Corrosion Failures and Analysis
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Lecture - 14
Preventive measures and advantages of galvanic corrosion

Welcome back to the course Corrosion Failures and Analysis. Today, we have lecture 14, and today's topic will be bit of galvanic corrosion, because in the last lecture, if you recall that we talked about the coating of coating philosophy whenever there is a galvanic corrosion situation is arising.

Now, wherever there is a galvanic situation; galvanic corrosion situation rather that time, we talked that cathodic part should be coated preferentially. Even you can leave the anodic part still that will be fine, but still the cathodic part should be protect should be coated in case of the in case if you would like to go for a coating.

So, that part needs explanation. And the second part is we would like to see that the corrosion galvanic corrosion the advantage of galvanic corrosion so it will be a bit kind of oxymoron that corrosion is advantageous. So, we will see that in fact, galvanic corrosion is advantageous.

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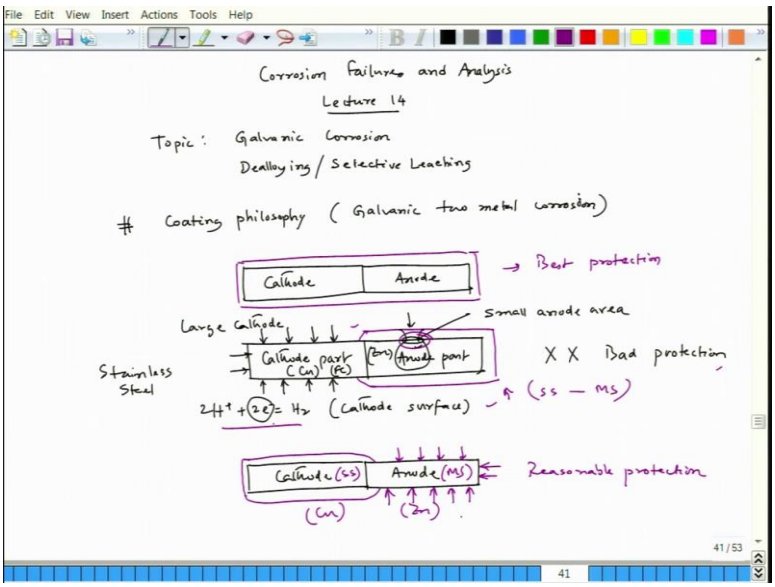

Now, this is lecture sorry, Corrosion Failures Analysis, Lecture 14, Topic galvanic corrosion and second is we talk about, we will step into dealloying or in other term it call it is called selective leaching.

Now, coming to the part what we would like to discuss is the coating philosophy, in case there is a galvanic two metal corrosion. So, here I have to mention two metal because galvanic corrosion, which is inherent to preferential cathode and anode that can also be possible on a same metal so, but here it is basically in case of two metal corrosion.

Now, that time for example, let us say you have two components two parts of a component one is cathode and one is anode, and preferentially one is cathode one is anode. So, now that time, if one has the possibility to coat so then it is better to coat the entire part entire part. So, that would give best solution best protection.

Now, if let us say the anode part cannot be coated; let us say the anode part is inside a pipeline or something, so that time it is better to coat the cathode part. So, but before that let us see what happens, if we coat the anode part only. So, let us say this anode part is coated; anode part is coated cathode part is left open.

Now, once we have this situation this coating let us say there is a possibility of mechanical damage. So, if there is a mechanical damage a small segment is opened up let us say. So, this segment this metal part is open to the environment.

Now, if it is in a acidic media let us say there is a cathodic reaction which is this. So, this cathodic reaction would happen on the cathode surface. And let us say the anode part is, let us say zinc and cathode part let us say copper, ok. So, the zinc would dissolve or if it is a cathode part if it is iron still it would be possible, this particular situation can appear and in case of iron let us say it is stainless steel stainless steel, fine. So, that time also it is possible ok.

So, now this reaction is taking place on the entire cathode surface so, that means, this it needs electron. So, this electron would be provided by the anode area and here anode section which is exposed is this much this much is the section, which is small anode area and the section where cathodic reactions are taking place is basically large cathode.

So, that means, the small anode area would supply huge amount of electrons to the cathodic reactions taking place on a large and cathode part, and that would lead to a huge amount of corrosion on that exposed part of that anode. And that would fail the system fail the structure very quickly. So, this is no no, this is a very bad protection.

I will explain I will bring come back to this particular example you will see also in the bathroom fittings, we do miss do we do commit this mistake; coating the cathode anodic part and leaving the cathodic part, we will I will talk about that.

But before, that in order to have such situations so that means, here is a large cathode and small anode area is coming into picture and the large small anode will corrode heavily. Now, if there is an option to coat one part. So, then it is better to coat the cathode part, I will come back to this this is anode this is cathode.

Now, if we coat this part; if we coat this part then, we do not have a space for this cathodic reaction. Because cathode this k this if it is a stainless steel; let us say stainless steel and this is mild steel, ok. So, in this case also if the couple is stainless steel and mild steel, then also this situation would arise.

But in this case if it is a mild steel and stainless steel or copper zinc, if we cover up copper area or stainless steel area, then you do not have this reaction, rather this on this surface since it is dipped into acid everywhere you will have uniform cathodic and anodic reactions and the corrosion mode will be uniform rather than localized.

In this case, the corrosion mode would be very localized around this area, but here it will be spreaded and so the corrosion rate of the anode would be less comparatively compared to this. Because this is localized so entire corrosion is taking place at that section. So, the cross section thickness would also reduce which actually takes the load. Now so this is better, better than this. So, reasonable protection ok, fine.

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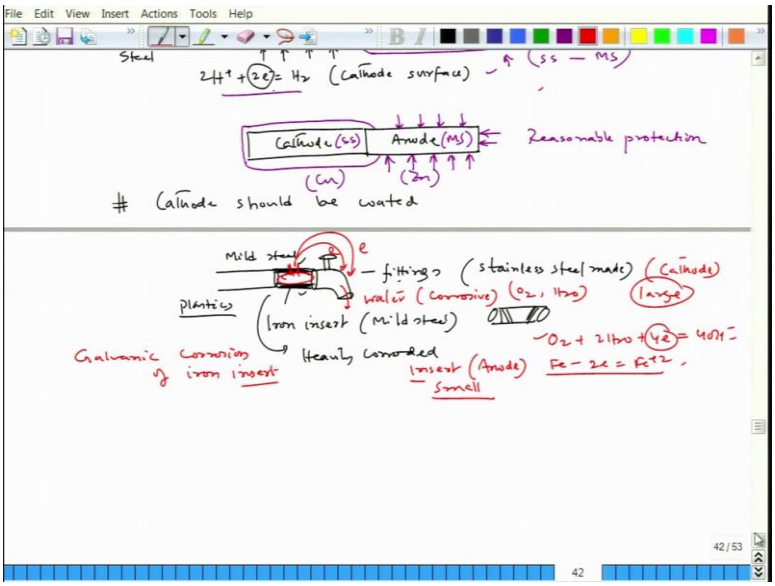

So now, let us so that means, it is very clear that cathode should be protect cathode should be coated whenever this situation arises. So, this is a kind of thumb rule, ok. Now, coming back to this, let us see whether this is possible in an actual situation.

Now, if you have noticed that in bathroom fittings, we have a pipeline which is a mild steel ok. Then you have pipeline fittings, which is the tap ok. And this is the tap and this one and this one they are connected by a small iron insert and this pipeline this is generally mild steel ok. This is a small section which is a small like this where we have threads and that thread is connected to the fittings to the main pipeline.

Now, this main iron nowadays people are using plastics, people are using plastics, previously people used to use mild steel pipe now they are using pipe plastics. But now, after that in order to protect this small inserts, we either use a kind of petroleum coating part or we just paint this part, we paint it. And this, this fittings; this is the fittings they are generally stainless steel made stainless steel made.

Now, fittings basically it is a shiny thing and it actually gives you a very good look. So, that is what you leave it open and it does not corrode. If you see that fittings that it remains silent remain it remains shiny even after 2-3 years it does not happen anything. But have you noticed that if there is a problem in some pipeline you have to open the fitting, this part this mild steel part is heavily corroded. And that is what it is very difficult to open sometimes sometime that entire insert comes out with the fittings.

So, it is a common failure in that particular see kind of situation. So, that time what is happening there, because it is painted that paint is not like a kind of permanent paint there will be perforation and mechanical damage is also possible.

Let us say a small opening is forming, small opening is formed in that case. Now, this is carrying water or there could be it can this water even if you consider potable water, this is mildly corrosive, even if it is mildly corrosive still this happens. Because now and this is containing oxygen as well as H2O and in the normal circumstances the cathodic reaction that will take place O 2 plus 2 H 2 O plus 4 e equal to 4 O H minus. So, this 4 2 4 electron that is needed should be supplied by some anodes.

Now, when this coating is done no problem, because that time the stainless steel will have its own protection, but inside is not protected remember the inside part is not protected. Now, question is if that inside part will have its own corrosion, because to supply and in the beginning and this insert part is a very small segment.

So, the inside part is corroding, because that time this iron 2 e equal to Fe plus 2 that is forming from the inside part. And since, it is a small section and the fitting is little larger so, then you have that differential area factor is coming into picture. And stainless steel is acting as cathode, this is acting as cathode where this reaction would take place and the small insert this insert acting as anode, ok.

So, now heavy corrosion is taking place in that inserts. But now, there is another in instance coming in that time, when we have only the bottom the inside part is exposed to the electrolyte, then this process is taking place from the inside part. Now once we have the outside part also exposed, the corrosion because outside also there are moistures the outside part is also having corrosion.

Now, since this reaction is continuing on the cathode part, then since this is opened up, so this will also supply electron to this sections. And finally, what would happen? There will be localized corrosion also. So that means, there is a small segment inside is corroding outside is also corroding wherever that paint is exposed.

And finally, you have a heavy corrosion in that small iron inserts, ok. Solution, you can use some plastic inserts, heavy plastic inserts or you just let us say you have used iron inserts you do not paint it, if you do not paint it the problem of this corrosion pattern

would be less it will last longer. But the best solution would be use a plastic painted plastic inserts which connects the stainless steel fitting to the plastic pipe. So, that would solve the problem.

So, this is a classic example of this kind of situation by the small anode which is the insert and large cathode which is the fittings and that would lead to a serious galvanic corrosion, iron insert, fine. So, this is one such example that what is the situation, if we have cathode area exposed and small anode area. This is a practical problem that is faced in the bathroom fittings.

Now, another example I would like to mention. So, that part I would request you to go to the book written by Fontana and Greene, Corrosion Engineering is a fantastic problem that they have explained.

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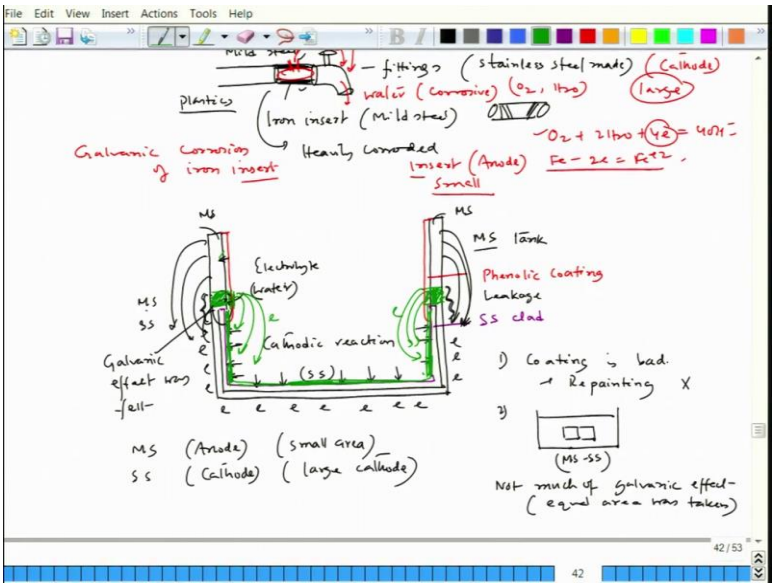

The problem is such that this is a large tank and this tank is made of mild steel MS pipe MS tank, right. Now, after 20 years it was replaced and while replacing people thought that the bottom part because, bottom part is mostly having corrosion related issues, they thought that the let us protect the bottom part.

And while doing that in the new tanks they put a stainless steel clad at the bottom, SS clad ok. So, this I am explaining from the book, what is given in the book by written by

Fontana and Greene Corrosion Engineering for academic purpose for actually teaching purpose.

Now, so this is the cladded plot and this is also mild steel right. In fact, it is there only this is this, this is this. Now, this part where stainless steel this is top is mild steel and then bottom is stainless steel, so that part because people thought that is a galvanic effect can appear.

So, its better to cover up the anode area. So, the anode area is covered up and it extended till this point, ok. So, this is a phenolic paint; phenolic coating right. So, this is the situation. Now, what happened?

With this situation, when operation started people saw that the thing was leaking the tank was leaking around this zone. Wherever the stainless steel clad and the mild steel is getting welded was welded, ok. So, that section the leakage was taking place and the leakage was mostly around this zone around that weld zone and closed by to that weld zone.

Now, they thought that and this leakage was taking place very quickly and they were wondering that the phenolic coating has not been properly made properly. So, they what they did? They removed the coating repainted ok, but still problem persisted. They wanted to see whether the galvanic effect is serious here.

So, what is the first thing; they thought the coating is bad so, repainting that actually involved lot of cost. Because in order to do that one has to do all sort of short blastings and all those things in order to sand blasting in order to remove the entire paint. Now, that did not work, still that leakage happened this is leakage around that zone.

Second part they thought that the galvanic effect is serious, so, then what they did? They did an experiment that experiment was in a in the same electrolyte for the water that is being contained in that particular tank. So, they had a mild steel and stainless steel couple exposed it to that solution and what happened not much of galvanic effect was noticed. So, in this case not much of galvanic effect, interestingly that time when the experiment was done equal area was taken.

And they still thought that still there is a chance of corrosion, so they thought that let us boil it boil that water and that while boiling the gases got removed and the corrosiveness drops down, but still the problem persisted ok, fine. Then what was the solution? Then what happened notice that, since phenolic coating is not impervious, there is a porosity there are things like that. So, the porosity because of that porosity, water can seep in or electrolyte can seep in and there will be a possibility of electrolyte metal contact.

Now, since this bottom part which is stainless steel part is exposed and there are oxygens, so the cathodic reaction was taking place on the entire cathode area; entire cathode area. So, who would supply electron? So, now, question is because of that particular seepage and because the failure of that particular the imper pervious nature of that particular coating, around this zone the galvanic effect was felt.

Why? There are other portion also it is getting that particular metal the mild steel electrolyte contact, but still around this zone galvanic was felt galvanic effect was felt, because electrons so this electron those are needed these electrons are needed here; electrons are needed here. So, in order to supply that, the entire segment would supply electron.

Now, since galvanic corrosion also has this factor of resistance ok. So, the resistance would prevent the electrons to move freely from higher move freely from in fact, it has to migrate over a large distance, even if it is a metallic conductor still it will be having that effect. That resistance offered to the metallic conductor to the electron flow if it is a wide distance cathode and anode.

So, the best possible way to avoid that resistance factor by the electron is it should try to come close to that segment around this zone; around this zone electron would come; electron would come. So, the corrosion is mostly there in this zone, in this zone ok. And, since we know mild steel is an anode and stainless steel is cathode. So, mild steel would corrode and stainless steel will act as a cathode for the cathodic reactions at the same time it is actually a small area and this is large cathode.

So, that is what the aggressiveness of corrosion in that small area anode around that region where the clad is welded to the mild steel on the side walls those segments is vulnerable for higher degree of corrosion, and there could be possibility of leakage and that is what happened. So, the solution was, if you and they what they did? They coated

the bottom part; they coated the bottom part. So, once it is coated bottom part, now you are actually decreasing the area needed for the cathodic reactions or the preferential cathode and preferential anode that particular factor it is stopped. So, that is what this tank the problem is solved.

So, that is what this is also a typical area the painting philosophy that the cathode area is painted leaving the anode area. So, this anode area if you leave no problem, but its better to coat the entire segments rather than only coating the bottom part, because there is you know there is a possibility we can coat entire segment. But still if you coat only the bottom part which is a stainless steel clad still the problem can be solved to a great extent.

So, this what I wanted to explain that coating philosophy in case there is a possibility of galvanic effect cathode should be coated leaving anode uncoated. So, that would also still give a very good or reasonably good corrosion resistance or corrosion protection.

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Let me show you some example of nail corrosion which is basically galvanic corrosion, where if you recall that I talked about the corrosion of a nail when it is inserted in a into an object the screw that, but the outside of that nail which is exposed to the environment that does not get corroded much corrosion still happens, but it is not heavily rusted. But if we can see the inside part for a long use after a long use that inside part can get corroded heavily, ok. Let me show you some of my collections.

So, this is one collections if you see this is a kind of handle, which is fitted to a door, ok wooden door.

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Now, if you carefully see that there are two screws, one screw is here, one screw is here if you see carefully this is the one screw this is the screw, and the another screw is here if you see this, so this is the another screw, ok. Now, this head of the screw in fact, I could not take it out.

The screw is fastened to the so tightly fastened, because of the corrosion products at the big at the where this particular slit is inside that slit the corrosion product is so heavy it has got it got fastened heavily, ok there is no welding remember, but its basically mechanical locking has happened because of the corrosion products.

Now, if you see those screw parts the inside part; the inside part is basically a small part which is coming out. If you see this the, if you see the pen position the nib position the screw top part is actually bottom part is protruded. Here also it is a protruded part, if you see this protruded part. The protruded part its there is a long screw, but that is long screw the some part has actually gone inside and little bit of part has gone out, if you see this the small thing gone out.

Now, if you see the top part; top part is corroded, but still it maintains that thread part you know that the slit part, in a screw there will be always a small slit going through the

center of that particular screw head it is there it is still there; here also if you find it is still there this particular head part. So, this is the head part head part is still there ok, but the inside part is completely almost completely corroded.

Now, you let us understand this particular phenomena. The top part is all the time having in contact with the moisture and oxygen. And, the part which is inside that is having less oxygen, but point is over the period that wood would allow little bit of moisture to seep in and there would be little bit of oxygen to seep in. And, the oxygen concentration would decrease as you start from this point this edge point to the inside of that particular wood.

So that means, the differential aeration cell is forming, the inside part the extreme inside part is having the least oxygen content and the top part is having the maximum oxygen content. The top part would become cathode the inside part which is very inside deep inside the particular wooden stuff that is actually anode.

So, the corrosion would be concentrated in that anode part and cathode part would be the top part. So, that so the top part is actually maintaining its shape as well as its the groove is also we are able to see that groove, but the inside part is almost eaten away because of the corrosion. And, this is a classic example of differential aeration cell, ok.

So, the inside is having less oxygen, anode the outside more oxygen cathode. So, cathode would not corrode much the bottom part would corrode high.

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So now another, so this is let me show you another example. This is the wooden stuff, it was see I generally collect materials from I look for this kind of examples. Look for this kind of examples wherever I find such situations I take those situation those things and then store in my bag just to demonstrate it to my students. Now, here also if you see this, this is the wooden thing which was fixed to a kind of object.

Now, if you see the top part of this particular screw, the top part you see this top part still its corroded yes it its corroded it is not like shiny, but the groove is completely visible if you see the groove this groove is there, ok.

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But if you see the inside part it is not for a long duration use, it was maybe couple of months. And then, what happen if you see the screw part inside part the thread of the screw has completely gone, if you see the thread of the screw is completely gone, but at the same time the corrosion that rust deposit is also there, ok.

So, that rust deposit the rust deposit it is also there and the truss deposit is forming because of the differential aeration for cell formation. The top part is exposed to the environment lot of oxygen, so cathode area would form here and the bottom part which is inserted into an another object that bottom part is not getting sufficient oxygen.

So, it will become anode. So, then differential aeration cell formation the bottom part the insert inside part would corrode high, the bottom part top part will get corroded will get protected, ok.

So, this is one classic example of differential different aeration cell formation and preferential cathode and anode. The previous part also it is basically a preferential cathode and preferential anode. The inside of an of the nail is actually anode and outside is cathode. So, this example I just wanted to show you for your understanding that galvanic corrosion.

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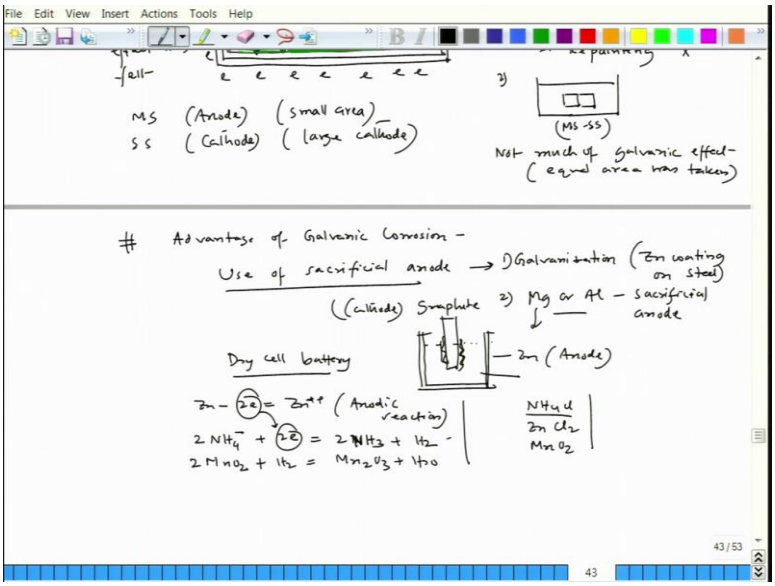

Now, coming to the second part, what has been said is basically advantage of galvanic corrosion.

Now, one advantage is use of sacrificial anode fine. So, this is used like widely talked about example is galvanization. Where zinc coating on top of steel or mild steel you can say normal steel. Now this is one, there could be possibility of use of magnesium or aluminium for sacrificial anode. And, one common example of magnesium anode is in our geyser ok.

So, if you see modern day geyser, it is actually having a magnesium rod inserted on top of it. Because nowadays this geysers are made of stainless steel normal steel ok, stainless steel you can use, but in fact that previously it used to it was made by a copper sheeting copper sheet, but now, it is stainless is steel made. So, that is what the magnesium rod is inserted which gives the protection to the steel casing of that geyser.

In fact, sometimes you might notice that when you take the water out, it actually smells bad. So, that actually that bad initial first time say for example, you have heated the water and you left it for some day. The first flow of water you would see that, it is having little smell, so that smell is coming because of the magnesium corrosion products ok. So, this is another example. So, these are used these are used for sacrificial anode protection of pipelines cross country pipelines they are protected by this sacrificial anodes fine.

So, the another use is dry cell battery, ok. So, there what happens you have a casing which is made of zinc and then you have a graphite cathode. So, this is cathode fine and this would, so this is the casing which is zinc casing which is anode fine. And now, what happens? Here you have NH_4Cl these are the things that are added zinc chloride and manganese oxide. So, these are the ingredients we have in this basically a kind of pest.

And now, what happens these are the following reactions that take place, zinc 2e zinc plus plus which happens in the zinc surface this is anodic reaction fine and then the cathodic reactions. So, then 2NH in fact, NH4 minus which is coming from here reacts with two electrons which is taken by this it will go to ammonia plus H_2 and then manganese oxide it reacts with this hydrogen which forms Mn_2O_3 plus H_2O. So, these are the reactions that take place.

$$Zn - 2e = Zn^{++}$$

$$2NH_4^- + 2e = 2NH_3 + H_2$$

$$2MnO_2 + H_2 = Mn_2O_3 + H_2O$$

So now, you see the electrons this is the battery voltage it gives you a certain voltage fine. So now, what happens? This electrons are supplied by zinc and that electrons are taken by this reaction. So, these cathodic reactions happens on this surface. So, it is a galvanic preferential cathode preferential anode, but it actually gives me electricity ok.

So, the battery is used for that. So, these are the two advantages I can think of; we can talk about the advantages of corrosion in a subsequent lectures in the subsequent lectures. When we talk about dealloying, you will see that actually this dealloying factor can be used to make exotic materials.

So, let us stop here. We will talk about dealloying in the subsequent in the next lecture, we will start with the dealloying fine.

Thank you.