Experimental Physics - III
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Lecture - 27
Measurement of Ionic Conductivity

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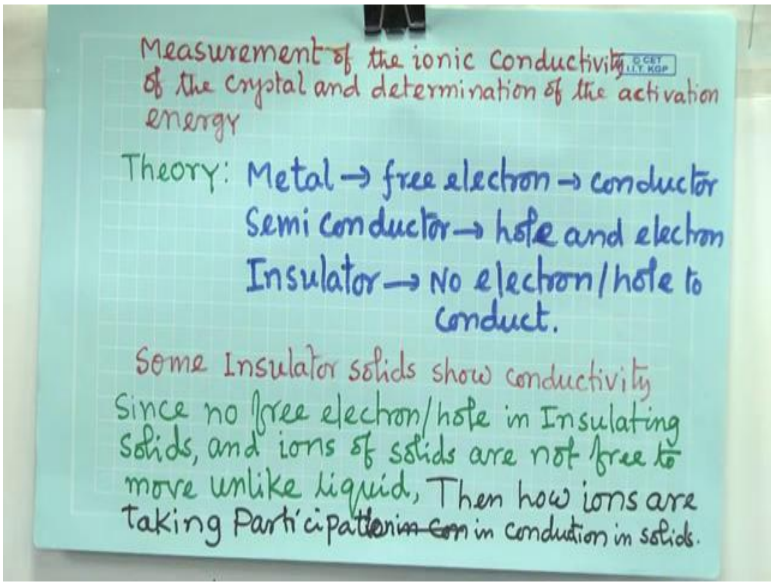

Today, I will discuss and demonstrate Measurement of Ionic Conductivity of the crystal and determination of the activation energy. We will measure conductivity of the solid of a crystal and we will determine the activation energy. If you take a solid this is a glass solid. Say, it is of course, amorphous, but say it is a crystal. Now this can be metal, if it is metal then there will be free electron and due to this free electron; we will get current applying voltage. In addition, from there one can find out the conductivity of this material.

Similarly, if it is semiconductor, then also it will have conductivity, measurable conductivity because it has electron and hole. If we apply electric field apply voltage then this carrier electrons or holes or both will move and due to the movement of this carriers along the electric field, it will give current. if you get current then, if you know the voltage one can calculate the resistance and from there one can find out resistivity or conductivity depending on the dimension of the material right.

Now if it is insulator, then its resistance will be huge means conductivity will be very low and it is not measurable.

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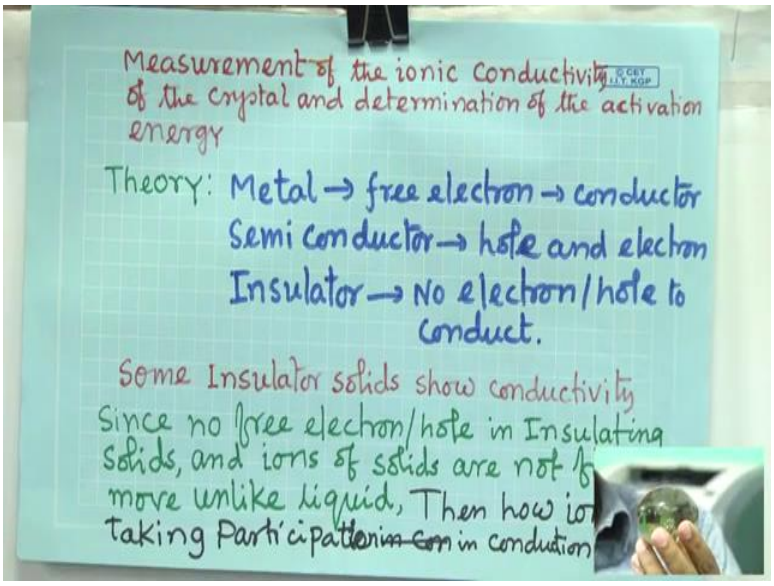

We tell that these are insulating material insulator that is what I have mentioned here, I have mentioned here. Now, whatever the conduction of carriers that either electrons or holes. In these materials, ions are there. If ions are in a liquid then, ion can move, if we apply electric field ion can move. Due to the I would have charged. due to the flow of charge you will get current. if this material is any material have ions, if it has free electrons or it has holes then, mainly current you will get due to these carriers, but if it is if is insulating material.

Negligible number of the electrons maybe there or may not be there at all but it has ions. Now, in solid materials; ions are localized, ions are fixed, they cannot move if we apply electric field you should not get any current in principle, but there are some materials insulating materials. there if although ions are fixed in the lattice, but if somehow ion can move after applying electric field and due to that, if we get current then we will tell that this materials have ionic conductivity. That is what this is the matter of discussion of today’s class.

Under which condition a solid insulating solid have this ionic conductivity and how we can measure this ionic conductivity and from there we can calculate the activation energy. activation is energy is related with ionic conductivity. Let us first find out how ions are taking participation in conduction in solids. that we should understand first and then we will go for experiment.

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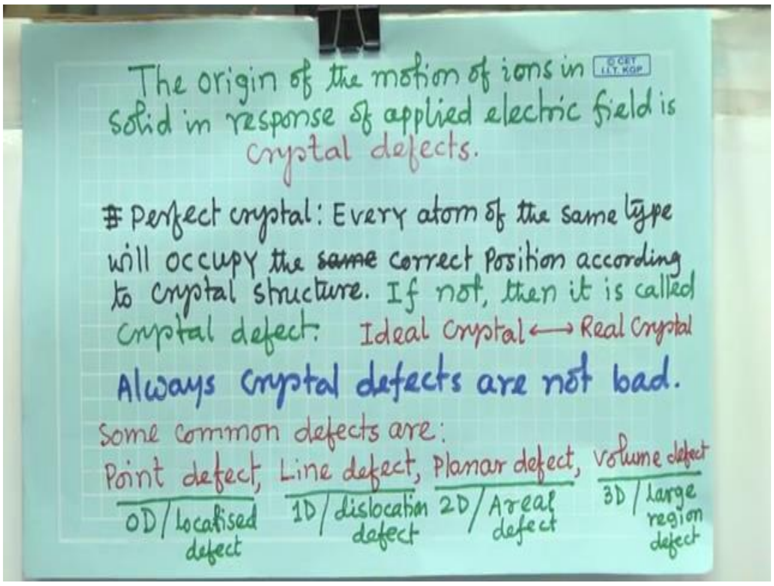

In next slide, the origin of the motion of ions in solids in response of applied electric field is crystal defects. perfect crystal or ideal crystal; every atoms of the same type will occupy the correct position according to the crystal structure. Then we tell it is a perfect crystal or ideal crystal. If not, then it is called crystal defect.

In reality, we will not get any crystal, which is ideal crystal. every crystal have some defects, now only matter of the density of the defects. If density of the defects are very low, it is a close to the ideal crystal. That is why in reality crystals we tell the real crystal; it is a deviate from the concept of ideal crystal that means the real crystal whatever we will use, they have some defects, crystal defects.

Always crystal defects are not bad. Sometimes intentionally, we create crystal defects which helps to enhance some property and which is applicable for device application. Some common defects are. What are what is the crystal defect that we should know?

Some common defects are one zero dimensional defect, it is the called point defects it is a zero dimensional defect or this is localized defect. Point defect is the zero dimensional defect and this defect is localized.

Then line defect; it is the one dimensional defect and this type of defect line defects are delocalized or dislocation defects, it is called also dislocation defect. Then planar defects; it is the two dimensional defect or it is called also areal defect. On a plane on a on a two dimension whatever the defects that is called planar defect.

Then volume defect; it is a three dimensional defect, it is the large region defect its area if defects in three dime in three dimension then it is the volume. Large defect. That we tell the volume defect. what are those defects let me discuss.

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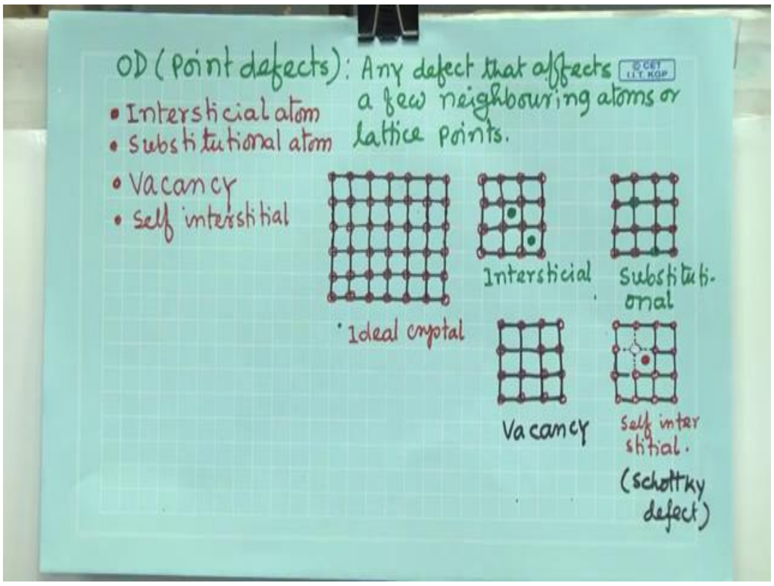

The zero dimensional defect or point defects, what is that? Any defects that affects a few neighboring atoms or lattice points, and then we tell this a point defects. There are different kind of point defects interstitial atom, substitutional atom, vacancy, self-interstitial. this different kind of point defects are there.

This this figure is an ideal crystal figure, ideal crystal structure. It is a two dimensional, actually it is three dimensional. These are the lattice point lattice points are nicely arranged It looks cubic crystal. Now, in reality this type of nice arrangement proper position of same type of atoms in crystal is impossible practically impossible. it will have always some defect only as I told the matter of density of defects, if it is density of defects is very small then, it is close to the ideal crystal.

Now what is interstitial defect? this is the crystal structure Now red atoms are placed at the at the lattice point If some impurity atoms are seating like in green position, seating like in green position then it is defect. This atom is not at the lattice point. It is in between somehow it is sitting, so that is why it is called interstitial. This kind of defect is called interstitial defects.

Sometimes, you can see that these impurity atoms are not sitting inside the lattice, but it is replacing, it is replacing the lattice point, atom at the lattice point and seating there. Then it is substituting the original atoms from the lattice. Then this is called the substitutional defect, point defect it is the point defect because that it will affect the pure neighbors. It is localized and it will affect the few neighbors of that of that defect. That is why it is called point defects and it is localized defect.

Then vacancy if from the lattice point if atom is missing, say here this atom is missing. then there is a vacancy at this place. Then it is a called vacancy defect and another defect is called interstitial, self-interstitial defect. It is also called Schottky defect. If one atom original atom are displaced from its lattice point and sitting at the interstitial position.

Its creating an interstitial defect as well as it is creating a vacancy it is producing a pair of vacancy and then interstitial atom this this type of defects is called the Schottky defects. these are the typical example of the point defects and most of the materials have these defects

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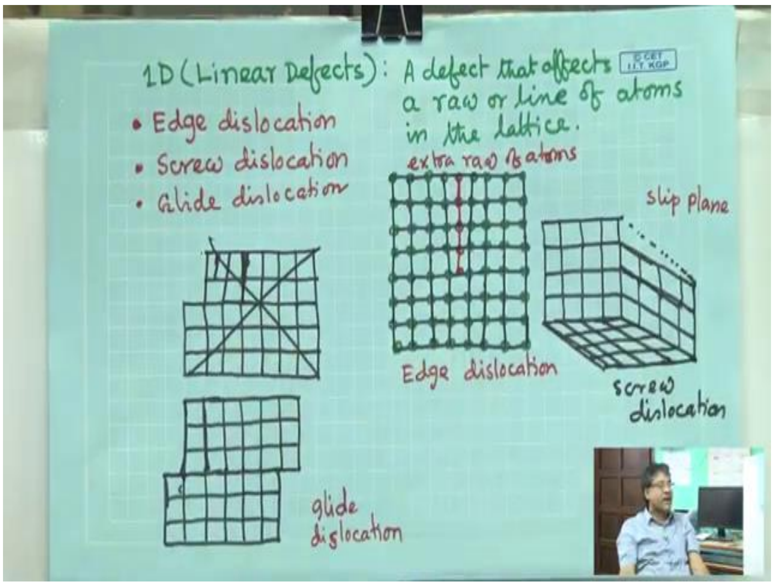

Now, the one-dimensional defect is a defect that affects a row or line of atoms in the lattice again this planar def linear defects whatever the defect it is also of different kind. Edge dislocation and as I told that earlier, that is the dislocation defect. There are different kinds of linear defect. So that, one is edge dislocation defect, screw dislocation defect, glide dislocation defect ok.

Here this is the ideal crystal structure then, suddenly at the top along a along a row, along a line you see extra row of atoms here this because of this extra row of atoms; this this both side atoms are displaced both sides atoms are displaced de delocalized, delocated. This kind of, this kind of and it is found only at the at the edge because at the edge because it has to it introducing a row of some atoms extra atoms ok.

This type of defect is called edge dislocation. It can be it can be found in the in the edge of the two planes edge of the two planes one can also see this type of defect that is why it is called edge dislocation. Then another is screw dislocation. here this if you see the slip plane, if you see the slip pane Step kind of pins, step kind of pins if you see step kind of pins ok, like this Step kind of pins and this was there originally, but now this just slipped this this slipped this way ok.

You will see a plane it is called slip plane. if you see this type of slip of slip of this of a plane. Then the it is deviated from the ideal structure and that type of defect is called screw dislocation defect and then glide dislocation; this is the you have to play you have you have crystal like this without this defect ok.

Now, if you for some by some means say if you push, if you push this from the side at the at the upper plane upper up side plane. Then there are few step with few steps it will slide, this top part will slide from the bottom part. Here that is why, but all of a sudden, it will not happen it happen slowly and step by step. That step I have not shown here, but ultimately we will see the slip of these of this upper portion from the lower portion. This type of defect is called the glide dislocation. these are the one dimensional defects of crystal.

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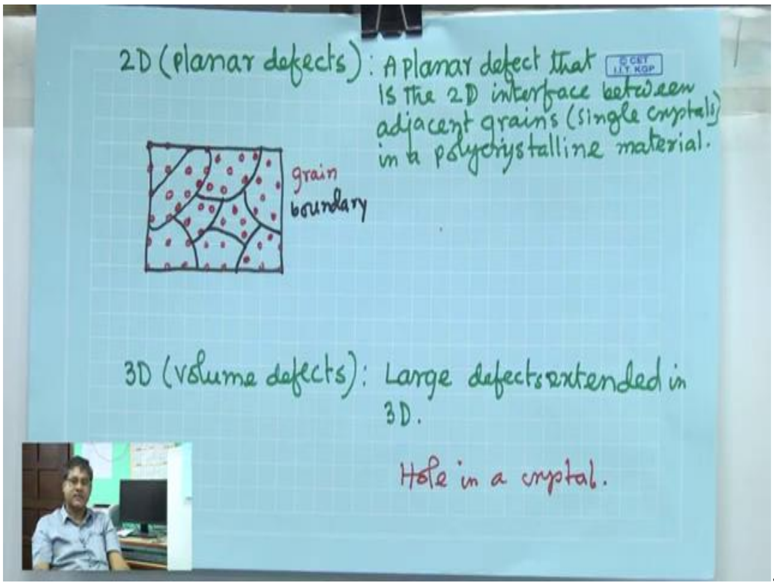

Then two-dimensional defects of the crystal. Two-dimensional defect is the planar defect. a planar defect that that is the two dimensional interface between the adjacent grains. Grains say, they are single crystalline. Now adjacent grains in a polycrystalline material. You know single crystalline and polycrystalline material and amorphous, because these materials are depending on their structure crystalline (Refer Time: 20:32), it is categorized into 2 into 3 group of materials amorphous materials. Where the atoms are randomly oriented randomly sitting in the material. There is no proper arrangement of the atoms, and then we tell it is an amorphous material.

Polycrystalline material; polycrystalline materials is this this if you this whole materials if you divided into it into many parts. each part we tell the grain each part we tell the grain. Now grain in in a grain atoms are nicely arranged following the crystalline structure. then it is a single crystalline. Now the next grain; this is also single crystalline, but orientation of this next grain and the previous grain are not seen in the in the material ok.

grains are grains are single crystalline, but they are randomly oriented in the material. If you consider just one plane, say 1 1 1 plane. for the direction of this plane for grain 1 if it is this direction that same plane in the other grain it may be the other direction. this their orientation are randomly random. then we tell this is the polycrystalline material. If the orientation of all grains are in same direction means we have to consider one plane say 1

1 1 plane if all are directed the 1 1 1 plane direction is up for all grains then we tell this is a single crystalline.

grain boundary; if grains are randomly oriented then at the boundary planes are in different direction. at the interface, there will be mismatch there will be deviation from the crystal structure. that is that will be defective. this grain boundary it is nothing but the plane between the interface between the two grains and this interface is defective and this grain boundary this boundary is defective.

This we tell the defect planar defect it is a plane it is in a along a surface, not surface better to tell interface of the two grains. it is defective, grain boundary if any crystal have grain boundary, have grain boundary then that is defect it's a two dimensional defect here I have shown the grain boundary. This density of the atoms in grain boundary is different from the density in in inside the grains this is the two dimensional defects.

In addition, three dimensional, this just defect is large Extended in three dimension, and then we tell is the it is the volume defect. As for example, this the hole in a crystal it is a three dimensional defect. It is a volume defect so far I have discussed about the about the defects, possible defects in crystal all sorts of defect one can see from the structural characterization. TEM Transmission Electron Microscopy is very useful to visualize this type of defect, visualize this type of defect

one can find out the quality of the crystal as well as what types of defects are there also one can find out the density of defects As I told that always defect is not bad. Sometimes we create defects for intentionally for some application.

Today whatever experiment we will see that is insulating material, but one can get the conductivity and that conductivity due to ion movement due to ion movement and this ion movement is only possible when defect is present in the crystal. In addition, defects of ion conductivity is related with the with the defect and for movement for movement of the of the ions the ions generally heavy compared to electron and hole. it needs the energy ok, it needs the energy and what, what is the minimum energy required to move? That we tell this activation energy. minimum that energy need to cost the barrier to move forward.

I think I will stop here. I will start the with the working formula next class and then I will demonstrate the experiment.

Thank you.