhibit reasonably good, fantastic specific capacitance and because of this conductivity, you can expect very good rate performance. So, both electron transport as well as ion transport for this redox reaction, you know that pseudo capacitor they have this charge transfer. So, electron, I mean the charges they charge transfer is operative here; it is not only the addition of the counter ions.

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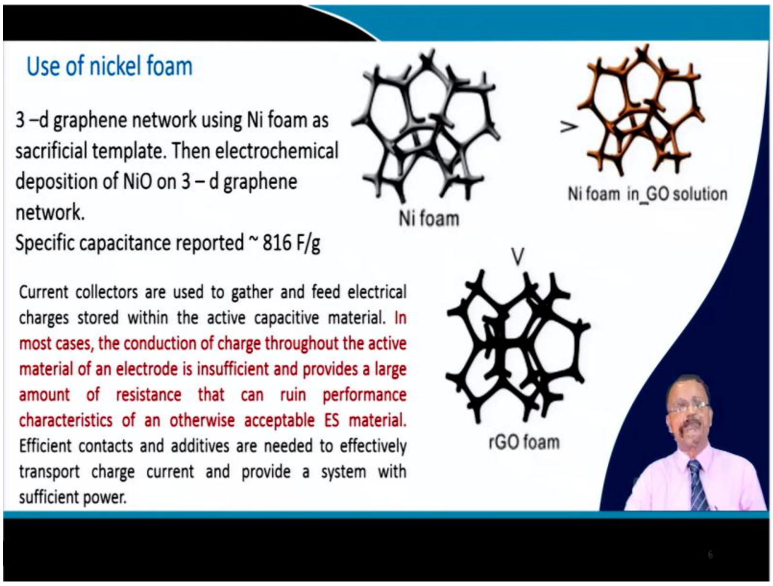

So, carbon paper is considered one of this electrolyte and nickel foam that is also used. So, this is a typical structure one can make. So, this is a foam made out of nickel. And this is basically a sacrifice template and then, electrochemically deposit nickel oxide on a 3 - d graphene network. This is also important to increase this specific capacitance.

So, this current collectors basically, so here the nickel foam as you can see it is dipped in a graphene oxide solution and then, it is reduced to foam reduce graphene oxide and then, this is sacrificing layer. So, it is just is removed. So, you eventually get a foam of rGO.

So, this current collector as you can understand, they take the electron or eject the electron into the active material. So, the conduction of charge throughout the active material that is really challenging and it is sometimes insufficient to provide a large amount of I mean it provides a large amount of resistance. So, that hampers the this thing the performance of the electrochemicals supercapacitors.

So, contact is important. So, this kind of architecture if one uses, then they have very good contact which is not otherwise if you do the tape casting on a simple metal foil. Then, this problem is there something similar to the battery what already we described that when the charge discharge takes place, volumetric expansion and depending on the material, volumetric expansion can be very severe and there is first thing that it happens is the delamination from the current collector and then, the performance is gone. So, something similar happens to super capacitor as well.

So, if you have this kind of structure, where the active material is very intimately connected with the with the current collectors or you have a conducting structure like this throughout with a defined porosity. So, certainly, your performance will be much better.

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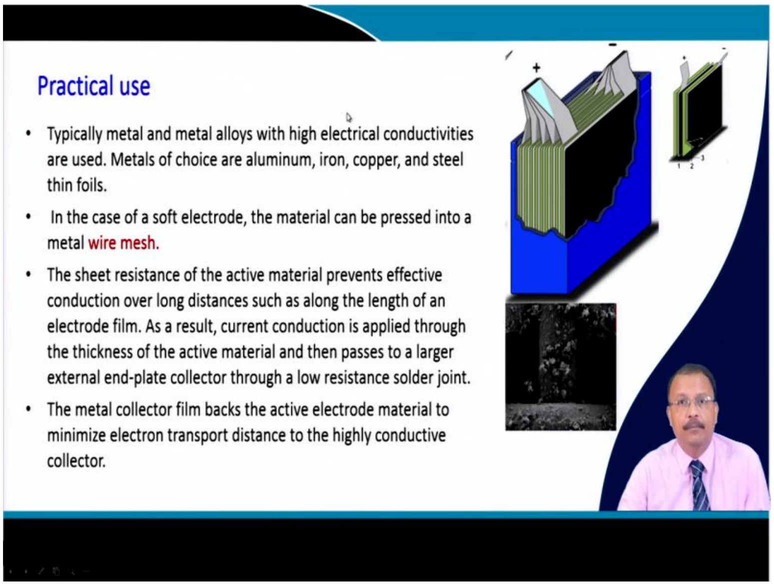

But in practical case, this is not industrially viable to make this kind of structure for bigger capacitors. So, usually, metal and metal alloys which are having reasonably high electrical conductivity that is used. So, this is a type of orientation that is done so that you have a parallel connected capacitors.

So, it gives a huge capacitance and then, they are basically packed. So, this part is usually done and then, just like a pouch cell if you remember, then all the positive and negative they are tapped together and then, this is connected to the external circuit. So, as I was saying, this sheet resistance of the active material, this sheet resistance active material that actually prevents the conduction particularly in the large region.

So, therefore, sometimes if the material is soft, then this kind of mesh is used, where this is this active material is pressed. So, you have a current collector mesh, where you press the active material and the mesh is highly conducting and you have a proper contact. So, that is also quite useful to get good electrochemical performance.

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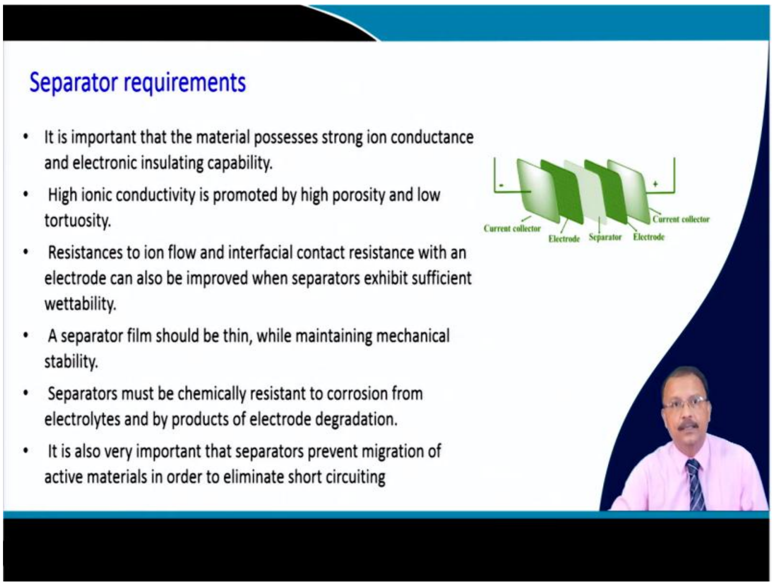

The separator is something similar. The use of it is something similar to that what we described in case of a battery. So, it should have a electronically insulating capability. So, the positive and negative electrodes should not touch and ion should pass through it and therefore, it should be porous in nature and resistance to ion flow and interfacial contact resistance with an electrode that also be improved when super separators, they exhibit sufficient wettability.

So, the electrolyte should properly wet the separators so that they are well connected with the electrode because the electrolyte this is not a bigger cell. But this is as you as I have shown that they are just connected with intimate contact. So, therefore, this should be quite thin as well because you need a defined volume, where you can pack maximum amount of active material by suitable rolling.

So, the separator itself, they are not electrochemically active. So, they should be thin and their stability should be there; mechanical stability should be there. If they are torn, then you know that the positive and negative electrode, they will connect to each other. They should be chemically resistant to the solvent that you are using, particularly when use the H_2SO_4 or KOH and it is also important that this active material should not migrate through the separators.

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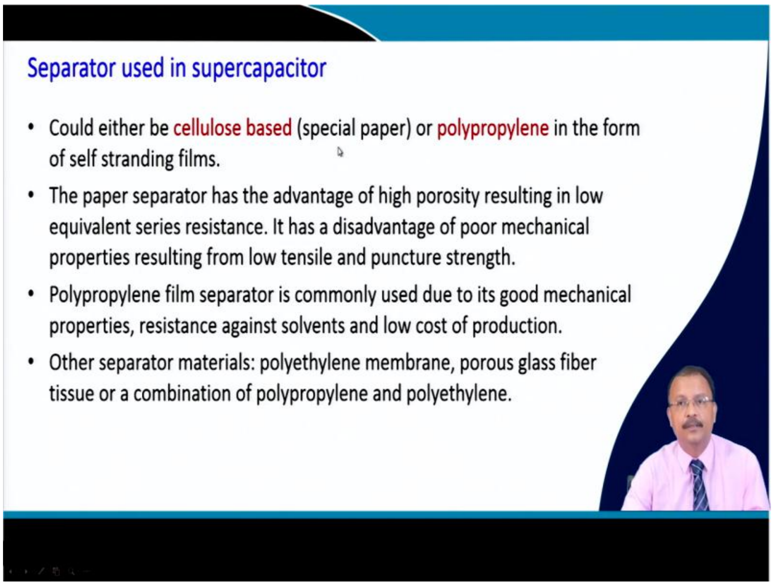

So, these are the primary requirement and usually, the cellulose base is a special paper some of one of the schematic, I showed that the paper separator is used or polypropylene, that is in the form of a self stranding films that is used. Paper separator, they are high porosity and therefore, low ESR value is obtained on the paper separator. But it has poor mechanical properties as you can understand.

So, polypropylene film separator, they are used due to their good mechanical properties and resistant again the solvent that is used and cost of production is also not that high. So, apart from that, people use polyethylene membrane, porous glass fiber, tissues or a combination of polypropylene and polyethylene. So, the separator material whatever has been used for lithium ion, many of them are similar to the lithium ion separators.

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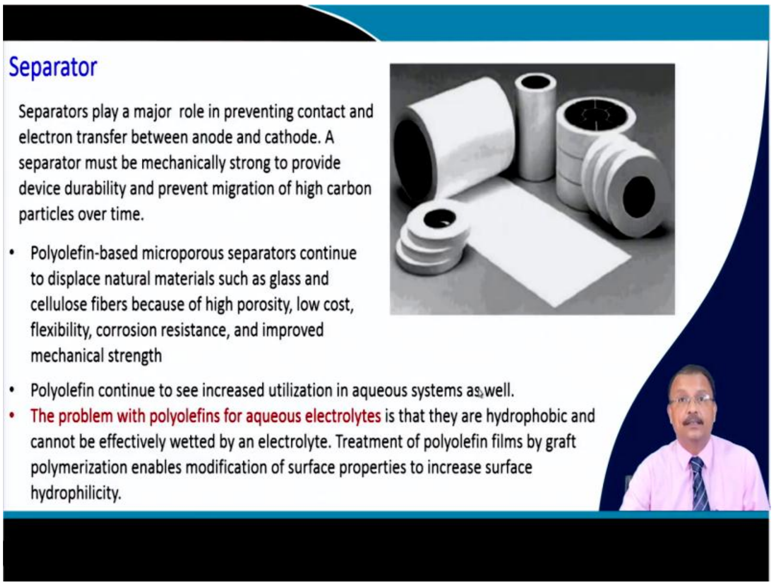

So, as I said that it prevents direct contact and electron transfer between the positive and negative electrode. It should be mechanically strong and durable. So, polyolefin based microporous separator. They are actually replacing this glass and cellulose fiber kind of things because of their porosity and cost of production is also quite low, they are flexible and for the flexible power I mean super capacitor they are quite adaptive for industrial use.

And in aqueous system also this type of separator is used, but it has a problem that usually they are hydrophobic. So, electrolyte cannot be effectively wetted particularly the aqueous electrolyte. So, sometimes this is graft polymerization people do which modifies the surface of this kind of separator and it increases their hydrophilic characteristics. So, it should wet with the electrolyte well. So, that process is adopted.

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So, this part of the lecture, you can find in the book given as a study material and apart from that the earlier references, what I told you should also look at it.

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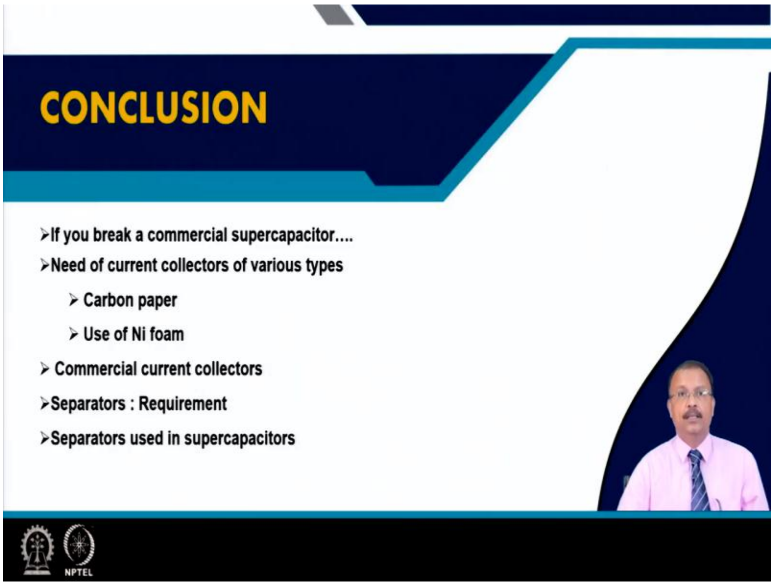

So, in this particular lecture, we talked about that if you break a commercial capacitor, how it will look like and why this current collectors of various types, they are needed; particularly, the carbon paper or use of nickel foam to make a template base current collector. Commercially, it is not adaptable I guess, but research is going on to have a better contact between the active material and the current collector.

Then, commercial current collector, mostly it is metal or metal alloy type that has been described. The separator, what are their requirements and separator used in the supercapacitor that has been described.

Thank you for your attention.