FACULTÉ DES SCIENCES ET TECHNOLOGIES
Département Physique

Université de Lille

Imperfections – deformation and microstructures in polycrystals

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8- Textures in metals

8- Textures in metals
a- Typical tests

Textures in polycrystals

- Complex phenomenon
- Need for multi-scale modeling
- Very dependent on material history

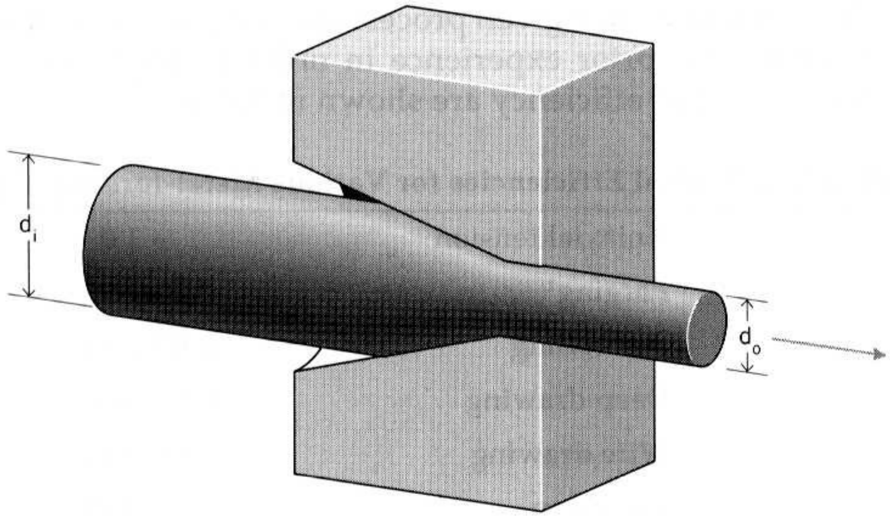
If deformation experiment is too complicated

- Complex textures
- Difficult to understand

Therefore, we often rely on a short set of typical tests

- Compression
- Tension
- Rolling
- And others

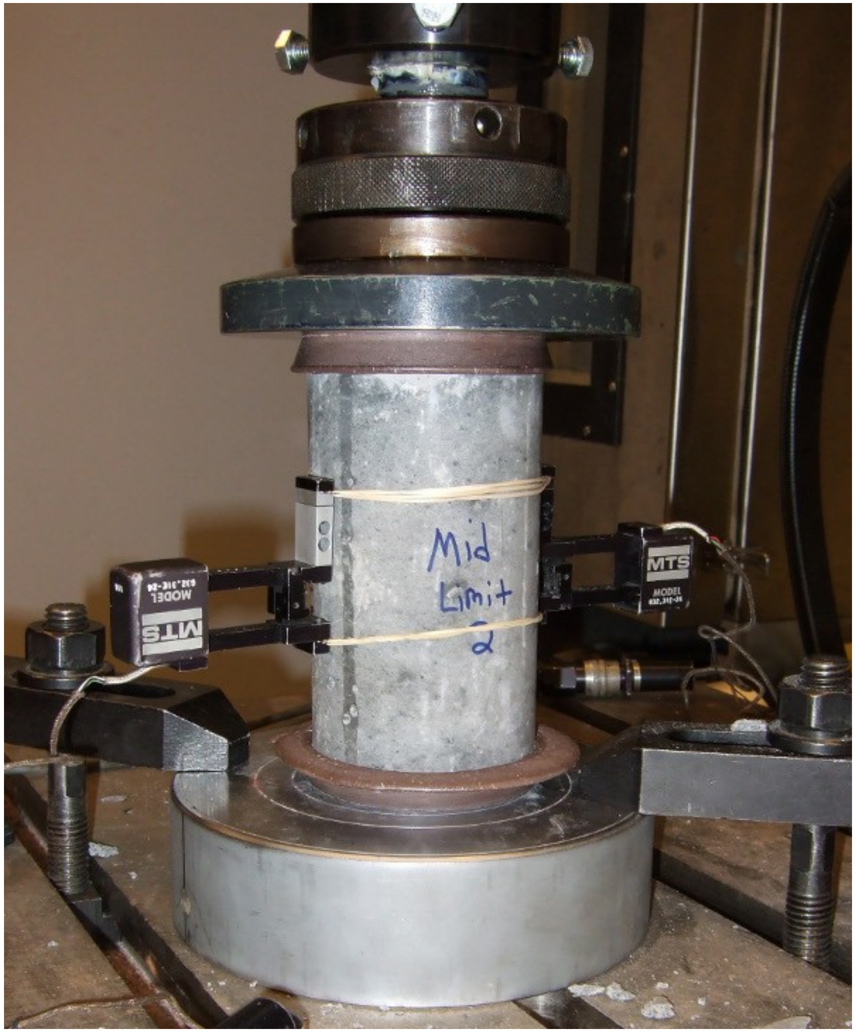
Tensile test / wire drawing



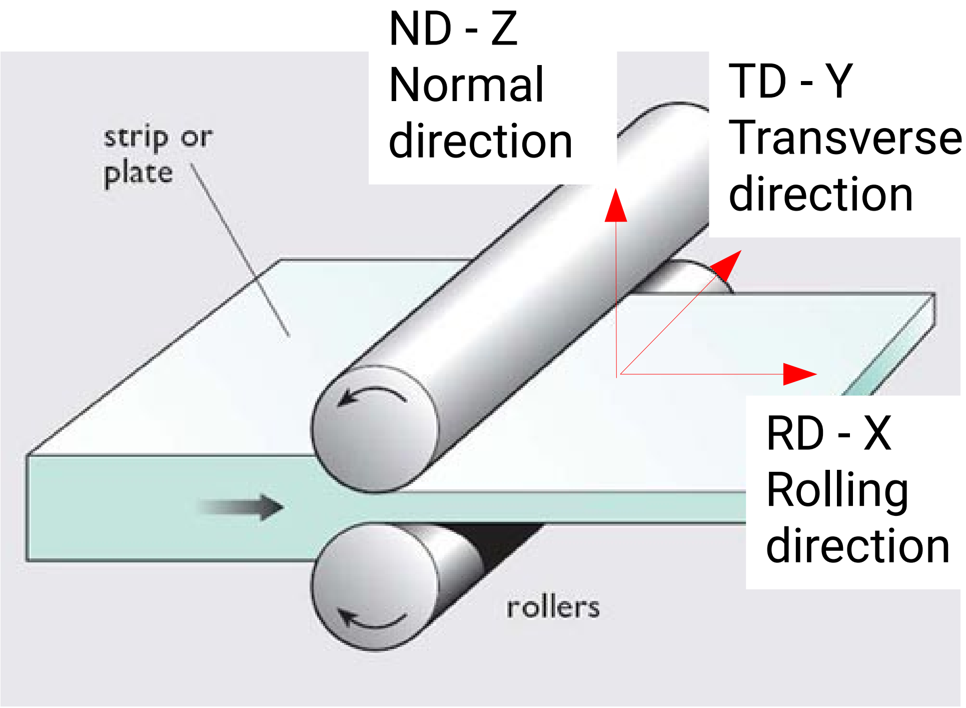
$$\epsilon = \begin{bmatrix} -\Delta/2 & 0 & 0 \\ 0 & -\Delta/2 & 0 \\ 0 & 0 & +\Delta \end{bmatrix}$$

Images :
- Wikipedia
- A. Rollet

Compression



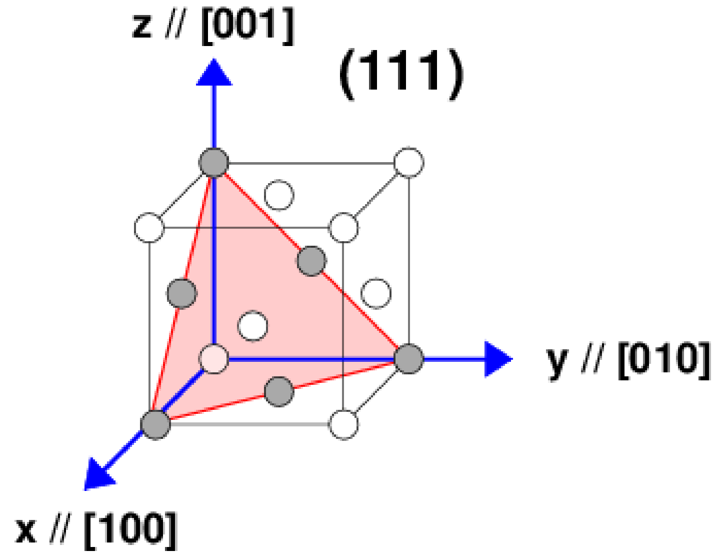
$$\epsilon = \begin{bmatrix} \Delta/2 & 0 & 0 \\ 0 & \Delta/2 & 0 \\ 0 & 0 & -\Delta \end{bmatrix}$$



$$\epsilon = \begin{bmatrix} \Delta & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -\Delta \end{bmatrix}$$

8- Textures in metals
b- Face centered cubic

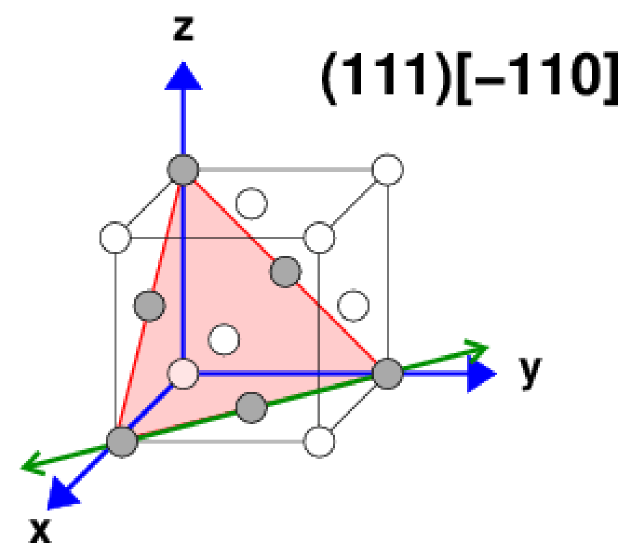
Slip systems – fcc



Slip systems in fcc metals:

- slip direction: <110>
- slip plane: {111}

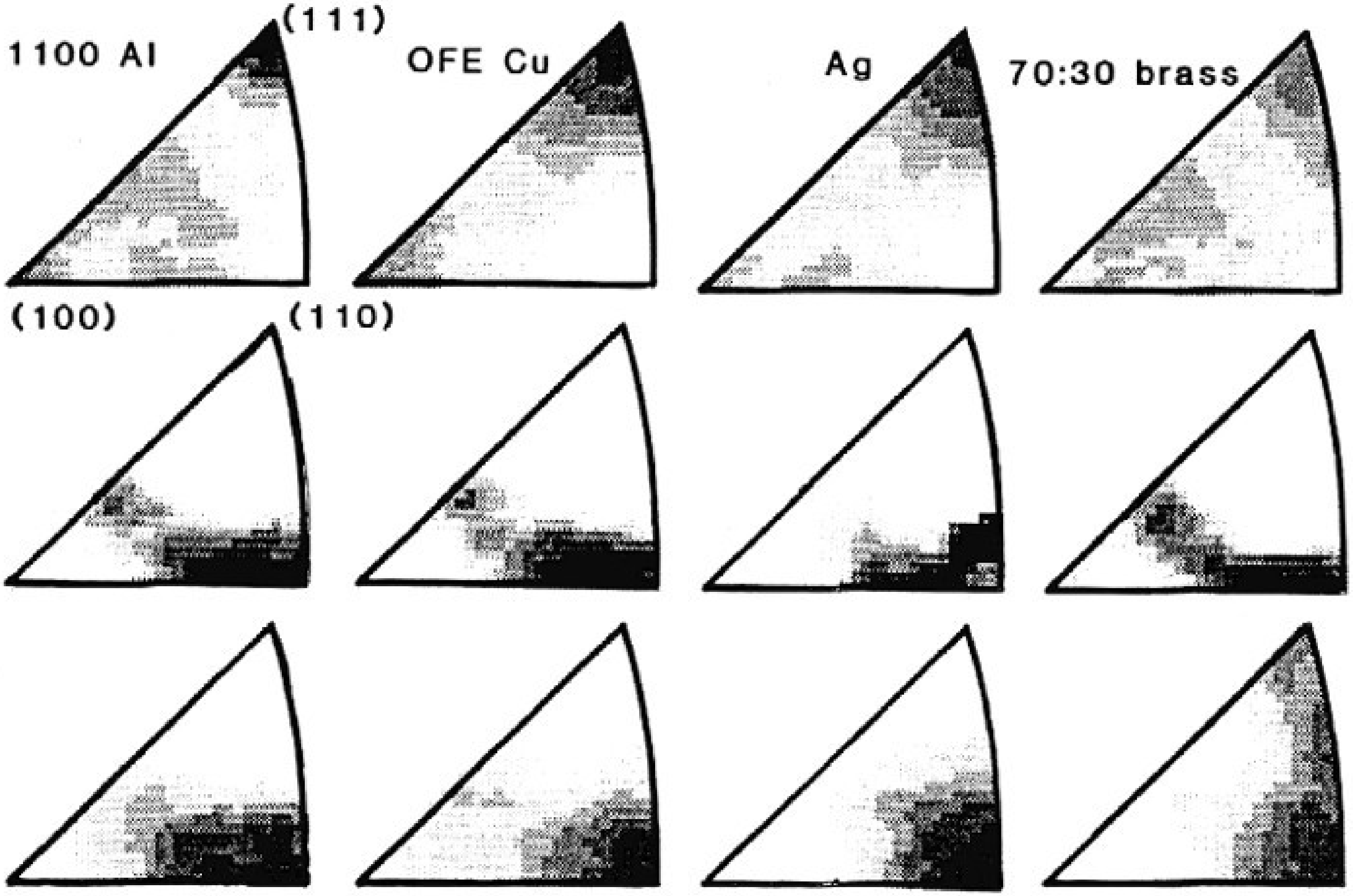
System: (111)[-110]



4 planes {111} : (111), $(\bar{1}11)$, $(1\bar{1}1)$, $(11\bar{1})$;

- For each: 3 directions <110>
- 12 systems, that can each operate in 2 directions (+ ou -).

Fcc – Compression Textures



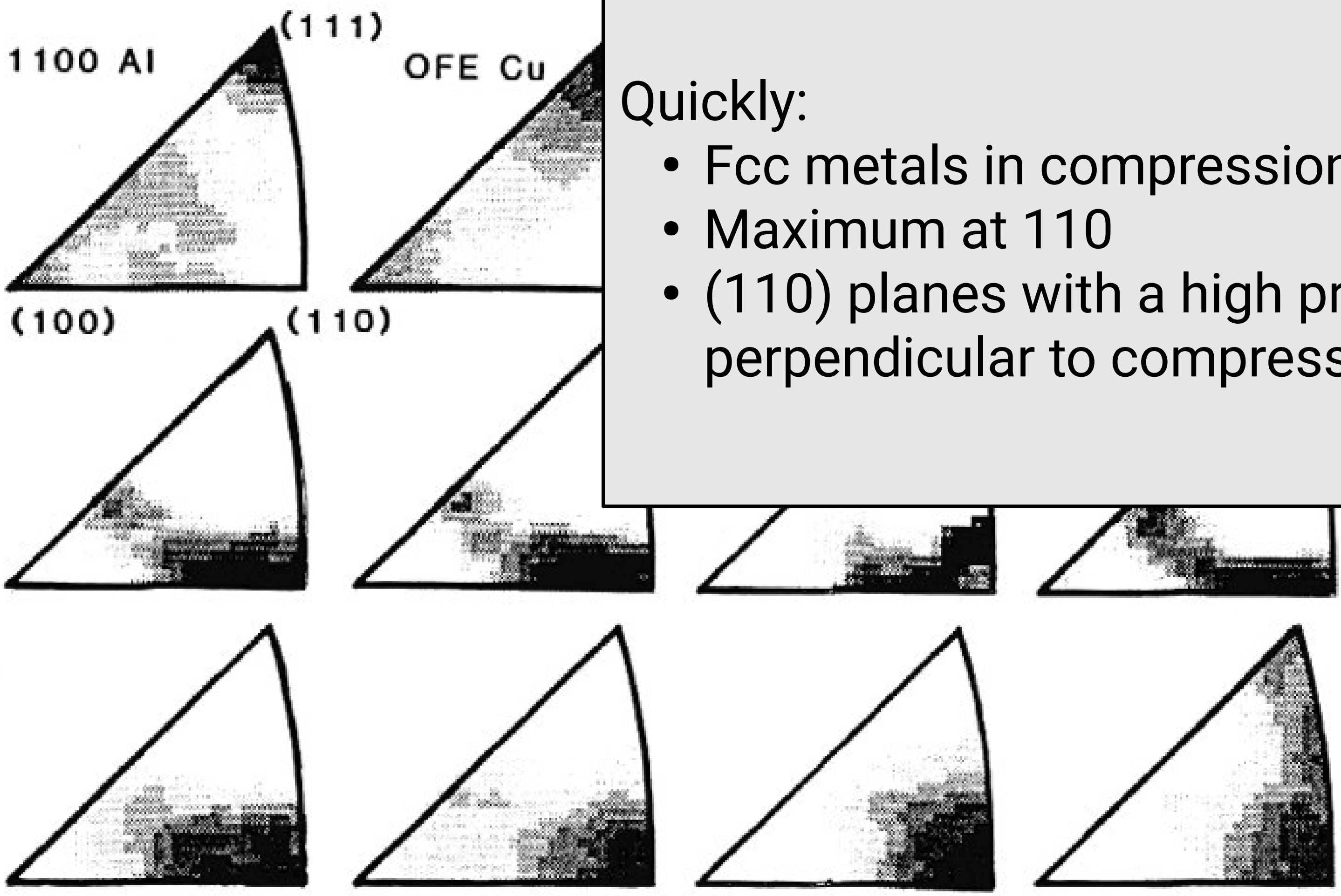
Starting texture

Simulated texture

Experimental texture

Image Kocks, Tomé, Wenk, 1998, Ch. 5

Fcc – Compression Textures



Quickly:

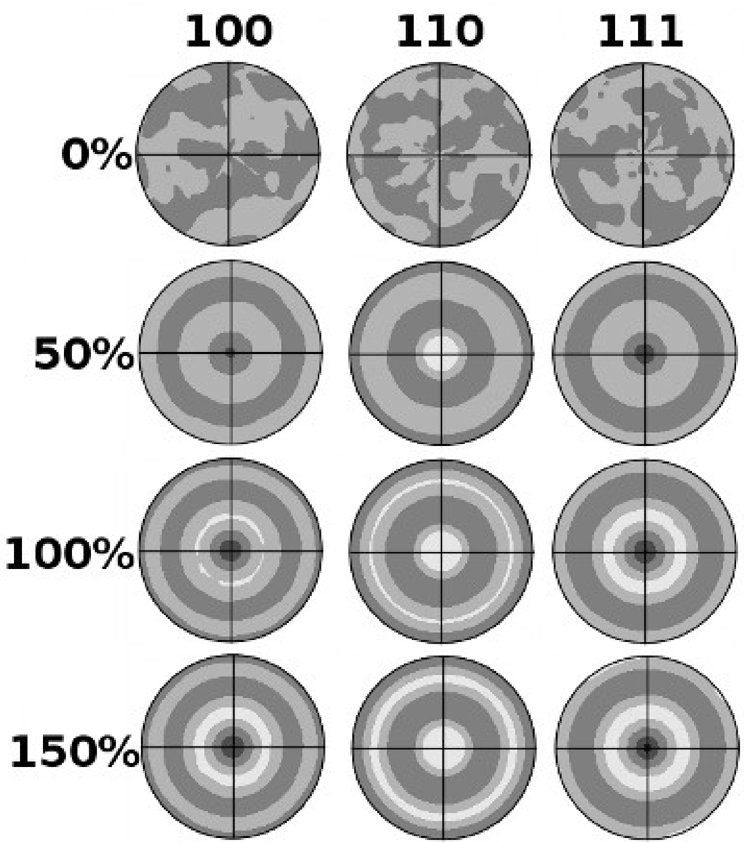
- Fcc metals in compression
- Maximum at 110
- (110) planes with a high probability of begin perpendicular to compression

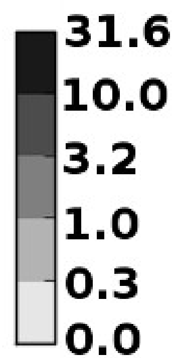
Experimental texture

Image Kocks, Tomé, Wenk, 1998, Ch. 5

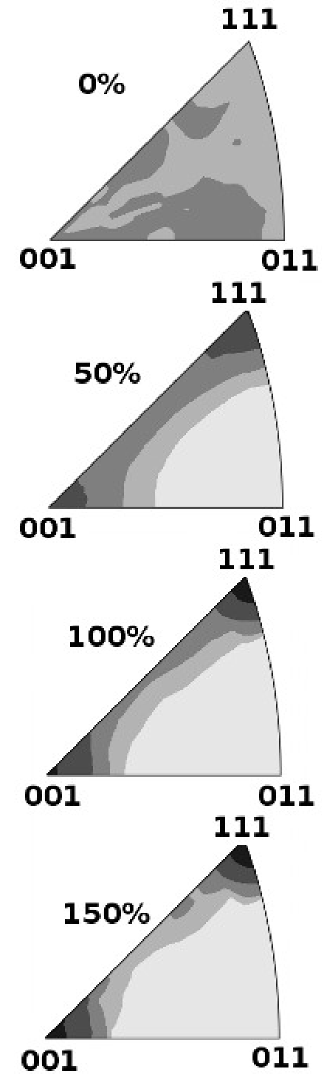
Fcc – Drawing Textures

Textures simulations for drawing of fcc metal



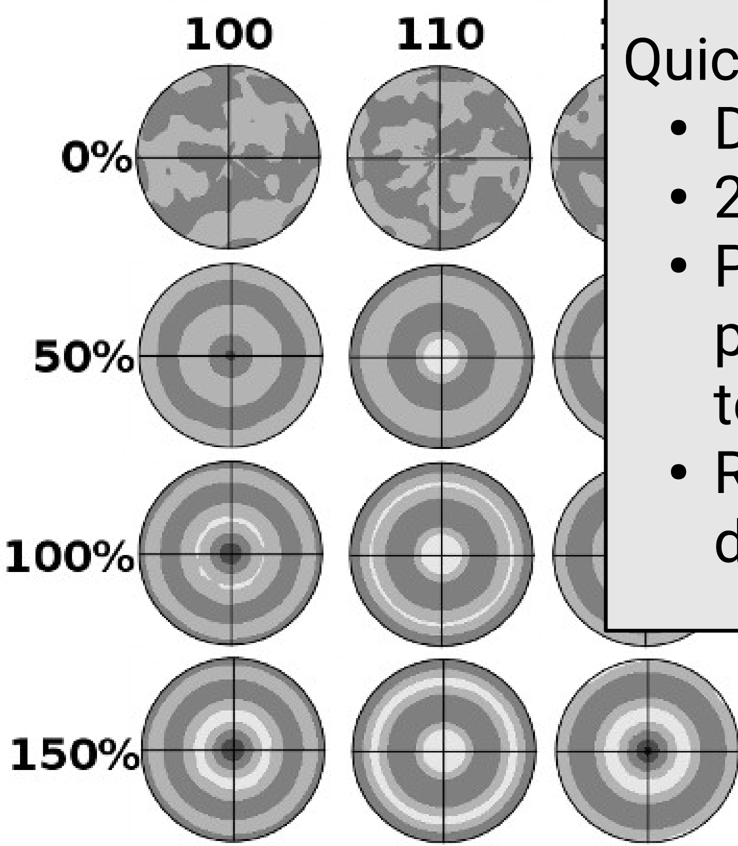


Pole figures (tension direction at the center)



Inverse pole figures of the tension direction

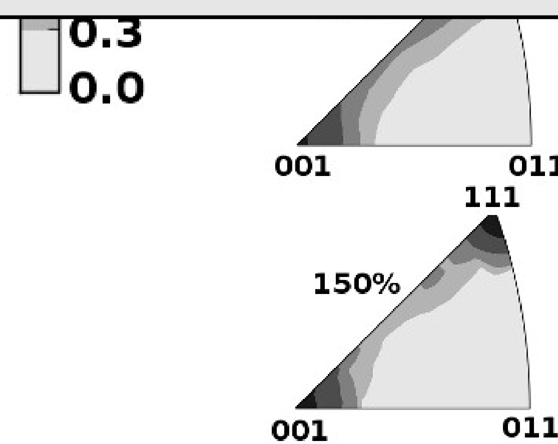
Textures simulations for drawing of fcc metal



Pole figures (tension direction at the center)

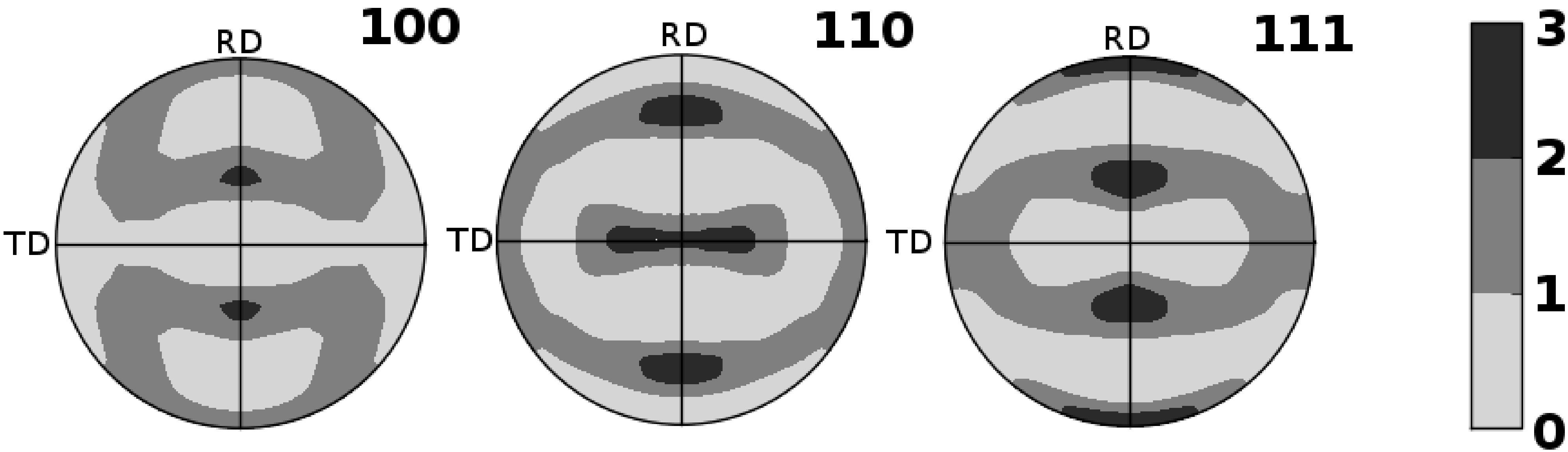
Quickly:

- Drawing of fcc metals
- 2 maxima at 100 and 111
- Planes (100) and (111) with a high probability to be perpendicular to the tension direction
- Relative weight of 100 and 111 depends on the material.



Inverse pole figures of the tension direction

Fcc – Rolling texture



Texture simulation after 50 % rolling for a metal with the fcc structure

Rough characteristics :

- (110) planes // rolling plane
- <1$\bar{1}$2> // rolling direction

In reality, one often compares the obtained texture to classical cases (copper, brass, etc).

8- Textures in metals
c- Centered cubic

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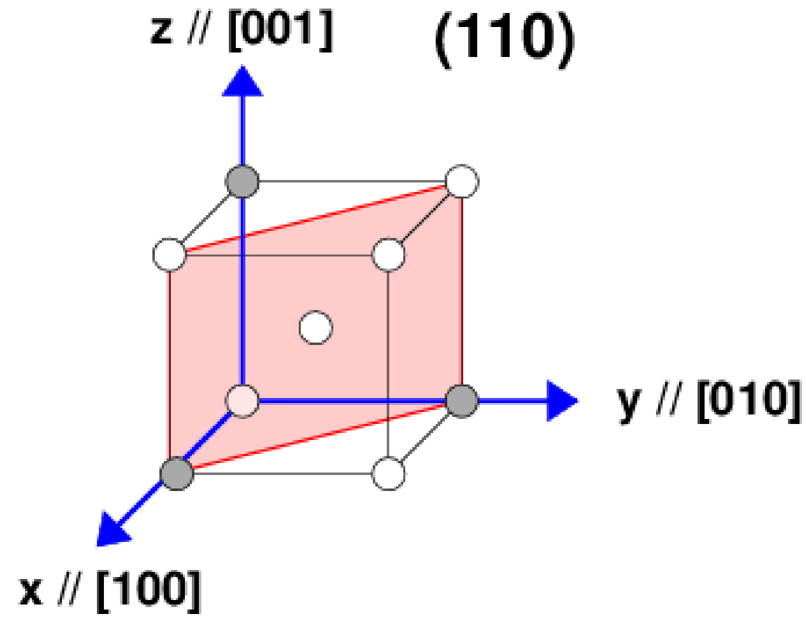
Slip systems – bcc

Slip systems in the bcc structure:

- Slip direction: <111>
- Slip plane: {110}

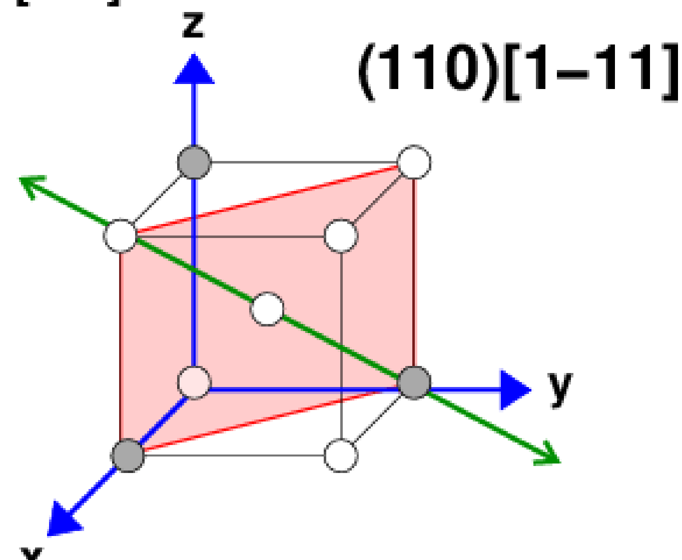
Slip system: (110)[1-11]

Other possible slip planes but slip direction is most-often <111>.



6 {110} planes: (110), (011), (101), $(1\bar{1}0)$, $(01\bar{1})$, $(10\bar{1})$;

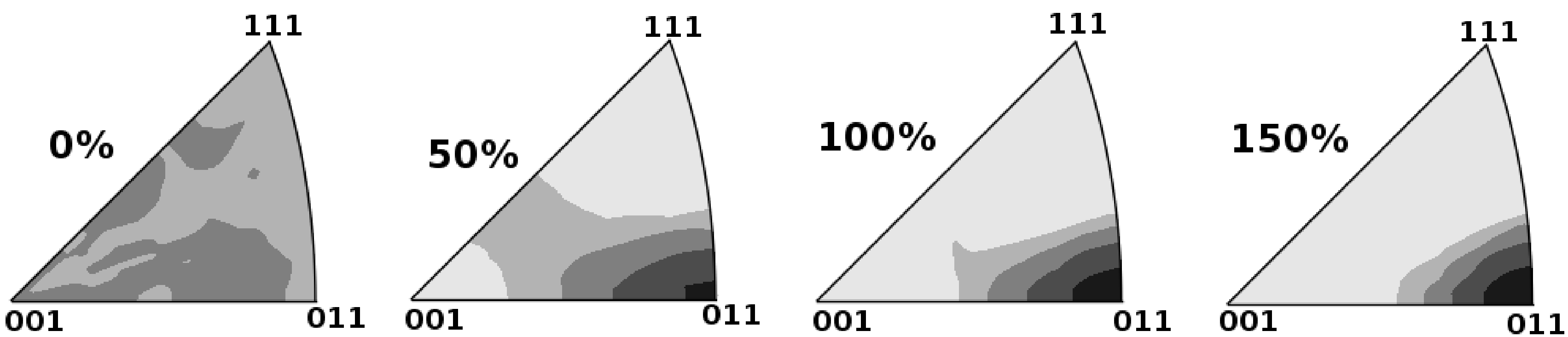
- For each: 2 <111> directions,
- 12 slip systems, each can operate in 2 directions (+ or -).

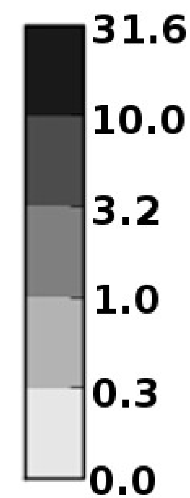


Bcc- Drawing and Compression

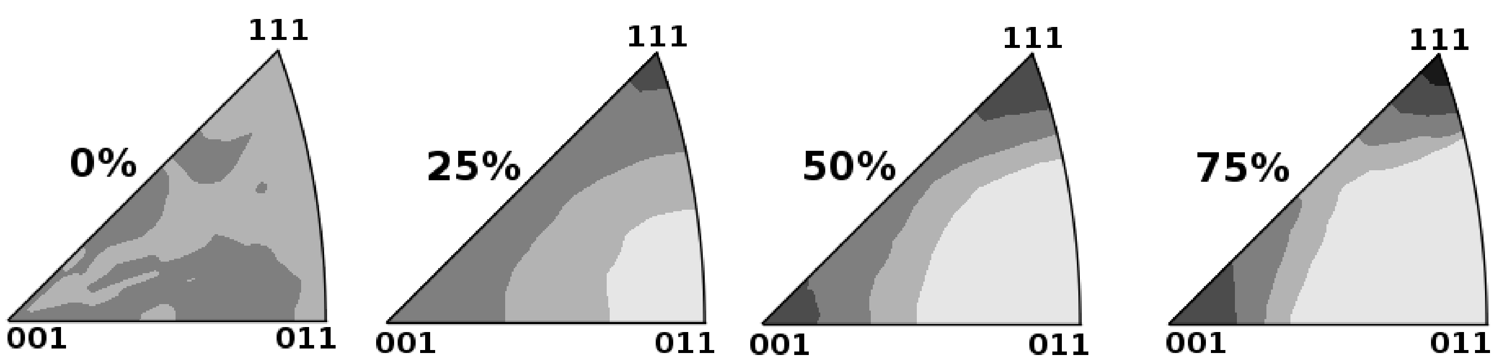
Simulation of drawing texture for a bcc metal

Same as fcc metal in compression





Simulation of a compression texture for a bcc metal



Same as drawing texture for fcc

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Fcc/ bcc Comparison

Fcc in compression
~ bcc drawing
Fcc drawing
~ bcc in compression

Slip systems:

- Fcc : (111)[-110]
- Bcc : (110)[1-11]

Drawing textures:

- Fcc : 2 maxima, in 001 and 111, minimum in 011
- Bcc : maximum in 011

Compression textures:

- Fcc : maximum in 011
- Bcc : 2 maxima, in 001 and 111, minimum in 011

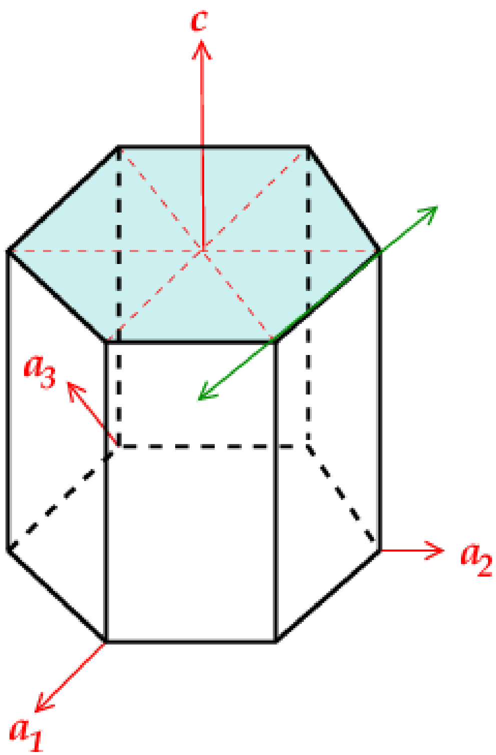
Rolling textures

- More complex.
- You can switch between fcc and bcc metals rolling textures by inverting the RD and ND directions in the projection.

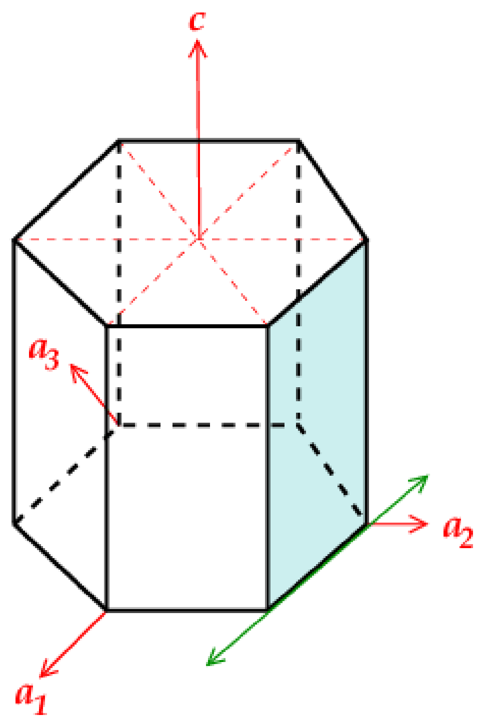
8- Textures in metals
c- Hexagonal closed packed

Hcp Slip Systems: $\langle 11\bar{2}0\rangle$

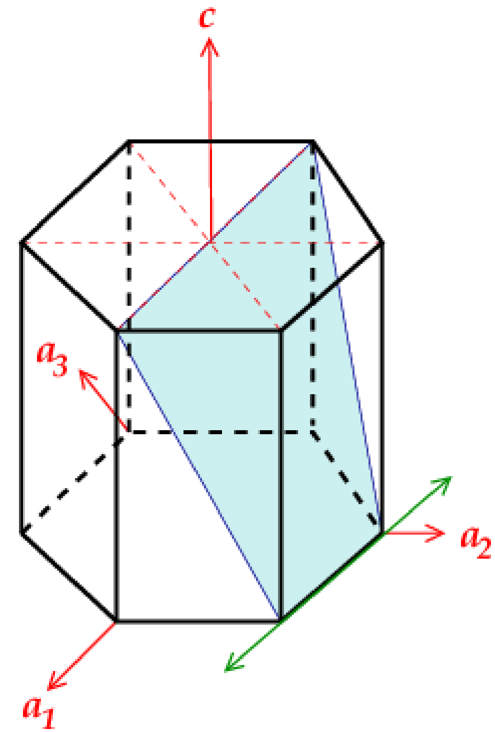
Slip slip systems with $\langle 11\bar{2}0\rangle$ Burgers vector
also called <a>



Basal slip
$(0001)[11\bar{2}0]$
3 equivalent systems



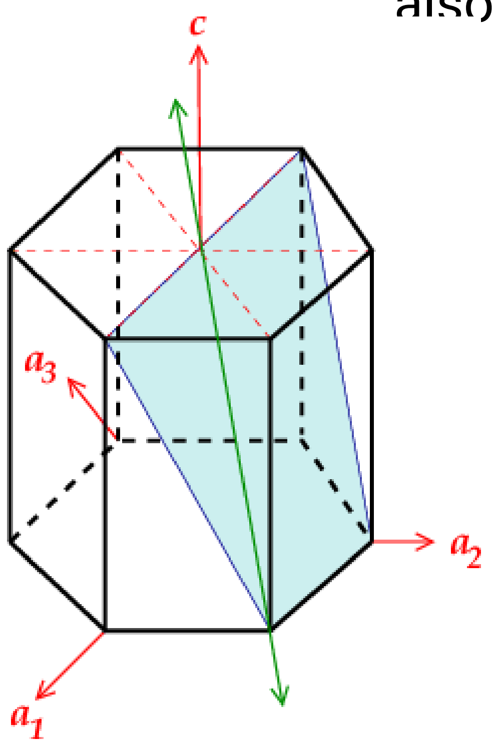
Prismatic slip
$(01\bar{1}0)[11\bar{2}0]$
3 equivalent systems



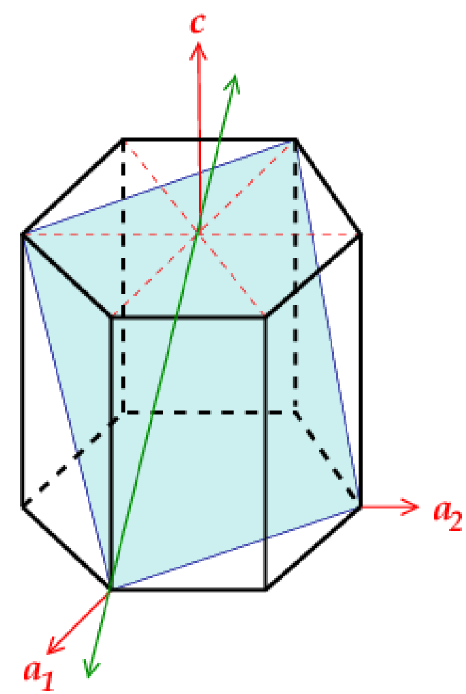
Pyramidal <a> slip
$(01\bar{1}\bar{1})[11\bar{2}0]$
6 equivalent systems

Hcp Slip Systems: $\langle 11\bar{2}3 \rangle$

Slip slip systems with $\langle 11\bar{2}3 \rangle$ Burgers vector
also called <c+a>



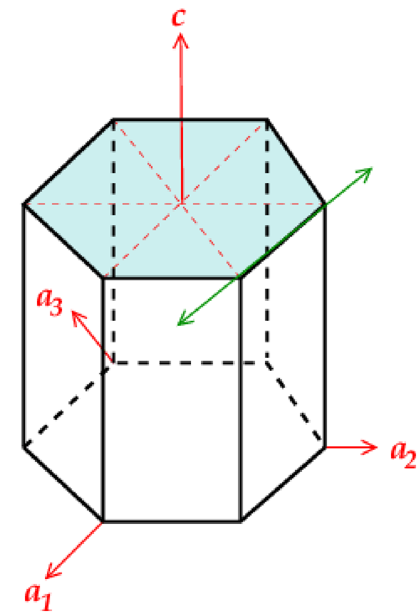
Pyramidal <c+a> slip
First order
$(10\bar{1}1)[11\bar{2}3]$
12 equivalent systems

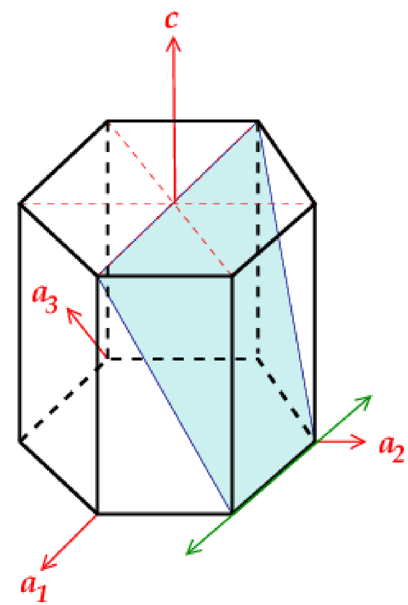


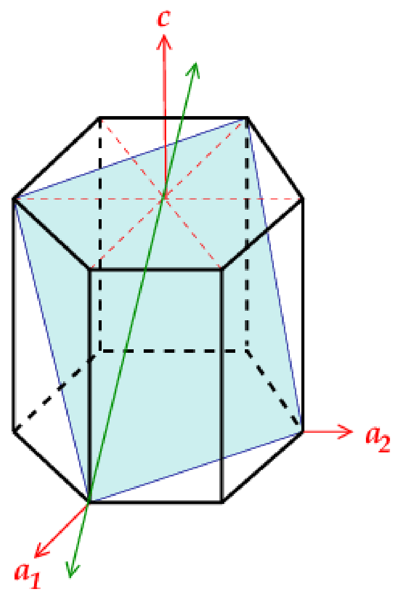
Pyramidal <c+a> slip
Second order
$(11\bar{2}2)[11\bar{2}3]$
6 equivalent systems

Hexagonal metals with c/a > 1.633

- Cd, Zn
- Basal slip
- Pyramidal <a> slip
- Pyramidal <c+a> second order
- Twins





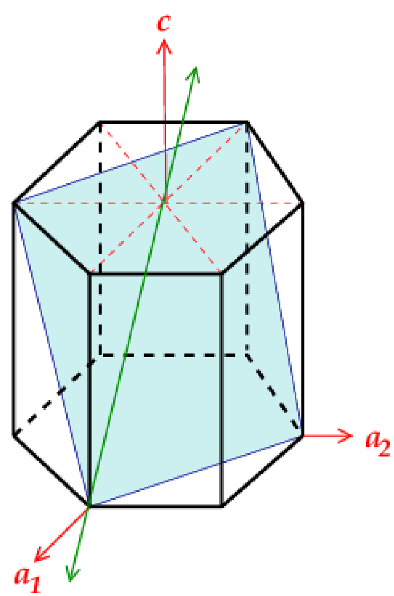


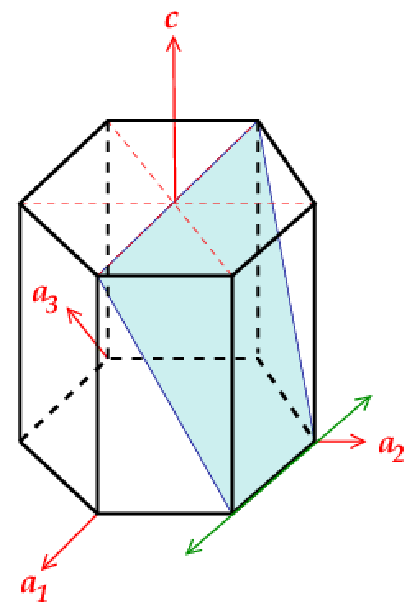
Notes :
- Basal slip is dominant
- Twinning is very important

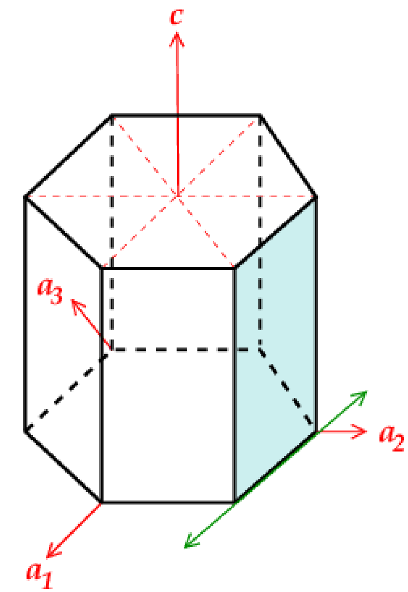
c/a < 1.633

Hexagonal metals with c/a < 1.633

- Zr, Ti, Hf ;
- Prismatic slip,
- Pyramidal <a> slip,
- Pyramidal <c+a> second order,
- Twins.







Notes:

- You can also have basal slip
- Twinning is very important

Hcp – Compression / Extrusion Texture

Pure Titanium

Extrusion:

- Maximum at 10-10

Compression:

- Maximum close to 0001
- 25° of 0001, ~ <11-24>

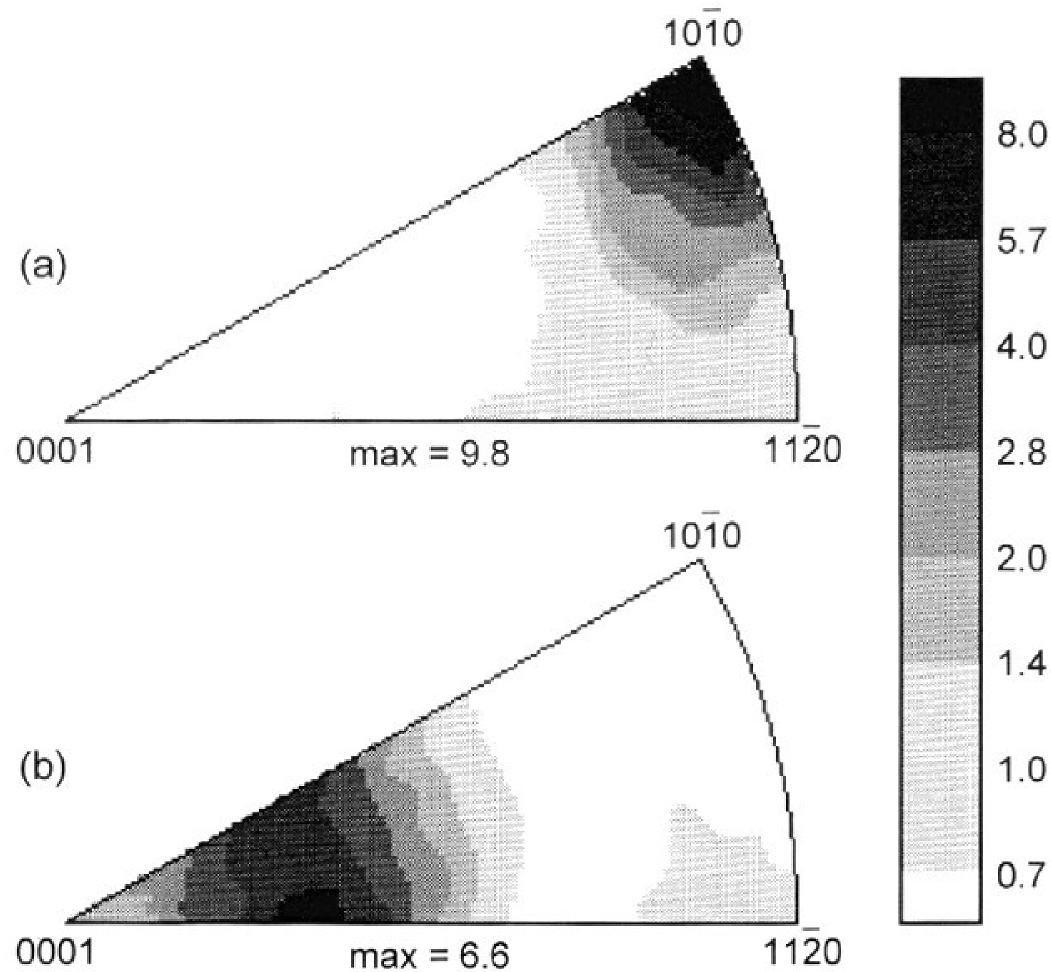


Fig. 20. Inverse pole figures of pure titanium: (a) extruded to a von Mises equivalent strain of 1.75 (extrusion-axis inverse pole figure), (b) forged and cross-rolled to a von Mises equivalent strain of 1.98 (plate normal inverse pole figure).

Comparison Titanium / Zirconium

General rule for hcp metals:

- Complex behavior due to activity of twinning modes
- Simple consideration on slip systems not always relevant

Compression Zr

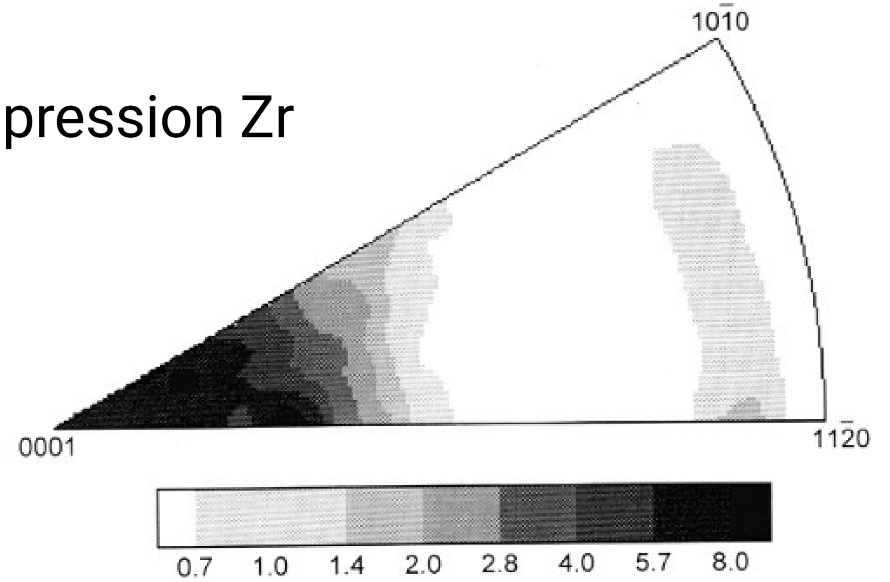
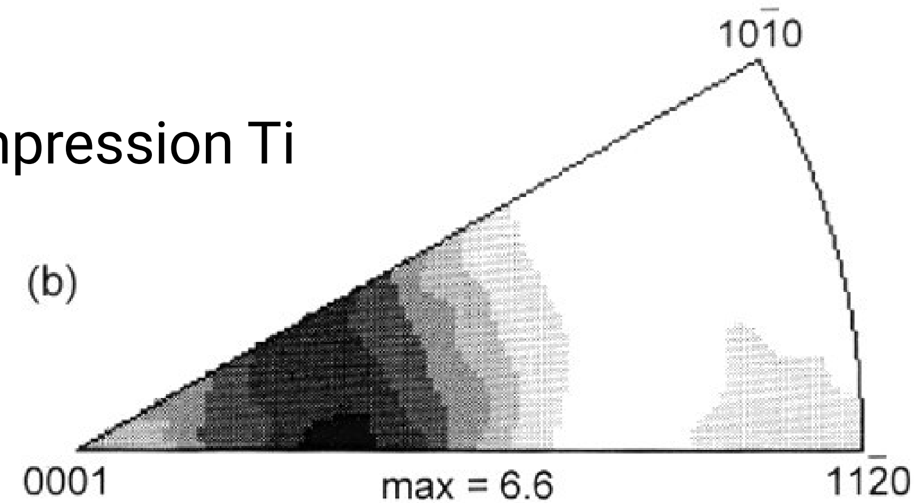


Fig. 21. Inverse pole figure (plate normals) for forged and cross-rolled zirconium.

Compression Ti



Hcp – Rolling Textures

c/a > 1.633:

0001 splits in two components in the plane between rolling normal and rolling direction

c/a = 1.633:

0001 perfectly aligned with rolling plane normal

c/a < 1.633:

0001 split in two components in the plane formed by the transverse and normal directions

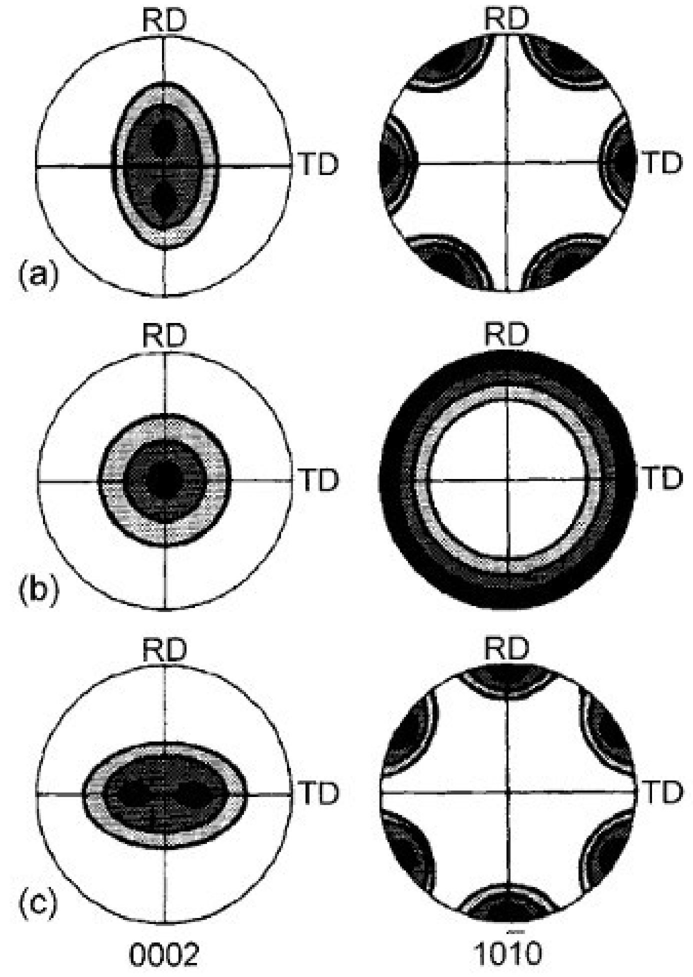


Fig. 22. Schematic rolling textures in hcp metals with *c/a* ratios of (a) greater than 1.633, (b) approximately equal to 1.633 and (c) less than 1.633. 0002 and 10$\bar{1}$0 pole figures. [TENCKHOFF 1988].