Phase Equilibria in Materials (Nature and Properties of Materials-II)
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Lecture - 28
Fe-C Phase Diagram (contd.)

So, welcome again we start a new lecture number 28.

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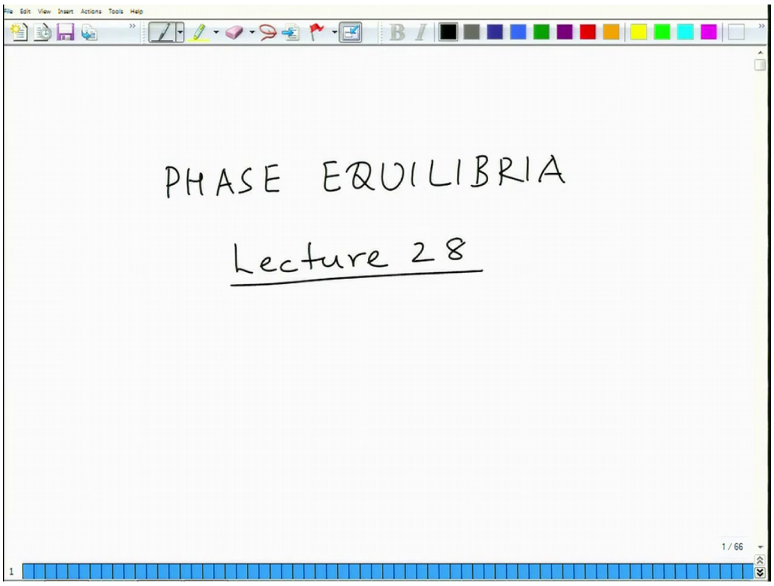

Phase equilibria course. So, we will just do a brief recap of previous lecture.

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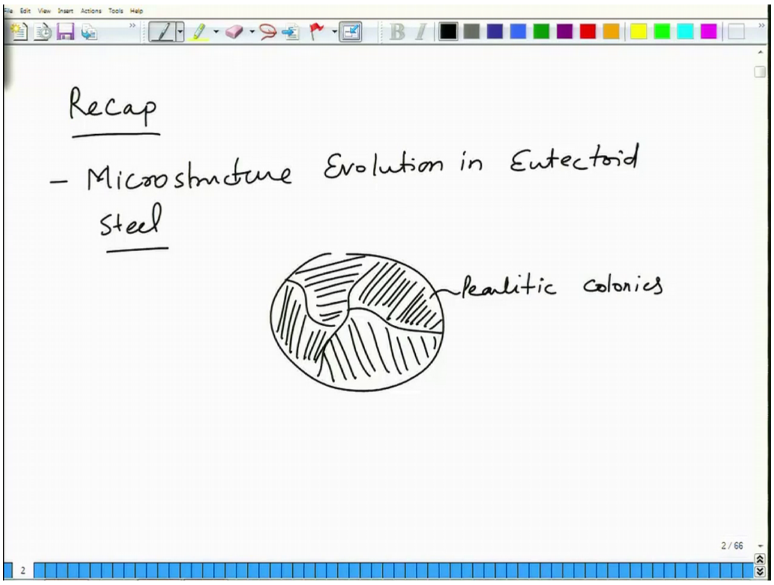

So, in the previous lecture we did we studied the microstructure evolution in eutectoid steel. Where we saw that you know you the micro structure consists of paralytic colonies and this perlite is basically a mixture of ferrite and cementite. So, next we will take up the microstructure evolution in hyper and hypo and hyper eutectoid steel.

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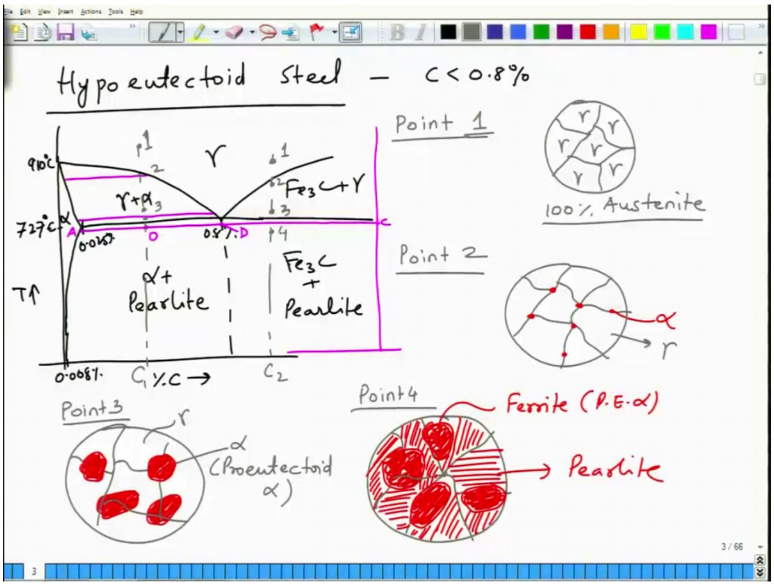

So, we will first look at hypoeutectoid steel.

Now, hypoeutectoid steel is the one which has carbon less than 0.8 percent ok. So, if I draw that part of phase diagram here, I will not complete part of the phase diagrams. So, you have this eutectoid temperature. So, goes all the way to. So, this is percentage carbon, this is temperature this is 727 degree centigrade and somewhere here you have 0.8 percent. So, this is gamma phase field and this is 910 degree centigrade and alpha gamma plus alpha and alpha plus. So, you can say alpha plus pearlite and here we are going to have Fe 3 C plus gamma and this is going to be Fe 3 C plus pearlite

So, when you have alloy composition of let us say this composition C 1. So, at this point 0.1 you will have 100 percent austenite. So, this is gamma austenite. Now when you come to point number when you come to this boundary between the austenite and ferrite at this point so, which is point 2, you have nucleation formation of tiny crystals of alpha. And these tiny crystals of alpha they form at the grain boundaries of gamma. So, this is tiny crystals of alpha forming at the grain boundaries of gamma. So, this is alpha and this is what is gamma. And the phase fractions and compositions can be determined using tie lines.

So, now as you get down to somewhere here point 3 then these alpha grains they grow bigger ok. So, the alpha would have grown to bigger sizes. So, this is ferrite grains. And as you come down to this temperature you will have left some austenite. So, you will have this as austenite and this as alpha which is pro eutectoid alpha. When you come to this point which is point 4 the alpha in there the gamma in there on gamma austenite changes to pearlite.

So, what you will have here is you will have these ferrite crystals which were grown like this. So, these are these are ferrites. And the remaining part will convert into pearlite. So, we will have these pearlite lathes lamellas all over the place. So, you will have this as a ferrite pro eutectoid alpha and this will be your pearlite. So, hypoeutectoid steel will show you a microstructure which consists of pro eutectoid ferrite and pearlite.

And if you cool it down to room temperature think much is going to change. Because the solid solubility as we know at this point is 0.025 percent this is 0.8 percent and at this point it is 0.008 percent. It is how it will change much as a result of phase fractions and compositions remain fairly similar. And if you want to look at the real microstructure, the real microstructure looks something like this.

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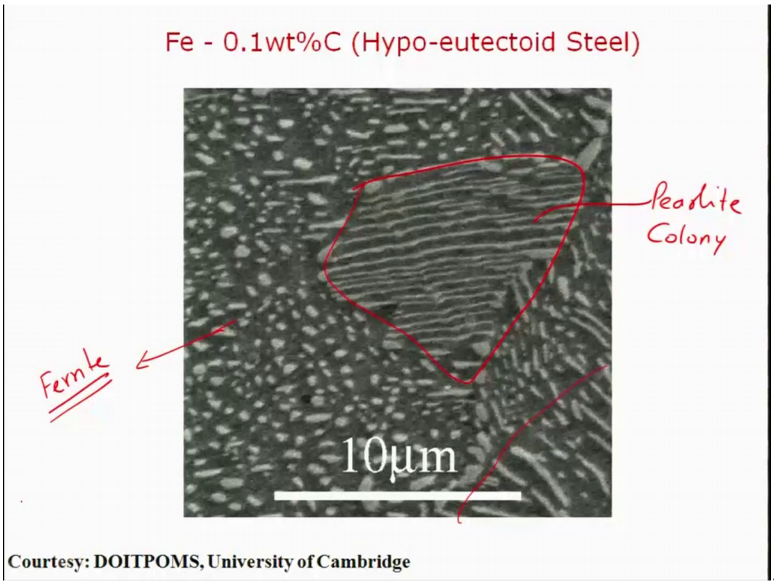

This is the real microstructure.

So, in the real microstructure you have these pearlite colonies. So, this is what is let me just use the pen. So, you have this as a pearlite colony and these are the you know cementite, some cementite that is formed and the whatever mostly you can have a lot of ferrite in here. So, this is also some pearlite you can see that lamellar shapes and rest all will be ferrite ok. So, the larger phase fraction is going to be ferrite and a smaller phase fraction is going to be pearlite colony.

So, this is a microstructure of it is very fine microstructure at the scale of 10 micron if you look at a bigger microstructure you will see a lot of ferrite in there. So, this is how the microstructure in hypereutectoid steel evolves. And again you can calculate the you can calculate the phase fractions by drawing the tie lines.

So, you can draw the tie line at this point you can draw the tie line at this point into all the tie line at this point, or if you go all the way up to here 6.67 you can draw that tie line. So, if you consider a point a C and o then you will calculate the fractions of alpha Fe and cementite, but if you consider the points a o d then you will calculate the percentage of pro eutectoid ferrite and pearlite.

So, this is what we did in eutectoid in the eutectic phase diagram earlier. So now, let us look at the microstructure evolution in hypereutectoid steel.

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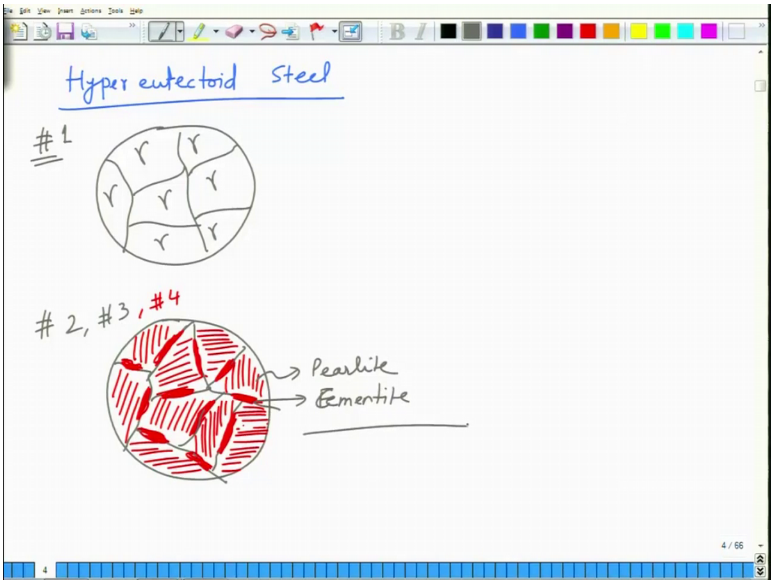

So, again we will follow the phase diagram which is shown here. So, we take. So, this is let us say C 2. So, you have point 1, point 2, point 3 and point 4 ok.

So, at point 1 you are going to have microstructure which is 100 percent gamma. And point 2 is going to be nucleation of cementite at the gamma grain boundaries. So, you are going to have cementite forming here and cementite is smaller in amounts as a result, it does not increase hallow of an amount and as you go to point 3 . So, if I again point 3 this cementite is going to go further.

So, you are going to have larger network of cementite at the grain boundaries. And what we are going to have here is basically a mixture of ferrite and cementite, when we go to point 4 when we have cooled below eutectoid we are going to have a spotlight all over the place. So, this is going to be as microstructure in schematic microstructure in a hypereutectoid steel which is going to be something like that.

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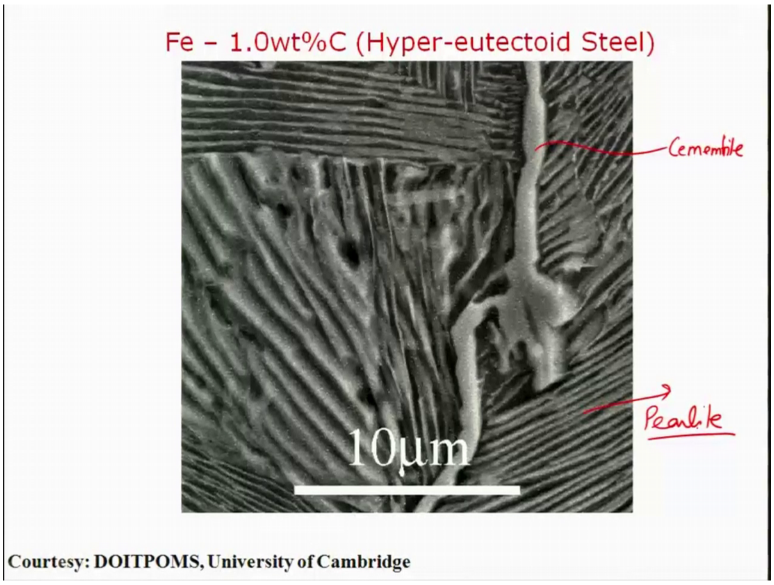

So, you are going to have these cementite plates, which are going to be the grain boundaries and other regions are pearlite.

So, this is how hypereutectoid steel is going to look like alright. So now, we move to. So, this is what is let me just now come to summary of this point.

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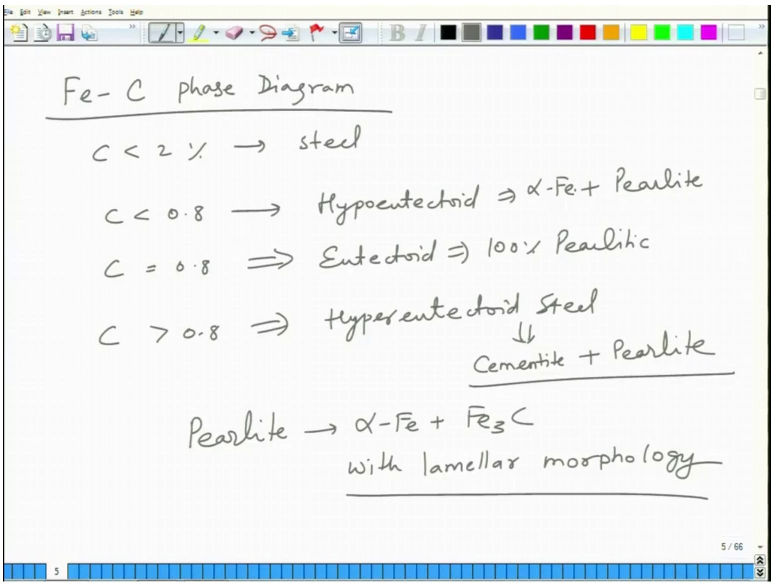

So, in the iron carbon diagram for carbon less than 2 percent we define a steel although it is defined as steel and carbon between less than 0.8 percent are hypoeutectoid steel carbon nearly 0.8 percent is eutectoid steel.

And carbon more than 0.8 percent is hypereutectoid ok. And this is how. So, let me just show you now let us go back to what we call as and these have different microstructures hypoeutectoid steel will have a 100 percent pearlitic microstructure. Hypoeutectoid steel will have alpha Fe which is pro eutectoid Fe plus pearlite the phase fractions will depend upon the carbon content and eutectoid steel will have cementite with pearlite

And pearlite as we know is not a separate phase it is a mixture of alpha Fe plus Fe 3 C with lamellar morphology. So, this is what is there about the iron carbon system and let me now show you a picture of.

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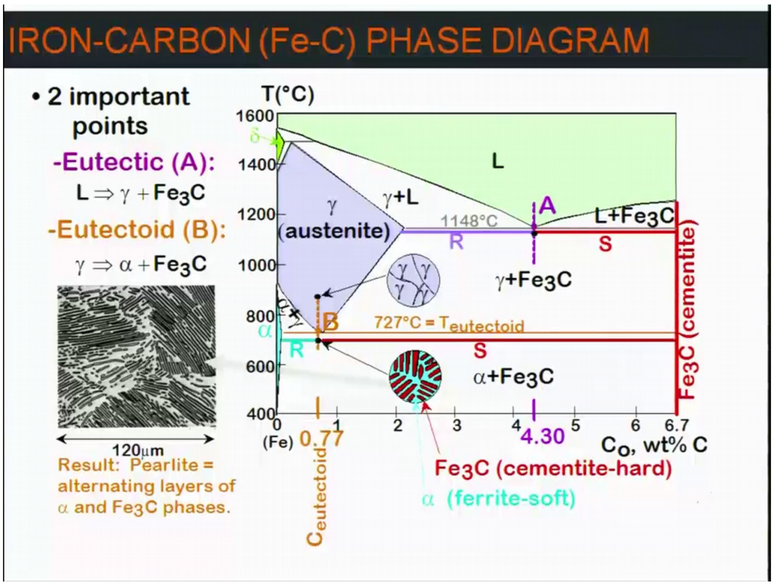

So, this is what is this is what we did. So, we have this phase diagram where we have a eutectic phase.

So, this we have discussed anyway. So, let us not worry about this.

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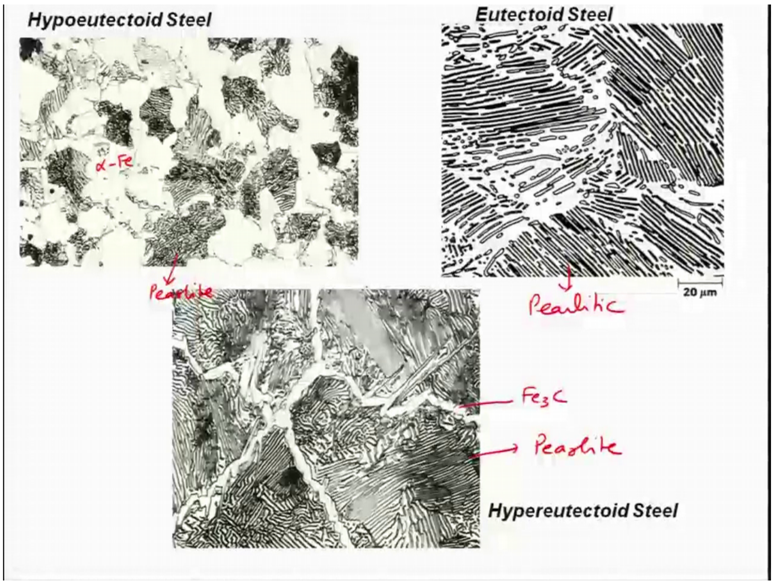

So, this is the hypoeutectoid steel on the left you can see that these are alpha Fe grains and this is what is pearlite. This is a completely pearlitic microstructure 100 percent pearlite. And this is what is hypereutectoid steel this is Fe 3 C and this is what is pearlite ok.

So now let us discuss what we look at the other part of the phase diagram of iron and steel iron and carbon that is the.

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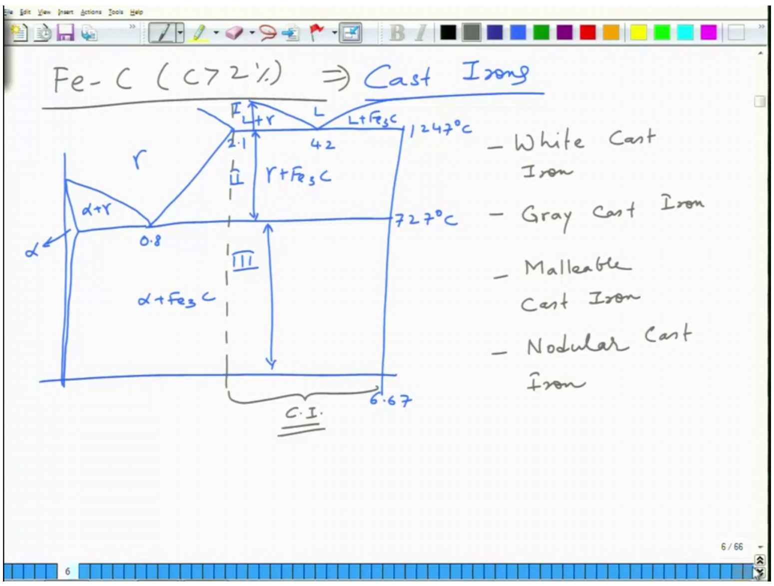

So now, let us look at F e carbon part of the phase diagram where carbon is more than 2 percent and this is called as these alloys are called as cast irons. So, now again let me draw the phase diagram of that particular part. So, you have.

So, I am not going to have complete phase diagram. So, this is 6. 67 this is 4.2 this is 0.8 this is 2.1. This is liquid this is liquid plus of gamma this is liquid plus Fe 3 C this is gamma plus Fe 3 C and this is gamma this is alpha plus Fe 3 C alpha plus gamma and this is alpha plus Fe 3 c. And this is where we have alpha.

So, this is the temperature of 727 degree centigrade and this is the temperature of 1247 degree centigrade. So, let us say this is zone 1 this is zone 2 and this is zone 3 as far as. So, temperatures above then this is zone 1 between these two is zone 2 and then zone 3 from eutectoid to room temperature. So, cast irons are alloys that I said is are the alloy which contain carbon content more than 2 percent. And there are there are various phases in this part of the we have basically going to consider the part of the phase diagram which is beyond this point.

So, this is where we are going to consider now cast iron. There are various types of cast irons there is something called a white cast iron. Then we have gray cast iron. Then we have malleable cast iron and then we have no nodular cast iron. There are some other cast irons as well but these are the most commonly known cast irons that we have in the literature, that we have in practice. So now, let us.

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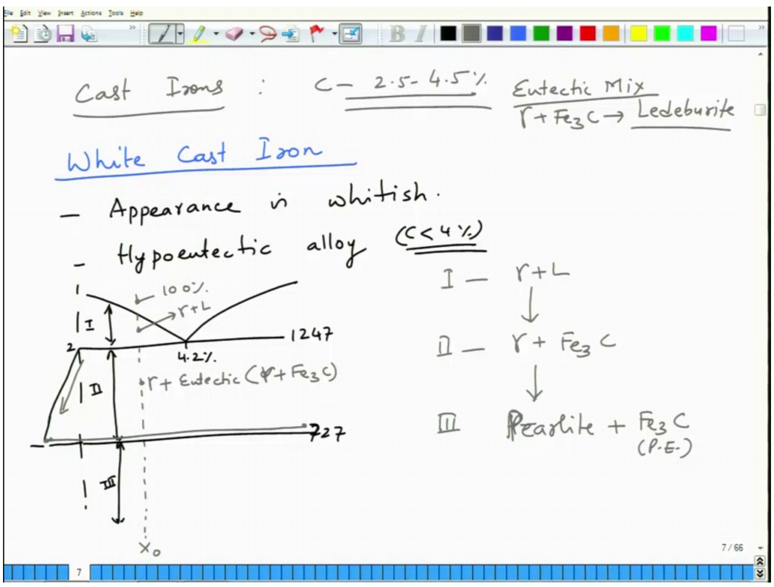

So, cast irons are generally commercially useful cast irons are those which contain carbon between 2.5 to 4.5 percent or so, roughly between 2.5 to 4.5 percent so, let us begin with a white cast iron.

Now white cast iron as the name itself suggests it is basically appearance is white. So, it is a whitish looking appearance and basically all the white cast ions are hypoeutectic alloys. So, which have carbon typically less than 4 percent.

Generally speaking and the way this microstructure is produced is. So, if you look at the part of the phase diagram, where we do this is the eutectic point and then you have the eutectoid point. So, let me say this is what this was 2 percent. So, this is what we are considering this is zone 1 this is zone 2 and this is zone 3.

So, this is 727 this is 1247. So, and this is 4.2 percent. So, you start from this particular this is x naught. So, you start from this point; obviously, you have a 100 percent liquid. Then you get into this regime you have gamma plus liquid. And then you come to this regime in which whatever remaining liquid is there that converts into eutectic.

So, what you will are you will be left with is alpha plus eutectic. And this eutectic mixture is of gamma and Fe 3 C and this eutectic mixture is called as in cast irons gamma plus Fe 3 C is called as ledeburite ok. And so, basically how you produce a white cast iron is you are in zone 1 in gamma plus liquid, then you fast cool and you reach zone 2, what you achieve is gamma plus Fe 3 C or you can say gamma plus ledeburite. And then you fast cool it and the third region you produce gamma plus sorry Fe 3.

So, the gamma will convert. So, this gamma will convert into pearlite plus Fe 3 C. And you can see that and as you cool down the solid solubility of solid solubility of carbon in iron decreases along this line. So, more and more carbon comes out of gamma. So, at this point you will have gamma of composition this and Fe 3 C of composition this. So, Fe 3 C composition fraction will increase a little bit as you cool it down and when you come to zone 3, you cool it fast you form the remain the gamma converts into pearlite, and whatever pro eutectic pro eutectic cementite was present. So, this was pro eutectic cementite and pearlite.

Now, this is basically a microstructure which consists of dendrites of transformed austenite which is converted into pearlite plus Fe 3 C. So, basically this cast iron consists of pearlite with cementite fairly similar to hypereutectoid steel, but different in carbon content. Now this is why it is called as white cast iron.

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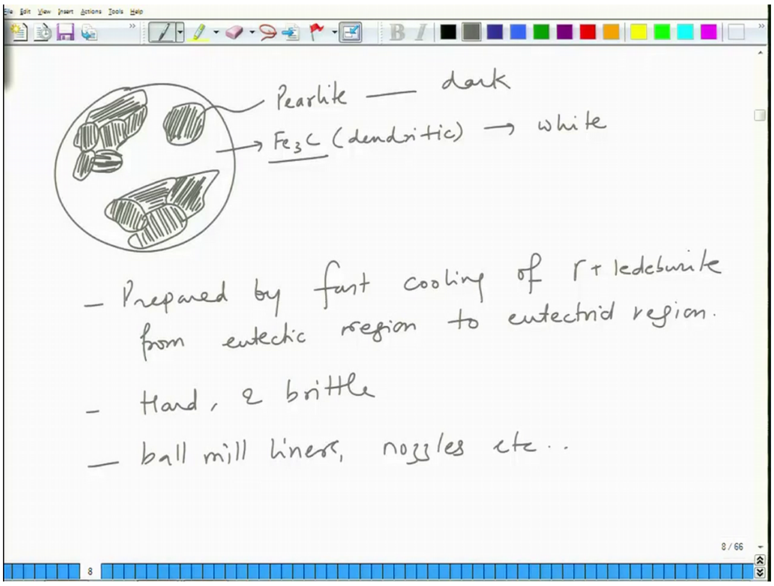

And so, in this generally you will what you will have is here, you will have a microstructure which will consist of these colonies of pearlite. So, you will have these colonies of pearlite. So, this is pearlite and what you are going to have here is basically dendrites of Fe 3 C.

So, this is both mostly represent in dendritic form. So, white cast formed as a result. So, if this is generally white and this is generally dark and that is why it is called as a white cast iron because the matrix is prominently white. So, essentially it is prepared by fast cooling of gamma plus ledeburite, from eutectic region to eutectoid region.

So, essentially the, I will show you the micrograph.

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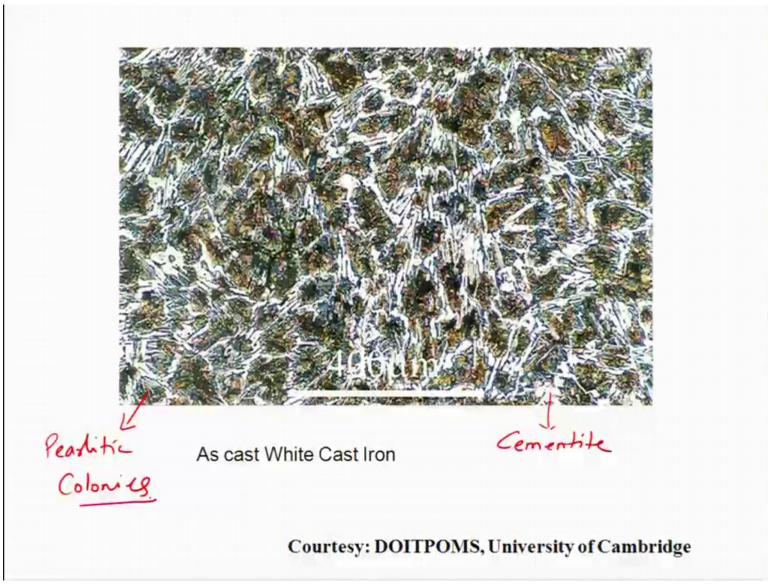

A micrograph of white cast iron is something like this. So, this is as cast white cast iron you can see the white phase here is cementite. And the gray phase is the pearlitic colonies.

So, this is what is a white cast iron microstructure.

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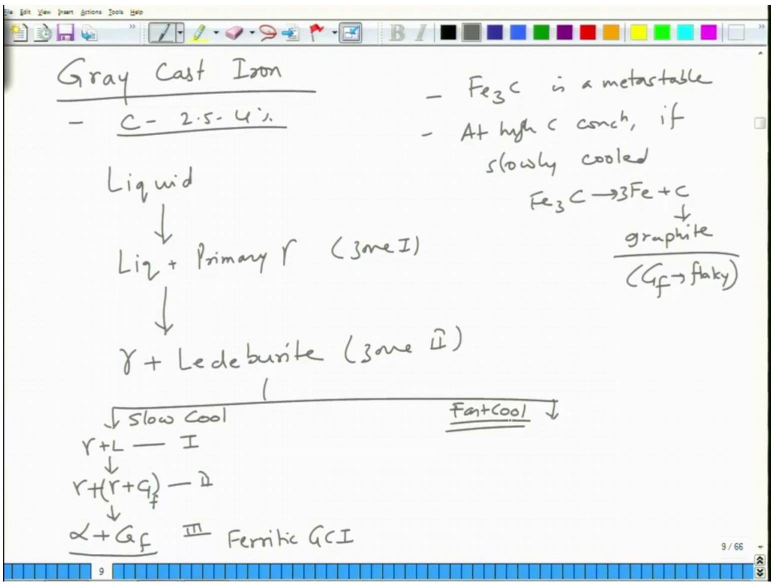

Now, the second important cast iron is gray cast iron. And the gray cast iron is one of the most widely used. So, one thing I forgot to tell you is that white cast iron that we have is extremely hard and brittle. So, it does not have too many applications, but it is found in for example, ball mill liners nozzles etcetera gray cast iron.

So now come to let us come to gray cast iron, gray cast iron is basically again hypoeutectic alloy which carbon between 2.5 to 4 percent. And what you do in this cast iron is you start from liquid state, then you go to liquid plus primary austenite and this then. So, this is as you into zone 1 and then you enter zone 2, which in this case the you form gamma plus ledeburite.

So, you have primary gamma plus the eutectic mixture, this is in zone 2 and depending upon how you cool it now because as I said earlier cementite is a metastable phase. And at high carbon concentration if slowly cooled Fe 3 C will convert to Fe plus C 3 Fe plus C. And this carbon is basically graphite this is the stable form.

So, what happens here is if I slow cool it. So, let us say this is slow cool ok, slow cool is you have gamma plus liquid in zone 1 and then you come to zone 2 as you cool it slow cool it. And the this liquid converts to essentially you will have transforming to liquid will transform to gamma plus.

So, gamma plus it will form the eutectic and this eutectic is a mixture of gamma plus Fe 3 C. Fe 3 C if you cool it slowly will decompose into graphite. So, you will have gamma plus graphite. So, this is graphite. So, this is graphite and these are typically in the flaky form we call it G f.

So, graphite is flake flaky and then when you. So, this is in zone 2 and when you further cool it down to zone 3, which is the below the eutectoid temperature the gamma converts into alpha plus Fe 3 C, but since Fe 3 C is unstable you have a mixture of alpha plus G f.

So, what you form basically is basically a cast iron which is a ferritic cast iron; ferritic gray cast iron ferritic gray cast iron. And when you first cool it as I will show you in the next lecture, you will end up with what we call as pearlitic cast iron because there is not sufficient time for cementite to decompose completely into graphite.

So, this is what we have learnt in today’s lecture. We have looked at the microstructure evolution and hyper and hypoeutectoid steels, which have a microstructure with pro eutectoid ferrite and cementite with colonies of pearlite depending upon the composition.

And then we moved on to the phase diagram of cast iron and how the microstructure evolves in cast iron of various types. We will further continue this in the next lecture.

Thank you.