Cryogenic Hydrogen Technology
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Week - 03
Lecture 14
SPE Water Electrolyser

Welcome to this lecture. We are talking about hydrogen production and in that connection, we were talking about the two different type of electrolytic process. One is the alkaline electrolyser, the other one being the SPE the what is called solid polymer electrolyser and we are going to talk today about this solid polymer electrolyser in this lecture. So, the topic is basically ah it is what are electrolysis and, in that connection, we will be ah talking about the solid polymer electrolyte. So, what is this solid polymer electrolyte ah before you know going into the details just let us have a look into the history and there we will find that ah it was ah in the ah year around 1950s the PM fuel cell was developed by General Electric G. So, then they have used a basically the sulfonated polystyrene electrolyte for the production of ah basically or basically this is the PM fuel cell where the it was used for generating the electricity or the power.

And in around 1966 there this ah material called Nafion that was used for NASA project that was the DuPont Nafion it is called and there there it was it is per fluorinated polymer membrane that has been used basically that is what is Nafion. And around 1973 it was first used to generate the ah water electrolysis to basically produce the hydrogen and oxygen. So, that is about the background of this ah solid polymer electrolyte. You can understand that in contrast to our earlier discussion where we have said we have the aqueous solution and to conduct increase the ah ionic conductivity or it is conductivity we have added some material like alkaline material or acidic material, but in contrast to this ah alkaline ah electrolyte here we have using a solid polymer.

So, it will definitely give certain advantages. So, we will look into that. First of all, this you know being a solid polymer ah it will have the advantage of you know ah very clean one and not only that they are quite you know thin ah I mean manufacturing processes are such that they can be made up to 150 to 300 micron thin. So, that we can achieve very high compactness for this kind of ah solid electrolyte solid polymer electrolysers. And ecologically clean it means that we do not use any high alkaline material.

So, there is no possibility of leakages of this high alkaline material and etcetera. Ah Then

it can be operated at a lower cell voltage and higher current density that is another advantage. And it is operated at a higher temperature and pressure we will when we will look into its construction we will be able to see that ah it can be you know ah you know ah the hydrogen can be generated at a higher pressure. So, that gives a advantage in terms of the storage that we will look when we talk about the hydrogen storage part we will see that if the hydrogen is generated at lower I mean higher pressure it can be stored ah easily or it can be compressed easily the work requirement will be ah much less. So, it can be operated at higher temperature and pressure we can generate the hydrogen and you know produce at higher pressure.

Then SP can reach high efficiency. So, as compared to the alkaline electrolysis this ah SP electrolysis is ah quite ah high highly efficient. And then as we in contrast to ah this alkaline electrolysis process where we have added you know KOH solution or you know NaOH solution. So, this is ah you know basically we are impuring the water or we are adding additional substances to pure water, but in contrast to that here what we need is completely ah you know ah what is called pure water or basically ah demineralized water will be used for production of hydrogen from solid polymer electrolyser and of course, this will be treated as a disadvantage later on when we talk about it. So, but since we are ah using the demineralized water.

So, ah there is the I mean purity is very high for the product hydrogen and we can achieve almost 99.99 percent of purity in the product. So, now let us try to look at this ah polymer electrolyte it is a you know ah complex structure ah and it is basically ah ah I mean this is the ah primary chemical structure of this nephew and it is having a side chain ah with which is terminated with the sulfonate as ion exchange group. So, we will not get into the details of this part only this we will look at this sulfonic acid group ah because that will be you know how this ah hydrogen will be generated that part we will try to look into it. So, this ah I mean Naphion will have ah high you know ah ionic conductivity and it will have very ah I mean they will they are impermeable basically to the gases.

So, that is an advantage and the membrane thickness as I have said earlier that is about 150 to 300-micron thickness and that means, you know we can achieve very high compactness particularly in terms of the fabrication of the solid polymer electrolyser. So, it is impermeable to water and product gas that means, it is basically a polymer which does not allow the passage of the product gas like hydrogen or oxygen that is an advantage that means, it will work also as a you know ah separator basically and it is impermeable to water also that means, water cannot pass through it ok. So, that is an advantage with this solid polymer electrolyser we do not need any additional you know separator for separating the product gases which we have talked about while talking the alkaline electrolyser we

need to put separate ah I mean separator between the ah product gases here that provision or I mean that necessity is not required ok. And it is having ah very poor electronic conductivity, but it is having high proton conductivity so, that means, ah it allows the hydrogen ions to pass through, but it will not you know allow the electrons to flow through it. So, that is ah I mean basically as you can understand from the as we have talked about the history of this solid polymer electrolyser you will understand that the same thing ah you know if we want to use it for production of hydrogen and oxygen that will be basically the electrolyzing the water, but in a reverse way if we want to produce ah you know the generate power out of it we can use hydrogen and oxygen and from there we can you know ah in in a just a reverse way we can produce the electricity.

So, while talking about the fuel cell will again we will come back to this ah you know this Naphion and the structure solid polymer structure, but at this moment let us look at this sulphonic acid group how it is generating the ah or helping ah this ah basically to conduct or carry out this hydrogen water ah I mean water splitting generating the hydrogen and oxygen. So, ah before that just let us have a exploded view of this solid polymer electrolyser we have the solid this is an of course, enlarged view quite I mean solid polymer ah membranes are quite you know ah 150 to ah 300 micron thickness and of course, they are not to scale ah. So, this is just for ah you know understanding we have the solid polymer electro membrane and on both sides we have the anode and cathode and then we have the current collectors and finally, we have the bipolar plates that will be connected on either side of it and between the cathode and anode we have the you know the cell that has to be connected or we have to supply some DC power. So, this is the exploded view of this cell structure. So, with this cell structure now we can have a look into the ah what is splitting how it is happening.

So, this ah sulphonic acid group as I have said that in the hydrated condition when you have it is coming in contact to the water it will break into this 2 components SO_3 minus and H plus ions and when the anode what happens this ah you know when it is coming in contact to the water they will you know form and hydroxyl bond. So, this X is basically ah is the active site this X is the active site where you know this water will be ah reacting in that active site and as a result they will form this hydroxyl bond and along with that we will have this proton and in electron will be generated, but this hydroxyl bond will further decompose and they will dissociate into ah XO and they will also generate you know further ah high protons. So, this XO ah basically will decompose into ah X and O this is the oxygen that will be generated at the ion and making this X or the that site where this first reaction took place or hydroxyl bond was formed this surface is or that site is now free the moment this O will ah form an O_2 and it will escape of this anode surface. So, we have to provide the passages ah for you know the easy escape of this O_2 and this site will be

free for a next ah you know ah reaction to take place. Now what happens to this hydrox I mean these protons or to be very precise they are the hydrated protons.

So, these hydrated protons will now move towards the cathode ok. So, they are positively charged they are hydrated and as we have learned earlier that these solid polymers will you know allow the protons to pass through and how will they pass they will you know pass or basically hop from one sulfonic group to the other group and thereby you know make a move through the solid polymer. So, that means, by you know putting the water on the anode side what we will have is that ah we will generate the oxygen on the anode and the dissociation of this water ah into this hydrated proton they will pass through the solid polymer and let us look into this diagram. So, where you know we are putting this ah this is ah the anode side where we are putting water into it. So, this water will what will happen we have seen that finally, you know this water will be forming the hydrated H plus ions and we will have the H plus I am sorry this is ah these are the H plus ions these are the ions and along with that we will have 2 O2.

So, this O2 will be passing through this passage and the hydrated H plus ions they will be allowed to come you know pass through this solid polymer to this side and where his H plus and H plus will you know ah pick up another electron and thereby you know this when this hydrogen ah I mean these protons are picking up the electrons they will have H 2. So, this is how this ah you know ah hydrogen and oxygen is getting formed. So, these are the bipolar plates as we have understood in the last class that there are 2 type of configuration one is the tank configuration or ah that is the parallel combination of the you know different cells, but there was another one that is the filter press type or the bipolar ah you know electrode. So, here comes you know the bipolar configuration where we have seen this is the you know anode and this is the cathode and back to back they will be connected we will see how they are connected you know in the bipolar filter press configuration. So, that will give us the advantage of you know connecting them in a compact fashion.

So, ah as such you know this overall reaction you can understand that we are decomposing water and this is 2H2O that is coming in and out of which we are generating 2 H2 and you know the oxygen in the anode. So, this is what is you know the basically the decomposition of water in a solid polymer electrolyte. So, now let us look into ah the different materials those are to be used in a ah solid polymer electrolyte because this is ah it is not only the solid polymer electrolyte that is only important it is equally important to look at the different materials you know why because one of the disadvantages of this solid polymer electro I mean electrolyzes is that they are ah costly and that is partially because of this you know the ah different materials those are in use. So, we have the anode and the cathode and now let us look into the different materials those are in use. So, first of all the polymer

ah membrane which is highly acidic in nature this ah Naphion as we have talked about ah ah I mean there are polymer different polymer membranes we will come across it other than ah Naphions, but they are highly acidic in nature.

So, we need to put materials which are you know acid resistant or you know they are non-corrosive to the acidic environments. So, obviously, the choice is a noble material material like you know we have iridium and iridium oxide and say platinum, rhodium, platinum, rhodium, platinum, ruthenium and etcetera. So, these are all noble metals and they have ah you know they are ah quite costly in nature and, but they are ah I mean plated very there is a thin layer of this ah I mean electrode on either side of the polymer membrane. So, ah they are required in a small quantity, but definitely they are costly in nature. In addition to that we have ah to ah current collector ah current collector is ah basically ah they are porous material and ah yesterday while talking about the ah or in the last class basically when we talked about the electrolytic process we said that it is not only the current but the current density or the surface area density is also equally important.

I mean we have to provide large surface area so that this gas bubbles are easily formed and they can easily escape we can have a large site like we have talked about this X plus H2O and this X you know has to be distributed over the entire surface. So, we need a large surface and for a large surface ah you know when we the have to the current has to be distributed we need a good distribution system and that is why we have ah porous ah plates and they have to be you know ah what is called the electricity has to be carried through it. So, there has to be conductor of electricity. So, on the anode we have the porous plates made of ah you know titanium and carbon on the cathode the choice is ah its carbon ok. And the bipolar materials the ah bipolar materials again as you have understood that the gases are coming in water is coming in ah or coming out this gas will be formed the gaseous hydrogen will be formed and hydrogen oxygen will be formed they have to come out the water has to come in.

So, all this ah you know easy passage has to be maintained through this porous bipolar plate and the popular choice is for this bipolar plate is graphite. So, this at the ends of this plates ah you know we will have the graphite plates. So, this is ah the ah I mean different materials those are in use for the solid polymer electrolyser it is not only the membrane, but we need this noble materials and ah of course, some porous materials like bipolar plates and etcetera to have a complete assembly of this. So, one small unit ah looks like as we have said on this side this is one small unit ah, but this is quite accelerated one ah quite ah I mean large one, but this total thickness will be only few you know micron. So, ah then ah what happens ah there as we have already talked about that they are having you know ah filter filter press configuration or bipolar configuration because it is ah this this is the

polymer and, on either side, we have this ah you know the bipolar plates on each side this is a one single unit.

So, let us look how they are assembled together because this only one unit will not be sufficient to produce a large quantity of hydrogen or oxygen if we need. So, we have to have ah similar such you know units ah maybe you know depending on the quantity of hydrogen and oxygen that is necessary we can put large number of such plates. So, they will be connected back to back. Now, we have a filter place ah filter press type configuration and there is zero gap, this zero gap is very important. So, they are very compact in nature you can understand that except this porous porous you know ah electrodes and this porous ah collector plates those are intrinsically ah porous which will allow the ah oxygen and hydrogen ah to you know pass through or come out and you know finally, give us the ah necessary ah supply of the product gas, but otherwise they are quite small in ah shape and you know there is a zero gap between it.

So, we can understand that the overall ah you know unit will be very compact in nature. So, this is what is that filter press configuration ah and this is comparable if you look at ah the last class when we have talked about this is the filter press type ah I mean unit where the terminals the end plates are connected with the two-ah voltage. So, it is ok and finally, this whole unit ah at the end it will be connected with some positive ah source and on this side you will be connecting it with the negative. So, here in this type of configuration we understand that the total voltage that will be necessary will be if there are n number of cells and if we need for a single cell V voltage. So, then the total voltage that we can apply on either side is you know n into V, but the current will be small I mean the same current will be flowing through all through this since they are in series connection, but ah in terms of you know making this kind of power supply it is easier to have a large power voltage with small current as compared to the other way where tank type you know ah configuration that needs a very large current with small voltage that is not that very easy though it is not impossible it is in practice it is there, but it is not that will be again some bulky instrument ok.

But to avoid that I mean this filter press configuration is having that advantage not only it gives a compactness it also makes the power supply unit simple as compared to the tank type ah configuration. So, this about this is about how we connect them in ah in the SPE unit. Then let us look into the different other type of SPE materials ah with the ah there are other than we have talked about Naphion and that was sometime in 1970s. So, ah since then there are many types of you know polymeric material has evolved and with the appropriate chemical modifications they can be used in ah ah water splitting. So, this is about the water ah splitting using the ah SPE materials.

Now let us look into the salient features of it and this is the references and which you can refer to. So, from there let us try to conclude what we have learnt here in this class. Here this type of SPE electrolysers ah are efficient reliable and safer and of course, the comparison is with alkaline electrolysers and there is no ah corrosive leakage or risk ok. So, as we have learnt that there is no alkaline solution used ah as compared to the alkaline electrolyser. So, it is a solid polymer pure water is the only you know thing that liquid that goes in and it gives us ah hydrogen and oxygen and there is no separate ah use of the separator this nephron or this polymer itself you know is impermeable to water and the product gases, but it only conducts the protons not even you know any electrons also.

So, there is no possibility of gas crossover as we have understood that they are impermeable to the gases and the high voltage and low current just now we have talked about that this kind of filter press configuration it is easier to you know have the power supply with high voltage and low current and typically we can apply you know 2 volt power supply and with typical 2 ampere per centimeter square of ah ah basically ah this is we are talking about a partial ah voltage and the current density. And finally, we have the advantage of high-pressure hydrogen production with this unit as this will give us an added advantage ah while storing the hydrogen and the high purity hydrogen production is possible with this kind of solid polymer electrolysers. Now with respect to this these are all the basically the advantage we are talking about, but in addition to that it will also have the disadvantage and disadvantage will be as I have told you that it will be in terms of the demineralized water that is you know we have to supply in and also ah it is a comparatively costlier unit. So, with this production of hydrogen ah you know using the electrolytic process comes to an end, of course there is on a lighter note that there is no cryogenics ah involved with the electrolysis of water. Next, we will come to another ah production means of hydrogen that is ah by ah thermochemical route that is again non-cryogenic process. Thank you for your attention.