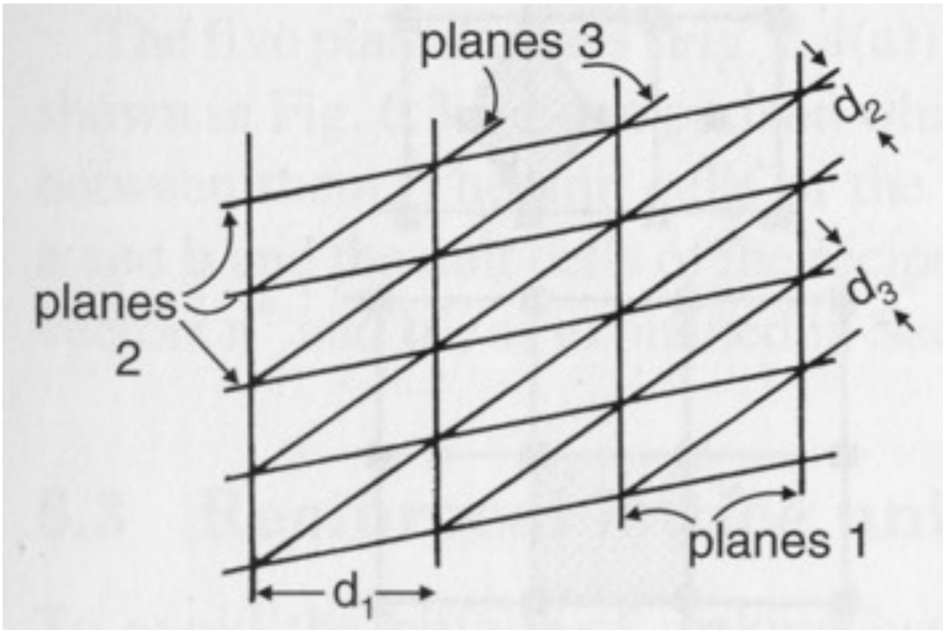
Texture and Anisotroy

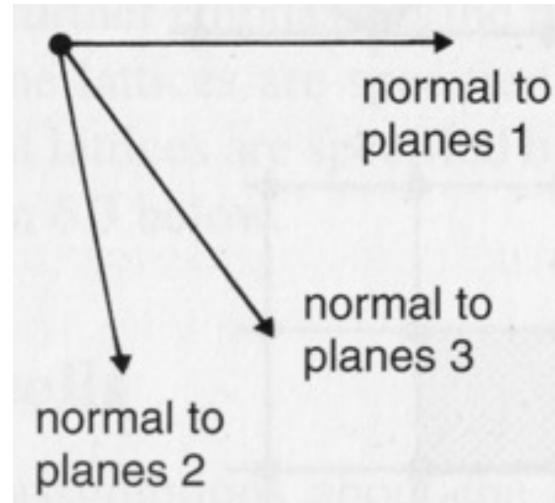
Part III:

Chapter 8. Transmission electron microscopy-based techniques

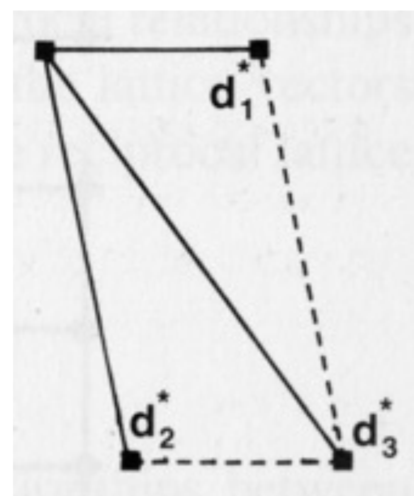
Construction of Reciprocal lattice

RL direction



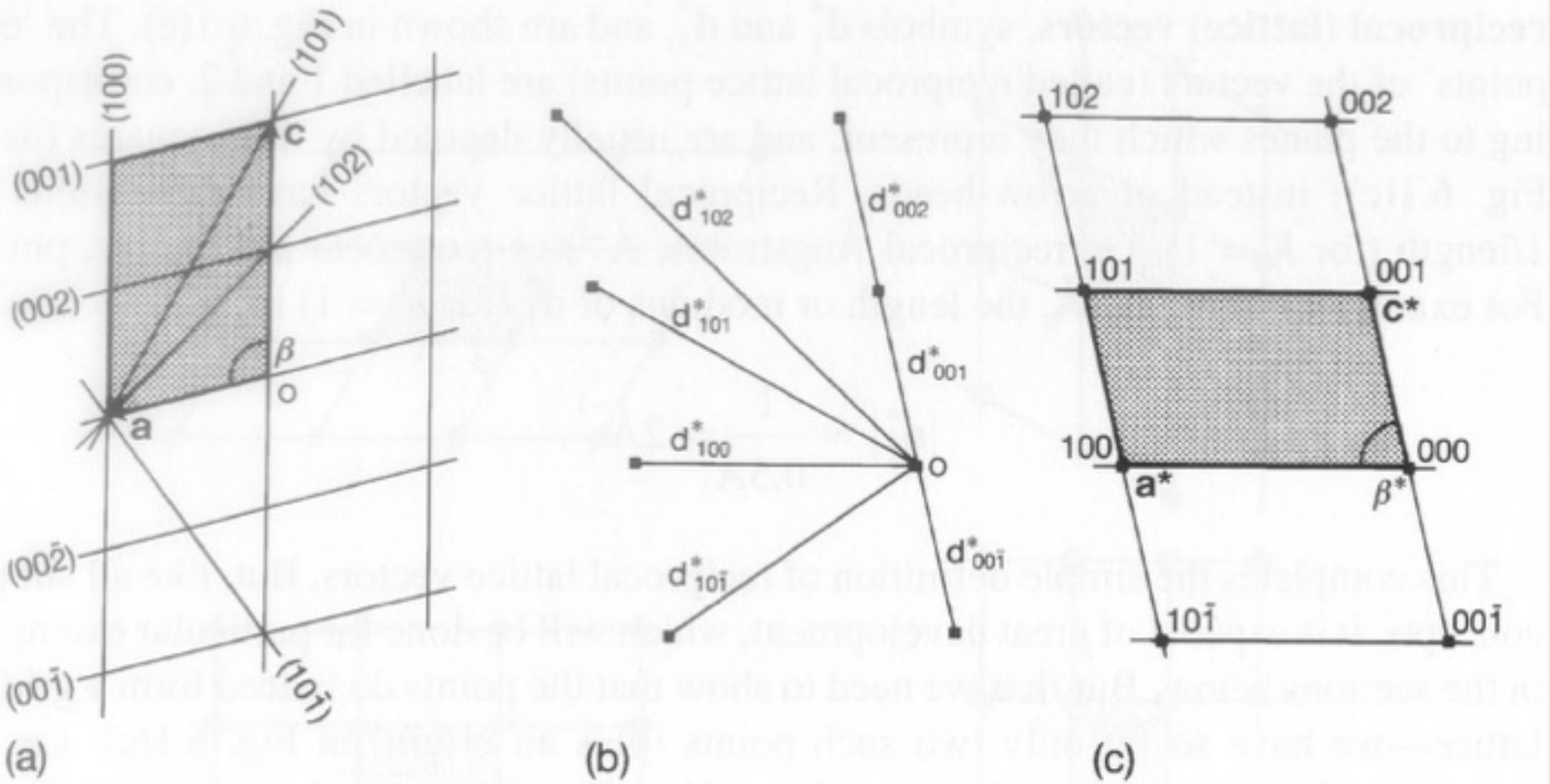


RL magnitude

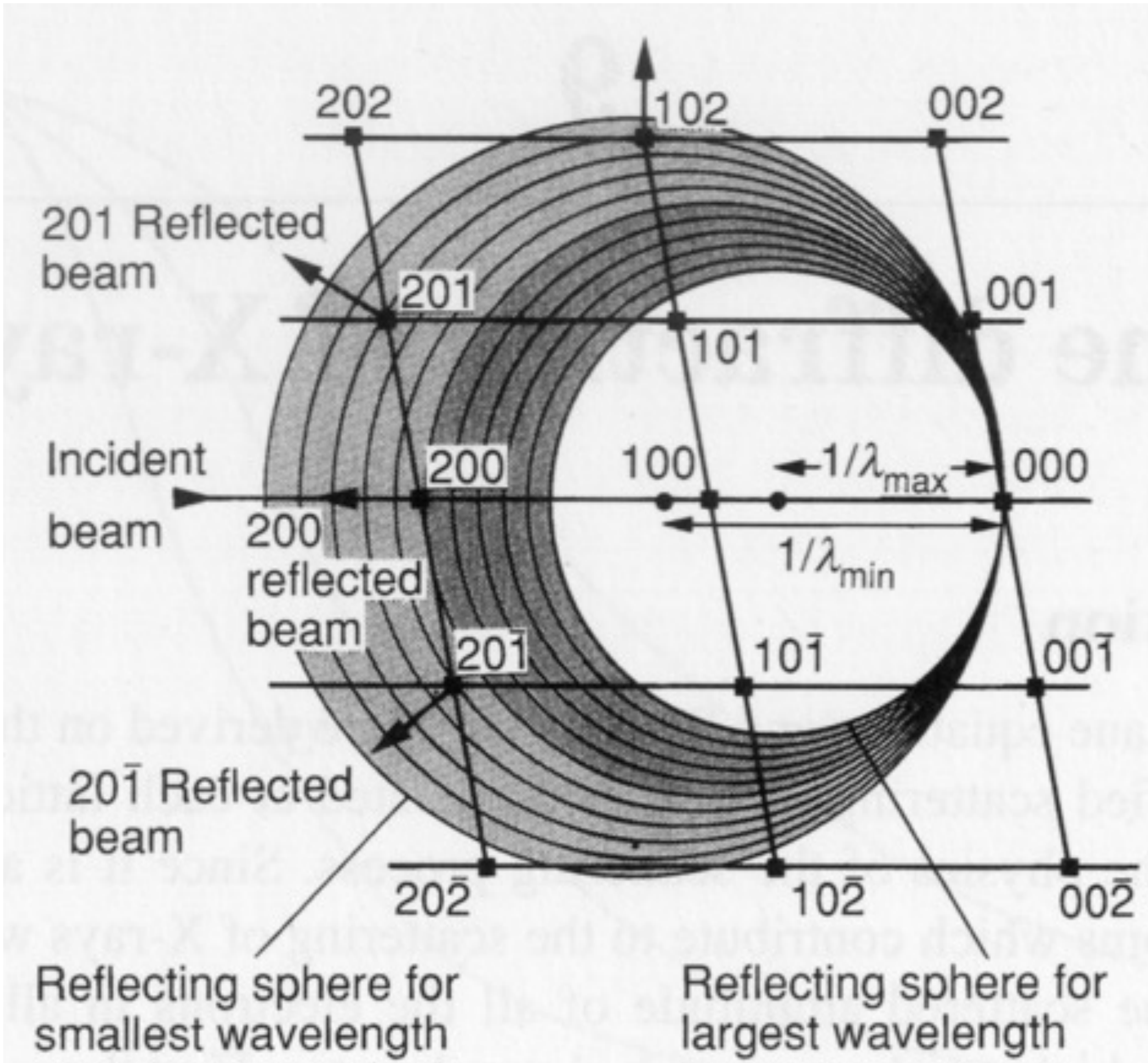


Real Lattice

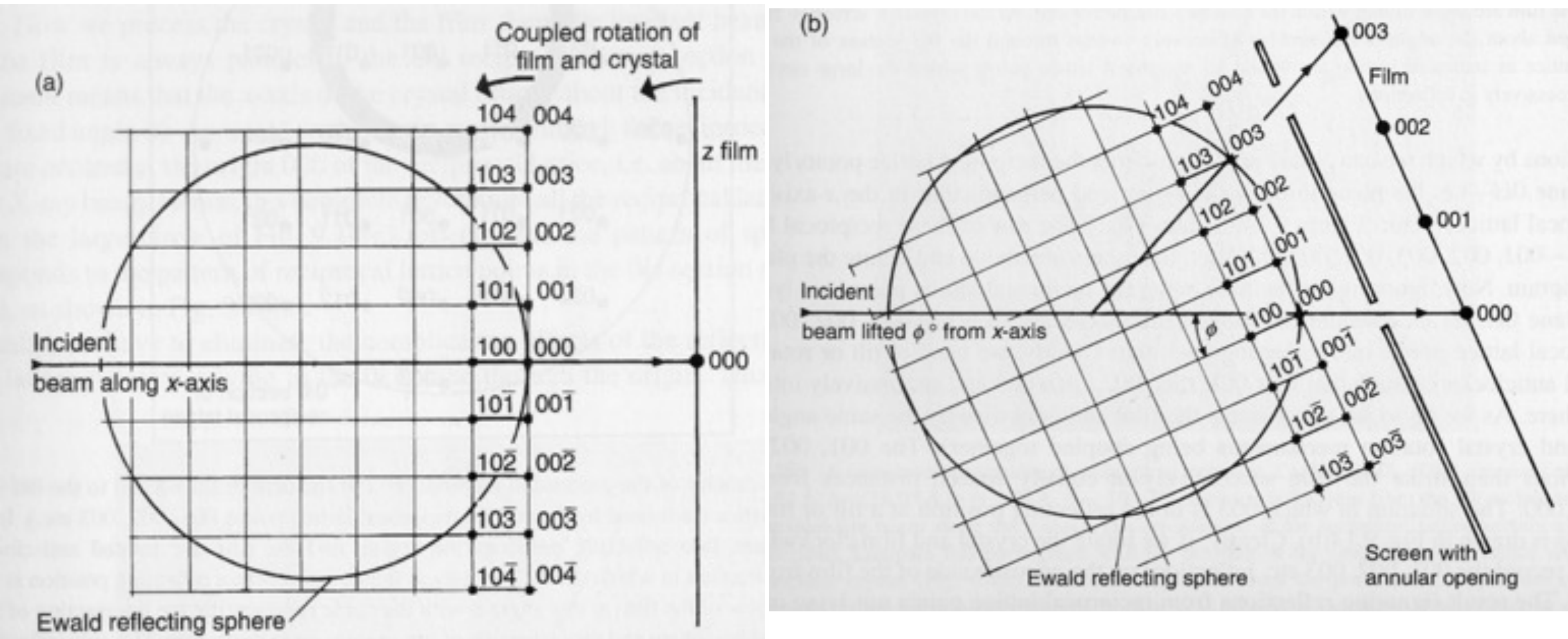
Example of Reciprocal lattice



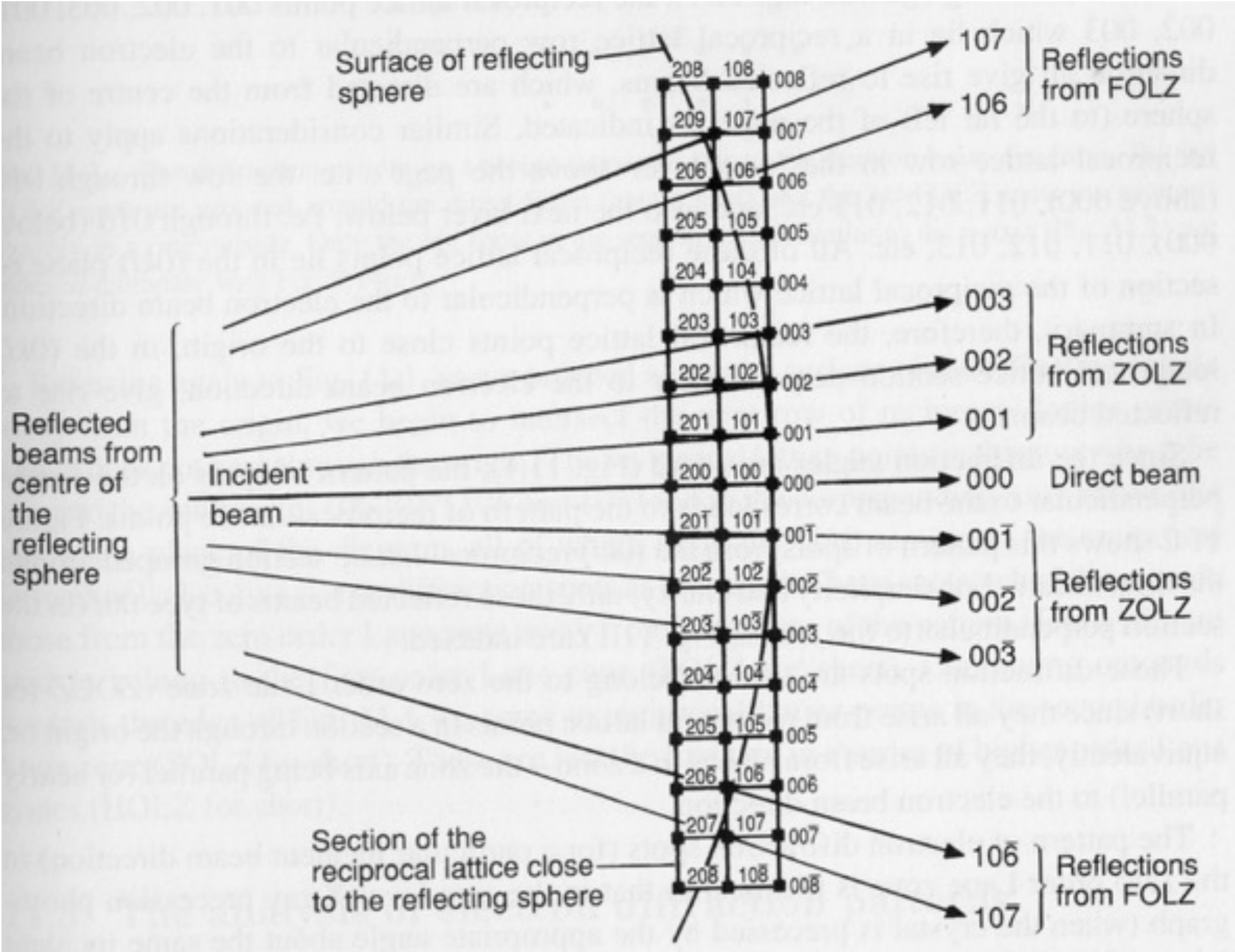
Laue diffraction in Reciprocal lattice



Rotation of Reciprocal lattice

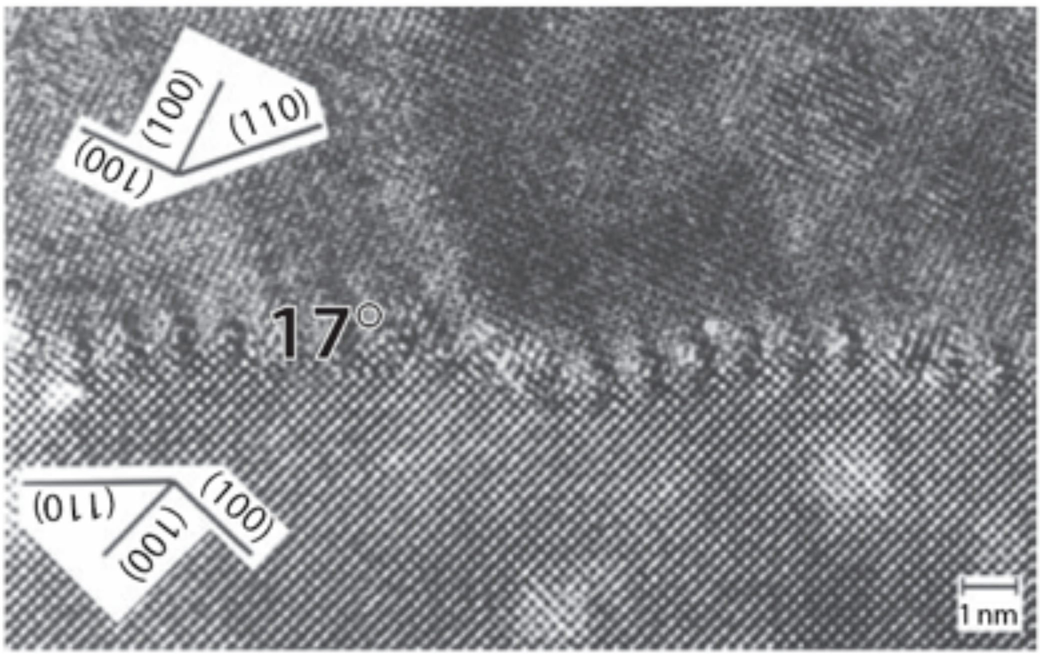


Reciprocal lattice in TEM



High-resolution electron microscopy

determine the atomistic structure and interfaces



Drawback:
- complicated operations
- imaging low-index lattice planes (spatial resolution=0.15nm)
- difficult sample preparations and very thin samples
- complicated interpretation

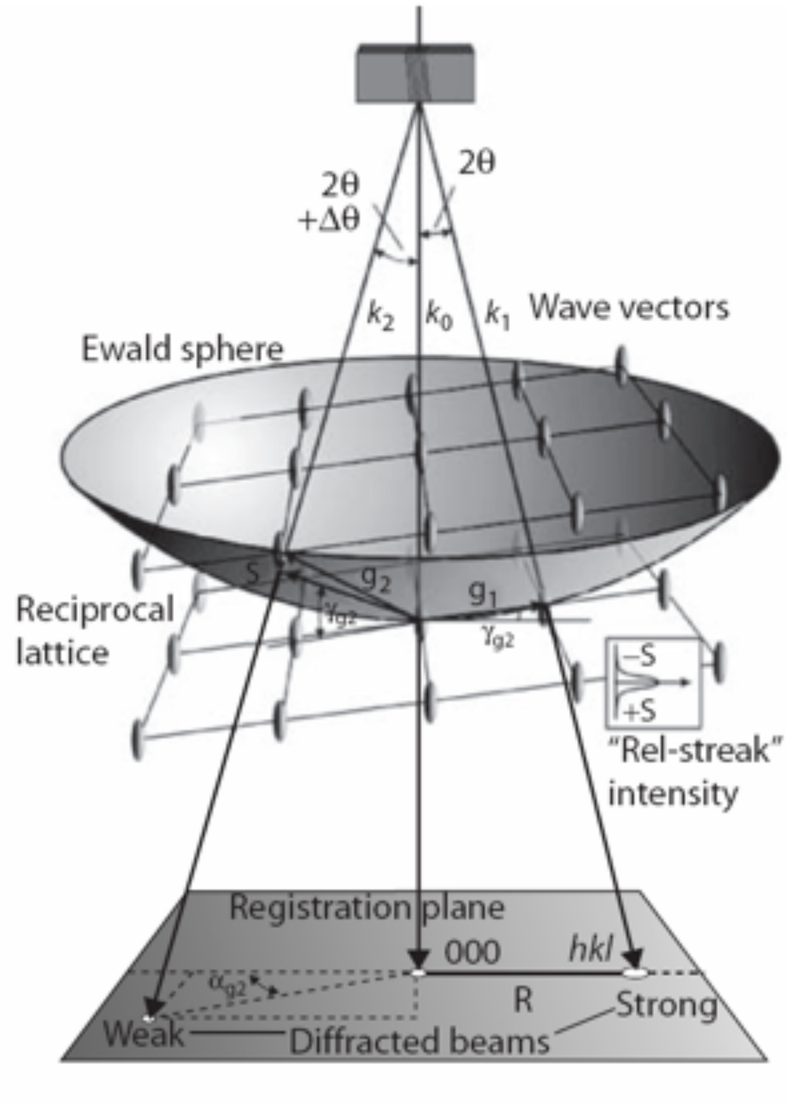
HREM photograph of a 17°/⟨100⟩ grain boundary in gold in which the interfacial structure can be resolved. (Courtesy of W. Wunderlich.)

Selected area diffraction patterns

Al with a <110> zone axis

Characteristic diffraction from single crystal yields a regular arrangement of individual diffraction spots.

Formation of diffraction spots I



$$n\lambda = 2d\sin\theta$$

$$2d\sin\theta \approx 2d\theta = \frac{2dR_{hkl}}{2L}$$

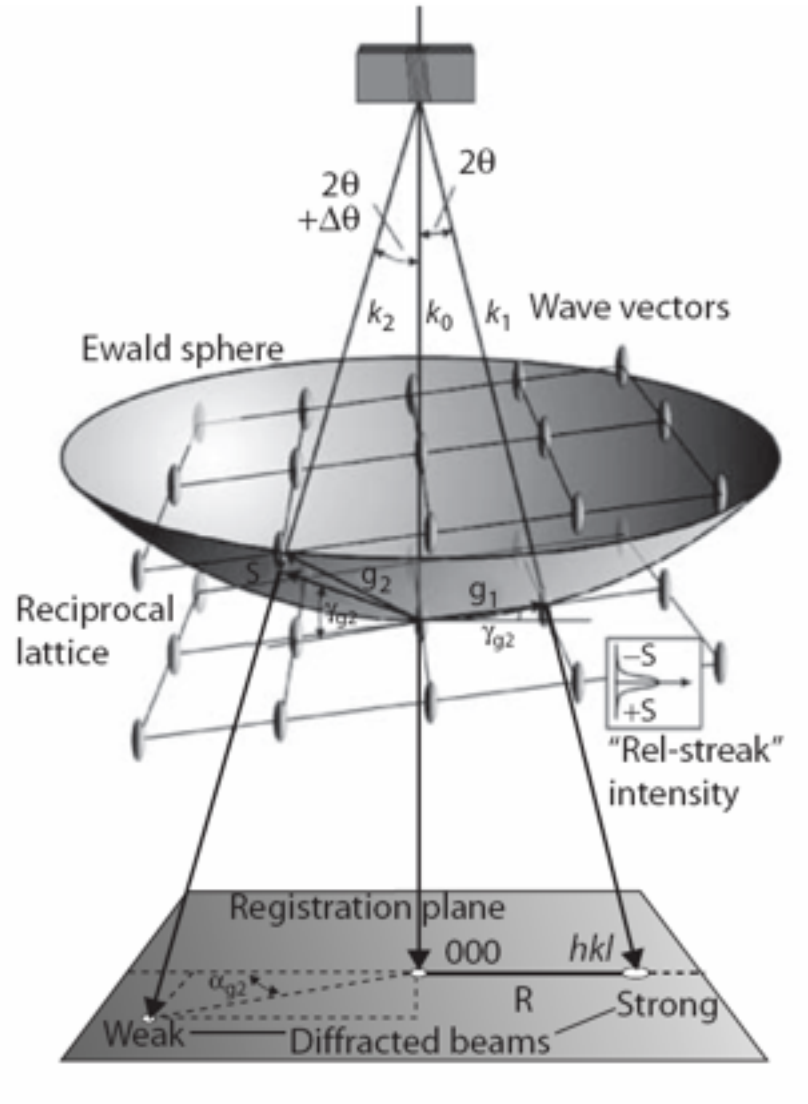
With n=1

$$\lambda L = dR_{hkl}$$

$$R_{hkl} = \frac{\boxed{\lambda L}}{d}$$

camera constant

Formation of diffraction spots II

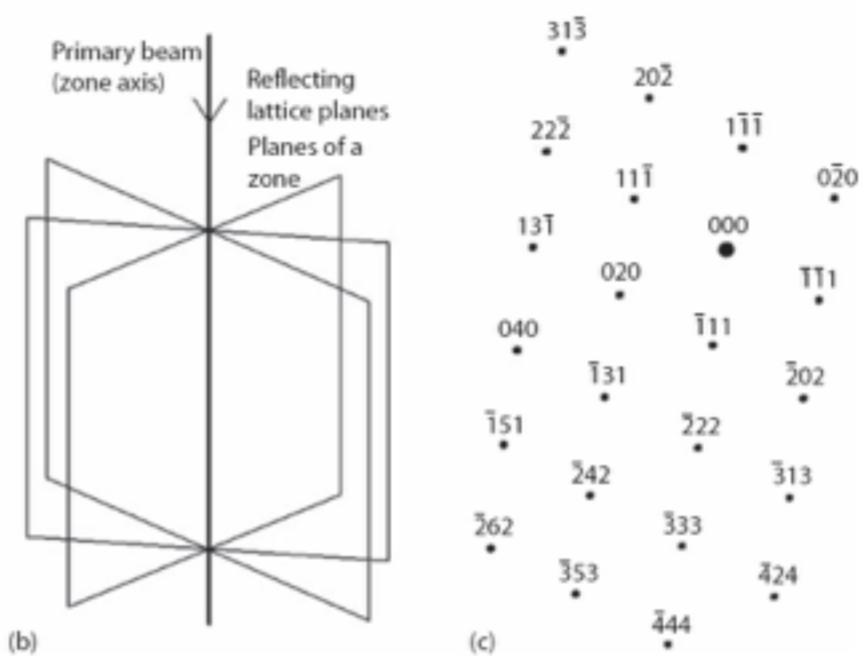


R_{hkl} the distance between a diffraction spot in the diffraction pattern and the primary beam (the length of the vector R_{hkl})

$$R_{hkl} \approx \frac{1}{d}$$

the diffraction pattern: intersection between the points in the reciprocal lattice and the reflection sphere in Edward sphere

SAD diffraction spots in TEM



with small apertures (5-10μm) the spatial resolution to 0.2-0.5μm

orientation determination error: 5^o-10^o, best angular resolution of 0.1^o

Schematic diagrams showing the formation of SAD patterns. (a) Formation of diffraction spots. (Courtesy of S. Zaefferer.) (b) Primary beam as a zone axis for several diffracting planes. (c) Indexed diffraction pattern of a [101] zone axis (see Figure 8.2).

Formation of SAD ring patterns in polycrystalline

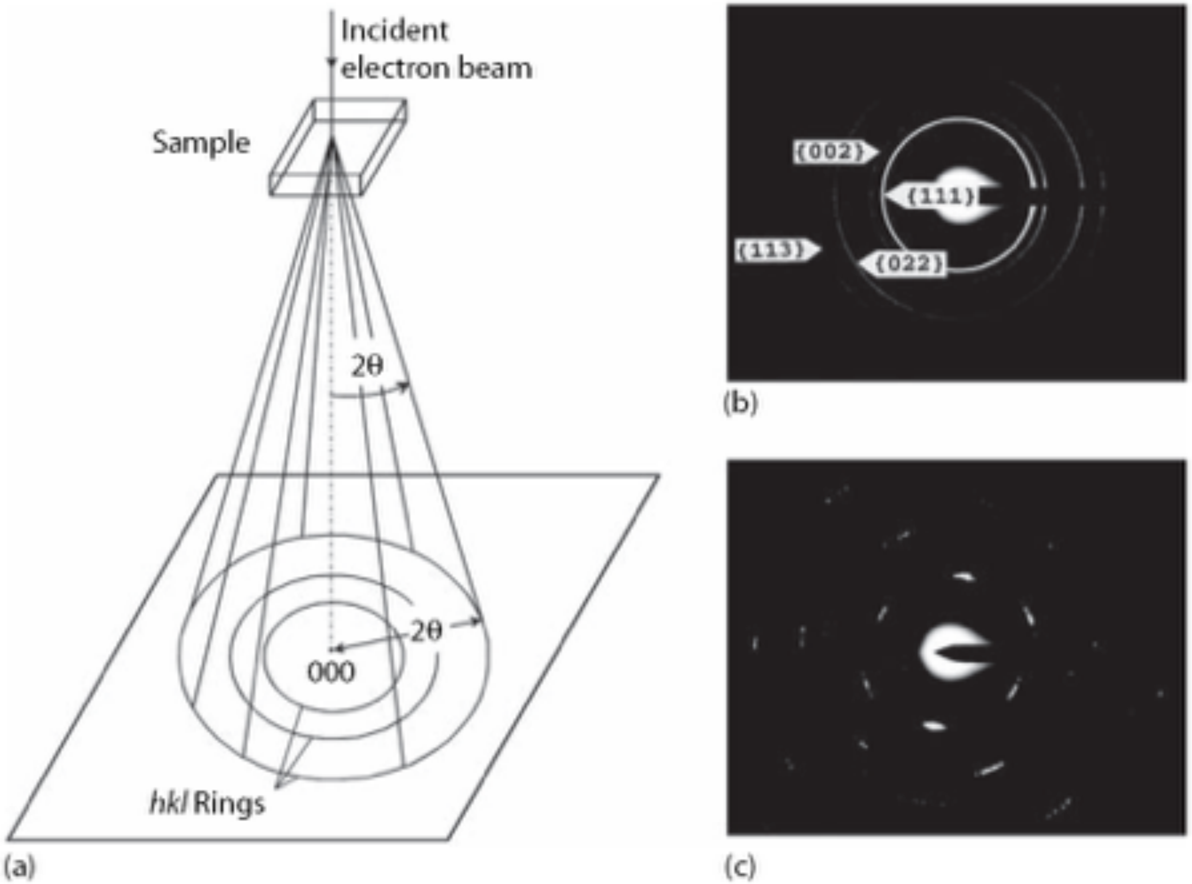
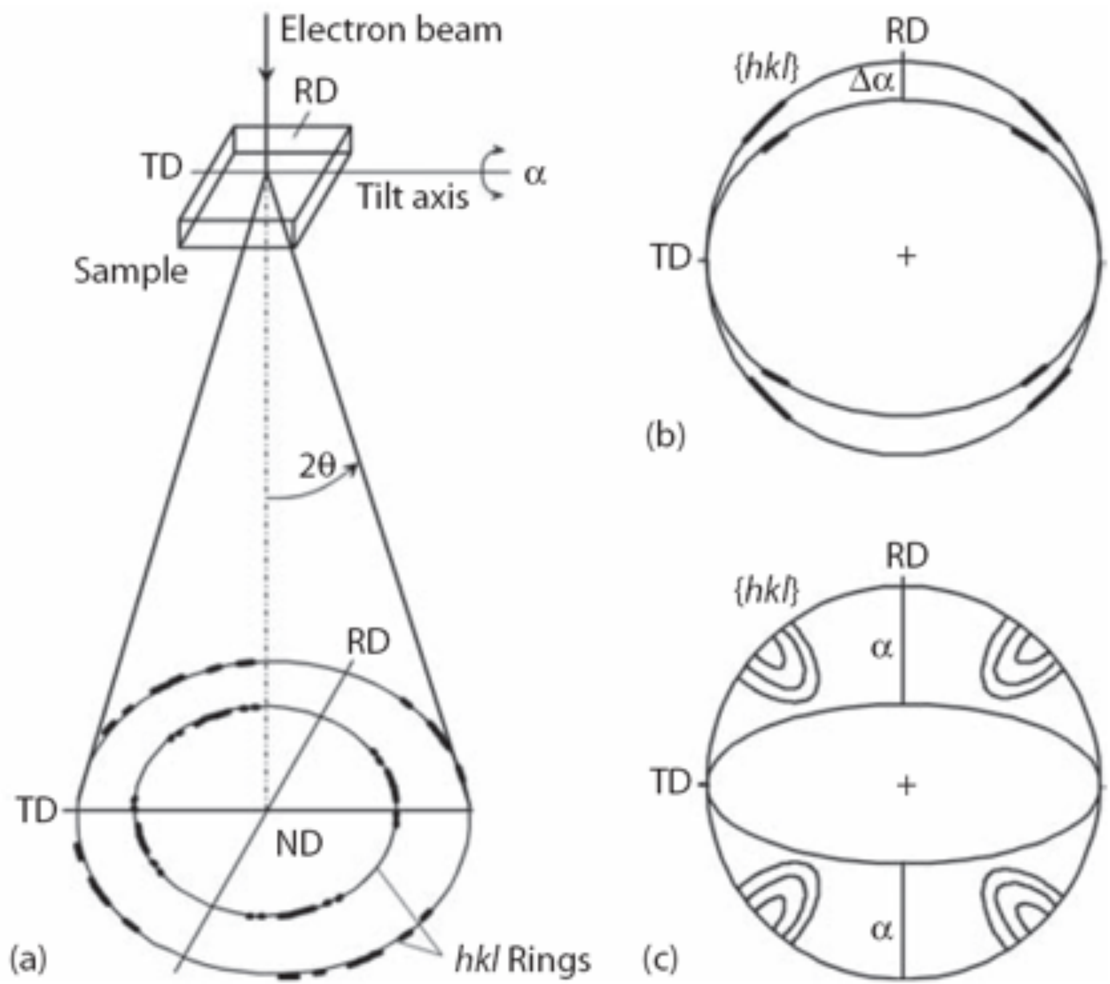


FIGURE 8.4
(a) Schematic illustration of formation of SAD ring patterns in polycrystalline assemblies. (b) SAD diffraction pattern of evaporated aluminum with random texture. (c) SAD diffraction pattern of cold-rolled aluminum with strong texture. (Courtesy of H. Weiland.)

Formation of SAD pole figures in TEM

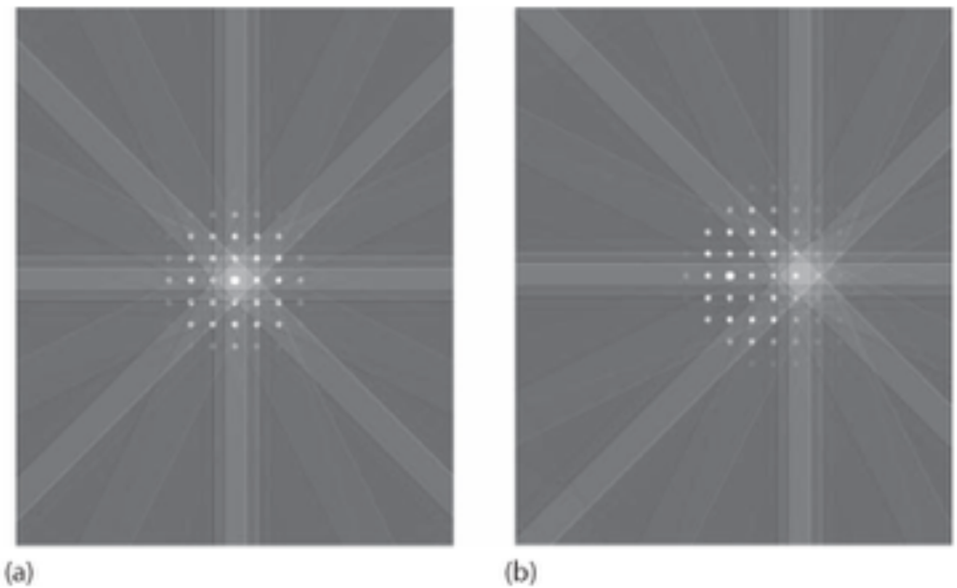


The tilting angle in TEM is limited to a range of $\pm 60^{O}$

$\alpha = \pm 60^{O}$

(a) Formation of SAD pole figures in a TEM; (b) and (c) coverage of the pole figure as the angle α is gradually increased.

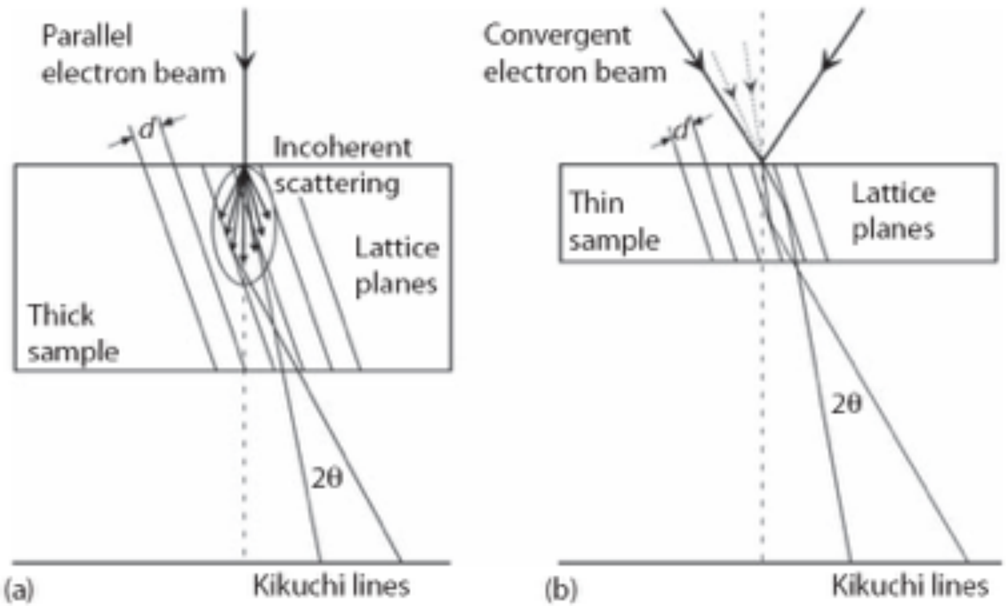
Kikuchi pattern in TEM



In the Kikuchi patterns an electron beam entering a crystalline is subjected to elastic or diffuse diffraction.
The elastic diffraction gives rise to distinct diffraction spots in the back focal planes (SAD).
In diffuse diffraction electrons arrive the atomic planes in all directions and these electrons undergo elastic (Bragg) scattering.

Simulated diffraction patterns for a [100] axis showing both SAD spots and Kikuchi lines for (a) untilted, that is, exact [100] orientation and (b) 2° tilted orientation. These patterns show that Kikuchi lines have much greater sensitivity to crystal orientation than SAD spots (simulation program TOCA by Zaefferer, 2002).

Formation of Kikuchi patterns in TEM

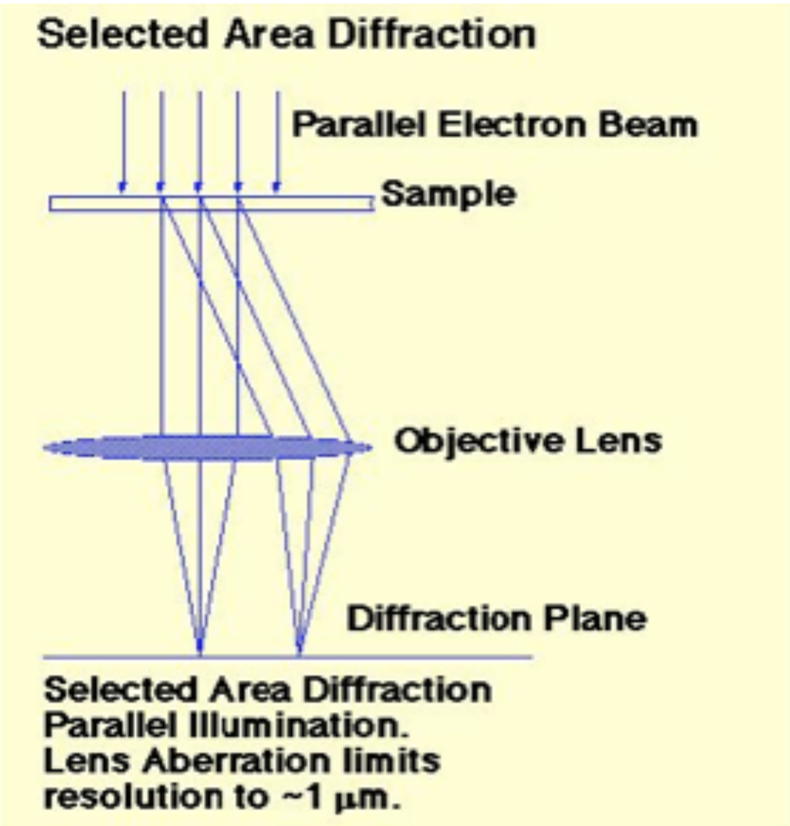


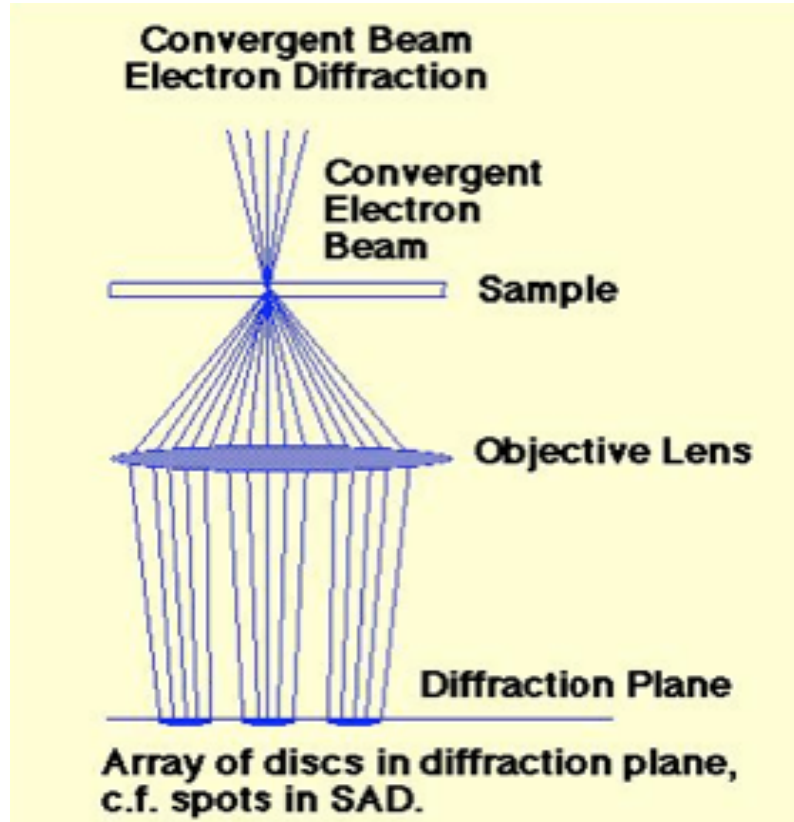
Spatial resolution: 1μm

In the Kikuchi patterns an electron beam entering a crystalline is subjected to elastic or diffuse diffraction.
The elastic diffraction gives rise to distinct diffraction spots in the back focal planes (SAD).
In diffuse diffraction electrons arrive the atomic planes in all directions and these electrons undergo elastic (Bragg) scattering.

Formation of Kikuchi patterns in a TEM for (a) parallel beam, thick sample and (b) convergent beam, thin sample.

SAD vs. CBED





From J. Mansfield (U. Michigan)

CBED

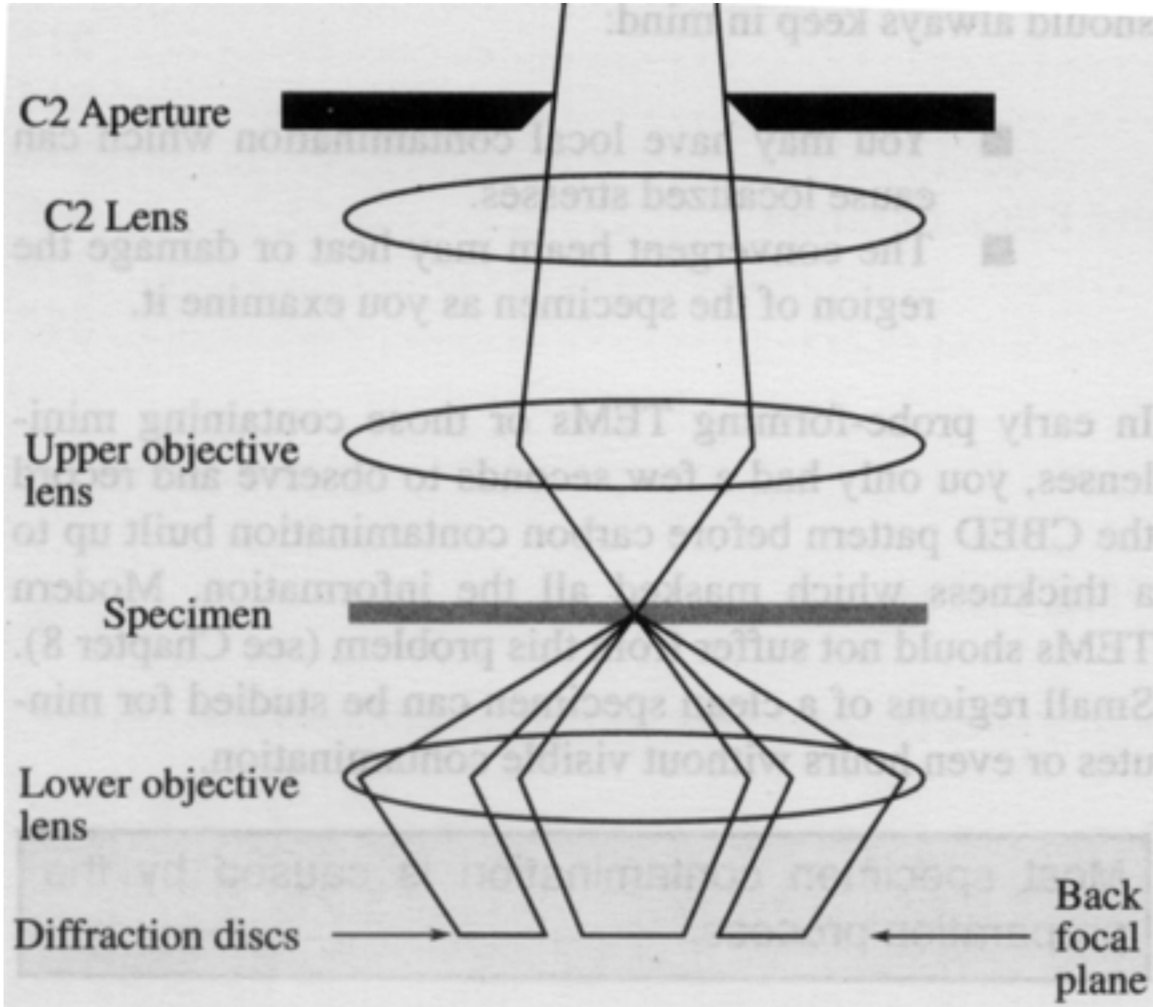
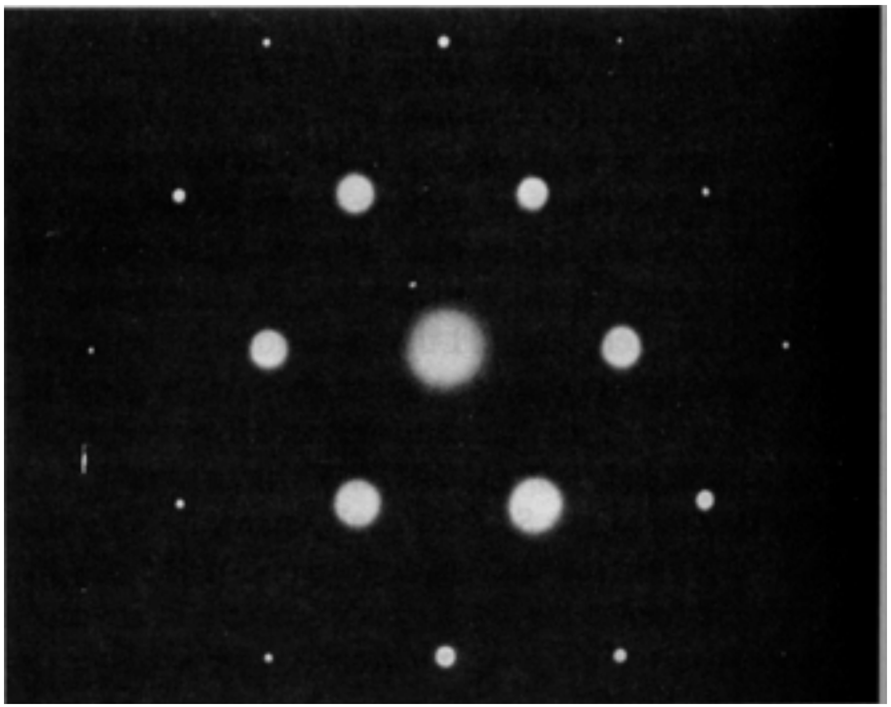


Figure 20.1. Ray diagram showing CBED pattern formation. A convergent beam at the specimen results in the formation of disks in the BFP of the objective lens.

SAD vs. CBED patterns



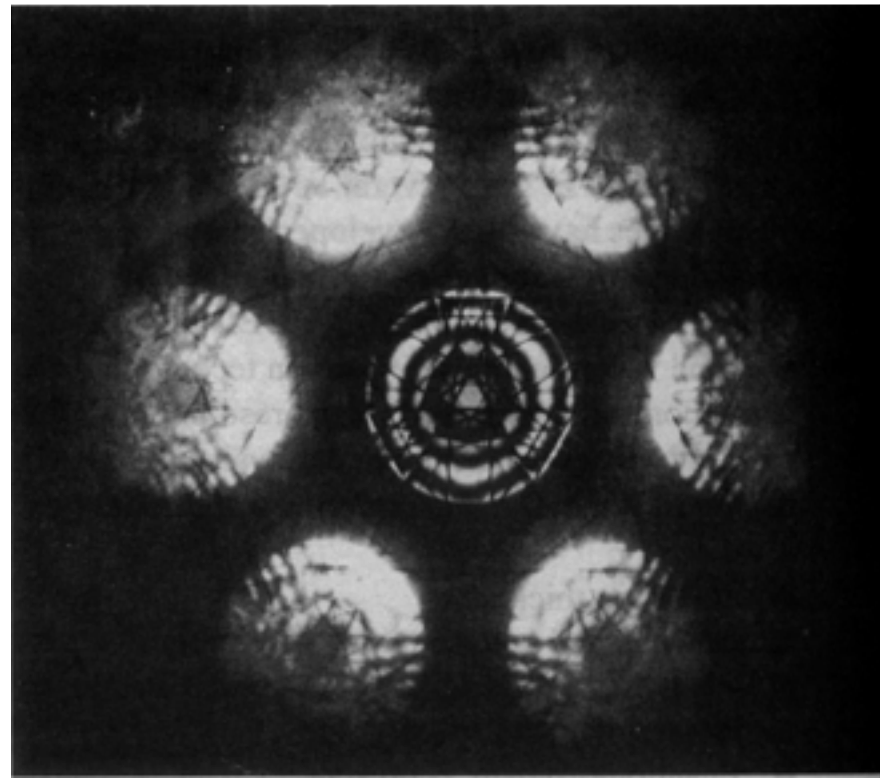
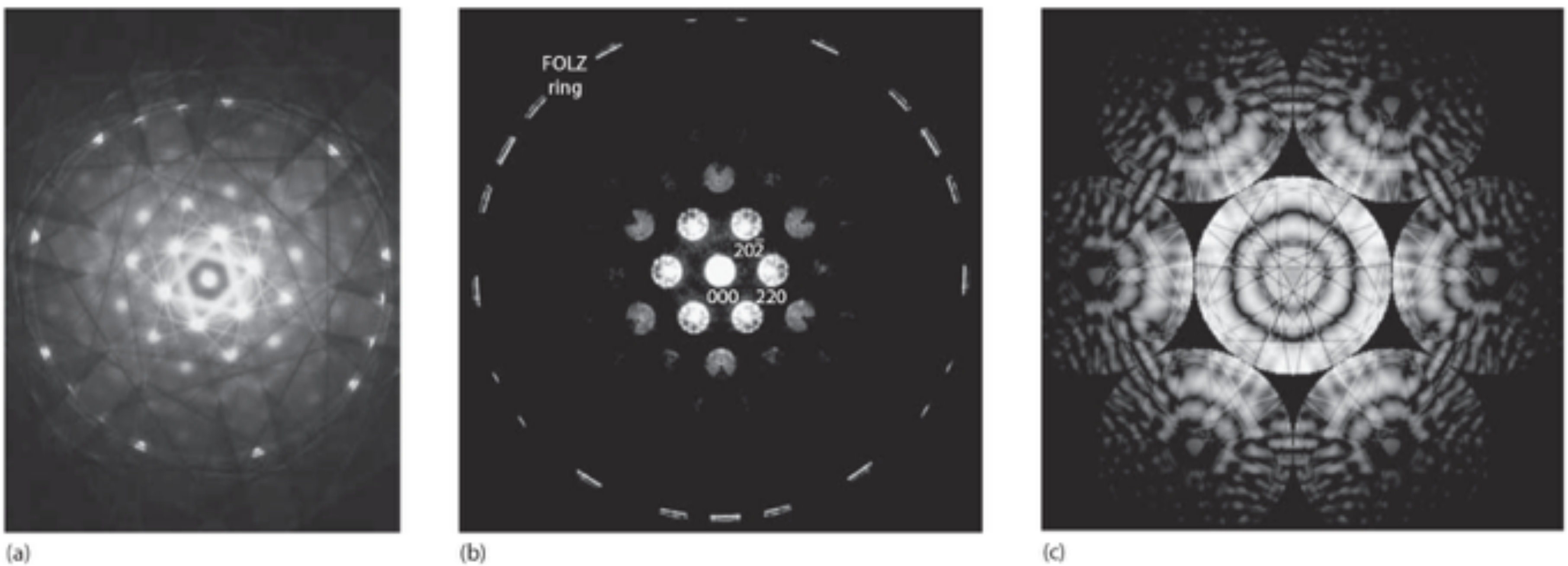


Figure 20.2. (A) SAD pattern from [111] Si showing the first few orders of diffraction spots but no Kikuchi lines. (B) CBED pattern from [111] Si showing dynamical contrast within the disks as well as Kikuchi and other lines.

Micro-diffraction patterns

With increasing convergence of the incident electron beam, the diffracted disks widen, with their diameter being controlled by the convergence angle. This give rise to CBED also referred to as Kossel-Moellenstedt diffraction. CBED is not directly used for microtexture measurements.



Microdiffraction patterns from [111]-oriented crystals obtained with increasing convergence of the electron beam. (a) Kikuchi lines and HOLZ lines in the zero-order Laue zone (ZOLZ) (Nimonic PE16). (b) Widened ZOLZ disks with intensity variations plus first-order Laue zone (FOLZ) lines (silicon). (Courtesy of K. Tsuda.) (c) Central diffraction spot with HOLZ lines (simulated). (Courtesy of R. Holmestad.)

Micro-diffraction patterns

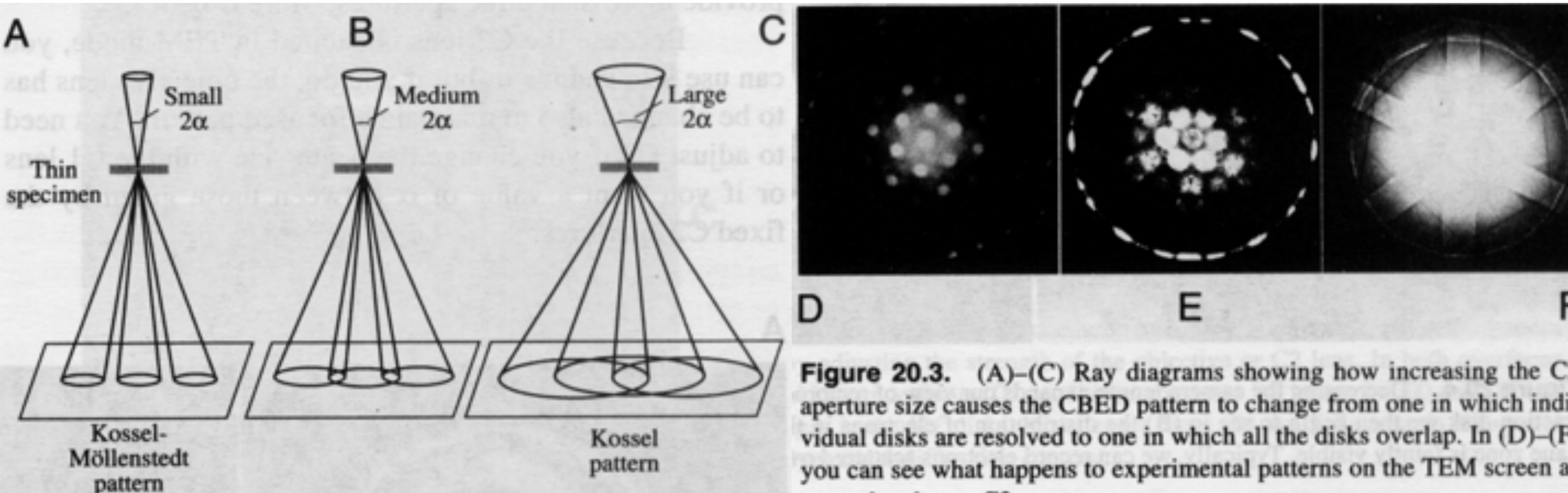


Figure 20.3. (A)–(C) Ray diagrams showing how increasing the C2 aperture size causes the CBED pattern to change from one in which individual disks are resolved to one in which all the disks overlap. In (D)–(F) you can see what happens to experimental patterns on the TEM screen as you select larger C2 apertures.