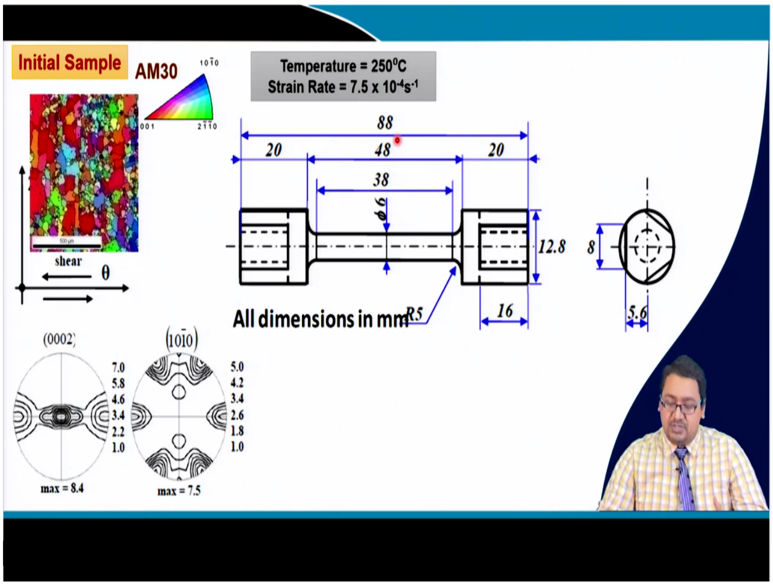
Texture in Materials
Prof. Somjeet Biswas
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Kharagpur

Module - 11
Theory of annealing texture evolution
Lecture - 56
Dynamic Recrystallization and Grain Refinement during Hot Large Strain Shear Deformation in Mg Alloy

Good afternoon everyone and we are doing the 3rd lecture of Module 11 that is Theory of Annealing Texture Evolution. This is the final lecture of the course this is Lecture number 56 and we will be discussing a small experimental study an experimental investigation on Dynamic Recrystallization and Grain Refinement during hot means high temperature and large strain; that means, large plastic strain shear deformation like shear means deformation like torsion in magnesium alloy. Let me take the laser pointer.

(Refer Slide Time: 01:29)



So, this is an example where an initial sample of an extruded magnesium alloy which is a commercial AM 30 alloy; that means, magnesium, aluminium nearly 2.8 weight percentage and manganese of about 0.2 percent is used which is a single phase magnesium alloy and is applicable as a light weight moderately strength structural material for aerospace application.

So, an extruded material if you look into it looks something like this this is the inverse pole figure microstructure, which comes with a inverse pole figure code colour key code right. We can see that most of the grains are red and few grains are present which are green and blue in colour. I would say that this is a microstructure where the vertical axis is the extrusion direction, whereas the horizontal axises are their radial directions right. And if we look into their pole figure you will see that the 0002 axis are you know parallel to the radial direction and are perpendicular to the extrusion direction.

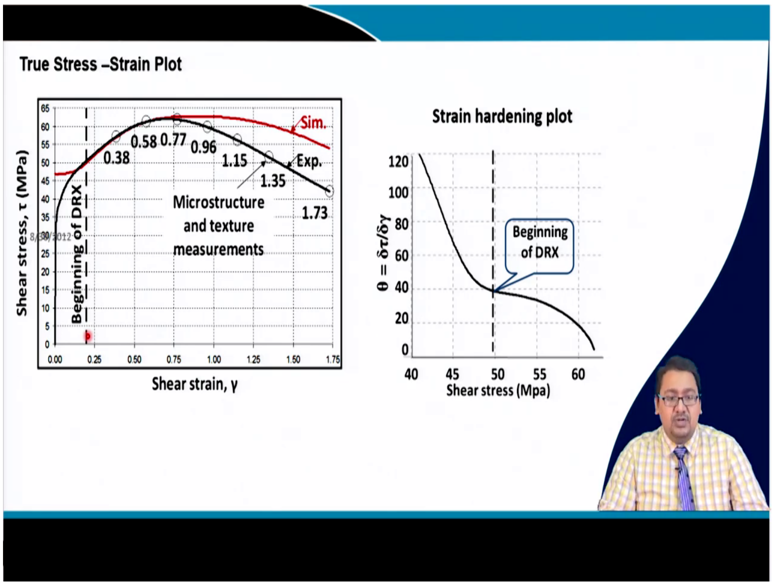
Now, the 101 bar 0 pole figure is shown the 101 bar 0 pole figure formed at 30 degree to the extrusion direction which indicates that it has an intensity of 112 bar 0 parallel to the extrusion direction therefore, the deformation texture is predominant in this condition even if this is a warm extrusion process. Now, a shear strain is given parallel to the radial direction. So, a shear strain right and how a shear strain is given, in order to give a shear strain to the material samples like this is prepared. Now, a sample like this is a you know circular cross sectional area sample of a diameter of 6 mm.

One can say means the axial direction of this sample is the extrusion direction whereas, the sample is twisted in such a way so, that the torsion could be given and this torsion is basically a free end torsion where the you know the length of the sample could increase and decrease freely with as a material property.

So, it is kept free so, that while the torsion is given the length can increase or decrease of the material as per the property of the material. So, it is known as a free end torsion this gives a pure shear to the material and this is a way where we can give a large amount of plastic strain to the material in order to study the microstructural behaviour dynamic recrystallization like situation.

As we all know that magnesium is an very brittle material. So, we considered a temperature of 250 degree centigrade. So, that a sufficient amount of plastic strain could be given to the material in order to observe the microstructural evolution throughout the deformation process a very small low strain rate of 7.5 into 10 to the power minus 4 per second is given, so that a large strain could be incorporated by using a small strain rate.

(Refer Slide Time: 06:06)



The true stress true strain plot in terms of shear stress in the y axis and shear strain in the x axis was given. Now, you can see that the experimental curve with the initial elastic behaviour changes into the plastic behaviour and the strain hardening increases and increases right.

So, in this shear stress strain true shear stress strain flow curve one can observe that the strain hardening of the material occurs up to a strain of nearly 0.77 whereas, the strain hardening rate was decreasing during this situation after that the strain hardening of the material does not occur and strain softening occurs.

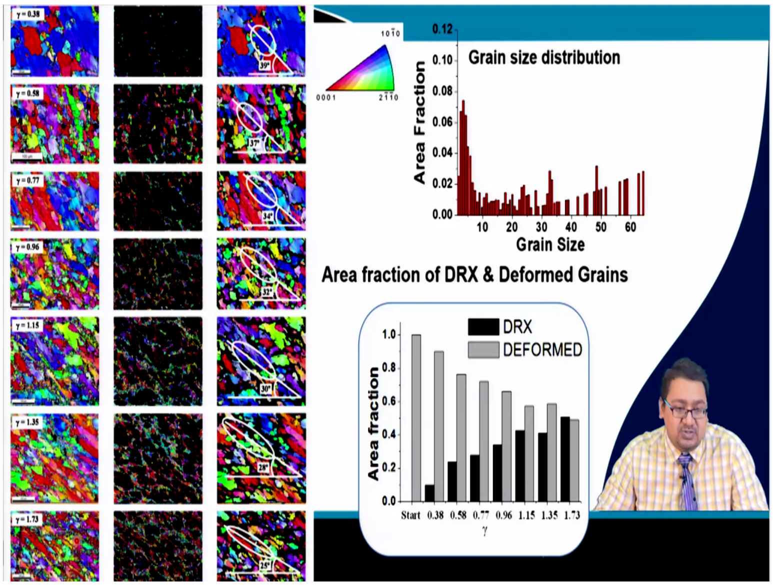
One can say that just before some amount of stress or strain before this particular you know ultimate shear stress the material started to dynamically recrystallize. We are showing here the beginning of dynamic recrystallization phenomena based upon our microstructural observation, which we will show later.

The simulation could simulate the strain hardening behaviour up to the point of the maximum UTS. But after that also it did not show the you know decrease in the stress with the increase in the strain and it goes something like this and we will explain this also this phenomena also this difference also in the coming slide.

Because the simulation cannot simulate the dynamic recrystallization behaviour the simulation which we did here is the viscoplastic self-consistent modelling can only show the deformation texture the evolution of deformation texture.

And as I said that with the increase in the strain there is a decrease in the strain hardening rate. So, if we look into this curve we see that there is a decrease in the strain hardening rate and the asymptotic point in this curve shows the beginning of the dynamic recrystallization which is nearly at 50 MPa which comes out to be this position. And we will not only be able to see this the beginning of dynamic recrystallization at the point of strain which is nearly 0.20 we will be able to diagnose this using the microstructure evolution. Now, let us go to the next slide.

(Refer Slide Time: 09:13)



Here in the next slide we are showing the microstructure of the samples which we stopped at various strains right and that what I failed to tell you in the previous slide. So, let us go to the previous slide and if we go to this slide if we look into the stress strain curve we will see that we have stopped the strain at 0.38, 0.58, 0.77, 0.96, 1.15, 1.35, 1.73 to observe the microstructure and texture evolution using electron backscattered diffraction in a scanning electron microscope.

So, if we look into the microstructure as you can see on the left hand side this is the microstructure for a strain rate of 0.38 we have taken a rather larger microstructure, but we are showing a small microstructure here so that it can be observed easily.

Now, if we look after 0.38 the grains are elongated because of the you know torsion that is pure shear that is given to the material and with the increase in strain to 0.58 you will see that small small grains starts to form. And now this small grains that are starting to form at a strain of 0.38 and 0.58 could not be observed right, from this microstructure it is better to show this microstructure incur in type of partitioning this microstructure.

So, if we look into all these microstructures together with the increase in the strain we will see that with the deformed elongated grains which are at certain angles at given by this angle in this position where my pointer is you will see that along the grain boundaries there are small grains forming. These grains that are formed are equiaxed strains they are forming due to dynamically crystallization processes and they are like necklace structure following in this microstructure.

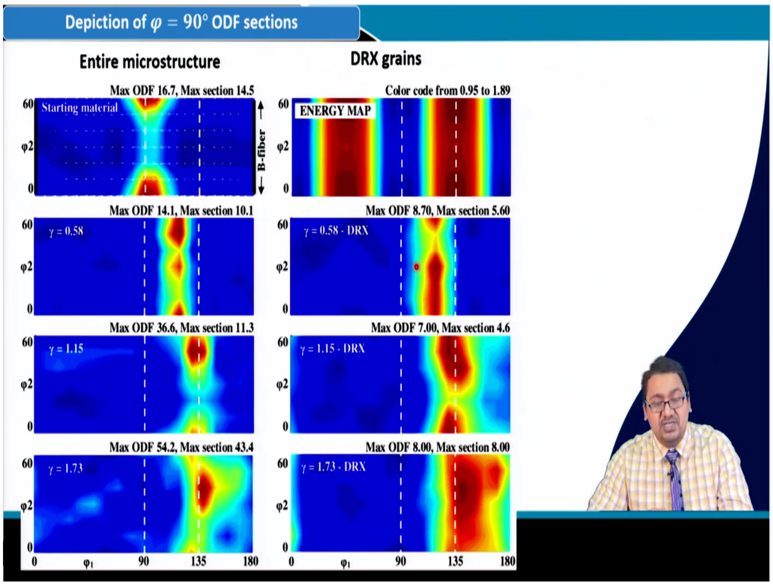
Now, we order to see these grains properly what we did is that we did the grain size distribution for all these microstructures separately and I am showing one of them. If you look into this grain size distribution, you will see abruptly that there is a bimodal grain size you see this is a peak and then there is a minima and then there is an increase in the grain size in all this you know cases in all these cases.

So, we observe that there is a minima at about 10 microns of the grain size and this led us to divide this microstructure or partition this microstructures into two regions those with grain size lower than 10 microns and with those with grain size greater than 10 micron. When we did we found that for each condition for strain of 0.38 we get smaller smaller grains and these grains are present at the grain boundaries of the deformed microstructure.

So, we could partition the microstructure into recrystallized microstructure and the deformed part of the microstructure and we can see that as the strain is increasing and increasing, the decrystallized portion of the microstructure having very small grains less than 10 microns are increasing. Whereas, we can see there is a clear division of the elongated grains also to the smaller grain size as the strain is increasing. So, a after the partitioning of the microstructure if we quantify the volume fraction of this smaller equiaxed grains and the larger deformed grains we can see basically as we are looking into the surface of the microstructure the volume fraction is usually represented in terms of area of fraction of the DRX and the deformed grains.

We can look that the area of fraction of the DRX grains or the dynamically recrystallized grains keeps on increasing with the increase in the strain whereas, the area fraction of the deformed grains which is this one that is the elongated ones keeps on decreasing with the increase in the strain in the during the deformation plastic deformation process.

(Refer Slide Time: 14:00)



Now, if we look closely into the orientation distribution function we all know that we usually show the phi 2 sections in case of all the deformation and in case of hexagonal close packed material under triclinic symmetry. Which is the situation of the torsion or shear we show phi 1 from 0 to 180 degree or 0 to 360 degrees and phi from 0 to 90 degree and phi 2 from 0 to 60 degrees.

We all know that the rotation of 30 degrees from the deformed grain along the 0001 axis forms or occurs during recrystallization phenomena of hexagonal close packed material as showed initially for the first time by Samajdar et al. Now, by using this we have also found out that this section is at phi equal to 90 degree section. So, this difference in the texture between the deformed grain and the recrystallized grain could be observed at phi equal to 90 degree section. Because at this section the deformed grains originates at phi 2 equal to 0 and 60 degrees and the recrystallized grains originates at phi 2 equal to 30 degrees because the deformed grain is associated with the 112 bar 0 along the you know extrusion direction or the rolling direction.

And the recrystallized grain is associated with 101 bar 0 which occurs by 30 degree rotation along the 0001 axis and therefore, at phi 2 equal to 0 and 60 degrees the deformed grains could be observed whereas, at phi 2 equal to 30 degrees the recrystallized grains could be observed.

Now, in order to see this it is also important to mention the reference direction used for the crystal structure. The reference direction used for the crystal structure is basically x equal to 112 bar 0, y equal to 101 bar 0 in this case where z remains 0002 or 0001, to observed observe the reformed texture at phi 2 equal to 0 and 60 and the recrystallized texture at phi 2 equal to 30.

In phi equal to 90 degree section, if x is taken as 101 bar 0, y as 112 bar 0, then the deformed texture will form at phi 2 equal to 30 degree section whereas, the recrystallization texture will form at phi 2 equal to 0 and 60 degrees. So, this has to be very clear and if we look into this phi equal to 90 degree ODF section for the starting material we can see that a strong texture is observed in the position of phi 2 equal to 0 and 60 degrees which indicates that this consist of mainly deformation texture.

While the deformation takes place up to a strain of 0.58, 1.15 and 1.73 we can see that the entire microstructure or the entire material contains texture at three different positions here. Here it may not show for this case, but if you see the increase in the strain the intensity at near to phi 2 equal to 30 degree basically increases.

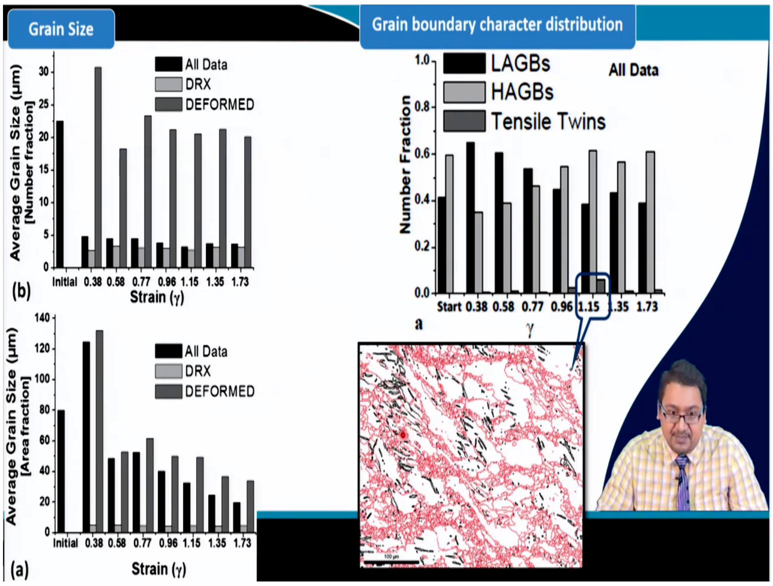
So, if we can partition the microstructure we can show the partitioned microstructure texture and so, here in case of the DRX grains if we look the DRX texture of after a strain of 0.58, 1.15, 1.73 we can see that most of the DRX textures are at the center that is at phi 2 equal to 30 degrees right. But, still there are few texture components which are present at phi 2 equal to 0 and 60 degree section, because we have done a microstructure partition based upon the you know grain size criteria where you see the phenomena will be initially during the deformation which is a continuous process dynamically recrystallized grains will evolve in the grain boundaries.

Whereas these dynamically recrystallized grains, which have texture that phi 2 equal to 30 degrees will be very soft and will be not having any dislocation density. So, with the continuous deformation process these grains will also start to deform and thereby rotate itself to form at phi 2 equal to 0 and 60 degrees too.

Here we are showing the energy map or you can say the plastic power map or this can be more perfectly said as the stored energy map, the plastic strain energy map, or the strain energy map. So, we can see that this strain energy map can be drawn to show the correlation between the texture and the strain energy. The strain energy will be higher at those positions where the deformation texture component form and we can see that these are the positions where the energy of the map is higher.

So, the plastic energy where the strain energy or the plastic strain energy is lower it should be the position where dynamically recrystallized grains will form to lower the plastic strain energy of the material and these positions are the position somewhere here somewhere here in the blue. So, if you see that the dynamically recrystallized grains slowly and with high intensity forms in the region of lower plastic strain energy position.

(Refer Slide Time: 20:35)



If we look into the grain size of this material we can look into the grain size average grain size in terms of number fraction or in terms of area fraction, as I said earlier sometime maybe in the lecture that number fraction grain size is the grain size or the average number fraction grain size is shown. Because that is the usual way of showing grain size in most of the literature and therefore, to compare the grain sizes that we are talking about in this research in this investigation showing of the number fraction grain size is very important.

But, the area of fraction grain size is the grain size which gives the actual average grain size of the material, because you see the grain size distribution in a material are usually having a large range you know the there are lots of smaller grains, there are lots of larger grains. But when we do a number fraction the consideration for the smaller grains are larger right and the larger grains are smaller but you see the larger grains are covers the most area of the microstructure.

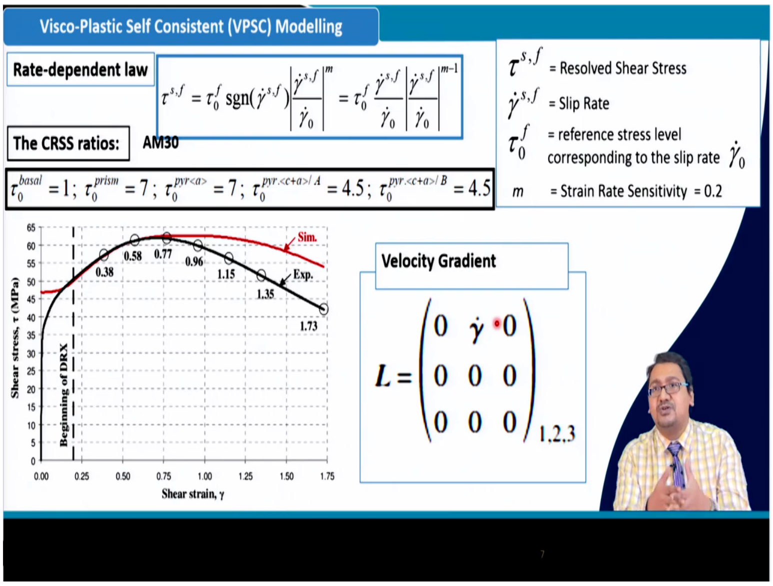
So, considering area of fraction of the larger grain is more important because larger grains occupy a larger part of the microstructure and therefore, it must influence the properties of the material more than the smaller grains. So, instead of using number fraction area fraction gives more appropriate value of the grain size average grain size or the grain size distribution. Now, if we look into the number fraction that is why if we look into the grain for the entire microstructure you can see the after a certain strain 0.38 the grain size reduces to a quite a small extent and it remains almost the same.

If we look into the deformed part of the grains the deformed part of the grains are larger and it always remains almost in a large you know grain size and remains the same. If we look into the DRX part it is the smallest and it also remains the same throughout the deformation but this must not be the case right. So, if we look into the area of fraction grain size distribution you will see that with the increase in the strain there is a decrease in the grain size of the entire data. There is a decrease in the grain size of the deformed microstructure and if you look the grain size average grain size of the dynamically recrystallized grains remains the same. This indicates that the dynamically recrystallized grains average grain size should remain always remains same with the increase in strain during the deformation.

Now, if we look into the grain boundary character distribution we will find that there is a increase in the low angle boundaries which are basically geometrically necessary boundaries that forms during the deformation. Whereas, you see that when the strain is increasing from 0.38 to 0.58 and beyond there is a decrease in the low angle boundary whereas, there is an increase in the high angle boundary which indicates that there is a lot of dynamic recrystallization that is going on. Once we reach a strain of 1.15 you will see that there is a increase in the low angle boundary after that and there is an increase in a some kind of special boundaries which are boundaries generated because of the formation of 101 bar 2 101 bar 1 type of extension twins.

So, such a situation I am showing the microstructure here and you can see the dark coloured boundaries over this red colour grain boundaries are basically twins and twin boundaries which indicates the deformation behaviour throughout the strain does not remain the same it changes right. So, initially it could be slip based and at some times it could become twinning based during the deformation.

(Refer Slide Time: 25:17)



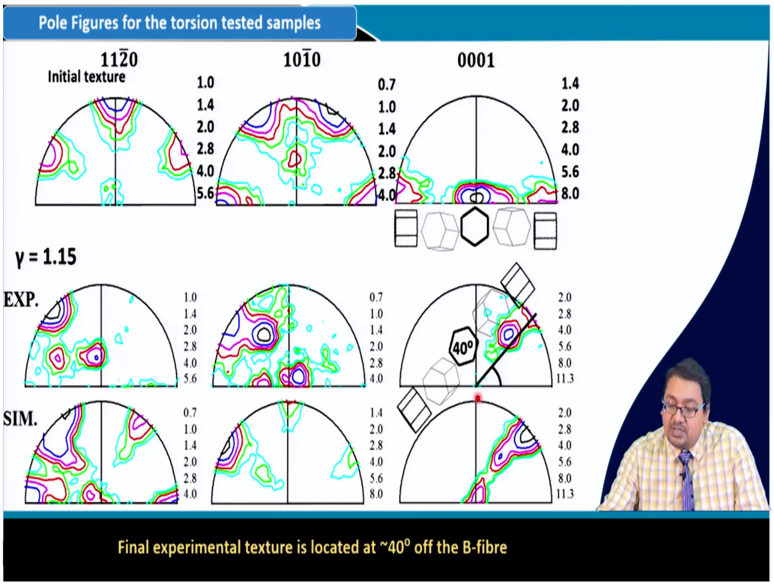
So, if we look into the plastic deformation phenomena what is occurring, the stress strain curve as I said it has a rise there is a strain hardening and then there is a strain softening in case of the experimental curve whereas, the simulation does shows this same you know strain softening, but at a larger strain.

We have used the same rate dependent law, which is tau s f equal to tau 0 times sin gamma dot s f gamma dot s f by gamma dot 0 m. We know that tau s f is the result shear stress, gamma dot s f is the slip rate, tau 0 is the reference stress level for gamma dot 0, slip rate which is the corresponding slip rate and m is the strain rate sensitivity which we have used in this case as 0.2.

We also know that SCP material has you know CRSS of you know critical result shear stress ratio of basal, prismatic, pyramidal a, pyramidal c plus a 1 type pyramidal c plus a 2 type has to be considered because these are all the slip systems that may operate at temperature of 250 degree centigrade in case of magnesium.

So, the CRSS ratio in this case was found out by matching the strain hardening behaviour that is the flow curve and the texture evolution. It was found out to be 1 is to 7 is to 7 is to 4.5 is to 4.5 for basal, prismatic, pyramidal a, pyramidal c plus a 1 and pyramidal c plus a 2 types. The velocity gradient that was used is this one with all 0's and the gamma dot here which represents the situation for pure shear that is occurring in the material.

(Refer Slide Time: 27:06)



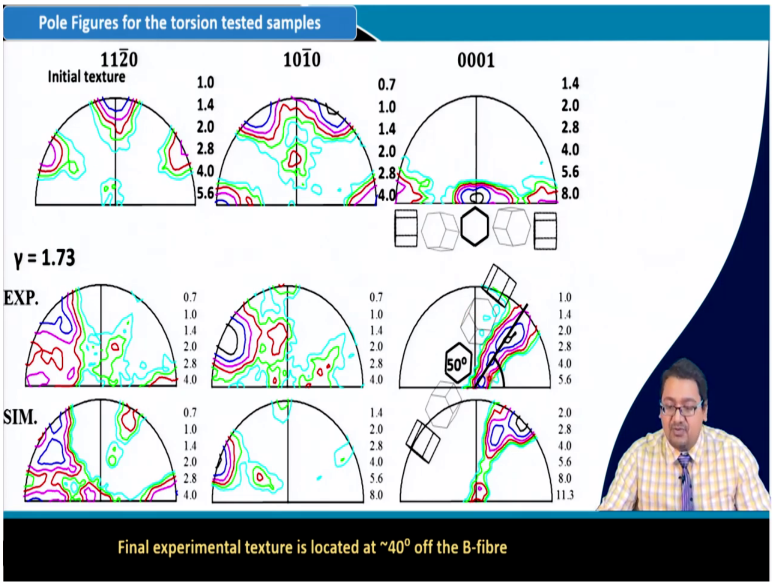
So, if we look into the pole figure for this torsion tested samples, we have already seen the texture evolution while we are observing the ODF section, but we have observed the ODF section phi equal to 90 degrees to see how the dynamically recrystallized grains have a different texture rotated by 30 degree about the 0001 axis.

But, if we look into the 0001 101 bar 0 112 bar 0 pole figure again we have looked into the initial pole figure 2 what we will see that the intensity of the 0001 are along this axis of the pole figure where this is the extrusion direction and these axis are the radial direction. I have shown few unit cells which indicates that how the unit cells are present with respect to the radial and the extrusion direction for the initial material. We can see that as the initial material is extruded and comprises of deformation texture there is an high intensity at 112 bar 0 poles along the extrusion direction whereas, the 101 bar 0 poles are present at 30 degrees to the extrusion direction.

And remember that I am showing here half pole figure because of the symmetry of the pole figure only half pole figure is sufficient. While we are showing this for the initial material the pole figure experimental and the simulation pole figure are being shown with the increasing strains, for the strain of 0.58 if we look into the 0001 pole figure we will see that the texture fibre have changed its position which was initially horizontal and now forms at nearly 25 degrees.

So, we can imagine that how the unit cells will get rotated while it forms the texture at 25 degrees angle to the initial radial direction, as this texture matches very well with the simulation texture and for this three pole figures that is the 101 bar 0 and the 112 bar 0. So, you can see the intensity of the 112 bar 0 poles here for the experimental and the simulation case which matches quite well right. So, as we increase the strength to 1.15 we could see the texture is now rotated by about 40 degrees.

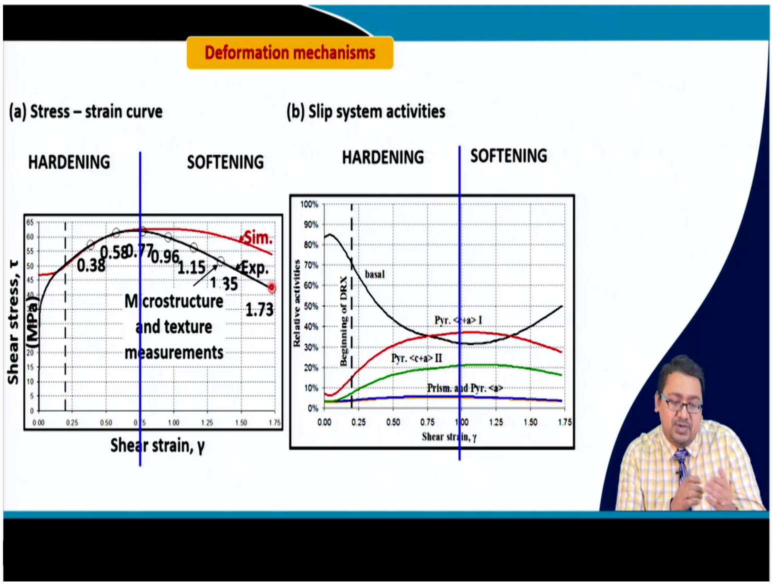
(Refer Slide Time: 30:06)



And if we increase further to 1.73 you will see that the texture increases a little bit to 50 degrees right. Now, the texture forms at 40 or 50 degree away from the initial B-fibre sorry the final or the ideal texture B-fibre that we showed that will occur at a larger strain of 4 in case of HCP material such as magnesium. So, the B-fibre if you do not remember is basically this fibre in case of the 0002 pole figure, but the texture basically forms at 40 or 50 degree which is 40 degree away from the B-fibre right.

Now, this occurred because during the deformation during the torsion the material magnesium alloy though the torsion test was carried out at 250 degree centigrade fractured at a strain of 1.73. So, it fractured before the ideal end orientation of the shear texture pure shear texture could be obtained which is at this fibre position. So, the material fractured at 50 degrees to the initial texture which is located at 40 degree away that is from here 40 degree away from the basal fibre right.

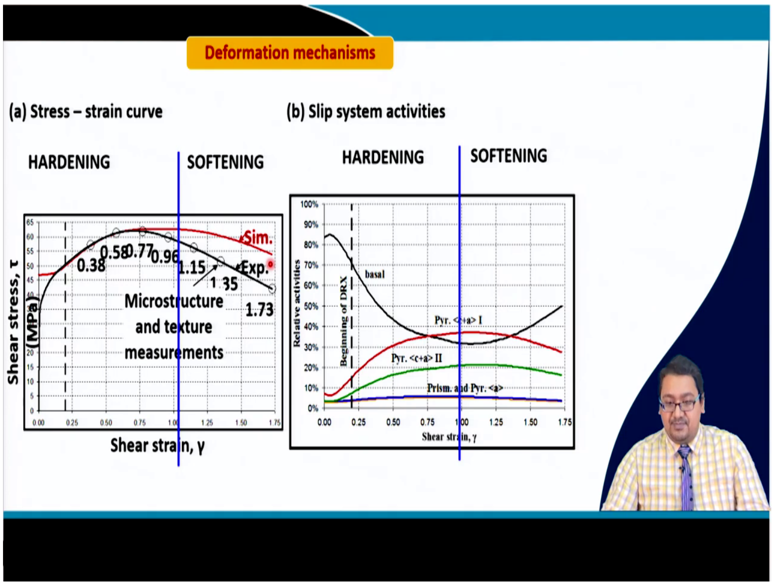
(Refer Slide Time: 31:39)



So, during the deformation as I said that initially there is a hardening and thereby there is a softening which is associated with dynamic recrystallization. I was also saying that viscoplastic self-consistent modelling you know deciphers the deformation texture, but it could not find out the texture which is associated with dynamic recrystallization.

And thereby the decrease in the strain hardening or the strain softening could not be observed similar to that of the experiment and we can see that even though there is a softening present in the simulation and the softening occurs in the simulation rather at a later strain and which is around 1.1.

(Refer Slide Time: 32:15)

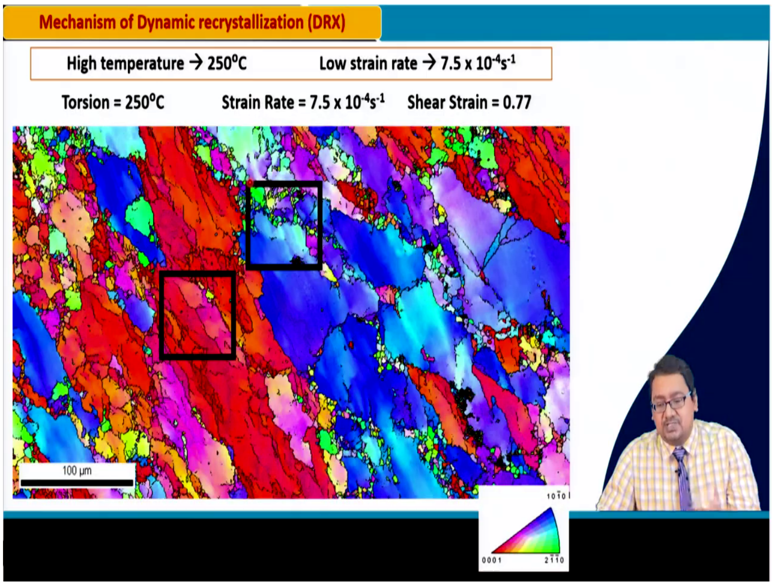


And why this sudden softening could be observed in the simulation, while the simulation could not experience dynamic recrystallization the sudden softening that is observed in the simulation could be answered from the slip system activities that could be observed from the viscoplastic self - consistent modelling.

The slip system shows the activity of the basal which is the softest slip system, which has the lowest critical resolved shear stress reduces with the increase in strain whereas, the pyramidal and the prismatic slip systems increases. But after a strain of 1 it can be observed that the there is an increase in the activities of the basal slip system whereas, there is a decrease in the activities of the pyramidal slip systems, which indicates that the activity of the softer lowers critical resolved shear stress slip system increases.

Whereas, the activity of harder slip system that is the pyramidal a and the pyramidal c plus a having high critical result shear stress decreases. This leads to the softening of the material and this could be related to textural softening which could be observed as a softening phenomena during the simulation.

(Refer Slide Time: 33:59)



So, apart from that this system of deformation that we choosed temperature of 250 degree centigrade a lower strain of 7.5 into 10 to the power minus 4 it is choosed because to see the dynamic recrystallization behaviour how it is taking place. So, as the material is extruded we can get different areas in the material containing different texture.

So, if we look in this larger microstructure and this is for a strain of 0.77 we can choose two different area, one from the grain which is deformed and is from a region which is 101 bar 0, another from a grain, which is red which is from the region 0001 entirely different texture so, to find out the effect of texture on the dynamic recrystallization phenomena.

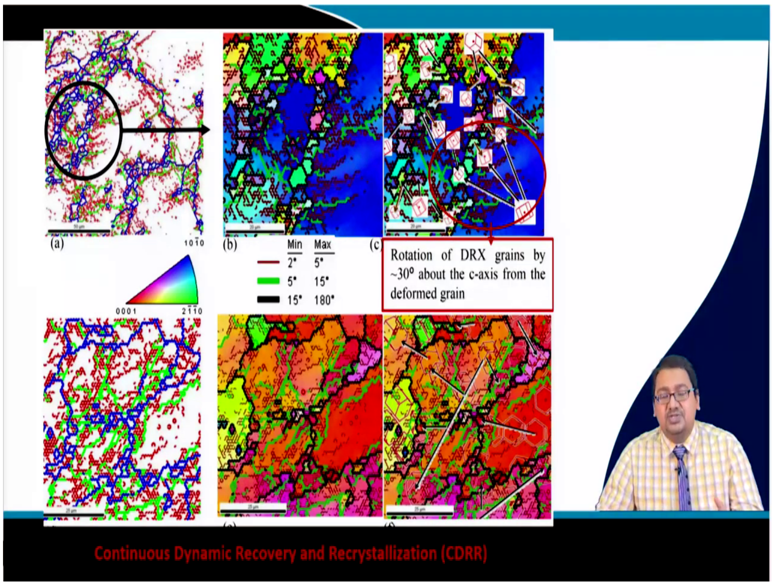
As we earlier in a certain paper observed that the texture influences dynamically crystallization mechanism basically not the texture, but basically it is the you know slip system activity. Now, it was found out that for pure magnesium basal plane has low stacking fault energy and the prismatic and the pyramidal plane have high stacking fault energy.

So, the cross slipping phenomena of screw dislocation and the climb of edge dislocation differs for the slip systems occurring in the prismatic pyramidal slip than that of the basal because in basal it is restricted because of the low stacking fault energy.

This information showed that when we observe the basal plane the probability to observe basal slips are more therefore, leading to discontinuous dynamic recrystallization leading to formation of random kind of orientation of the newly recrystallized grains. Whereas, in case of prismatic pyramidal slips it was observed continuous dynamic recovery and recrystallization following that 30 degree rotation orientation relationship that we are observing here along the 0002 axis.

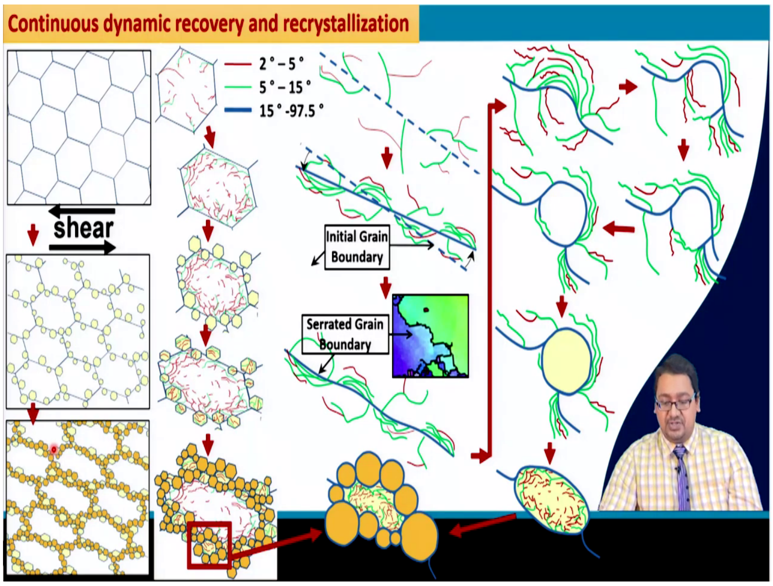
So, in order to see that what is happening for this commercial Mg point Mg 3 Al 0.2 Mn alloy. So, two different microstructural situations were taken and the DRX mechanism was analysed.

(Refer Slide Time: 36:35)



And when we look into these two different areas we found out that in most of the cases the deformed grains and the recrystallized grains are just rotated by 30 degrees along the 0001 axis irrespective of the you know orientation of the grains. Which indicated that in both the cases continuous dynamic recovery and recrystallization occurs, such a situation shows that the whole dynamic recrystallization behaviour in case of a magnesium alloys.

(Refer Slide Time: 37:16)



Now, if we look into the deformation mechanism, which leads to the microstructure evolution by this continuous dynamic recovery and recrystallization phenomena we are showing this by schematic here. And if you see if the initial microstructure is equiaxed presence of dodecahedron isoko dodecahedron type of grains which looks hexagonal type if we look on the surface that is equiaxed grains.

And if say this is the extrusion direction this is the radial direction and the shear is given along the radial direction what we observe that at a low strain small grains starts to develop at the grain boundary triple junctions and even in the grain boundaries. Which looks something like this and when the strain is larger the microstructure looks something like this a fully necklace type of microstructure having you know recrystallized grains throughout the grain boundaries.

So, if we look at this microstructure at lower strain we may say ok this is a discontinuous dynamically crystallization that is taking place, but when we look at the microstructure at this stage we will say that this is a continuous dynamic crystallization. Now, we will I will say that I will prefer saying this as continuous dynamic recovery and recrystallization process because of the mechanism that I am suggesting.

Now, if we look into a single grain if we look into a single equiaxed grains the single equiaxed grain will look something like that with there will be inside the grain the presence of geometrically necessary boundaries. Which will be 2 to 5 degrees that are showing in red, 5 to 15 degrees that are being shown by green, and 15 to 92 degrees that are being showing by blue which are the grain boundary basically this one right.

Now, when the deformation will take place these geometrically necessary boundaries will increase along with the elongation of the grain leading to the increase in the grain boundary area while the deformation will further increase there will be formation of equiaxed grains as the highly stressed region of the microstructure. So, it will start from triple junctions of the grain boundary and then at the grain boundaries and the microstructure will start to look something like that.

Now, while the further deformation the microstructure the initial grain will further elongate, but now in this case you will see that the recrystallized grains. Which are forming have are softer in nature rotated by 30 degrees will also start to deform and thus as I showed in the ODF section of the DRX grain phi equal to 90 degree section the DRX strain also shows high intensities at phi 2 equal to 0 and 60 degrees because of this deformation.

Finally, because of the deformation of this newly DRX grains and elongation of it large number of secondary DRX grains nucleate over it forming a structure, which looks something like this right. Now, if we look if we go further into the details of this microstructure evolution we should look into a single grain boundary right. So, if we look into the single grain boundary we will see that during the deformation that is shear; a shear is given like this right. So, if a boundary is present like this right. So, there are presence of geometrically necessary boundaries around this boundaries in both side of these boundaries in both the grains.

Now, as the deformation progresses the there is a stress which tries to rotate this boundaries from here to here right, such a rotation means if the boundary is like this it is trying to ok the if the boundary is like this it is trying to rotate the boundaries you know like this right. Because of the presence of grains on both the side and because of to maintain the grain boundary continuity the boundary cannot rotate independently like that right. So, there will be an increase in the dislocation densities in certain regions of the boundaries whereas, there would not be increase in the dislocation region density in the other regions.

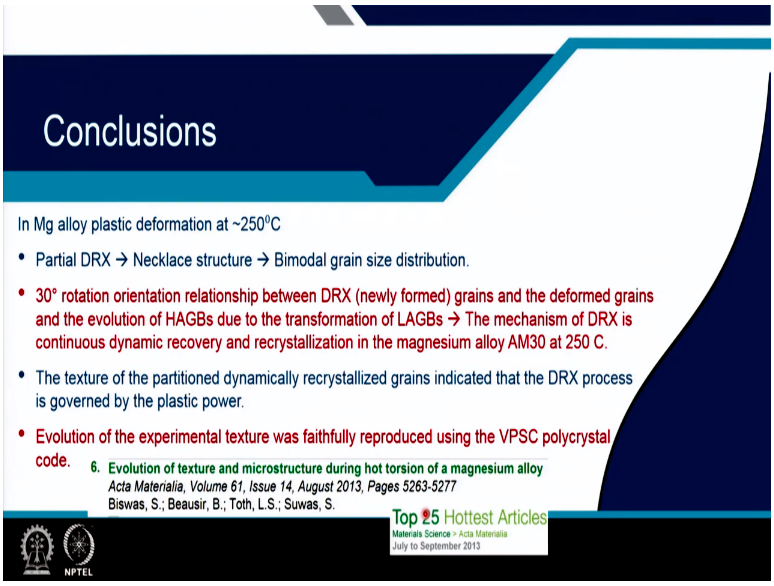
So, if this is the initial boundary and the final boundary should supposed to be like this and the final boundary cannot be like this because of the presence of this plastic deformation scenario and the presence of heterogeneity of the dislocation density. There is a formation of serration in the boundary as we have discussed earlier in the last lecture.

This serration of the boundaries could be observed in the microstructure throughout the microstructure and this happens. So, there is bulging the bulging occurs to the high dislocation regions. So, the bulging occur in this direction, bulging occur in this direction, bulging occurs in this direction and bulging occurs in this direction. If we look at a single bulge it will look something like this right if we look at the single bulge it will look something like this and the bulge is increasing. So, there is presence of large amount of dislocations here and there is presence of less dislocations here right in form of geometrically necessary boundaries.

So, while the deformation progresses the bulge of the grain boundaries you know enters into the large dislocation dense region in order to lower its energy and it forms this kind of bulge. Whereas, the dislocations which are present here also start to merge together in order to annihilate some and to rearrange some into dislocation arrays and slowly slowly if you see this dislocation will form as in a form of a new you know grain is forming.

So, you see slowly and slowly if you see the schematic a new grain starts to nucleate once the whole you know grain whole boundary is converted into high angle boundary the new grain really emerges and this is a situation, which could be observed here and here right. So, after that the deformation is continuous and the deformation is going on. So, as the larger grains is deforming this newly formed softer recrystallized grain will also start to deform and it will also start to develop you know geometrically necessary boundaries that is low angle boundaries inside it. So, under such situation the same process will occur in this grain too in these grain boundaries too and then new recrystallized grains can form along this grain along these grains at the grain boundaries and this could be observed here, such a situation is shown largely here. In this case and this is the mechanism by which continuous dynamic recovery and recrystallization takes place in case of a single phase magnesium alloy which has a high stacking fault energy actually.

(Refer Slide Time: 45:12)



So, from this lecture which is the final lecture for this course textured in materials I will conclude that in magnesium alloys plastic deformation at 250 degree centigrade if takes place. Partial dynamic recrystallization followed by necklace structure and bimodal grain size distribution develops. There is a 30 degree rotation between the orientation of the DRX and the deformed grains and the evolution of high angle grain boundary due to the transition of low angle grain boundary to high angle grain boundary by the mechanism of DRX is continuous dynamic recovery and recrystallization right.

The texture of the partially dynamically recrystallized grains indicate that DRX process is governed by the plastic strain energy it is related to reduce the plastic strain energy associated with the deformation strain. So, its position is different from the deformation strain and in a relation that is 30 degree about 0001. So, the excess angle position of 30 degree and the 0001 will produce a CSL type of boundary right. Finally, the evolution of experimental texture could be faithfully reproduced by the viscoplastic self-consistent poly crystalline modelling. So, this is a paper from which this today's lecture is taken and to understand it in more detail please look into this paper.

And I would like to say that thank you for bearing with me for this Texture in Materials course and this was the last lecture of this course and I am very grateful that you are going through this course and completing this course up to this final lecture, thank you so much.

Thank you so much.