Fluid Inclusion in Minerals: Principles, Methodology, Practice and Application

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Lecture – 03
Introduction (Contd.)

Welcome to the third lecture on the series of lectures on Fluid Inclusions in Minerals. We have so far, got a brief introduction about what this fluid inclusions are and I have looked into, the mechanism that can be visualized for the entrapment of this tiny of tiny fluid cavities, within the growing crystal.

This primarily correspond to the fluid, the parent fluid which is, which gets entrapped within growing, crystal in when the crystal grows from the fluid, medium or is recrystallizing in presence of a fluid. Essentially, it is a fluid, present situation and corresponds to the, close time relationship or we can say that the same time at which the inclusions are getting entrapped is exactly the time, at which the crystal is primarily growing.

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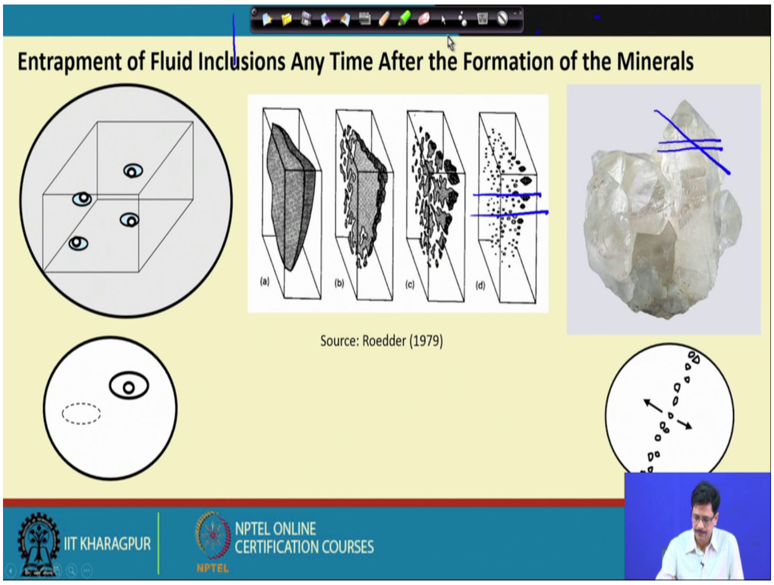

Now, we will see, if we remember while defining this, these fluid inclusions, we said that this inclusions are tiny cavities within the minerals that form either during the primary growth of the mineral or any time after words. So, now, we will just have to look in terms of the, the mechanism of course, remain the same that the inclusions will be entrapped or encapsulated within the crystal lattice, but here.

So, once the single crystal that, we have visualized or in case of a polycrystalline aggregate that we, described through the sketches. So here, we can visualize that the crystal or the particular mineral veins for that matter has already formed as a polycrystalline aggregate and then if this particular polycrystalline aggregate is deformed later on and this essentially has to be brittle, deformation. So, that deformation suppose, we are looking at this particular diagram, this particular repeats the very first stage in which, if this represents a, single crystal then this, there is a fracture in that crystal and the fracture space is again filled up by fluid. This fluid could possibly be not all related to the fluid which originally formed this particular crystal.

Now, if this, this process is also operating, somewhere in the sub surface at pressure temperature condition, which are different from operating on the surface. They only point is that the processes that will operate on the surface will be far more slower at, and under that kind of condition. We cannot expect much of, mineral to form recrystallize even though, it is not even though it is not 0.

So, imagine a situation. So, then this particular fluid, within the fractures space is also started to interact with the host mineral and then, deposit the same material of the host mineral on the fracture, which we, can say that the fracture is getting basically, getting healed. Now this, this particular, fluid will interact with the crystalline and will get, by virtue of it the chemistry of it and will start, healing up. This particular fracture and this, the subsequent diagram and here, it is shows the progressive, stages by which this particular fluid is healing up this fracture and finally, we see that, this was essentially a fracture. After it is, after it gets healed up it is left with a new works, a numerous tiny such, inclusions, the fluids which also are inclusions and have the same, characteristic more or less in terms of their optical characteristic as you will see later same as the, inclusions which are trapped during the primary growth of this mineral.

So, we will just for your; so, this same quartz crystal. Suppose, there is a fracture that is created, if we say that this particular quartz grain is just fractured and within that fractured space fluid is (Refer Time: 4:46) and this particular fracture has been healed and tiny inclusions are entrapped and if we take a section from this particular quartz here, were are taking a section which is that we just the we discussed before which is about 100 bio current in it is thickness and observe under the microscope ok.

So, if we take a section from this quartz; suppose, there is a fracture over here and we are taking a section from this particular quartz, then we what will see here is that when we see them under the microscope. We see these inclusions which are arranged in a linear trail compared to what is the situation here when these inclusions which were trapped during the primary growth of this particular crystal and those inclusions were trapped randomly at any particular at any, anywhere within the growing crystal in it is lattice. And to differentiate between the two, if we take a section of this particular crystal, the same section kind of it is a wafer then if we see under the microscope. Then will see the inclusions which will be, and we since their present is different, depths from the surface, because this, this particular thing is a 300 micron thick, slice doubly polished wafer. And these inclusions will get focused at different depths, but randomly within the field of view.

Here, the situation is that this inclusions will not be focused randomly on the field of view, but they will be aligned with we on a linear array and this linear array will apparently, move depending on the; suppose, this is the fracture and when we are taking a section of this. So, this particular, this, this, this fracture is inclined in this manner and when we see them under the microscope raise or lower the stage of the microscope. This particular trail moves either way depending on whether we are raising or lowering the microscopes stage.

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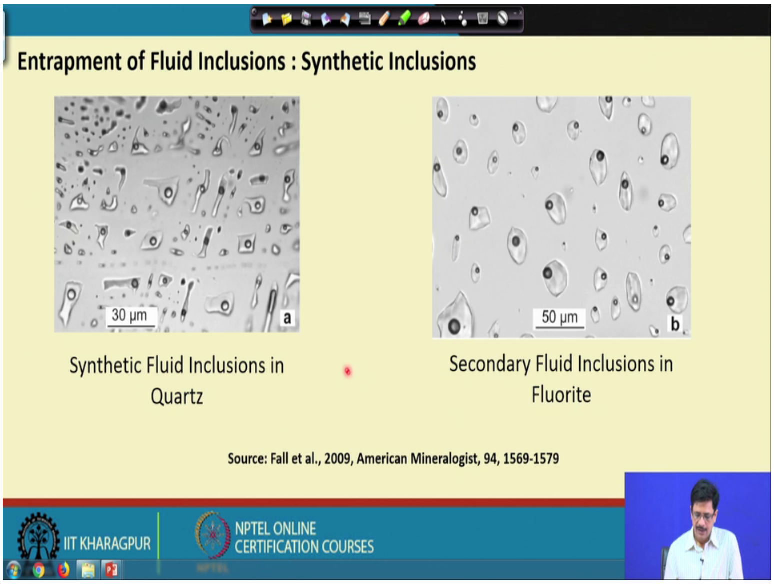

So, this is one example, this particular photograph has been taken from literature from fall, from as shown here. So, this mechanism of formation of this, inclusions after the growth of the host mineral by healing the cracks or the fractures which are created within the mineral or the polycrystalline aggregate is now, very well, demonstrated or very well supported by synthetic fluid inclusion experiments where what we see here on this particular left side of the diagram is essentially, the inclusions which were trapped in the laboratory. And these entrapment process is brought about by taking inclusions free quartz, creating fractures in them and then putting them in to, an apparatus where, which are the hydrothermal apparatus, where taking fluid of desired composition and almost, this mimicking, the natural condition of healing the, fracture of the mineral and by in this process trapping the fluid inclusions.

So, what we can see here within this? This is an example of the synthetic inclusions, which are essentially trapped by the same mechanism of healing of the fracture and this is an example of, fluid inclusions and fluorite where the, if this represents a fracture plane, which is almost parallel to the surface of the wafer on which we are examining and we see a very large number of such inclusions being focused, at the same plane and ok.

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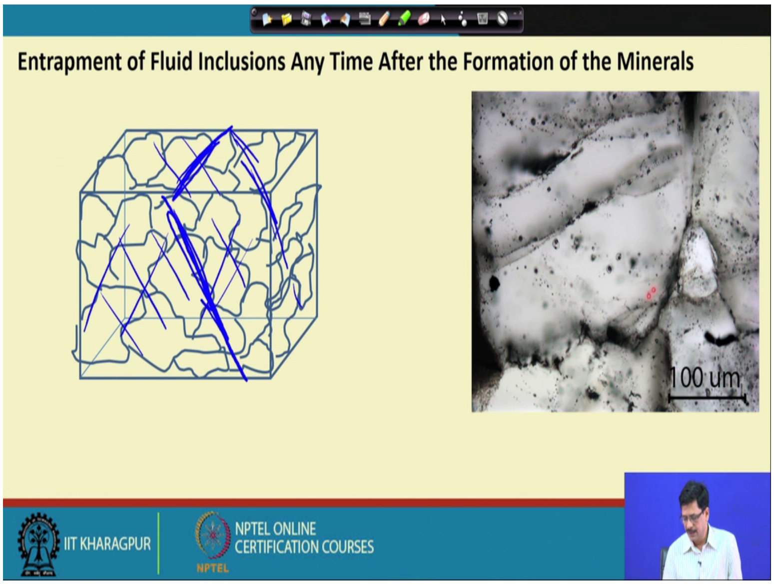

So, this is essential what can be explained in this way, so the fractures. So, this is suppose a block of polycrystalline aggregate and this could undergo the fracturing. This is a fracture and fluid will percolate through this particular fracture space. This fracture is very unlikely to be occurring in just an isolation, there could be many such, parallel fractures or could be depending on how the fracture is generated could be, there are some conjugate sets of fractures also that could have taken place in this particular polycrystalline aggregate.

So, now when we see them under the microscope, we see this is an example of one particular, grain or particular polycrystalline aggregate of quartz where, we could see that this fracture. So, what is seen here, these are the parallel sets of fractures and even we could see even intersecting sets and all these are essentially populated by this tiny inclusions and this is how we see them.

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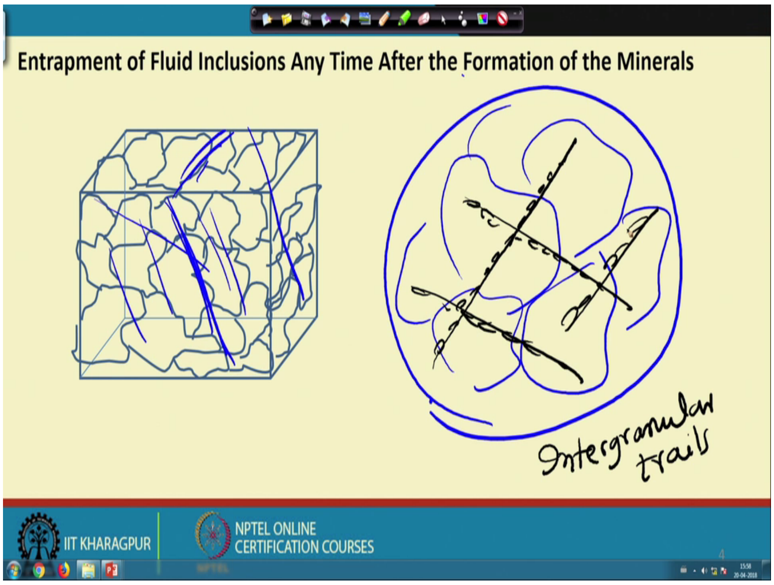

For example, coming to the same diagram where we had this fracture and may be parallel sets of fractures or intersecting sets of fractures. So, if we see them under the microscope and these will be the quartz grains. Suppose, this is a aggregate of quartz.

So, what we see here is that these kind of fractures will always be, will be transgressing or actually will be, trans granular; that means, traversing through many such, grains of the, minerals and these, we will define what actually will be the trails which will call them as the inter granular trails and within which we will see that there are numerous, inclusions which will be observable and exactly the same way that I just described that we see under the microscope, we see the inclusions.

Well I mean very much arranged a linear arrays and those kind of arrays, they move when we raise or lower the microscope and some of such kind of features will be better seen through videos which will be posting and as against that it could also so happen that.

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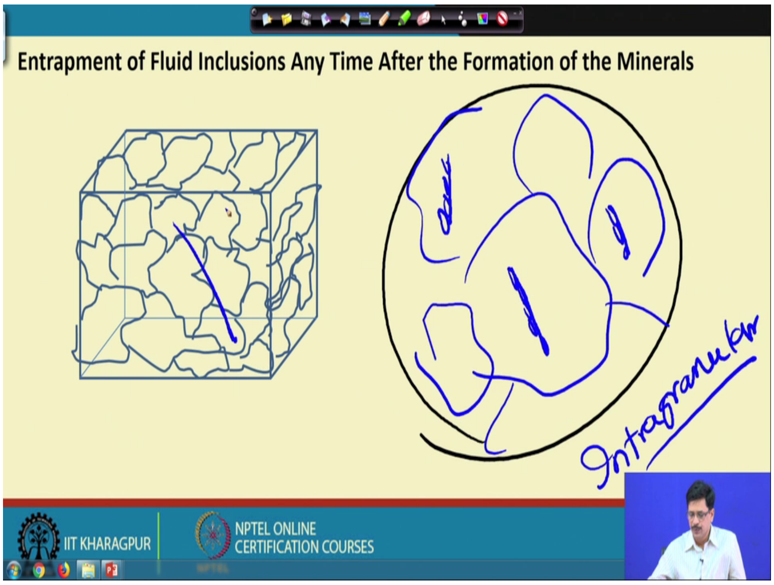

If we have this mineral, this is the aggregate of that the section, that we have taken from the sample of quartz. Sometimes we might see that there are fractures, which are just, terminating within one grain, within the single grain of this particular host mineral and we are seeing inclusions within these particular trail.

So, these two situations actually represent, two different, conditions in the first case where the, the fractures or the cracks are trans granular and, traversing through many of this, grain of the host minerals. There we, very sure that the particular fracturing took place after the formation of the vein after the formation of the polycrystalline, material that we are seeing.

For example, our quartz vein now, when we see such kind of a situation, it gives us an idea that it could be a situation where these concomitant fracturing and the mineral growth that was taking place in formation of a vein as we illustrated, earlier it might have. So, happened that the earlier stage of, quartz grain which we you are forming and we are subjected to fracturing and later stage of fluid has only just made the quartz grains over grow on the existing quartz grains. So, such kind of situation is likely to occur.

So, you might get such situations where there are, fracture spaces, but the fracture spaces or the trails continuing, these inclusions are just tolerated or just truncated or within the grain itself not traversing the many of this grains. So, they these, kind of situation depict three different situations; three different conditions origin of this entrapment of this inclusions and we have not yet introduced the exact term the by which we actually call the three situations.

In a first situation where the inclusions are actually a part of the random three dimensional network, where they will get, focused on different planes just randomly when we see them under the microscope. The other situation is that they are aligned in trans granular healed cracks in the, in the, mineral aggregate and the third situation is that they are arranged in healed cracks, but not traversing through many grains or they are not trans granular in nature, but rather they are intra granular.

One of the possibilities of some such kind of a intra granular fracture could also result from, for example, if there is a fracture that is taking place and this fracture is just been (Refer Time: 16:27) through some of the grains, but actually truncated at some of the, because a fracture is when in a if it is looking at a microscale, if it has to truncate or it has to die out at some point then it also might so. And one thing also we have to remember that what we are seeing while examining the fluid inclusions under the microscope that we are making only a two dimensional view of what exact, what the things are in three dimension.

So, sometimes it might. So, happen that a fracture which was actually traversing through many of many grains like the shown here would have terminated here within one particular place up beyond, which the fracture did not propagate and we happened to take a section just where that we could see the fracture within this particular grain..

So, in that case, it could be a situation where it needs a proper evaluation that whether such kind of situation is because of a intragranular or intergranular hill tracks the here also.

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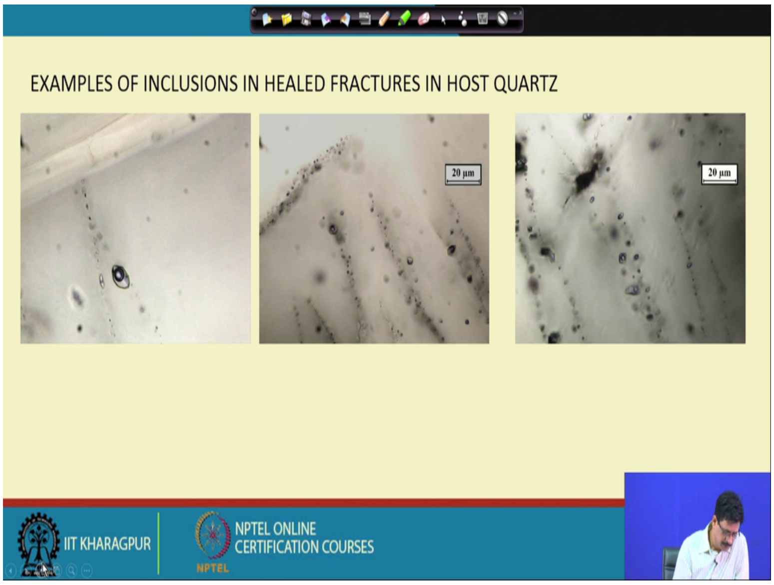

There are some two or three illustrations which would make it clear. Depending on so, it could have such kind of the middle figure even this figure also Here, there are we could see that very nicely adding sub parallel trails in which we could see fluid inclusions of variable sizes. Here, the micron bar is 20 micron. Here, it is mentioned.

So, we can imagine that so, first thing that we learned from here is that when these kind of suppose, in that this particular heal crack is trans granular or intergranular and it is given rise to entrapment of the fluid inclusions by healing of this particular crack. So, it generally results in inclusions which will be very much variable n their size.

Similar is the case here and once such fracture which looks to be terminating at this point. So, then this raises the possibility that whether we could categorize into a third category that particular this. Even this fracture also even though they are at a high angle to each other this seem to be terminating at a particular point here and this is the example also that we have this kind of a heal crack within that heal crack. We see that there are inclusions which look to be very regular shaped and perceptively a large size inclusion, where we could identify and in, in a population of much smaller other inclusions.

So, therefore, this regards to the origin of this inclusions, the mechanism that we have seen they are essentially they arise out of the growth, irregularities, imperfections during the growth of the crystal

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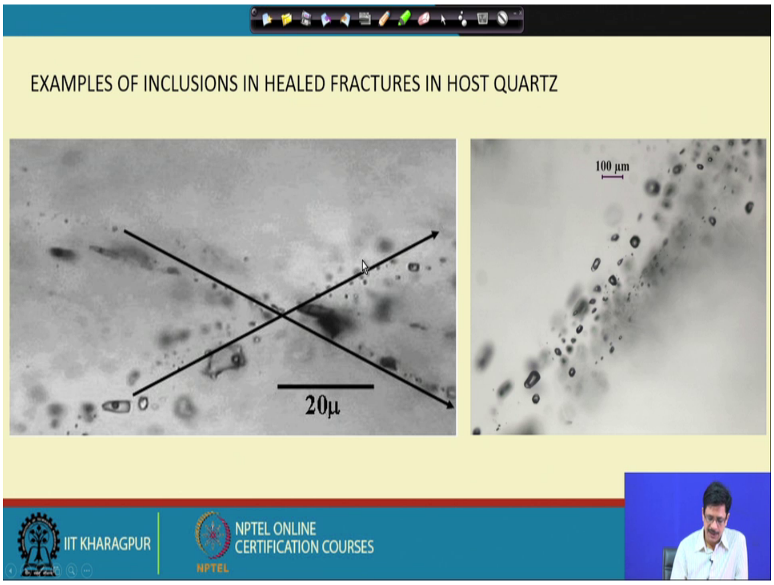

When we are talking about, the primary growth of the crystal from the fluid medium., there could, there are situation in which, the fluid inclusions also can be entrapped with in a mineral after it is formation and it is formation anywhere in the subsurface in the form of a vein or any matrix, mineral in a particular rock.

So, they can be subjected to later deformation and brittle deformation like fracturing will always allow later fluid to percolate through it and this situations are sometimes could be very close operating at a pretty close temporal spectrum or they could be, separated in time very very consequently or substantially in that case the characteristics of the fluids occurring as, inclusions for their first category or the inclusions of the thing that we are considering. Here, in healed cracks they could be different.

So, here also in good example of how such kind of trails intersecting, trails continuing a population of inclusions. We shown here the sizes of the inclusions are also quite different ok.

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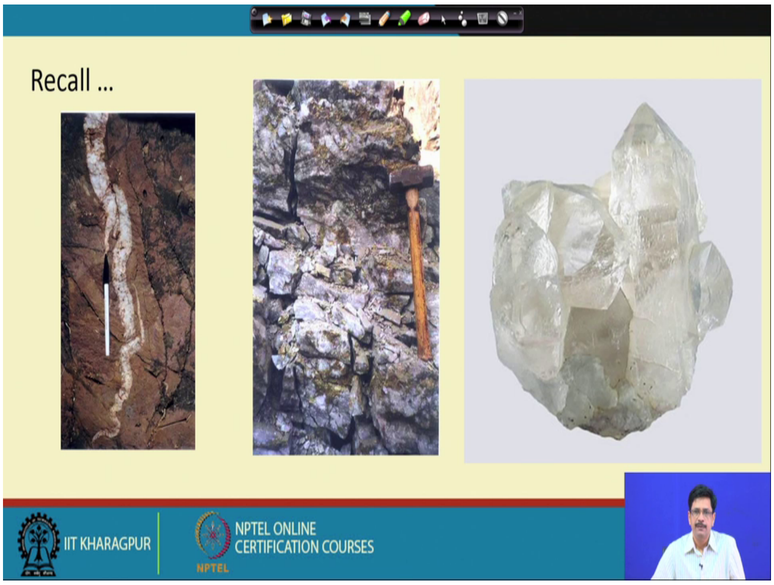

So, we now we will go on to discuss. We go a little bit close to this, fluid inclusions in minerals and we see their optical characteristics. How we can identify them when we see them under the microscope it of course, requires a bit of practice and after which getting a bit of a acquaintance or a longer period of observing and looking at them and then, but then still we can describe these inclusions based on the optical characteristics which is observable.

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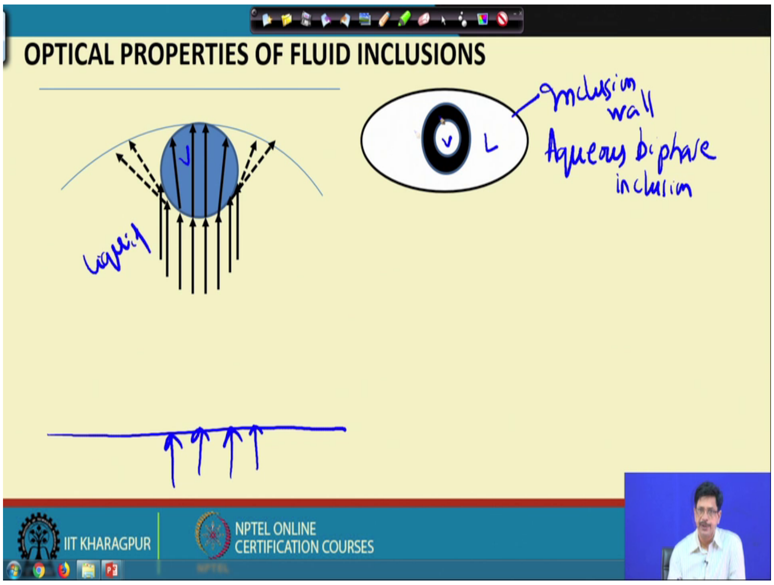

Now, we will be looking will be considering, different types of inclusions that we see in minerals, in general; what we see here is an example is a sketch represented in sketch of what we say as a aqueous biphase inclusion.

So, this actually is the liquid and the object which is at the central part is the vapor and this particular inclusion is actually aqueous biphasic inclusion. I have even though at the very same, very first instance; I one can always ask that how do I know that it, it is an aqueous liquid and vapor.

So, if we first make a tentative identification let us say that yes, it is an aqueous bi phase inclusion, this is the liquid part, this is the vapor part. So, what about the observe here and these inclusions will always be very distinct optically, because they are within the solid host and the surrounding of that particular. So, if we define this particular black line as the inclusion wall as a inclusion wall and so this means surrounding of it is the solid crystal and the refractive index of the there is a refractive index contrast between the solid host and the material which is inside which is liquid. So, it is quite obvious that this refractive index contrast will always make them very distinct, optically when we see under the microscope in transmitted light.

So, what we see here that is a vapor, but characteristically we see that this vapor is surrounded by a dark rim this particular dark rim could be a variable width as will be seeing them later. So, now, the even though it is not of a very important consequence, but we always we should be knowing that why this typical aqueous bi phase inclusion has a has an appearance like this we shall see them. Already I have seen them some examples and will see them some more.

So, what exactly happens here that this particular taking a very regular shaped. Suppose, this is exaggerated view of an inclusion which is roughly spherical in it is shape and it has this part is the water is the liquid. Liquid means we always refer to water, watery liquid and then this part is a vapor.

Now, this liquid and vapor also have a contrast in their arrays. Liquid will be have a higher array then the vapor and we are putting this inclusion. We are seeing this inclusion in the solid host, where we have a wafer and this wafer is the below surface is here and light is coming from the light source of the microscope in a transmitted light and when the light enters in to this particular inclusion.

Since, there is a ri contrast. So, the light most of part, most of the part here will be perpendicular to the interface of the liquid and vapor, because the light is going from a denser to a rarer medium, it is always will be refracted away from the normal. And so, this particular bunch of raise which will be near perpendicular to the vapor liquid into phase will actually be able to pass through without much of deflection.

Whereas those which will be following at a gradually higher and higher angle on the liquid, vapor interface will experience refraction. And when the angle will exceed the critical angle, they will not be able to pass through and will be undergoing total internal reflection and that we will explain.

Soa part of this particular vapor bubble from where there will not be any light, it will be the, light will not be able to penetrate through some part of this and when we see them under the and a two dimensional view of this particular inclusion, we see them in the microscope. They will have a look that the vapor will always be in variably be surrounded by a dark rim whose the dark rim thickness of that the width of the dark rim will vary. Let us have an example of what exactly, we have demonstrated here.

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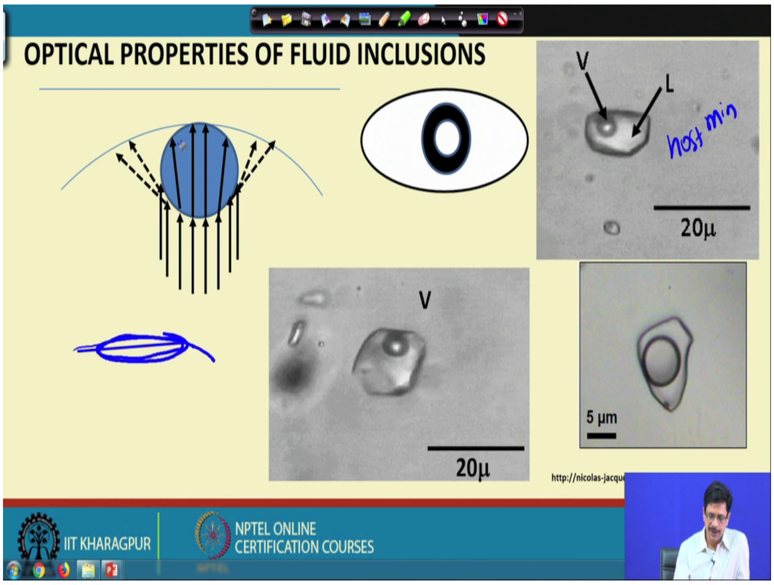

This is the, inclusion. So, here this inclusion is in a quartz, sample of quartz and in this quartz, we could see the solid require the host mineral and if the surrounding part is a host mineral. So, there is an eye contrast. So, this is the host mineral quartz well. There are other inclusions are also distributed and this is the, inclusion cavity and this inclusion cavity.

We could see that this is the vapor and the central part of the vapor is bright surrounded by dark grain which exact we just explained now. And, because of some of the light also just being totally internal reflected and passing through this liquid. So, this liquid also has a brighter appearance just surrounding the vapor. And so, this is one example, this is also another, this is another example. Here, also we see that, this is another inclusion and this micron bar is 20 micron. So, you can, imagine we can always, estimate the width or the maximum dimension of this particular inclusion which should be around 12 to 15 micron in this case and the similar case here. These two inclusions are of different, shape.

Now, looking at this inclusion will make our so, it depends on how this particular inclusion geometry is, if the inclusion geometry is of a regular shaped inclusion, regular shape and then the vapor bubble is exactly occupying the top surface part, the way we have, described here.

But there can be many variations depending on the ratio when the proportion of the vapor bubble to the inclusion, total area of the total volume of the inclusion and the way the if it is happens to be a flat kind of an inclusion where the vapor bubble also is kind of occupying a kind of a flat geometry. Then the dark rim around the vapor bubble will all be very thin and a situation corresponding to this by the vapor bubble is perfectly spherical [vocalized-noise.] There the dark rim will be much wider again.

So, we have to, keep it in mind that we are not able to see the third dimension when we are examining them under transmitted light. We can only just have a can see their the shape and the size as you can measure in two dimension can represent in terms of a maximum dimension or if it is happens to be a regular, circular shape. We can tell in terms of the diameter and the bubble in most of the cases invariably, the bubble will have a circle outline though it may be different depending on the inclusion geometry and sometimes also.

In the many of the instances whereas, we have seen that this particular vapor bubble, sometimes executes little bit of a random moment which mimics the Brownian movement in molecules in gas. So, that is why it is termed as a Pseudo Brownian movement. And there are many other, characteristics of this kind of fluid inclusions. As we see them under transmitted light and their optical characteristics will continue discussing on this topic, in the next class.

Thank you.