Heat Treatment and Surface Hardening - II
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Lecture - 36
Grain size measurements methods

Will in the last couple of lectures we have discussed the fundamentals of stereology. And I thought today I will discuss a little bit or I will elaborate a little bit on grain size measurements, because as grain size measures are an important characteristic of microstructures and they influence different properties of the material. So, I am going to talk about some grain size measures in this lecture to begin with.

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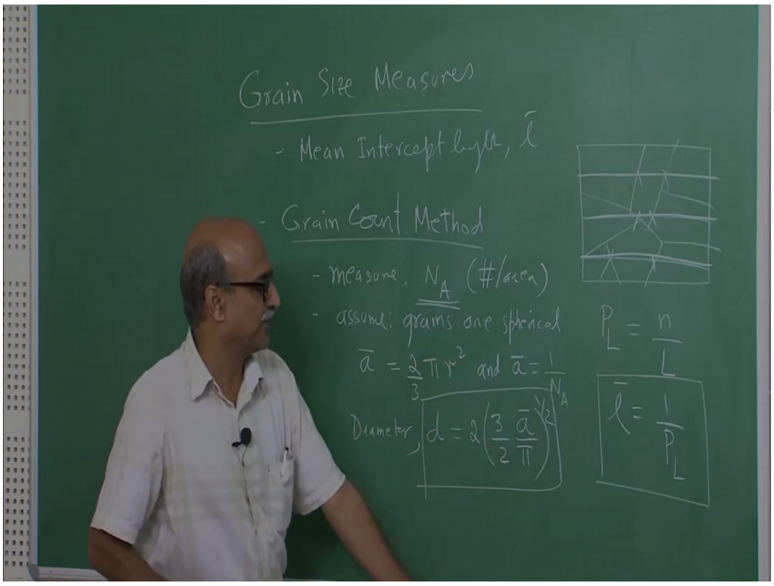

We saw in the last lecture one particular grain size measure which was called as the mean intercept length, and which as a symbol I put it as l bar. And in this what we do is if you have a polycrystalline microstructure with grains, and I want to get an average grain size out of this, I had put a grid of parallel lines on this. And counted the number of intersections that these lines may with the grain boundaries. And from that we obtained intersection count per unit length as P L which is n small n the number of intersections that this grid of parallel lines that has made with the grain boundaries divided by the total length of the grid. From that we got a mean intercept length of 1 upon P L.

This is very useful measure, and today a very commonly used measure of grain size; however, let us take a look at some of the other possible grain size measures that are used and many of them In fact, particularly one of them is particularly used in industry. So, to begin with let me also take another kind of measure which use is grain counting. So, the grain count method.

In the grain count method you measure number of grains per unit area N A, this is number per unit area. So, I will recounting this grains and then dividing it by the total area over which I have measured the count. If we can make the assumption that my grains in 3 dimensional are spherical. If they are close to this spherical shape, then I can relate the average area of a grain a bar to be equal to 2 by 3 pi r square where r is a radius of the grain. So, and how can I get a bar the average area of a grain? Well, I have already measured the number of grains per unit area, and hence a bar is nothing but 1 upon N A. Because in a unit area if I measure so many grains the reciprocal of that would give me the average area of a grain.

Now, from this it is easy to go to the diameter of the grain. So, the size measure that I am using is the diameter. So, I come to the diameter of the grain if I call that as d is nothing but 2 times 3 by 2 a bar upon pi to power half. And this simple relationship for the grain diameter is really coming from right from here, I essentially get the radius from here multiplied by 2 this factor 2 that comes from there gives me the an estimate of the let us say the average diameter of the grain, if we can assume that the grains are spherical in 3 dimensions.

So now I am able to relate the diameter to the experimental measure of number of grains per unit area. Here I had make the measure of the mean intercept length. And let us see can I relate the diameter of grain to the mean intercept length if we make the assumption that the grains are spherical. Well, again there is a another stereological relationship.

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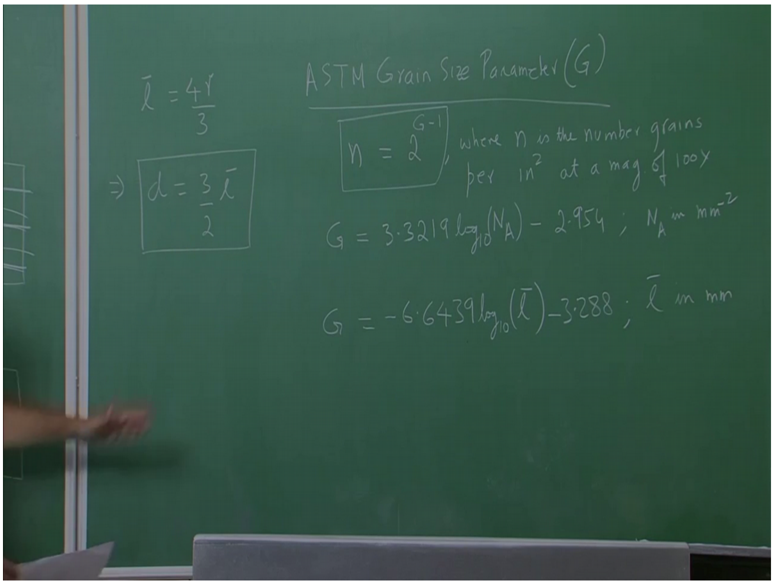

For the mean intercept length if the grains are spherical of radius r. And that is simply 4 r divided by 3 of course, I have not derived any of these relationship, but these are directly coming from the principles of stereology. From here it is very clear that the average diameter of the grain in terms of the mean intercept length is nothing but 3 by 2 l bar. So, this is another grain size measure that I can convert the mean intercept length into a grain diameter, if it is reasonable to assume that the grains are is spherical.

Now, this third and final measure of grain size that I want to introduce today, and it is still used in industry quite a lot is the ASTM grain size parameter. And I will use the symbol G, capital G for this now what is this ASTM grain size parameter. Well let me give you first the original definition of the ASTM grain size parameter, and let me write down the relationship with G, that n is equal to 2 to power G minus 1, where n is the number of grains visible in the microstructure per inches square. So, this is a very old definition and that is how the measure of inch comes in. And this is measured at a magnification of 100 x.

So, we take the sample put it in a under a microscope look at it at 100 magnification, and then put a mask on it and to measure how many grains are there in one inch square. Now of course, we can do this; however, we can also use this measure of N A number of gains per unit area at 1 x. So now, the magnification is taken into account not 100 x thousand x whatever at simply 1 x. What is the number of grains present? And I can So, it is essentially conversion of this formula to different units using N A, and one can write the ASTM grain size parameter in terms of N A as 3.3219 log to the base 10 N A minus 2.954, where units of N A are n per millimeter square.

So, in one millimeter square I have so many grains. I put it in this relationship and I get the value of the ASTM grain size parameter. I can also relate the ASTM grain size parameter to the mean intercept length. And that is given by the relationship G equals minus 6.6439 log to the base 10, l bar minus 3.288, where the mean intercept length units are in millimeters. So, these are 2 relationships one can use to get a grain size measure in terms of the ASTM grain size parameter.

One interesting thing that one should look at it, and one should look at this particular definition of ASTM grain size number that as G number of grains per unit area is increasing your grain size parameter will increase. Now what does this mean? So, larger values of G implies larger number of grains in a given area which means the grains are smaller. So, larger is the grain size parameter G implies smaller are the grains. So, this is this, this should be noted, that large values of G implies small grains small values of G implies large grains.

Now, with this I will just conclude this these are the some of the important grain size measures that I think you ought to be aware of. And then finally, in many of our stereological measurements metallography measurements we are measuring or counting grains we are counting particles. So, we should have a good idea how to properly count grains or how to properly count particles. So, that we get an unbiased estimate. And to do that I will just briefly take you to a methodology for counting of polycrystalline grains. For example, to begin with and then we will also have a look at a similar methodology for counting of particles.

So, methodology of counting of polycrystalline grains. Let us take a look at it.

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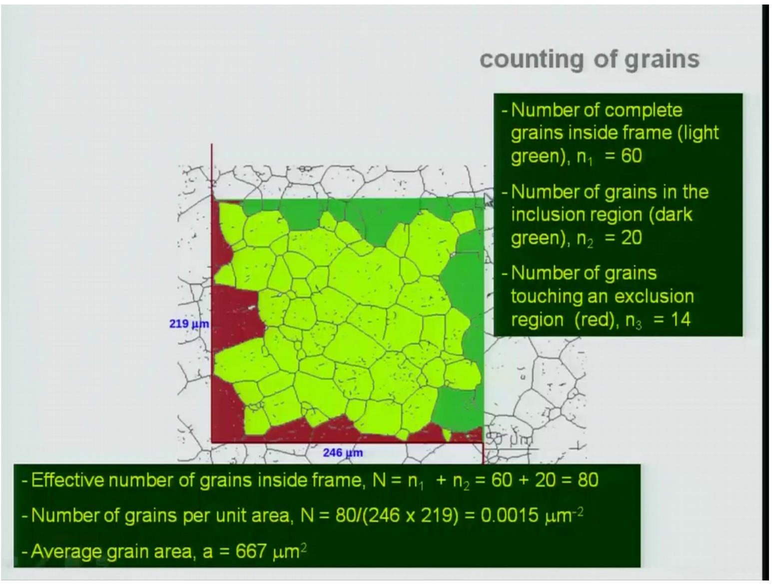

I have here microstructure of a single phase polycrystalline material and you can see the grain boundaries and the grain and the grains very clearly in this. So, what we do is we super impose a counting mask. So, as you can see this is my counting mask of dimension 219 micrometer times 246 micrometers. Within this mask I am going to count grains in such a way that I get an unbiased count. Now what is a problem at hand when we are counting grains?

The problem is as follows that grains which are completely inside can be counted as whole, but what do we do with the grains which intersect with the boundaries? How much or how big a part of that grain we count? So, this methodology describes a technique for counting. So, that I get a statistically unbiased estimate now you will notice in this mask, that there are 2 sides of the mask have red line. And then I have the green line on the other 2 sides. The red line is considered as the forbidden zone. So, if for grain intersects are red line we do not count it at all. If a grain intersects a green line we count it as a whole grain. And of course, any grain which is not touching any of whether the green line or the red line of the mask, but it is completely inside the mask will be counted as a whole grain.

So, here is my mask. So for example, this grain intersects the red line. So, I have actually marked it as a red grain that I have not gone a consider that in my count. Similarly this is another red grain and a get another one and here in fact, this is the grain which intersect both the green and the red, but since it is intersecting the red we will ignore in the count. So, all of these grains would be ignored in the count. Now rest of the grains that are there we must count. So, for example, these grains which intersects only the green line will be counted. So, all of these grains are intersect the green lines the green line or the mask will be counted and they are marked as dark green. Then there are grains which are completely inside the mask, and these are marked as light green and they will be counted as whole. And so, will be the rest of the grain.

So, if I look at this count I get number of complete grains inside the frame. So, these are the light green once here. They are 60 in number. So, we will count them as 60, number of grains in the inclusion region. So, the grains which are intersecting only the inclusion region the green lines will be counted and they are numbered 20. Number of grains touching an exclusion region, exclusion region is the one where the red line of the mask is there which are 14 and they are going to be ignored.

So, the total grain count that I have the effective number of grains in this mask are simply the first 2 number 60 and 20 and 14 will not be counted. So, I have 80 grains in this area, hence N A the number of grains per unit area. I have only written here as n, but it is n sub a as I had put on the board that these are the number of grains per unit area, which is nothing but 80 divided by the area of this mask, which is 246 into 219. Hence this gives me the number of grains per micrometers square, it is 0.0015. I like in convert this into per millimeter square as well by multiplying it by a factor of 10 to power 6.

So, what is a average area of a grain as I just stated on the board? The average area of grain is the reciprocal of the number of grains per unit area. So, it should be the reciprocal of 0.0015. If I take the reciprocal the average grain area is nothing but of the order of 667 micrometer square. Now I can use this to calculate my ASTM grain size or if I assume my grains to be almost spherical, then I can get an idea of the grain diameter using this count.

Now, a similar methodology can be used for counting a particles as well. These are isolated particles for example, the microstructure that I show you here are the graphite nodules.

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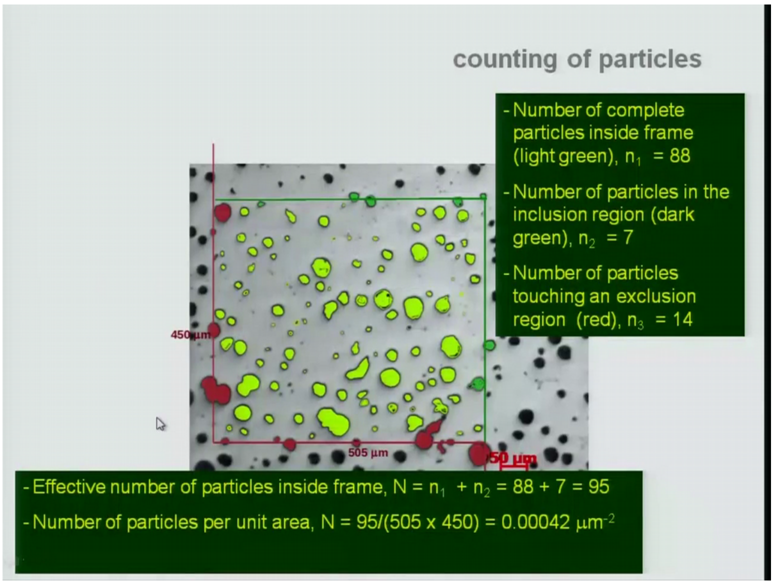

And I want to have a count of the number of graphite nodules per unit area. Again I put a mask on the microstructure of a red line the forbidden zone and the green line which is the inclusion region. Again all the particles which intersect the exclusion region that is the intersect the red line of the mask will not be counted. So, these are all particles which shall not be counted.

Similarly, I have these dark green particles which are intersecting the inclusion region will be counted, and as well as all the particles which are completely inside which are not touching either of the exclusion or the inclusion region will also be counted. So, if I look at this particular count number of complete particles inside the frame which are these light green once are 88 in number. Number of particles in a inclusion region are 7 in number of particles that are touching an exclusion region are 14 and which will be ignored in the count. So, for example, this particular particle even though it is set of a caller it is touching an inclusion zone, but it is also touching the exclusion region and hence will not be counted.

So, the total number of particles that I have effective number of particles inside the frame are just the n 1 plus n 2 or 88 plus 7 and giving me total count of 95. Number of particles per unit area hence is 95 divided by the area of this mask which is this length 505 microns multiplied by 450 microns, giving me the number of number as 0.00042 per micrometer square.

So, this was a simple process a simple procedure for counting of grains and particles. With this all my discussion regarding quantitative metallography is complete.