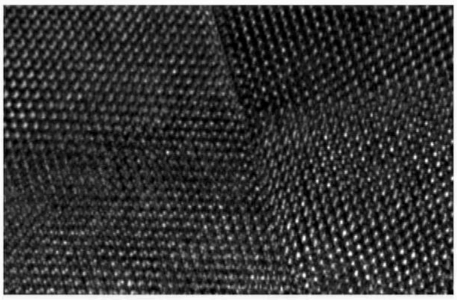
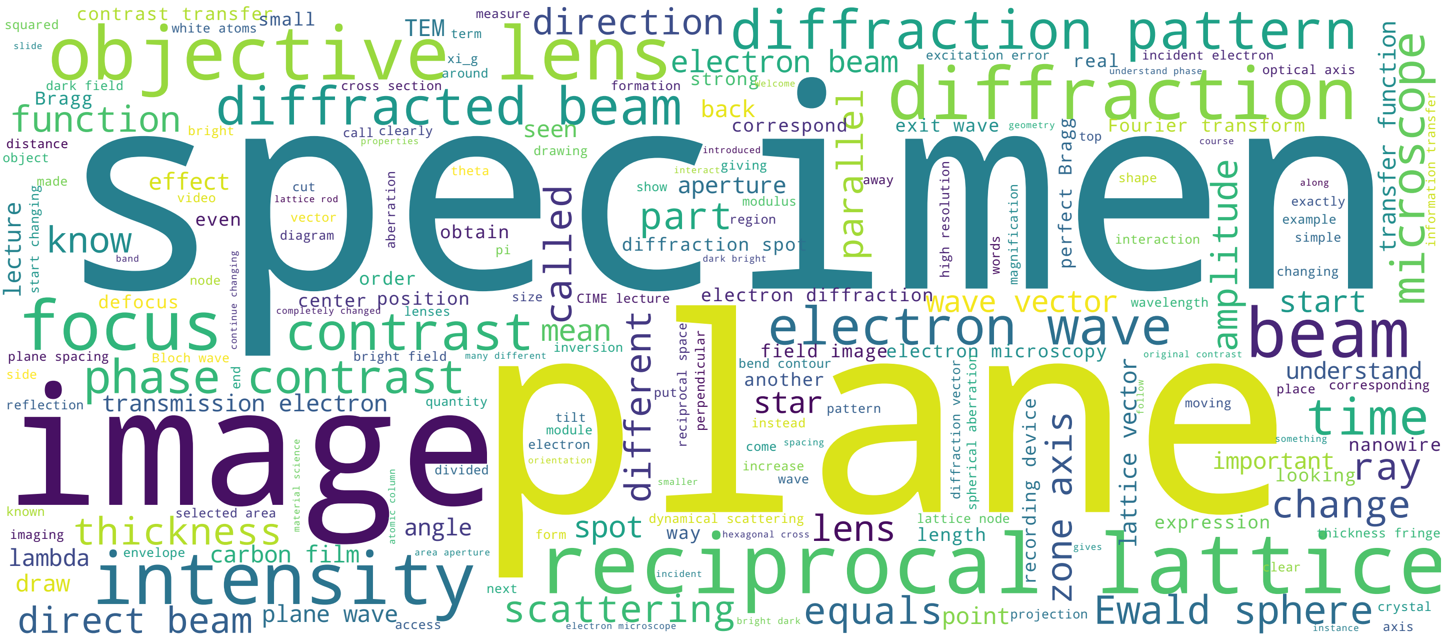
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE



Phase contrast: introduction

Transmission Electron Microscopy

Prof. C. Hébert & Dr. D. Alexander



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Video

EPFL

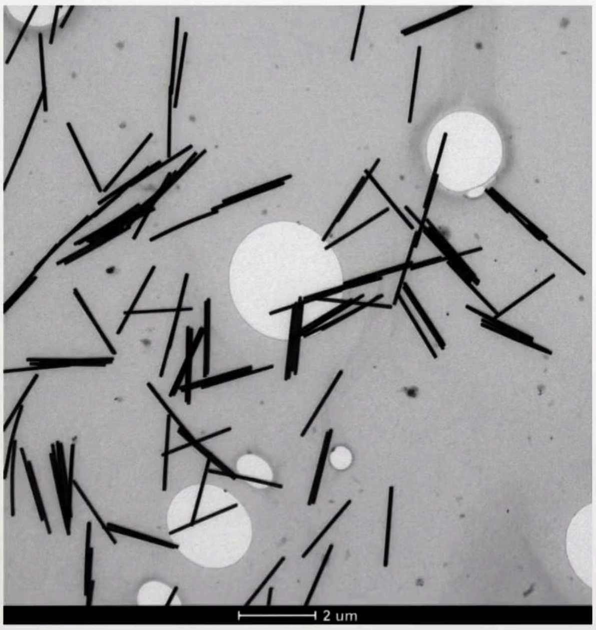
Welcome to CIME's lecture on transmission electron microscopy for material science. In the previous module you have learned a lot about diffraction and diffraction contrast. In this module I want to take you to the world of phase contrast for which it is important to know that electrons are waves. But before starting this, let's go to the microscope.

Notes

Summary

0m 05s

Demonstration at the TEM



InAsSb nanowire. Sample courtesy Anna Fontcuberta i Morral, Heidi Potts

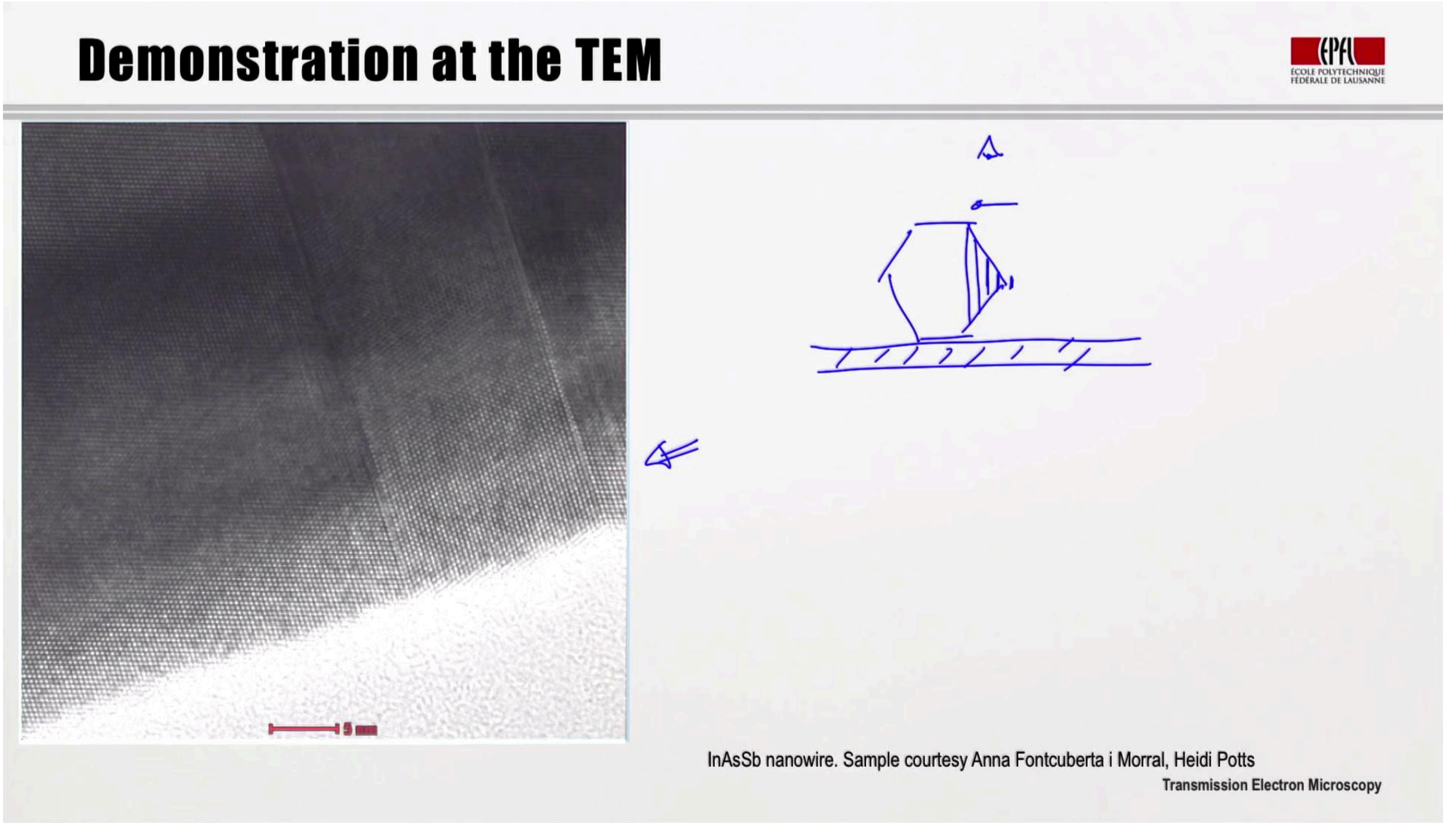
Transmission Electron Microscopy

My sample is made of indium arsenide tin nanowires. You have them at low magnification here on the carbon film.

Notes

Summary

0m 28s



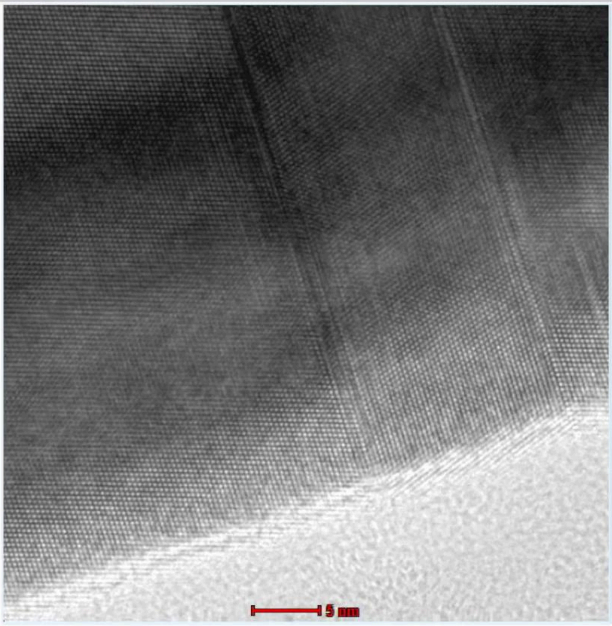
Now I have only one of them, in so-called high resolution mode. This nanowire is well crystallized and has an hexagonal cross-section and it is lying on the carbon film. So if I make a sketch of the specimen I will have my amorphous carbon film and the nanowire with the hexagonal cross-section lying on it, which means that from the side of the nanowire towards the center, I have an increasing thickness. That is why you recognize the bright, dark, bright, dark, bright, etc. bands which are thickness fringes, you have seen them with Duncan. But on top of this, because the nanowire is very well oriented in zone axis, you also recognize, especially at this position, the periodic contrast of white dots. it is very tempting to call this atomic column, or atomic contrast and to think that what we have there is just a projection of the well ordered atomic column seen from the top. But on the other hand, while the contrast is very clear in that region, you see that it is getting messy in this intermediate part and then I have an inversion of contrast before I start again with something looking like white atoms in the next band. And then again, inversion of contrast and later on white atoms.

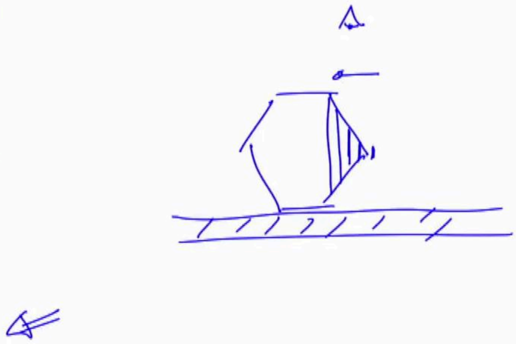
Notes

Summary

0m 39s

Demonstration at the TEM





InAsSb nanowire. Sample courtesy Anna Fontcuberta i Morral, Heidi Potts

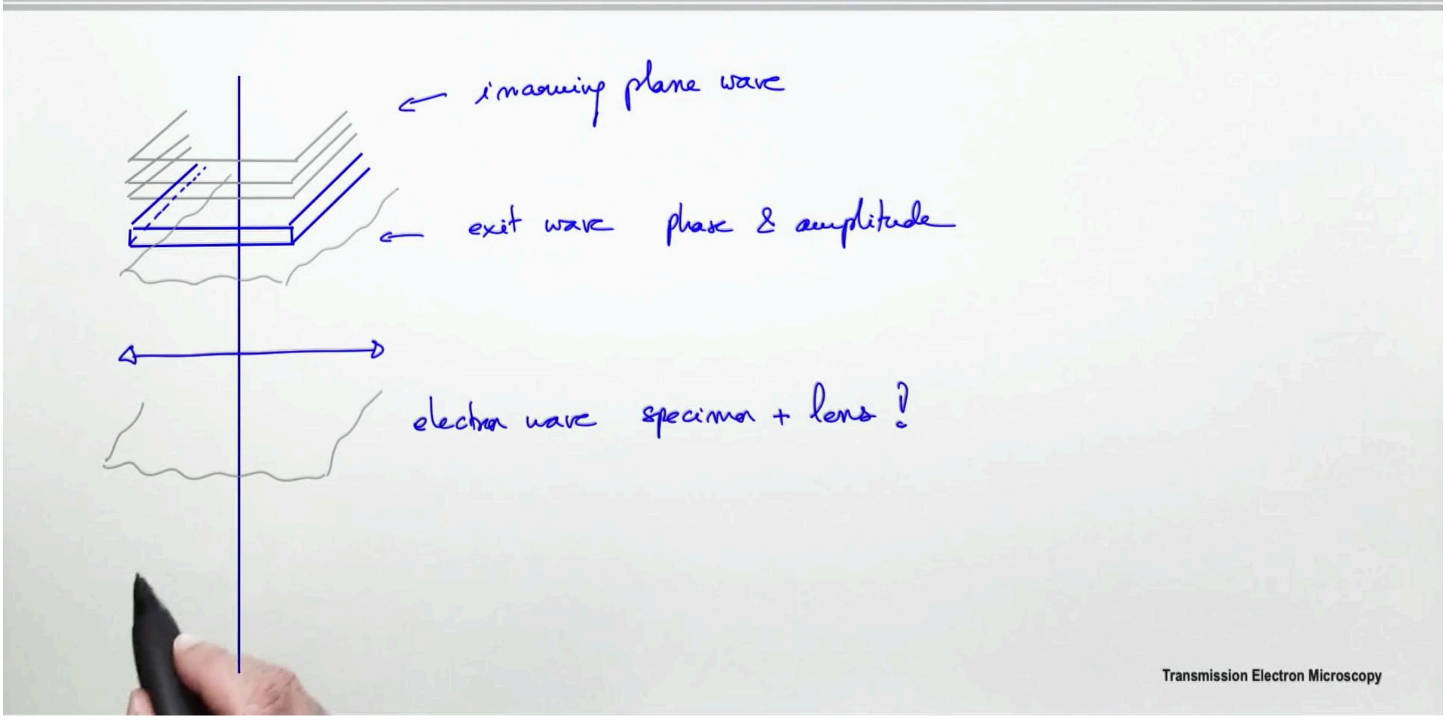
Actually, things will get even more complicated if I start changing the focus. Now I start changing the focus of the objective lens. Concentrate on the band close to the edge of the specimen. You see, I have reached a focus where the contrast has completely changed. I continue changing the focus now and I'm back to the original contrast. And then, again changing back to the original contrast. Well, actually I'm only changing the focus in the same direction. Now I continue changing the focus changing the direction of focus and you see, again, how these contrasts are moving. So, clearly there is an interplay between the focus of the objective lens, the thickness and the crystallinity of the specimen and the kind of image that I get.

Notes

Summary

2m 43s

The specimen and the lens

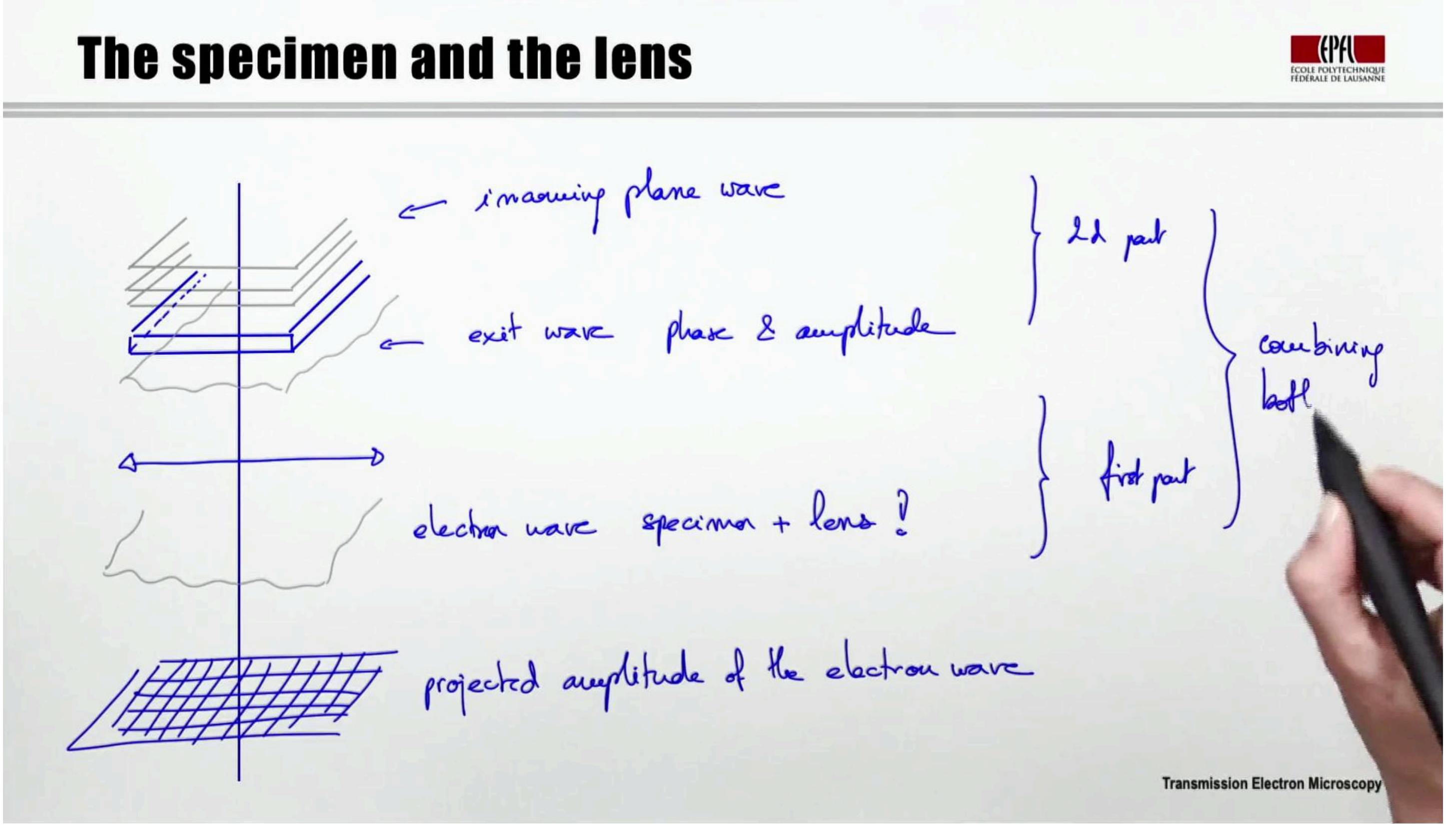


To understand phase contrast we need to take everything into account, what the electron wave has interacted with. If we take the optical axis as the vertical axis, we have the electron waves that can be considered as plane waves. Those electrons will first interact with the specimen. After the specimen, the electron wave will be completely changed. It will have changed phase and amplitude. We draw it as a distorted wave. This is the incoming plane wave and this wave is called the exit wave. It carries everything we would like to know about the specimen. It is a complex quantity which has phase and amplitude and it is actually the quantity that we would like to access to. But in order to access it, we then have the objective lens bellow the specimen. Unfortunately, the objective lens is not a perfect lens, so instead of transmitting the exit wave perfectly, it will transmit it mixed up with some properties that are due to the lens, like aberrations or cut off by the aperture. After the objective lens, we have the electron wave that carries information about both specimen plus the electron lens. And then we need to measure it.

Notes

Summary

3m 57s



Usually we have a recording device, like a CCD camera with pixels on which we will project our electron wave, but this recording device we can only measure the amplitude. So we have the projected amplitude of the electron wave. it is very different from the exit wave. In order to understand phase contrast, we need to understand this whole chain of information transfer. And to make it a little bit simpler, we will start in the first part by describing the interaction of the electron wave with the objective lens. In the second part, we will see how the specimen will affect the plane wave. And then finally, we will combine those two approaches to get the complete information transfer by the system and then understand what we obtain from the projection on the recording device.

Notes

Summary

5m 49s

Basically, this will be the subject of this module about phase contrast. So, let's start with the next video to see how the objective lens affects the electron wave.

Notes

Summary

7m 01s