Electrochemical Energy Storage
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Module - 12
Other types of batteries
Lecture - 58
Ni-Cd and Ni-MeH Batteries: Operational principles, main characteristics and applications

Welcome to my course Electrochemical Energy Storage. And this is module number 12, where I am describing other types of battery other than lead, lithium, ion and sodium ion batteries and the other batteries which already we have talked about. And in this lecture; lecture number 58, we will be describing the nickel cadmium and nickel metal hydride batteries, their operational principle, main characteristics and applications.

So, the voltage that you get out of this battery is pretty low as compared to lithium ion battery which is in 4 volt range. So, this battery you get the open circuit voltage is about 1.2 even less than the your dry cell, or alkaline cell, but these batteries were in use in 90s. I remember that we used to use it with our Walkman. It is no more there the cassette players we used to play. So, we used to use these batteries. So, it was very popular in those days this nickel cadmium chemistry.

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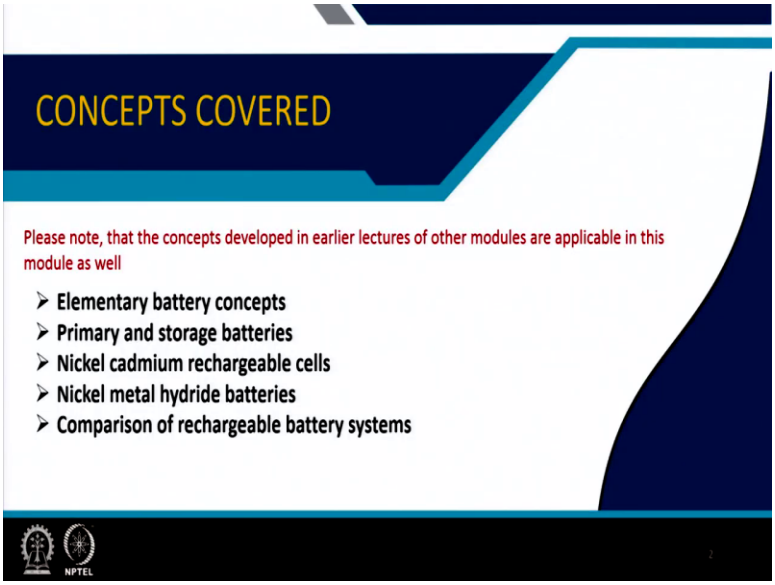

So, in this particular lecture we will first introduce the elementary battery concept and a recapitulation of primary and storage batteries, what are the different types of battery I just tabulated and then particularly nickel cadmium rechargeable cell. The chemistry will talk about their characteristics and then we will introduce nickel metal hydride batteries.

And then I made an attempt to compare the rechargeable battery system to see where, why this lithium ion battery technology they have taken away all the positive things and why they are so popular as compared to lead acid battery nickel cadmium battery nickel metal hydride battery. So, why your lithium ion battery is so popular?

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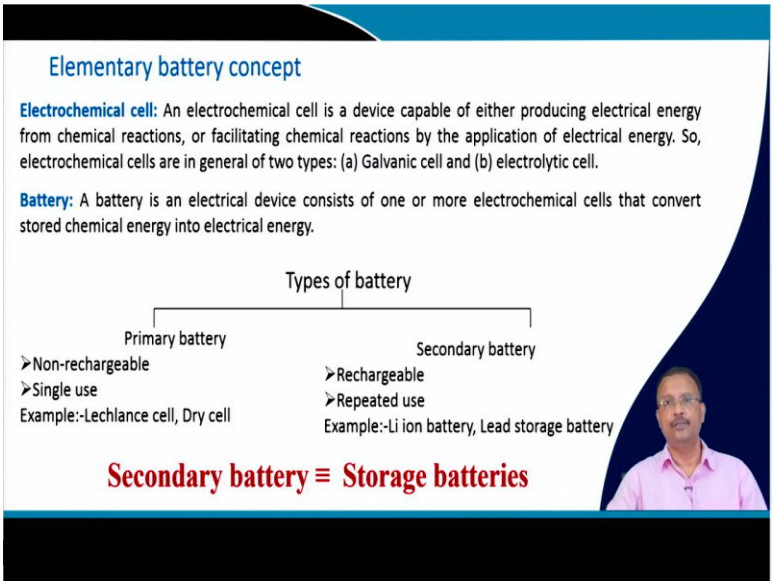

So, this is a recapitulation. We defined already electrochemical cell. So, that is a device that is capable of either producing electrical energy from chemical reactions or facilitating chemical reactions by the application of electrical energies. So, this basically the electrochemical cells they are of two types. One is galvanic type and one is electrolytic type and the battery is an electric electrical device that is having one or more electrochemical cell that converts the stored chemical energy into the form of electrical energies.

So, the types of the battery we already described that one is of primary battery type. They are non-rechargeable battery single use. After single use you throw them out the. Example is dry cells, lechlance cell, alkaline cells and the second type variation is the secondary battery which are rechargeable. We can use it repeatedly and lead acid battery

is one of them lithium ion batteries is another one. So, secondary battery they are called the storage batteries.

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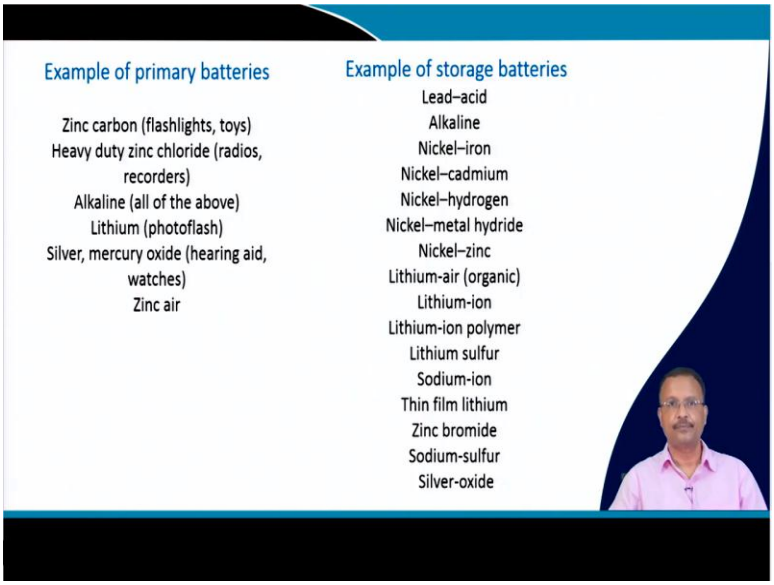

So, the primary batteries they are various varieties are there. Some of them I have introduced or explained in the in this course. So, zinc carbon is one of them which is basically used in flashlights or toys, then alkaline cell which are very common in a shop. You can purchase it and usually it is used in as a remote control remote for AC remote, for TVs and silver and mercury oxides that chemistry is used for hearing aids.

So, they are one time use and then you just throw it. Storage battery they have different various types of chemistry. So, we introduce lead acid, then we introduce we are going to introduce this nickel cadmium and nickel metal hydride chemistry lithium air. We have talked about lithium ion batteries; we have talked about lithium sulfur batteries, sodium ion batteries.

So, most of them I already introduced not all of them of course. So, for example an important category is lithium ion polymer batteries or the thin film lithium ion batteries that is excluded in this course, but you got the flavour of the rechargeable battery and the current conventional technology.

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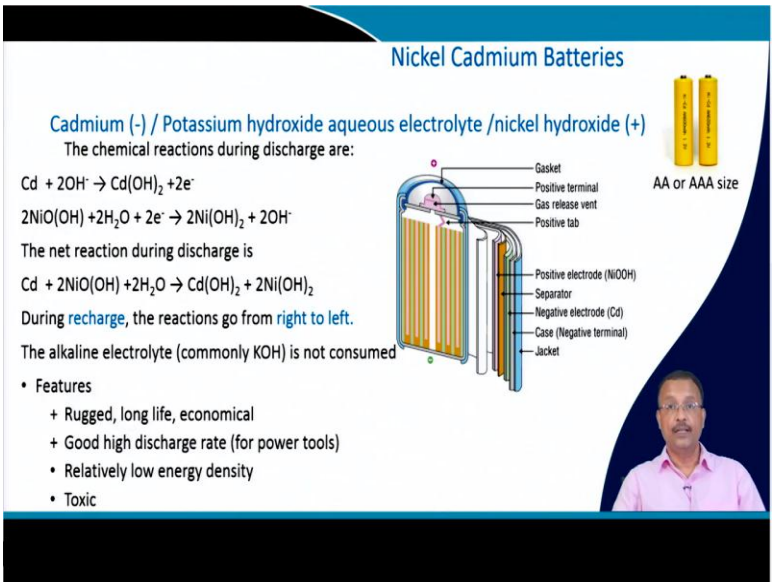

So, nickel cadmium battery, the chemistry is again straight forward what you are using cadmium as your negative electrode and potassium hydroxide aqueous electrolyte that is used and nickel hydroxide that is used as the positive material. So, this is the reaction that takes place in the anode and the nickel oxy hydroxide that reaction is taking place in the cathode. So, the net reaction is and the just the reverse reaction goes from right to left during recharge.

So, you get back again cadmium and you get back again the nickel oxy hydroxides. So, the construction is very similar to the cylindrical cell that already I have described for the lithium ion batteries. So, exact similar type of configuration that also you have and this is the typical picture of nickel cadmium batteries commercial batteries and they can be either AA type which is slightly thicker and or AAA type which is a thinner one.

So, the prominent feature of this battery is they are quite rugged although the voltage is not that great. It is not like your lithium ion batteries. But they are rugged and they give long life and they are quite economical and for power tools still one can use it because it has extremely good rate capability. So, high discharge rate you can use, they you can operate this.

So, therefore the power tool for drill machine or power hungry device nickel cadmium is a solution, but they have relatively lower energy density and they are toxic because of the use of this cadmium.

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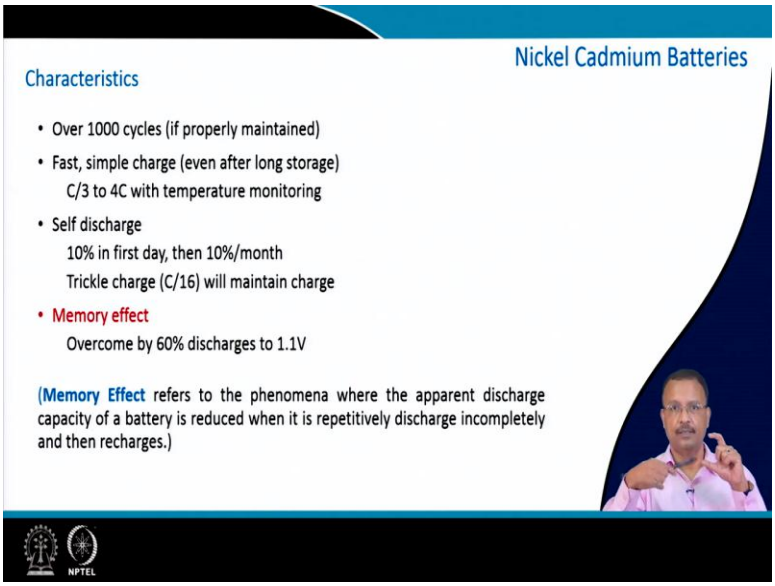

So, if you go through this characteristics a reasonable well cyclability if maintained properly. If you do not have use the battery, you can do a fast charge even 4 C you can charge it. You know that 1 C means 1 hour, 4 C is 15 minutes you can charge the battery. Self-discharge is there. 10 percent per month is a good figure and it has a memory effect that is the problem.

And this memory effect is that say you charge the battery you are using it and discharge it say up to 60 percent and then again you charge it. So, then it will remember that 60 percent is the deep discharge case. So, basically you will lose the remaining 40 percent. So, that is known as the memory effect.

So, that is the apparent discharge capacity of the battery is reduced when it is repeatedly discharged incompletely. So, unless you fully discharge it and then again recharge it back if you just terminate your discharge at relatively higher level higher soc level. So, then it will remember it. So, that is the memory effect that is having for this kind of batteries.

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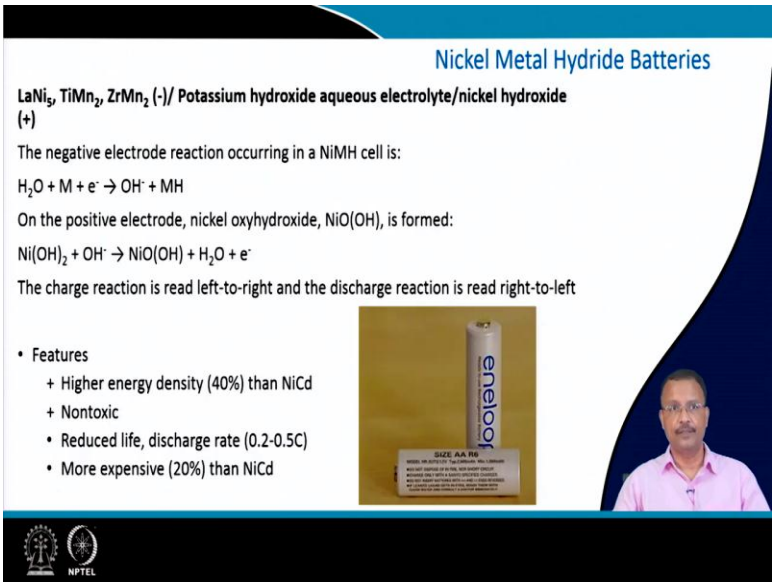

Nickel metal hydride battery, they use of course nickel in the form of various types of alloys and potassium hydroxide aqueous electrolyte is used because it is 1 volt 1.2 volt is the range of voltage that you are getting. So, aqueous electrolyte can safely be used and nickel hydroxide is used as positive material. So, this is the typical reaction that takes place in this positive and negative electrode.

And the charge reaction is just the reverse and it is having a relatively high energy density and then, nickel cadmium about 40 percent higher energy density that you can get nickel cadmium. It is not toxic; it is non toxic in nature and relatively it is having reduced life. The discharge rate is 0.2 to 0.5 c that is the common operation that one can do. And as compared to nickel cadmium, it is more expensive.

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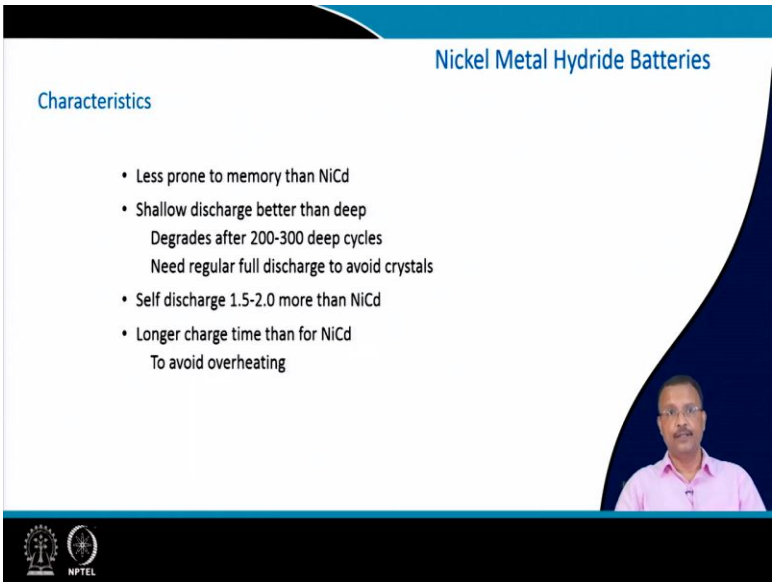

So, they it does not have a memory effect as compared to nickel cadmium. Nickel metal hydride, they do not have the memory effect and one can go to deep discharge and 200 to 300 cycles. It can withstand and self discharge if you keep it in charge condition, then the self discharge is more as compared to nickel cadmium battery and it cannot be charged that fast.

So, it has longer charge time because you cannot charge it at 4 C as compared to lithium nickel cadmium. They have lower longer duration of charging and that that is basically if you charge at higher rate, then overheating is a problem and overheating is not desirable for the cell and therefore, one should be cautious about charging these batteries.

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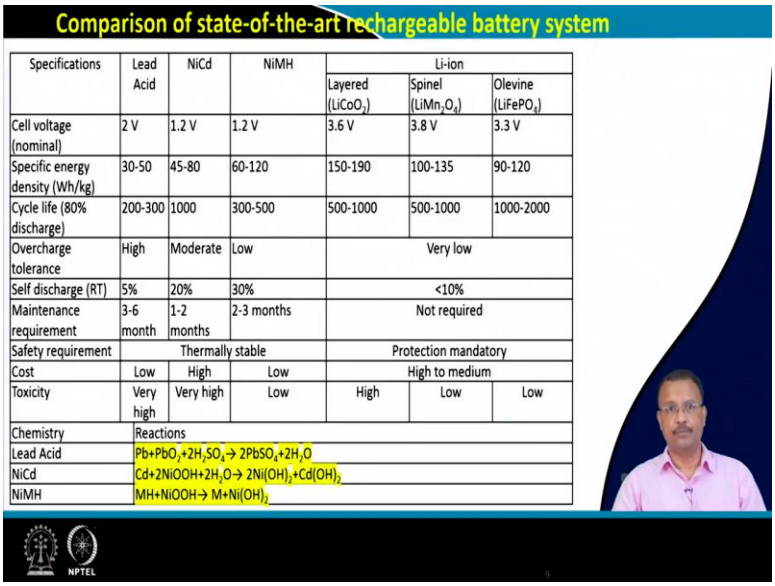

So, now if you compare this lead acid, the cell voltage as you can see lead acid gives you about 2 volt. I assume that you will be able to calculate the theoretical voltage of lead acid chemistry lead and lead oxide from your acquired knowledge. And same thing applies for nickel cadmium and nickel metal hydride batteries.

So, this voltage is relatively low 1.2 volt and for lithium ion you have different types of positive electrode material and basically always you get higher voltage than this. So, it is 3.6 3.8 for lithium manganese oxide spinel type and for olevine lithium iron phosphate is 3.3 volt that already we have covered in the earlier lectures.

Specific energy density is also not comparable nowhere as compared to this lead acid battery. We need to increase it further. So, that is why lithium sulfur battery is coming into picture. Lithium air batteries we have already discussed that that they give huge energy density and that is required for electric vehicles applications and you can see that as compared to this battery even lithium ion battery where they stand.

Cycle life also is not that great except lithium, sorry nickel cadmium batteries. So, that is also not comparable with lithium ion chemistry. So, overcharge tolerance is moderate in case of nickel cadmium and for lead acid, it is quite high, but for lithium ion you need a special circuit to cut it.

Because for example, lithium cobalt oxide you cannot take all the lithium out, then the whole structure will collapse. So, that is very low over charge tolerance. Self discharge is very high in nickel cadmium as well as nickel metal hydride as compared to lead acid battery and it is reasonable in lithium ion batteries maintenance requirement. It is there for lead acid battery for VRLA type. The maintenance requirement is not there, it has a vented bulb. So, even the gas accumulation is there.

So, it will release the pressure by that opening of the bulb in lithium and battery no maintenance is required. So, thermally they are very stable. This three technology lead acid, nickel cadmium nickel metal hydride, but some kind of protection is mandatory in case of lithium ion batteries particularly for their high energy density and if the electrolyte reaches the flash point, then it will very quickly catch fire.

Cost is high for nickel cadmium batteries were low for lead acid battery and nickel metal hydride battery and lithium ion battery because of the scarcity of some material like lithium and cobalt, they are relatively expensive. So, people are trying to replace cobalt with manganese which are readily available. Nickel is also expensive or iron this transition metal lithium iron phosphate, they are relatively cheaper.

So, this is high to medium. That is why it is written. So, toxicity wise as you can see here lead is involved, here cadmium is involved. So, they are very toxic in that. So, you cannot dispose it here and there. So, a proper recycling mechanism is required. Nickel metal hydride is relatively safe to use. For lithium ion if you use lithium cobalt oxide, then of course cobalt is toxic and for manganese base or iron base, they are relatively low the reactions that already I have described for all this chemistry. So, I mean you are familiar with that.

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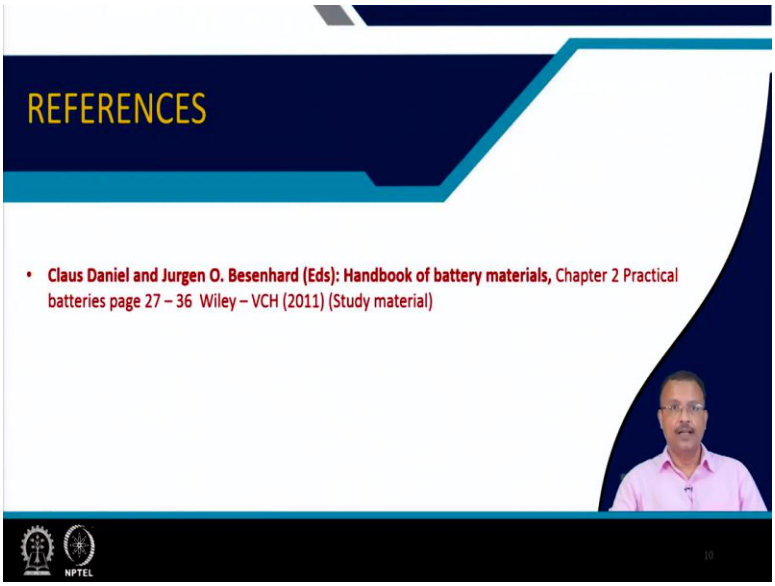

So, this book by Claus Daniel and Jurgen Bessen Hard, there is an edited book. It is a good handbook for battery materials. Maybe you can have a look particularly chapter number 2. They talk about the practical batteries and page number 27 to 36, they talk about nickel cadmium and nickel metal hydride batteries otherwise this is a good book for battery as such. So, that is a good reference book.

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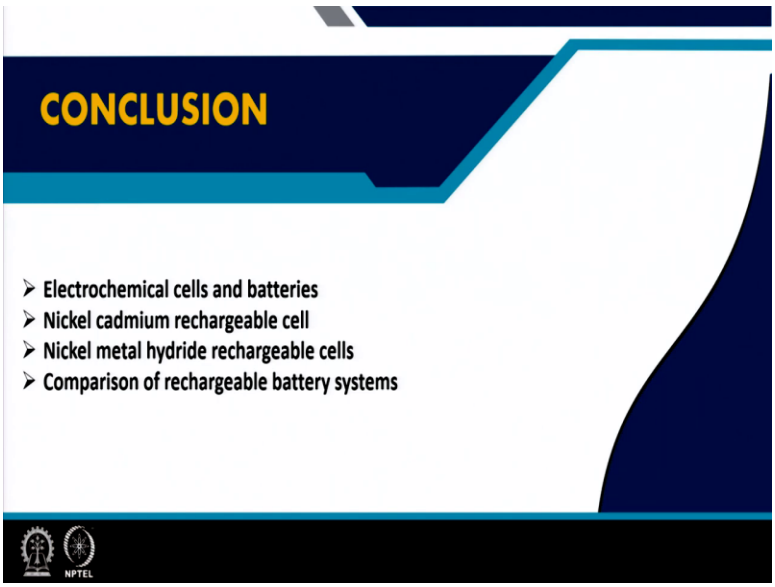

So, in this particular lecture I introduced again recapitulate the electrochemical cells and battery concept and introduced nickel cadmium and nickel metal hydride chemistry, their

operational features, charge discharge reactions. And I compared the different chemistry where we stand and why lithium ion battery is acceptable in modern society.

Thank you for your attention.