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Lecture-19
Materials Characterization
Fundamentals of Scanning Electron Microscopy

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Hello every one. 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 the secondary electron and backscattered electron signals. And I also maintained that, there are some more special contrast mechanism possible in an SEM and today we will look at some of them very briefly if not detail for the fake of completion of all the contrast mechanism possible under SEM. So, what I will do is I will just write in on the black board.

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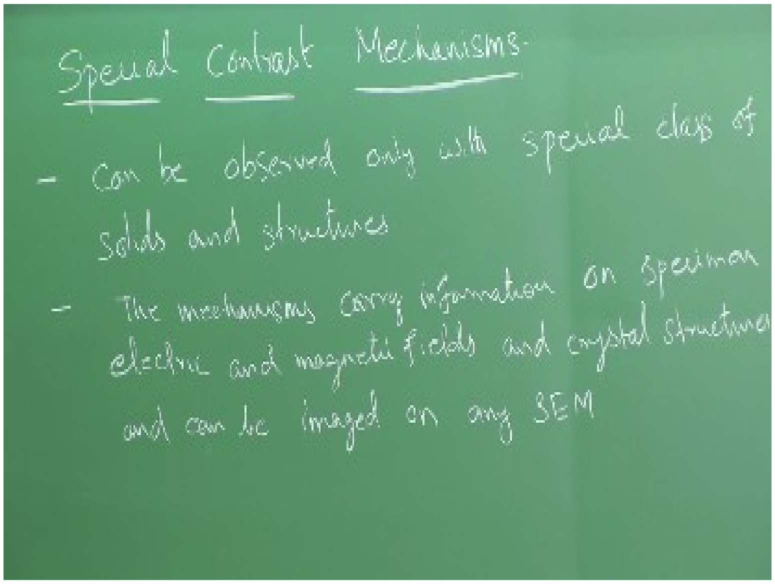

Special Contrast Mechanisms-

- Can be observed only with special class of solids and structures
- The mechanisms carry information on specimen electric and magnetic fields and crystal structures and can be imaged on any SEM

So, when we say that is a special contrast mechanism, this can be observed only with the special class of materials or solid and structures. And typically, these mechanism carry the information on the specimen electric and magnetic fields and these two structures and this can be imaged in any of the scanning electron microscopy. First, we will look thorough the electric fields, how it can be imaged and what is the idea behind it. And then we will move on to the magnetic fields so first is electric field.

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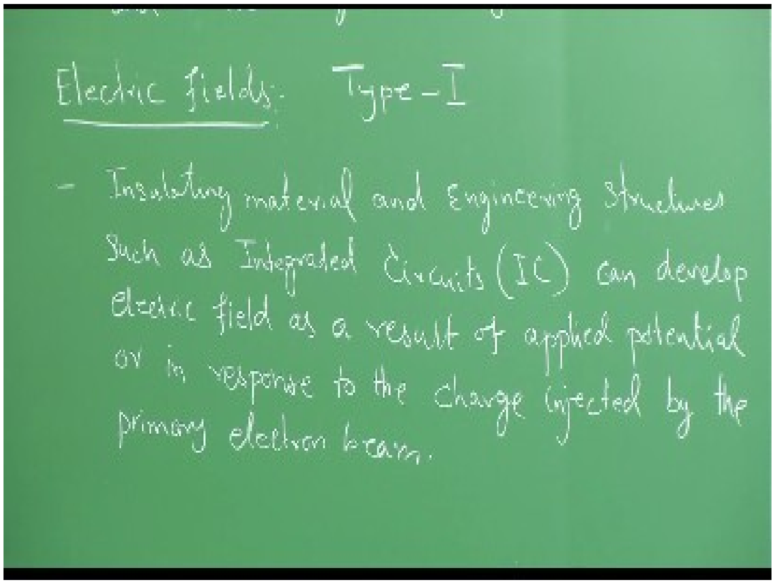

Electric fields: Type-I

- Insulating material and Engineering Structures such as Integrated Circuits (IC) can develop electric field as a result of applied potential or in response to the charge injected by the primary electron beam.

So, we will first look at the how to image this electric fields. There are two types. What we now going to look at it is type 1 where you have the insulating material and engineering structure such as integrated circuits can develop electric field as a result of applied potential or in response to the charge injected by the primary election beam. So, what is that causes the image that we will see now.

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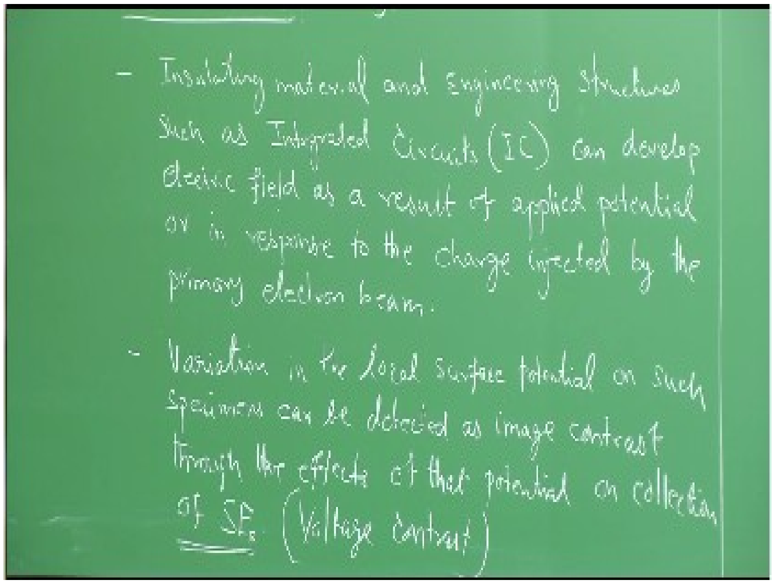

- Insulating material and Engineering structures such as Integrated Circuits (IC) can develop electric field as a result of applied potential or in response to the charge injected by the primary electron beam.
- Variation in the local surface potential on such specimens can be detected as image contrast through the effects of that potential on collection of SEs (Voltage contrast)

You see, when this electron beam interacts with this any inculcating 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 the potential on collection of SEs, collection of secondary electrons through the ET detector like we have seen in the other mechanism. See, this potential aids in collecting the secondary electron which is come out of this structures could be IC circuits are any insulating material because of the variations in the local surface potential. It can be imaged as voltage contrast.

So this is one type we will look at the other type.

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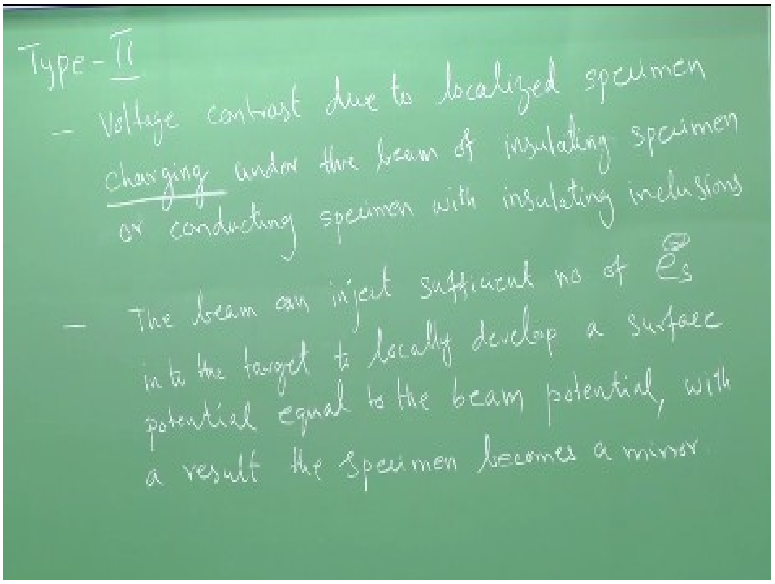

Type-II

- Voltage contrast due to localized specimen <u>charging</u> under the beam of insulating specimen or conducting specimen with insulating inclusions
- The beam can inject sufficient no of $\overset{\ominus}{e}$s in to the target to locally develop a surface potential equal to the beam potential, with a result the specimen becomes a mirror

You see, this is another very important aspect of SEM operation itself. Some of you would have seen or may see that sometimes your specimen is getting charged. Whether your operate tell this or if you are operating the machine you yourself will observe it. That is a voltage contrast due to localize the specimen charging under the beam of insulating specimen or a conducting specimen with insulating inclusions.

So, non-conducting inclusion we also cause 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 to the specimen becomes a mirror. Actually, you are just looking at the beam. You can say that. So, that is why you get the images of a charging effect.

You can see that, in a grey micrograph some parts, some portions wherever you have this insulation material or insulation insulating inclusions, you will see that very white bright spots which may not be actual feature of your material or of a microstructure. So, this is another type of imaging using this voltage contrast in a base Sem. Now, we will look at the magnetic fields.

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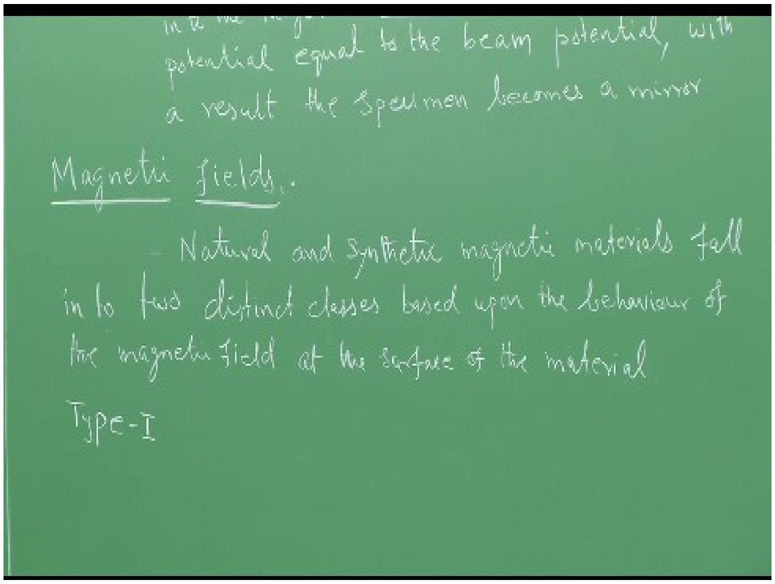

potential equal to the beam potential, with
a result the Specimen becomes a mirror

Magneti fields.

- Natural and Synthetic magnetic materials fall in to two distinct classes based upon the behaviour of the magnetic field at the surface of the material

Type-I

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 behavior 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.

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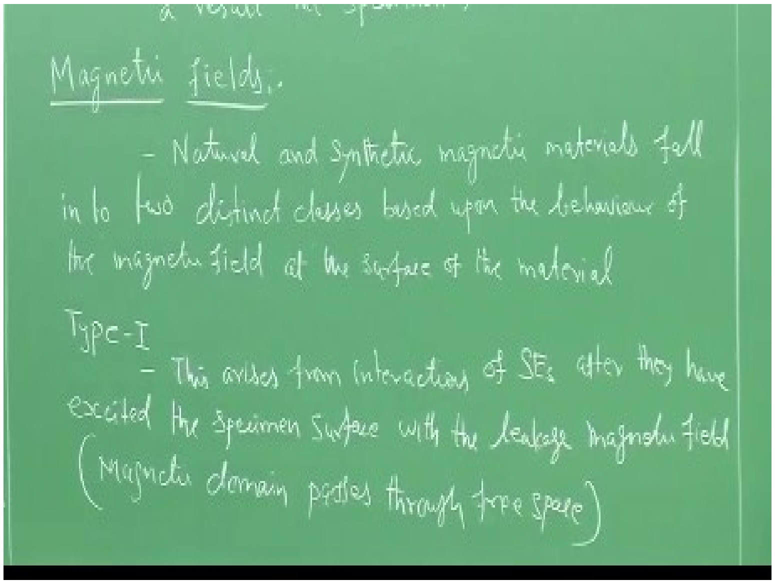

Magnetic fields:

- Natural and Synthetic magnetic materials fall in to two distinct classes based upon the behaviour of the magnetic field at the surface of the material

Type-I

- This arises from interactions of SEs after they have excited the specimen surface with the leakage magnetic field (Magnetic domain passes through free space)

So, the first type of the magnetic field imaging fall into the this category, where this contrast arises because from the interaction of secondary electrons after they have excited this specimens surface with the leakage magnetic field of the magnetic specimen. So, what is leakage magnetic field? So, you see in a magnetic material, you have all the spins oriented in same direction called the 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. A magnetic domain passes through free space where it is called a magnetic field leakage. So, the interaction between that field with the secondary electrons gives the net contrast. So, I will just need to draw a schematic for that.

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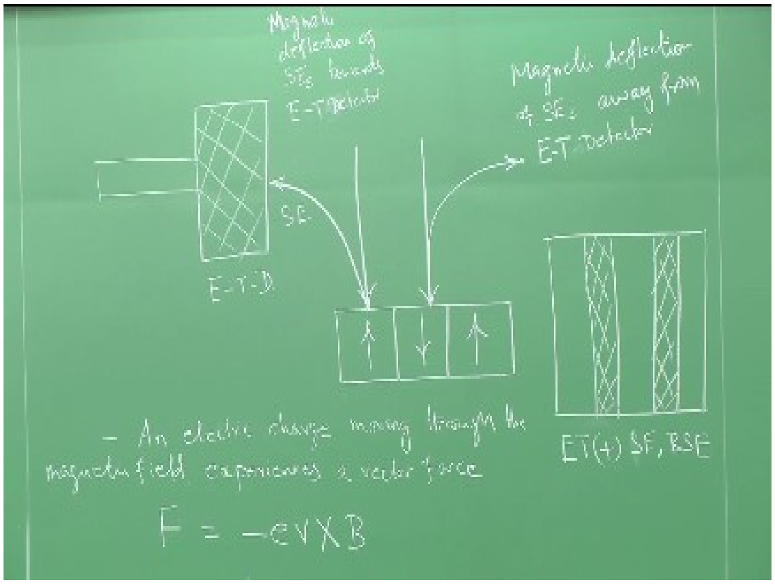

- An electric charge moving through the magnetic field experiences a vector force

$$F = -eV \times B$$

So, you see a schematic which I have drawn here is, this is an ET detector and this is the specimen we talked about. And there are two distinct events happen here. Because of this an electric charge moving through the magnetic fields expresses a vector force

$$\mathbf{F = -e * V * B}$$

Where **V** is the velocity of vector of secondary electron, **B** is the magnetic field, **e** is the electronic charge. So, what happens is and this field the job of this 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.

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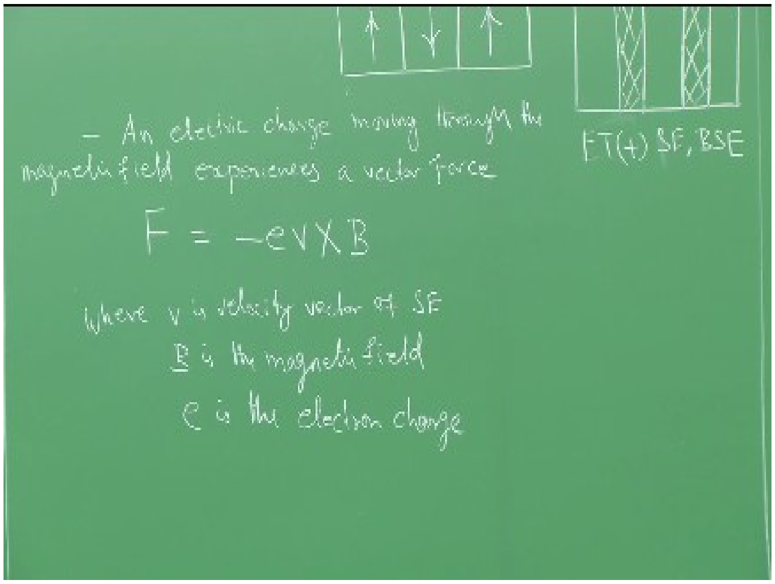

- An electric charge moving through the magnetic field experiences a vector force

$F = -ev \times B$

where v is velocity vector of SE

B is the magnetic field

e is the electron charge

ET(+) SE, BSE

So, in that process what happens is, you have this a spin of particular orientation where the magnetic deflection of SE towards ET detector. And where you have the opposite domain where the magnetic deflection of SE is away from the ET detector. So, you know now very well, when you do this then 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 have you develop a dark and a bright band in the specimen image. So, that is how the, the image contrast is produced. We will write it down so that we would miss the point.

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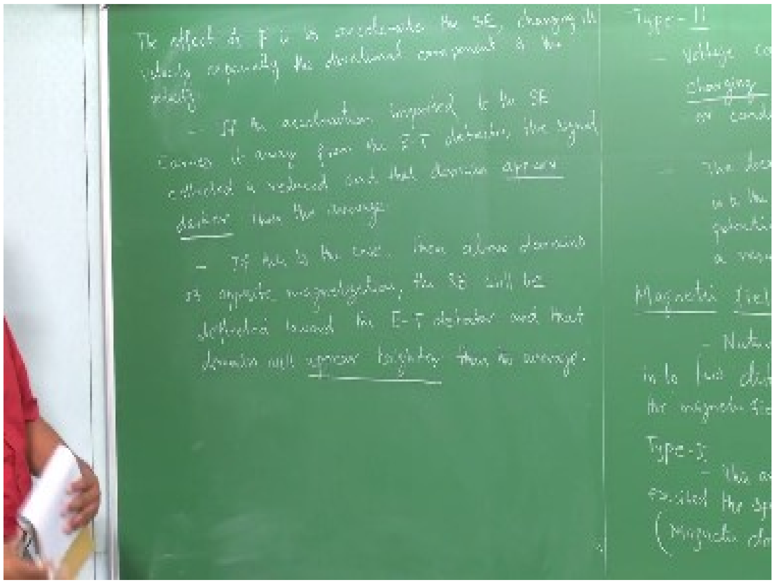

The effect of force that is F is to. So, whatever is shown in the schematic, we have put them in the form of couple of sentences. To the effect of this force F is to accelerate the secondary electron, changing it is velocity, especially the directional component of the velocity. So, when you have the control on directions then you have both the options. If the acceleration imported by the secondary electrons carries it away from ET detector, then the signal collected is reduced and the domain appear darker than the average. So, we are talking about, suppose if you have the, this is an image. So, we are talking about this parker domain. Suppose if you suppose if this is the case then the above domains of opposite magnetization the secondary electron will be deflected towards the ET detector and that domain will appear brighter than the average. So, you will have bands of a dark bright, dark bright, dark bright kind of an image, which actually you are imaging the magnetic domains of particular orientation. So, this is about type 1 of magnetic field imaging. Then we will look at the type 2.

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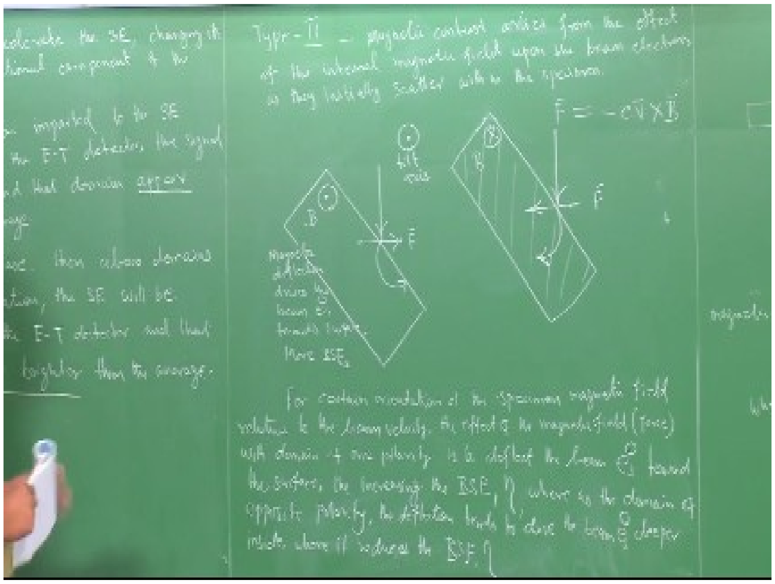

Type-II – magnetic contrast arises from the effect of the internal magnetic field upon the beam electrons as they initially scatter within the specimen.

$\vec{F} = -e\vec{v} \times \vec{B}$

For certain orientation of the specimen magnetic field relative to the beam velocity, the effect of the magnetic field (force) with domain of one polarity is to deflect the beam e⁻ toward the surface, thus increasing the BSE, η whereas in the domain of opposite polarity, the deflection tends to drive the beam e⁻ deeper inside, where it reduces the BSE η

So, this type 2 contrast or magnetic contrast arises from the effect of internal magnetic field upon the beam electrons as they initial scatter within the specimen. So, it is the interaction between the internal magnetic field and the beam of electrons after they initially scatter within this specimen. I need to draw one schematic again based we will use the same equation here also F=-vxB so you have.

See, what we have drawn here as a schematic is again a magnetic specimen and this is a tilt axes of this. So, it is kept in this one direction and then operate tills and it is in another direction.

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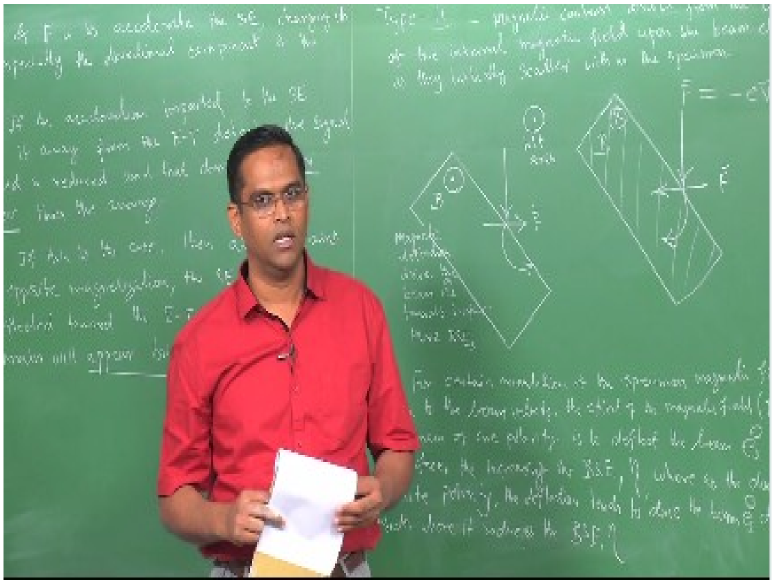

So, what is shown in this schematic is, for certain orientation of the specimen, magnetic field relative to the beam velocity, the effect of magnetic field that is force with the domain of one polarity to deflect the beam of electrons towards the surface that is this case. For this polarity, the magnetic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

The deflection tends to drag the beam electrons much deeper inside the specimen, where it reduces the BSE yield. Low backscattered electron yield in this case. In this case it is a more backscattered electron yield. So, that produces again a similar contrast a bright and a dark band in the image of the respective specimens. So, this is a type two a magnetic contrast which one can appreciated the scanning electron microscopy and to more contrast mechanisms I would like to discuss namely the electron channeling 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 EDSD maps using SEM thank you.

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