Fundamentals of optical and scanning electron microscopy

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Module – 03
Unit-7 Instrumental details and image formation
Lecture – 19
Special contrast mechanisms
Electric field contrast
Magnetic field contrast
Interaction volume – by Monte Carlo simulation

Hello everyone. Welcome to this material characterization course. In the last class, we looked at the details of the image contrast in the scanning electron microscopy. And then and we also looked at some of the parameters, which significantly influence the image contrast. And typically the topographic and atomic number contrast, is primarily controlled by this secondary electron and backscattered electron signals. And I also mentioned that, there are some more special contrast mechanisms possible in an SEM. And today, we will look at some of them; very briefly, if not detail for the sake of completion of all the contrast mechanism possible under SEM.

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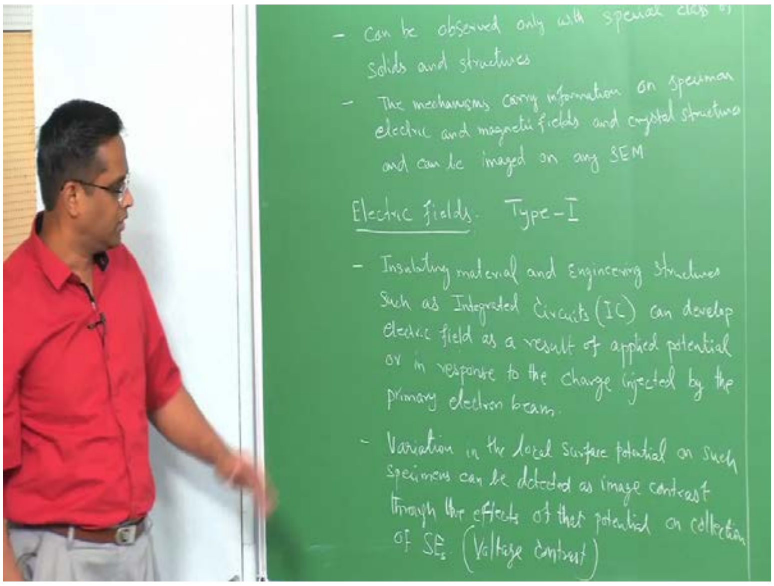

So, what I will do is I will just write it on the blackboard. So, when we see that it is a special contrast mechanism is can be observed only with the special class of a materials or solids and structures. And typically these mechanisms carry the information on the specimen electric, and magnetic fields and crystal structures, and this can be imaged in any of the scanning electron microscopy. So, first we will look through the electrical fields, how it can be image and what is the idea behind it and then we will move on to the magnetic fields. So, first is electric field. We will first look at how to image these electric fields; there are two types; what we are now going to look at is it is type 1, where you have the insulating material and engineering structures such as integrated circuits, can develop electric field as a result of applied potential or in response to the charge injected by the primary electron beam.

So, what is that, that causes the image that we will see now? You see when this a electron beam interacts with this any insulating material or the IC circuits. The variation in the local surface potential on such specimens can be detected as the image contrast, through the effects of that potential on collection of Ses - collection of secondary electrons through the E-T detector like we have seen in the other mechanisms. See this potential aids in collecting the secondary electrons, which is coming out of this structures, it could be IC circuits or any insulating material because of the variation in the local surface potential, which can be imaged as a voltage contrast. See this is one type.

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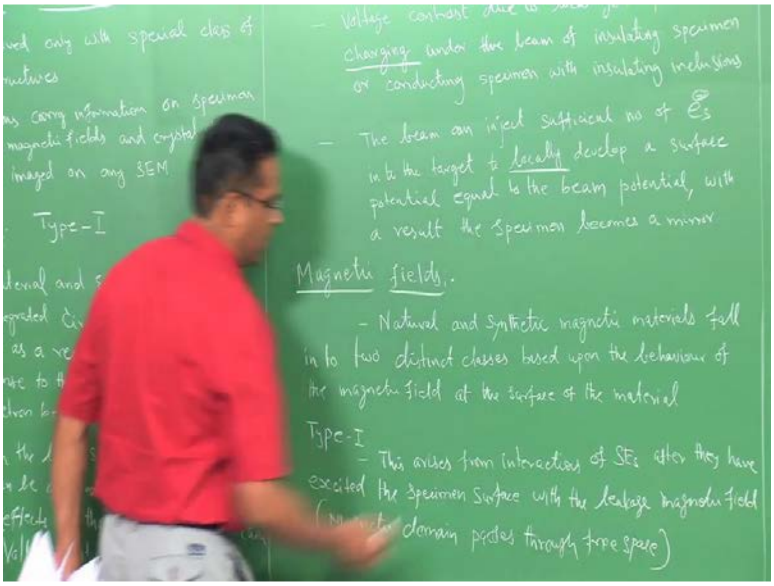

We will look at the other type. You see this is another very important aspect of SEM operation itself. And some of you would have seen or you may see that sometimes, your specimen is getting charged, whether your operator tell this or if you are operating the machine you will, yourself will observe it, that is a voltage contrast due to localized specimen charging under the beam of insulating specimen or conducting specimens with insulating inclusions. So, non conducting inclusion will also cause this charging effect. And that is because of so what happens is, in the insulation material, the beam can inject sufficient number of electrons into the target to develop a surface potential locally, equal to the beam potential. So, with the result, the specimen becomes a mirror. Actually you are just looking at the beam. We can say that, so that is why you get the images of a charging effect. You can see that in a gray micrograph some parts or some portions wherever you have this insulation material or insulating inclusions you will see that very wide bright spots which may not be the actual feature of your material or part of micro structure. So, this is the another type of imaging using this a voltage contrast in order to SEM.

Now, we will look at the magnetic fields. So, in the case of magnetic fields imaging where you have the natural and synthetic magnetic materials fall into two distinct classes based upon the behaviour of the magnetic field at the surface of the material. There are two types. First, we will see type 1 imaging so, that is based on, so the first type of the magnetic field imaging fall into this category, where this contrast arises because from the interaction of secondary electrons after they have excited this specimen surface with the leakage magnetic field of the magnetic specimens.

So, what is leakage magnetic field. So, you see in a magnetic material, you have all the spines oriented in same direction called magnetic domain; and then when the magnetic domain reaches the surface, a free space, there it is called magnetic leakage. You can write in the bracket, (magnetic domain; a magnetic domain passes through free space) where it is called a magnetic field leakage. So, the interaction between that field, if the secondary electrons give the contrast.

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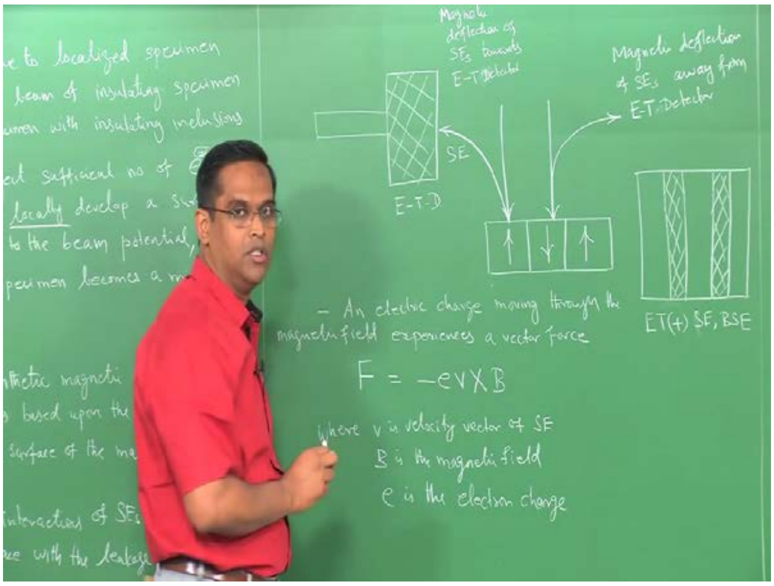

So, I will just need to draw a schematic for that. So, you see the schematic which I have drawn here is; this is E-T detector, and this is the specimen we talk about. And there are two distinct events happened here because of this, electric charge moving through the magnetic field experience is a vector force; F equal to minus e V cross B. Where V is the velocity of vector like a vector of a secondary electron B is the magnetic field, e is the electron charge. So, what happens is and this field the job of the field is to accelerate the secondary electron, it is not just the acceleration of the secondary electron, but also the making directional component of the secondary electrons, directionality is also controlled by this force.

So, in that process, what happens is, you have this a spin of particle orientation where the magnetic deflection of SE towards E-T detector, and where you have the opposite domain, where the magnetic deflection of SEs away from the E-T detector. So, you know now very well, when you do this, when you are making a secondary electron yield very high, and when it is moving away from the secondary electron, the yield is reduced. So, in that sense, you developed a dark and a bright bands in the specimen image, so that is how the image contrast is produced. We will write it down, so that you would not miss the point.

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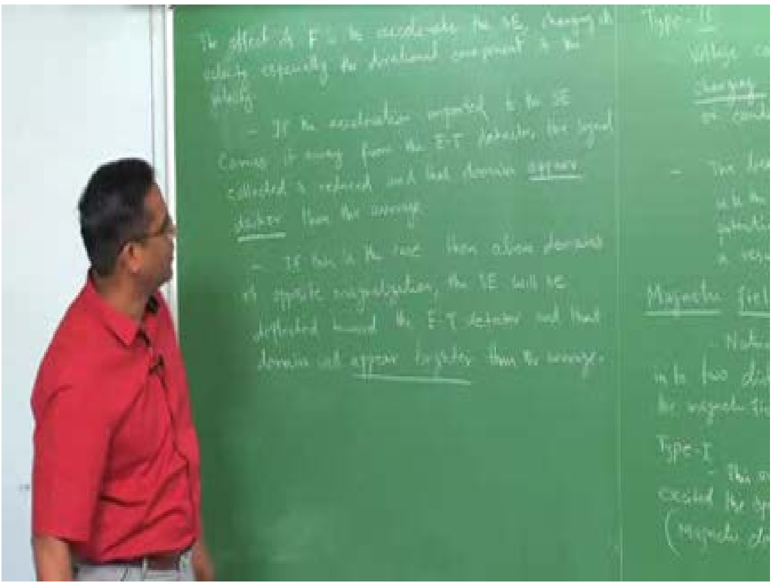

The effect of force that is F is to, so whatever is shown in the schematic, we have put them in the form of couple of sentences. To the effect of this force, this F is to accelerate the secondary electron, changing its velocity especially the directional component of the velocity. So, when you have the control on direction, then you have both options. If the acceleration imported by the secondary electron carries it away from E-T detector, there the signal collected is reduced and the domain appears darker than the average.

So, we are talking about suppose if you have the this is the image, so we are talking about this darker domain. Suppose if this is the case, then above domains of opposite magnetization, the secondary electron will be deflected toward the E-T detector, and that domain will appear brighter than the average. So, you will have a bands of a dark, bright, dark, bright, dark, bright kind of an image, which actually you are imaging the magnetic domains of particular orientations. So, this is about a type 1 of a magnetic field imaging then we will look at the type 2.

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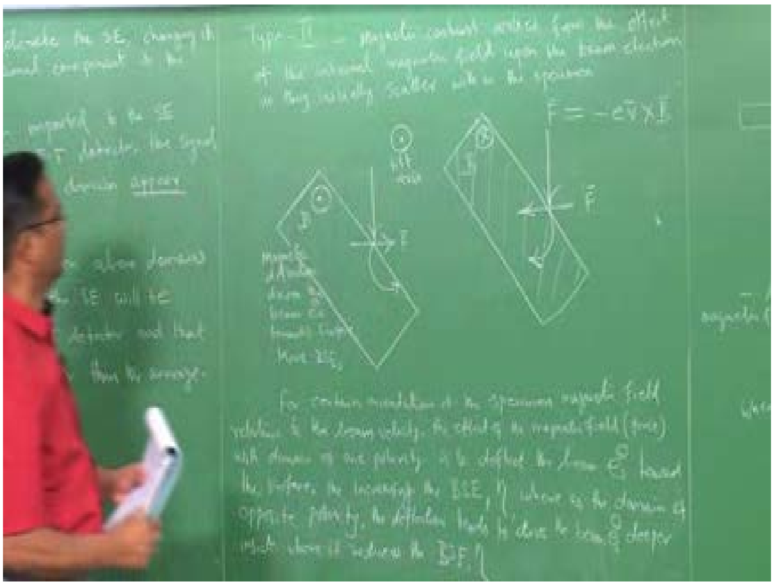

So, this type 2 contrast or magnetic contrast arises from the effect of internal magnetic field upon the beam electrons as the initially scattered within the specimen. So, it is the interaction between the internal magnetic field and the beam of electrons, after they initially scattered within this specimen. I need to draw one schematic again based we will use the same equation here also, F is equal to minus e cross V. So, you would have see what we have drawn here, as a schematic is again a magnetic specimen and this is a tilt axis of this. So, it is kept in this one direction and then after it tilts and it is in the other direction.

So, what is showed in the schematic is, for certain orientation of the specimen, magnetic field relative to the beam velocity, the effect of magnetic field that is force, with the domain of one polarity to deflect the beam of electrons towards the surface that is this case. For this polarity, the magnetic deflection pushes the beam of electrons towards the surface that means, I get more backscattered electron signal here, because of this force then that increase the backscattered electron yield.

Whereas, the domain of opposite polarity; for example, if this is an opposite polarity, the deflection tends to drive the beam electrons much more deeper inside the specimen. Where it reduces the BSE yield, low backscattered electron yield in this case; it is a more backscattered electron yield. So, that produces again a similar contrast of a bright and a dark bands in the image of the respective specimens. So, this is a type 2 magnetic contrast which one can appreciate in the scanning electron microscopy.

And two more contrast mechanism I would like to discuss namely the electron channely and as well as electron backscattered diffraction - EBSD. These two I will briefly discuss in the next class. And I will also show some of the laboratory demonstrations how we are going to acquire this EBSD maps using SEM.

Thank you.