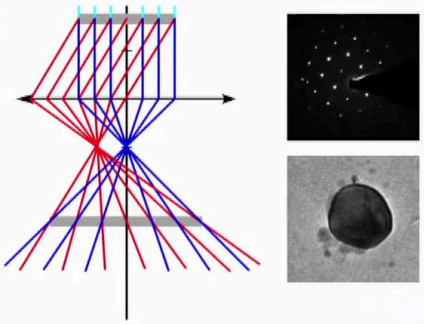
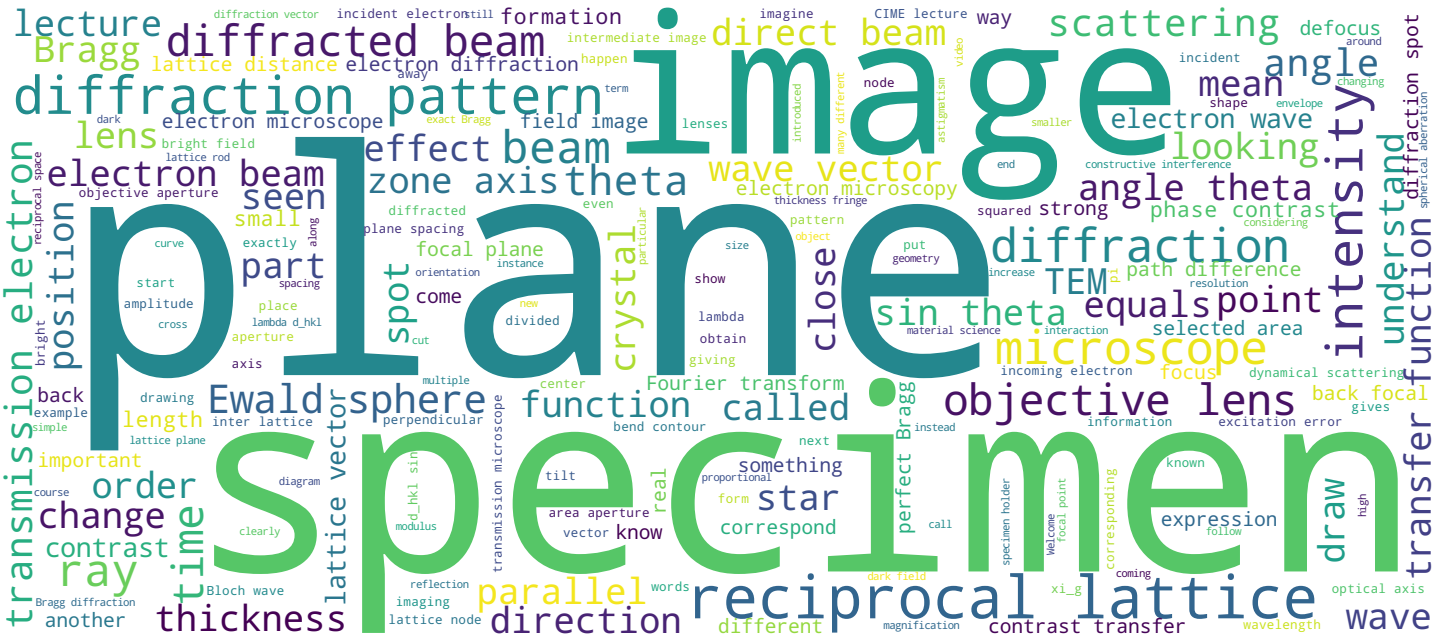


Bragg's Law in the TEM

Transmission Electron Microscopy

Prof. C. Hébert & Dr. D. Alexander



Search MOOC

Video

Introduction

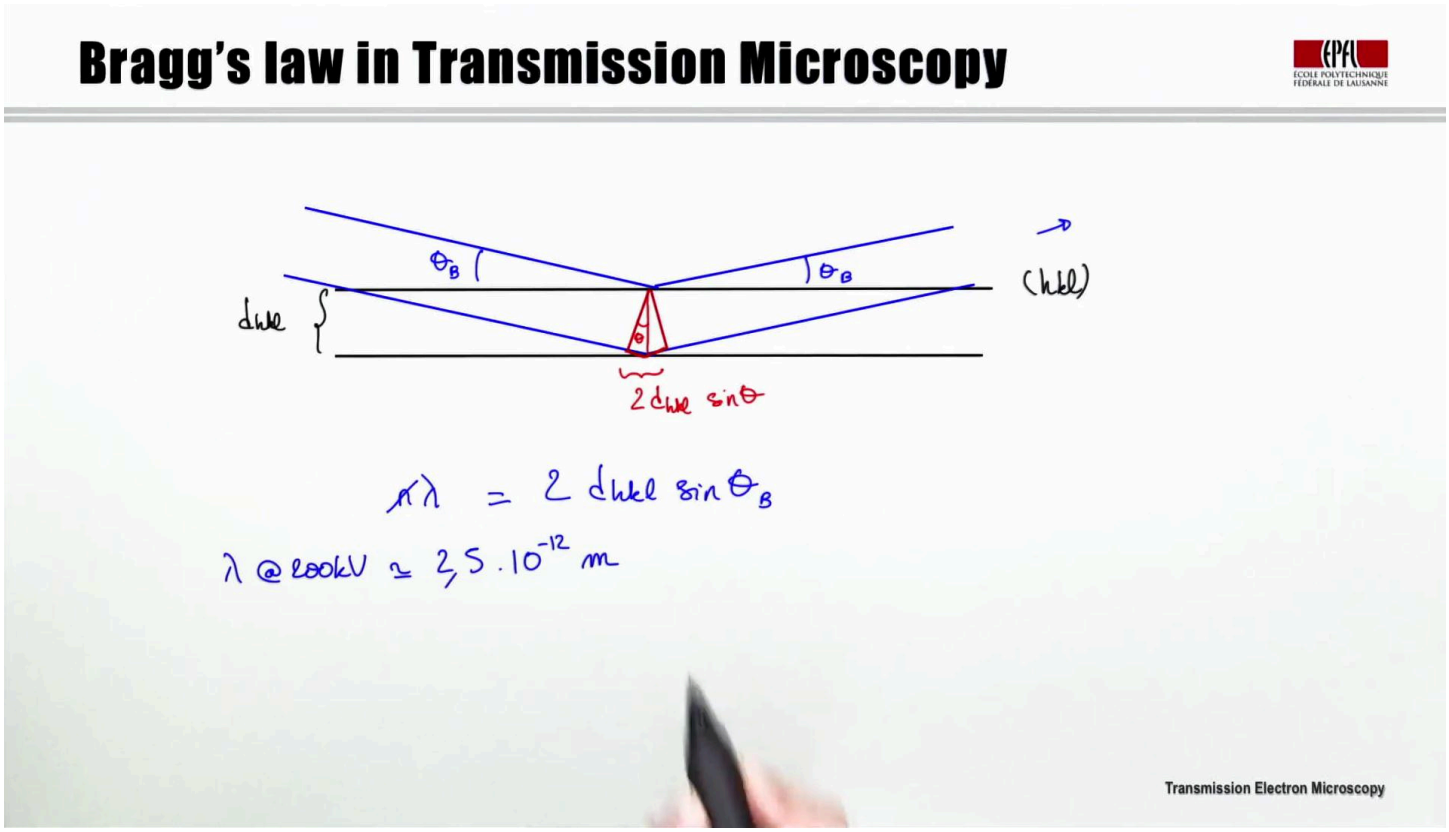
Welcome to CIME's lecture on transmission electron microscopy for material science. In this video we will see Bragg's law, which is a simple way to understand the formation of diffraction pattern in a transmission electron microscope.

Notes

Summary

0m 05s

Bragg's law in Transmission Microscopy



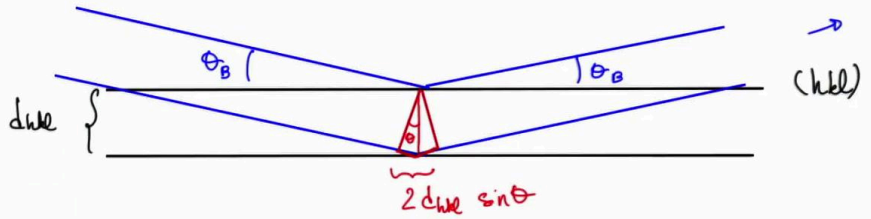
In a crystalline specimen we can draw lattice planes hkl with inter-lattice distance d_hkl. An electron wave will come and impact on the specimen with an angle theta. It will be reflected with the same angle theta. If I draw the wave on the second plane it will arrive also with the same angle theta and have the same reflection angle. The second ray has a path difference with the first one. If I want to see something in that direction, I need to have constructive interferences between those two waves. That will only happen if the path difference is a multiple of the wave length. The path difference can be found on the graph at that position. It is the sum of those two paths and since I have the angle theta again here the lengths of those two segments is 2 times d_hkl sin theta. Thus the condition for constructive interferences is n times lambda = 2 d_hkl sin theta. This angle theta in the case when I do have diffraction is called theta b for theta Bragg. And in the transmission microscope we only have the first order so n = 1. Looking at some orders of magnitude, lambda at 200 kilovolts is equal to 2.5 picometres 10 to the minus 12 metres.

Notes

Summary

0m 19s

Bragg's law in Transmission Microscopy



$n\lambda = 2 d_{hkl} \sin\theta_B$

λ @ 200kV $\simeq 2{,}5 \cdot 10^{-12}$ m

$d_{hkl} \simeq 2{,}5 \cdot 10^{-10}$ m

$\sin\theta_B \simeq 5 \cdot 10^{-3}$ $\quad \theta_B \simeq 5$ mrad

Transmission Electron Microscopy

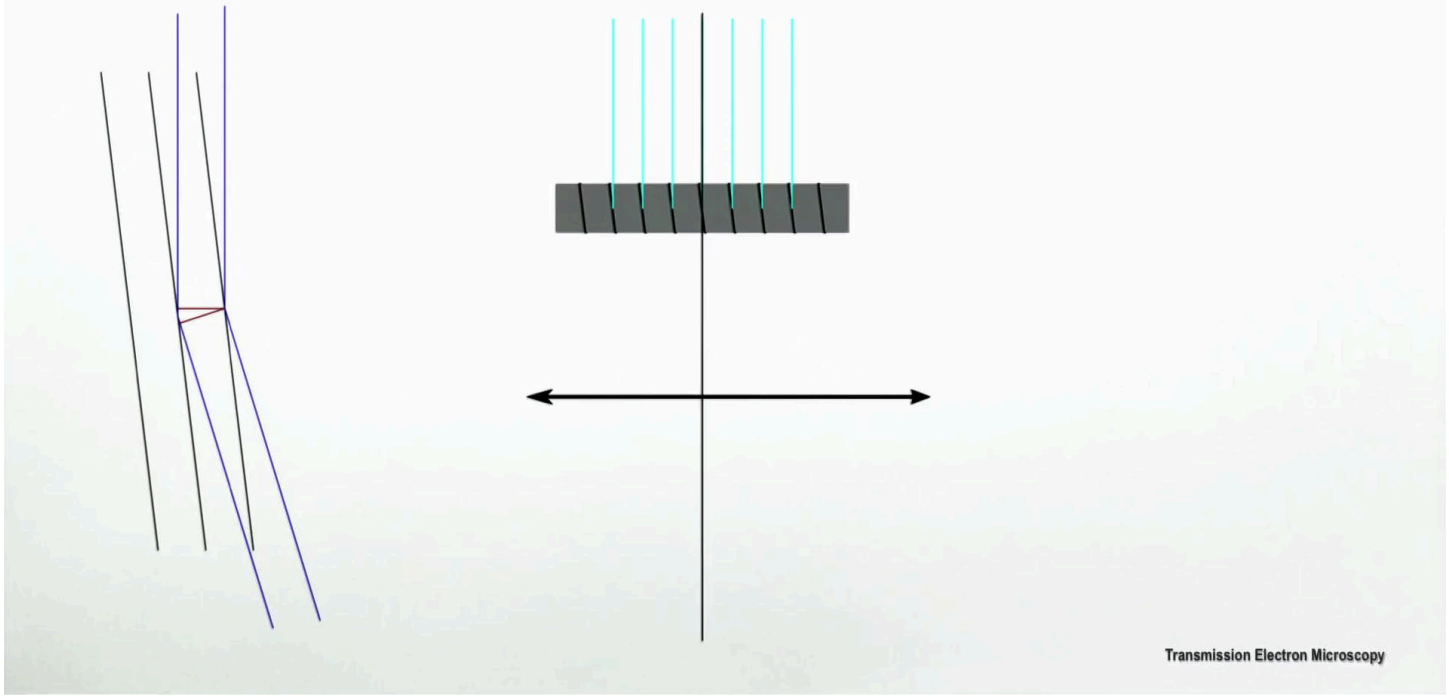
In a typical crystal we can imagine that we have inter-lattice distances in the order of magnitude of 2.5 Angstroms. Let's take d_hkl = 2.5 10 to the minus 10 meters, that gives me sin theta b close to 5 10 to the minus 3. It is small, it means that theta b is close to sin theta b, theta b is close to 5 milliradians. Usually, the microscope is vertical. In that case the electron wave is arriving close to the horizontal. It is not realistic, so if we want to draw it like it is in the microscope it is more something like this.

Notes

Summary

2m 22s

Bragg's law in Transmission Microscopy

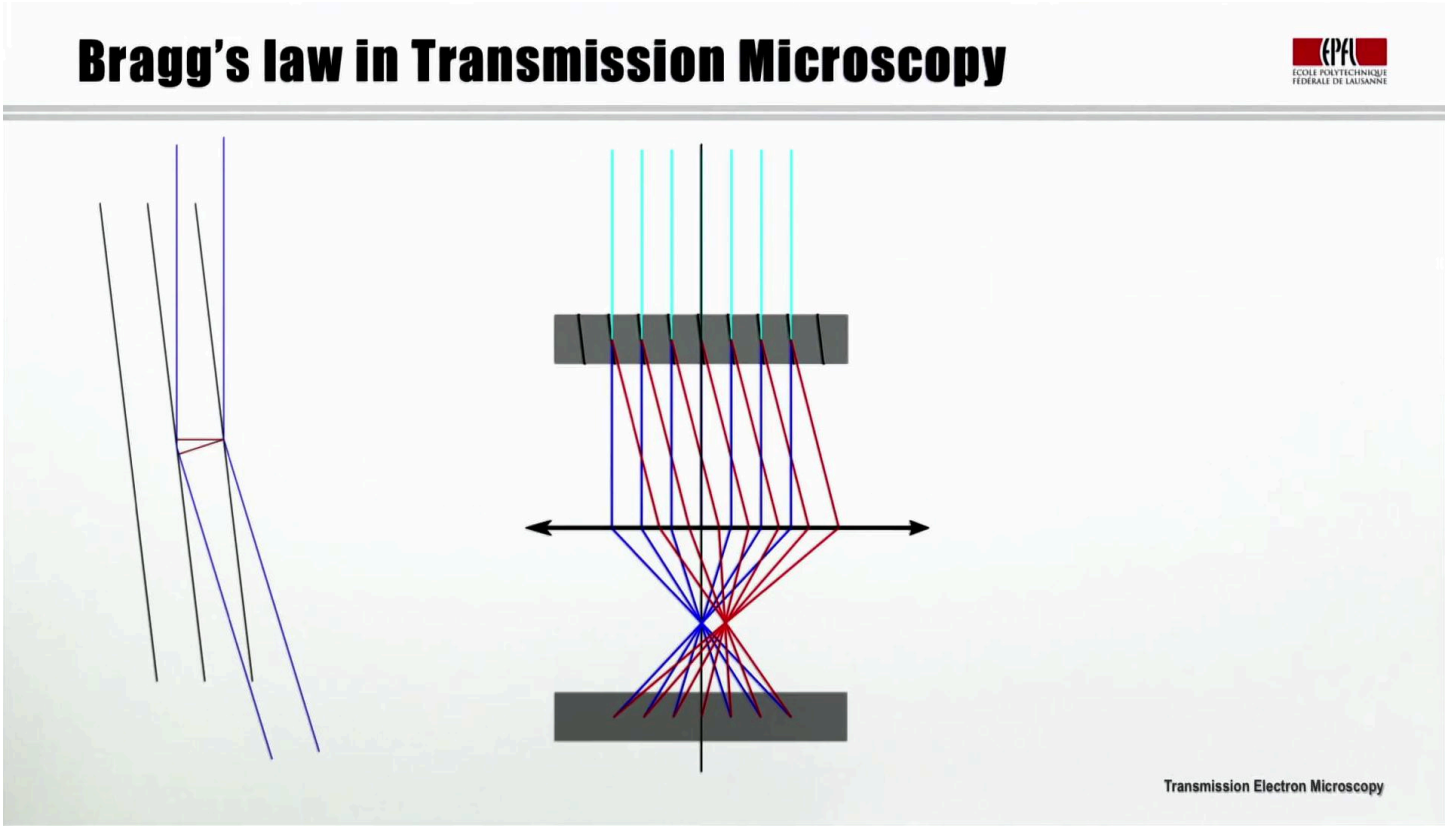


I have the incoming electron wave and the planes of my crystal. But actually I don't have such a large crystal, I have a thin specimen in the microscope which means that I have a drawing looking like this, with the specimen, the objective lens and the place that will be in the right position for Bragg diffraction. If I illuminate this specimen with a parallel beam of electrons, so parallel to the optical axis, I will have some rays that will pass through the specimen and some rays that will be diffracted.

Notes

Summary

3m 20s

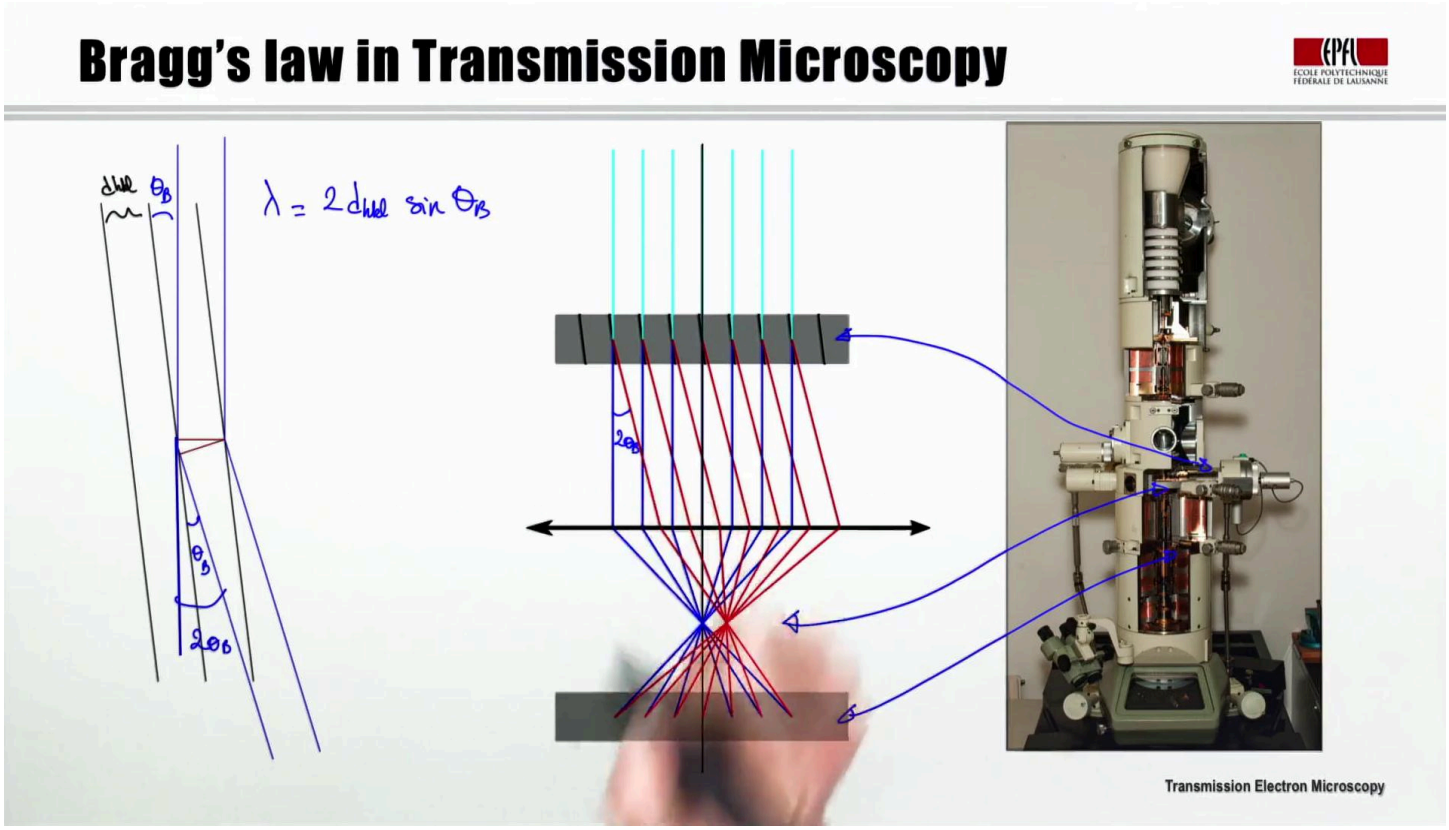


They will be imaged by the objective lens, and as we have seen before in the back focal plane, I will have the formation of the diffraction pattern and in the first intermediate image of the specimen, I will have my image.

Notes

Summary

4m 06s

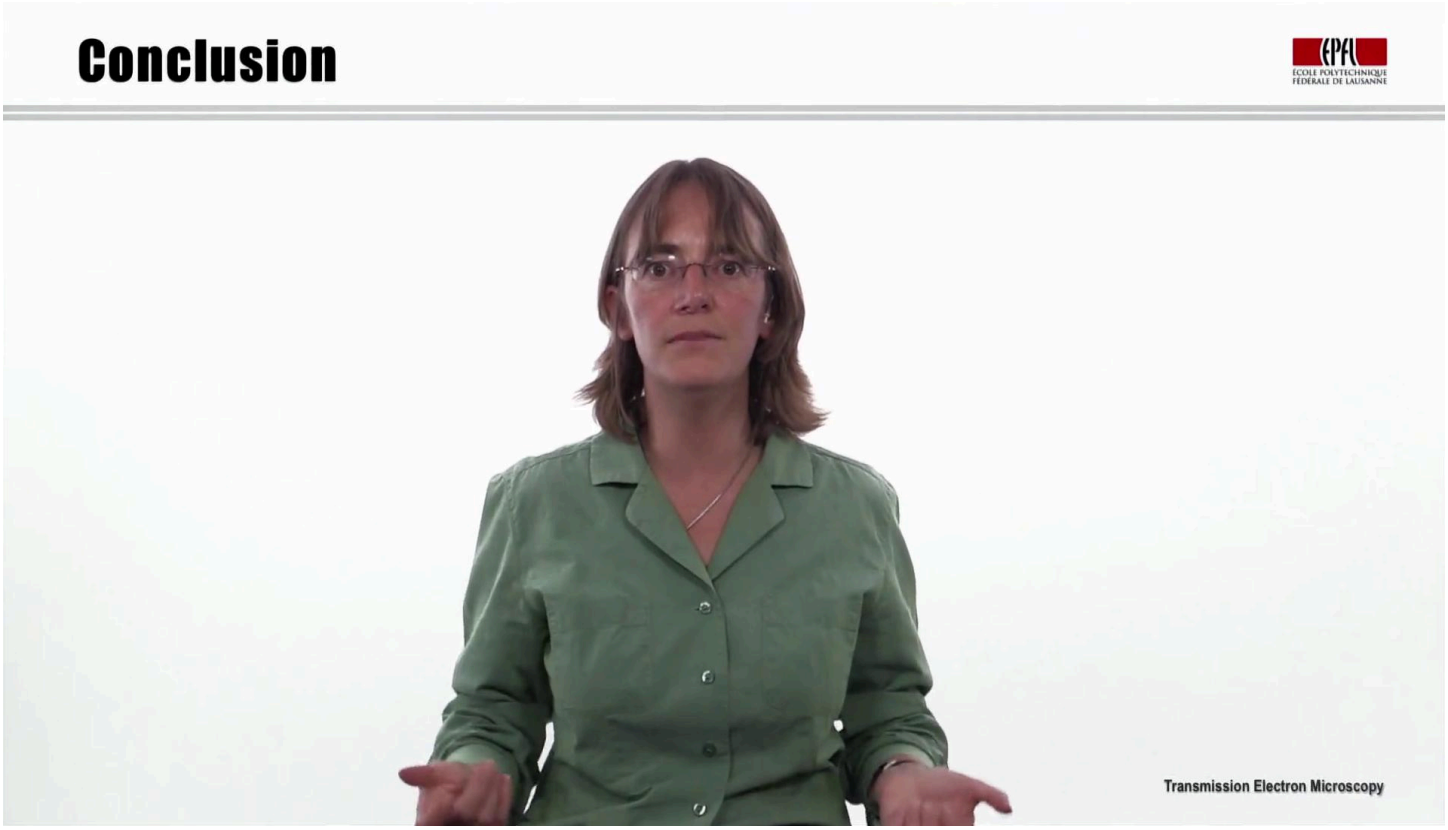


This can be connected to the microscope that we have seen before in the following way: the specimen is in the specimen holder at that position. The diffraction pattern is in the back focal plane of the objective lens, where I have the contrast aperture or objective aperture. And the first intermediate image is where we have the selected area aperture. Again, we have to be careful, that was the incidence angle that we had before, and that is the theta b after the specimen. The inter-lattice distance is d_hkl and Bragg's law tells us lambda = 2 d_hkl sin theta b. But in the transmission microscope we look at the angle between the incoming electrons and the outgoing electrons and actually, if we look carefully, the incoming electrons are continuing like this, this angle is 2 times theta b, so the angle that we find there is 2 theta b.

Notes

Summary

4m 24s



With this you have a sufficient understanding of diffraction in the TEM to understand the main operating modes of the transmission electron microscope that we will see in the next video.

Notes

Summary

5m 50s