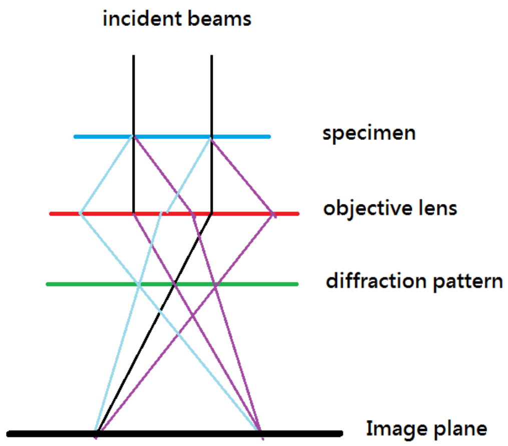
XII Electron diffraction in TEM

JEM-3200FS Transmission Electron Microscope

The JEM-3200FS Field Emission Microscope is a 300kV analytical TEM, used here to explain the electron diffraction in TEM. You may find more information of JEM-3200FS from the website http://www.jeolusa.com



This is a simple sketch of the beam path of the electrons in a TEM after the illumination system. A parallel beam of electrons enters the specimen and are scattered in various directions. The objective lens is used to collect all scattered beams originating from the same point on the sample in one point in the image plane (bottom). Note also that in the back focal plane (marked 'diffraction pattern') electrons originating at different point on the sample, but scattered in the same direction, are collected. Observing the electrons in this plane gives the diffraction pattern, containing information on the angular scattering distribution of the electrons. The diffraction pattern and the image are related through a Fourier transform.

12-1. Electron radiation

(i) ~ hundreds Kev

$$\lambda = \frac{h}{p}$$

highly monochromatic than X-ray

(ii) electrons can be focused

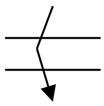
c.f. x-ray is hard to focus

(iii) easily scattered

$$f_e = 10^4 f_x$$

where f_e and f_x are form factor for electron and x-ray, respectively

(iv) need thin crystals



< 1000Å, beam size $\approx 10\mu m$

12-2. Bragg angle is small

$$2d_{hkl}\sin\theta = \lambda$$

for 100Kev $\lambda = 0.037$ Å

$2 \cdot 2\sin\theta \approx 0.04$; where d is estimated to be 2Å

$\theta = 0.5^\circ$

12-3. d spacing determination is not good

First express $2d_{hkl}\sin\theta = \lambda$ as $2d\sin\theta = \lambda$ for brevity.

For a fixed λ,

$$d = \frac{\lambda}{2\sin\theta}$$

$$\frac{\partial d}{\partial \theta} = \frac{\lambda}{2}\left[-\frac{1}{\sin^2\theta}\right]\cos\theta$$

$$\frac{\partial d}{\partial \theta} = \frac{\lambda}{2}\left[-\frac{\cos\theta}{\sin^2\theta}\right] = d\left[-\frac{\cos\theta}{\sin\theta}\right] = -d\cot\theta$$

$$\frac{\partial d}{d} = -\cot\theta\,\partial\theta$$

As $\theta \rightarrow 90^o$, $\cot\theta \rightarrow 0$, $\partial d \rightarrow 0$

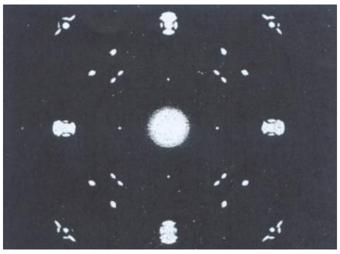
In other words, we can get more accurate d at higher angle.

However, $\theta < 0.5^o$ in electron diffraction in TEM

This leads to worse resolution in determining d spacing using electron diffraction in TEM.

12-4. electron diffraction pattern from a single crystalline material

Example: epitaxial PtSi/p-Si(100)

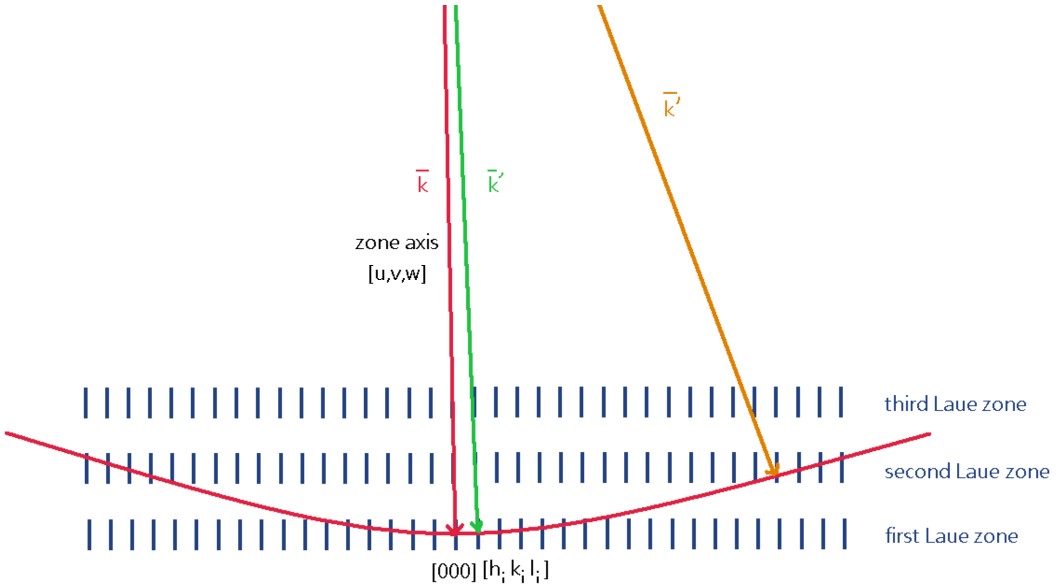


Ewald sphere construction:

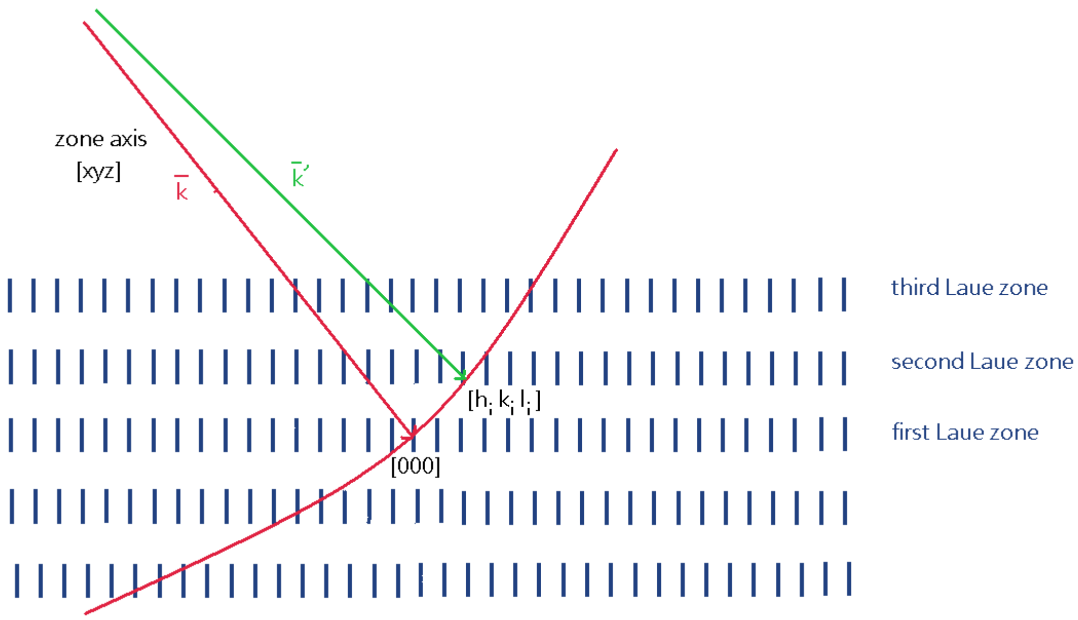
λ is very small

k is very large compared to the lattice spacing in the reciprocal space

1) An electron beam is usually incident along the zone axis of the electron diffraction pattern.



The sample can be tuned along another zone axis [xyz] . All the spots in the diffraction pattern belongs the zone axis [xyz].



12-5. electron diffraction pattern from a polycrystalline material

Example: polycrystalline PtSi/p-Si(100)

Ewald sphere constructions for powders and polycrystalline materials.