CARNEGIE MELLON UNIVERSITY

DEPARTMENT OF
MATERIALS SCIENCE AND ENGINEERING

Typical Textures, part 2 FCC Torsion, BCC textures

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27-750

Texture, Microstructure & Anisotropy

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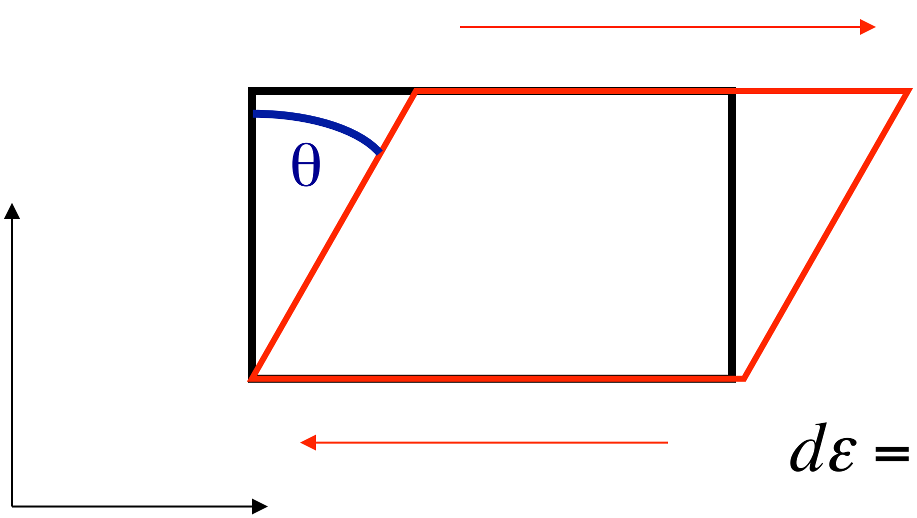
Objectives

- Part 1 of the slides covers shear (torsion) and rolling textures; part 2 covers some aspects of textures in BCC metals.

Shear Texture

- Shear strain means that displacements are tangential to the direction in which they increase.
- Shear direction=1, Shear Plane ⊥ 2-axis

2 = *Torsion Axis* = *{hkl}*



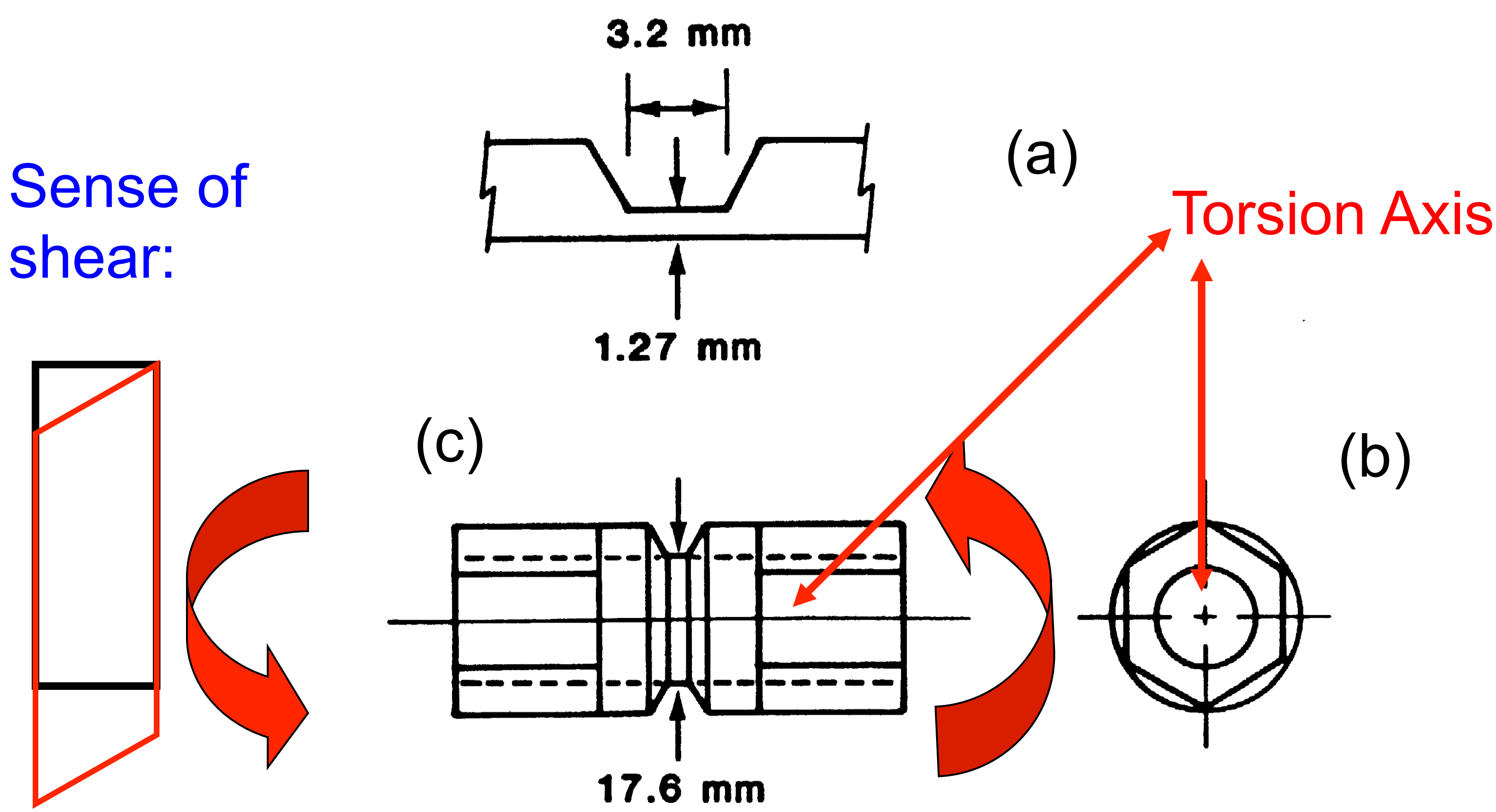
1 = Shear Direction = <uvw>

$\varepsilon_{12} = \tan\theta$

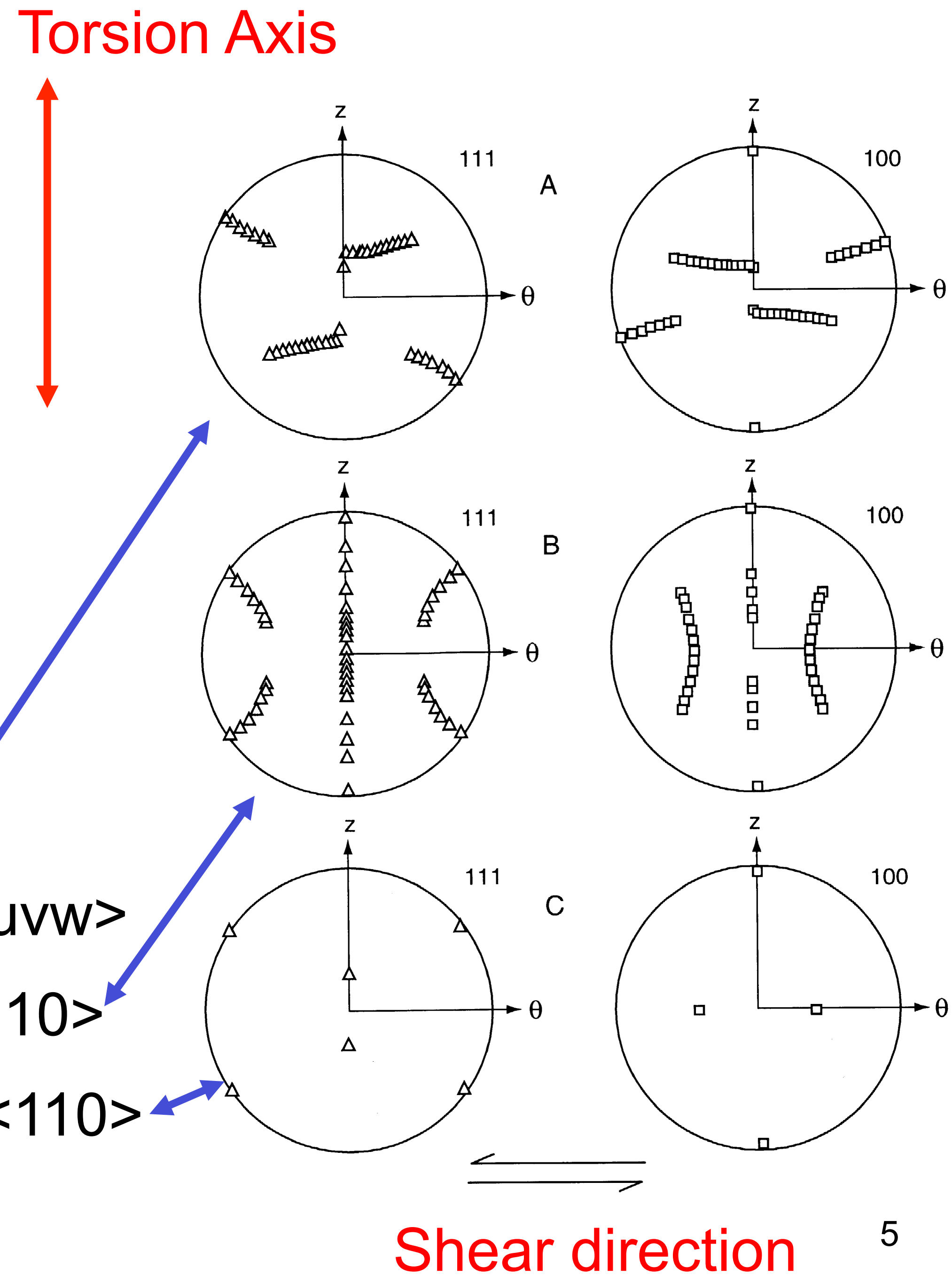
Note the definition of strain, ε_{ij}, as the derivative of the displacement u_i with respect to coordinate x_j.

$$d\varepsilon = \begin{pmatrix} 0 & +\Delta & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

Torsion Textures: twisting of a hollow cylinder specimen



Shear Textures: idealized texture components for FCC *metals*



A partial fiber {111}<uvw>

B partial fiber {hkl}<110>

C component: {001}<110>

Shear Texture Components

- Why study shear textures? Shear strain is common near the surface of rolled parts, for example.
- Partial Fibers:

Partial Fibers:	A/D	{111}<uvw>…<110>
	B	{hkl}<110> … {112}
Components	C	{001}<110>
	D	{112}<111>
	E	{011}<111>
	F	{110}<001>

{100} Pole figures

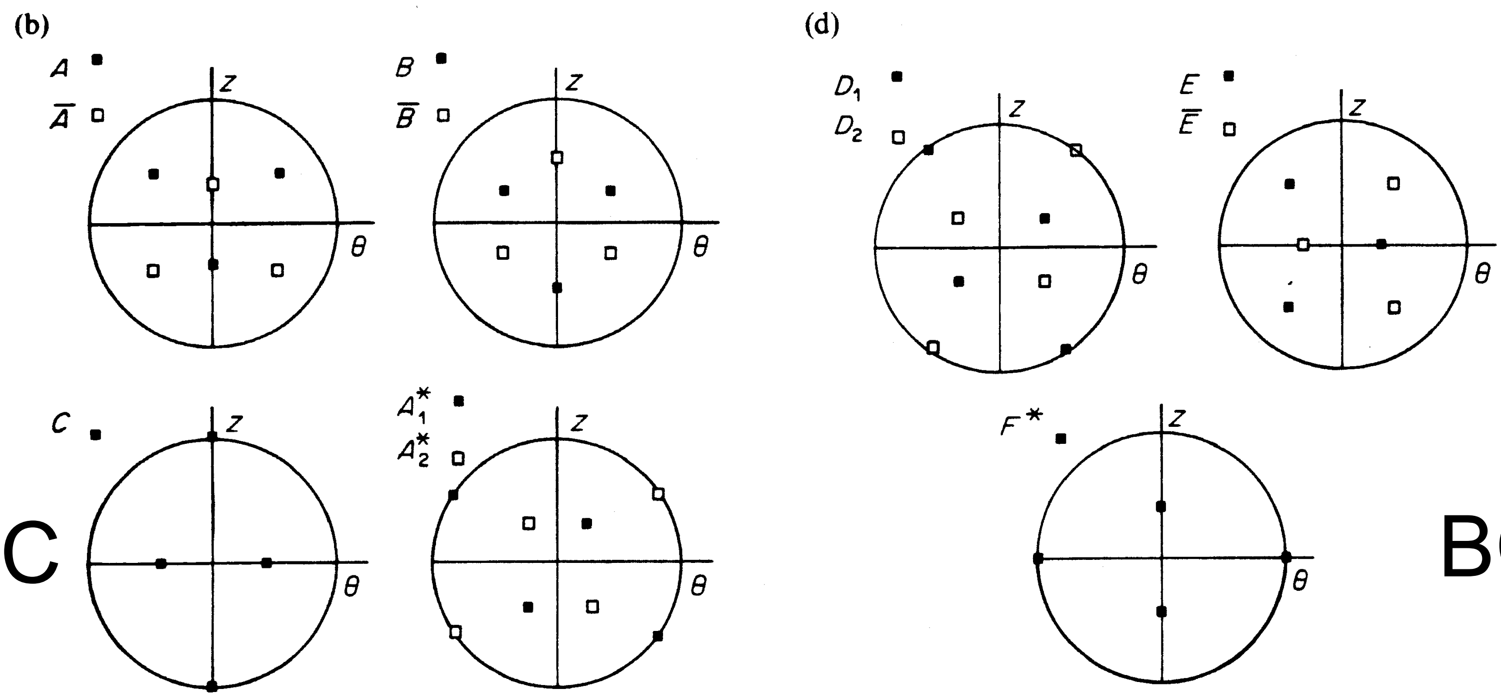
Montheillet et al.,

Acta metall., 33, 705, 1985

Table 1. Notation and Miller indices used for the different ideal orientations

A	$\{1\bar{1}1\}\langle110\rangle$	C	$\{001\}\langle110\rangle$
$\bar{A}$	$\{\bar{1}1\bar{1}\}\langle\bar{1}\bar{1}0\rangle$	D_1	$\{1\bar{2}1\}\langle111\rangle$
A_1^*	$\{\bar{1}\bar{1}1\}\langle112\rangle$	D_2	$\{\bar{1}\bar{1}2\}\langle111\rangle$
A_2^*	$\{11\bar{1}\}\langle112\rangle$	E	$\{0\bar{1}1\}\langle111\rangle$
B	$\{1\bar{1}2\}\langle110\rangle$	$\bar{E}$	$\{01\bar{1}\}\langle\bar{1}\bar{1}\bar{1}\rangle$
$\bar{B}$	$\{\bar{1}1\bar{2}\}\langle\bar{1}\bar{1}0\rangle$	F^*	$\{110\}\langle001\rangle$

FCC



BCC

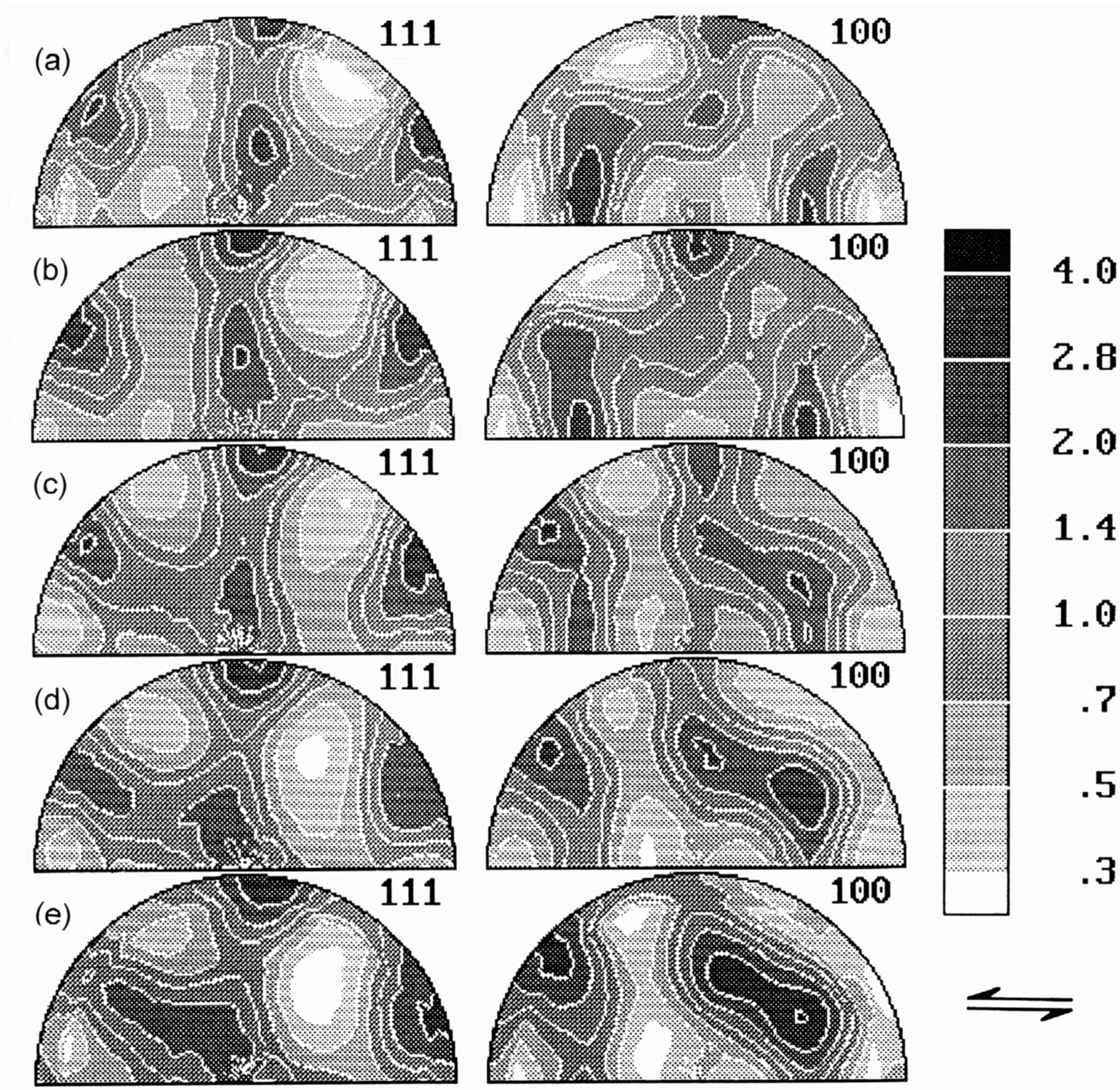
Fig. 4. Stereographic plots of the ideal orientations listed in Table 1. (a) and (c): inverse pole figures showing the orientations of the **j** and **k** unit vectors for the f.c.c. (a) and b.c.c. (c) components. The angle ψ is defined in Section 5. When $\phi = 0$, **j** and **k** coincide with the θ and z axes of the specimen, respectively. (b) and (d): {100} pole figures associated with the f.c.c. (b) and b.c.c. (d) ideal orientations.

FCC Torsion Textures

Plots of {111} and {200} pole figures (equal area projection; torsion axis vertical) for the following materials deformed in torsion; the shear direction points to the left in these figures.

a) Nickel at γ=3.6
b) Copper at γ=3.5
c) Silver at γ=3.5
d) Cu-30Zn at γ=3.5
e) Ni-60Co at γ=3.2

Note that the partial "A" fiber is present in Ni and Cu, but is absent in the other materials. Silver, brass and Ni-60Co show instead a "D" fiber which is similar to the A fiber but rotated approximately 90° about the torsion axis. The B fiber is present to varying degrees in all the materials.

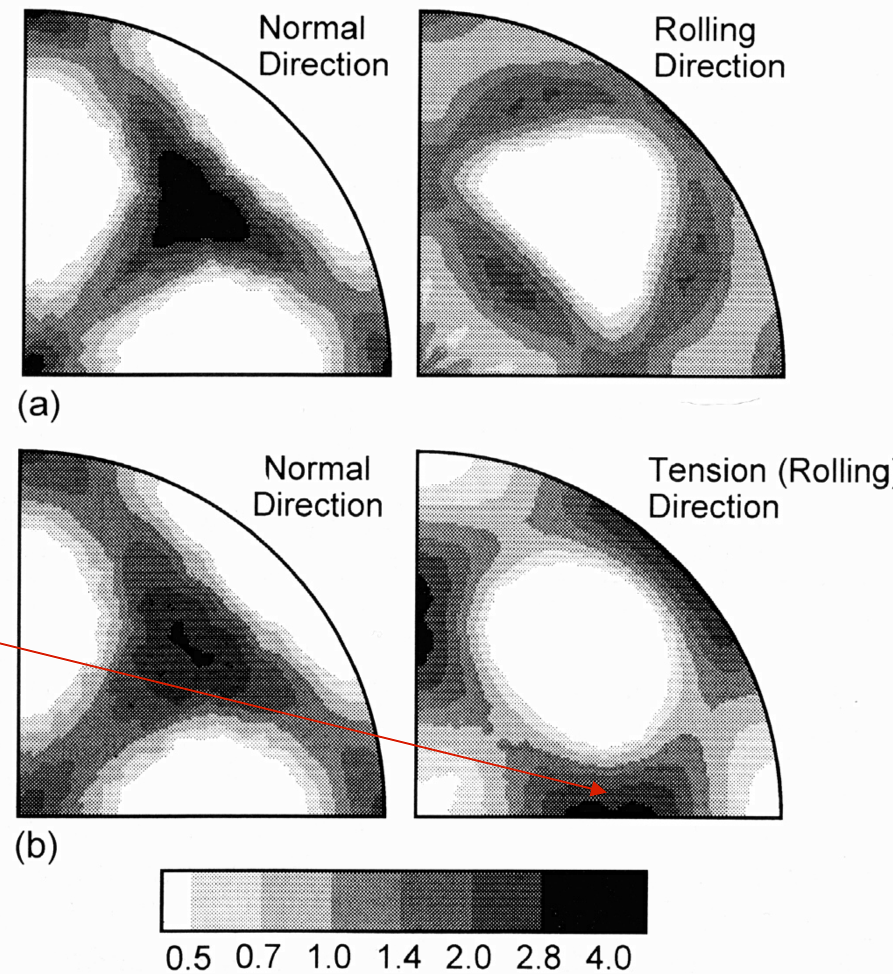


Kocks, Ch. 5

BCC uniaxial textures

92% rolled Ta
Tensile test in original RD to strain of 0.6:
<110> fiber

(a) Normal and rolling direction inverse pole figures (equal area projection) of 92% rolled Ta and (b) Prior normal and rolling direction inverse pole figures for (a) tested in tension to a strain of 0.6 (tensile direction coincident to prior rolling direction).



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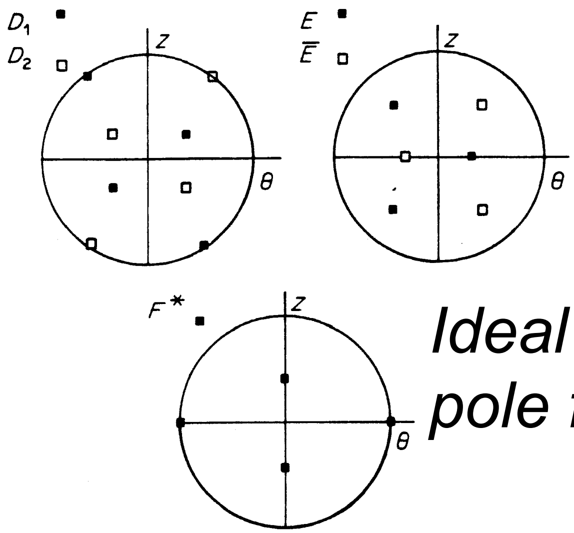
BCC torsion textures: Fe



Ideal |{100} pole figures

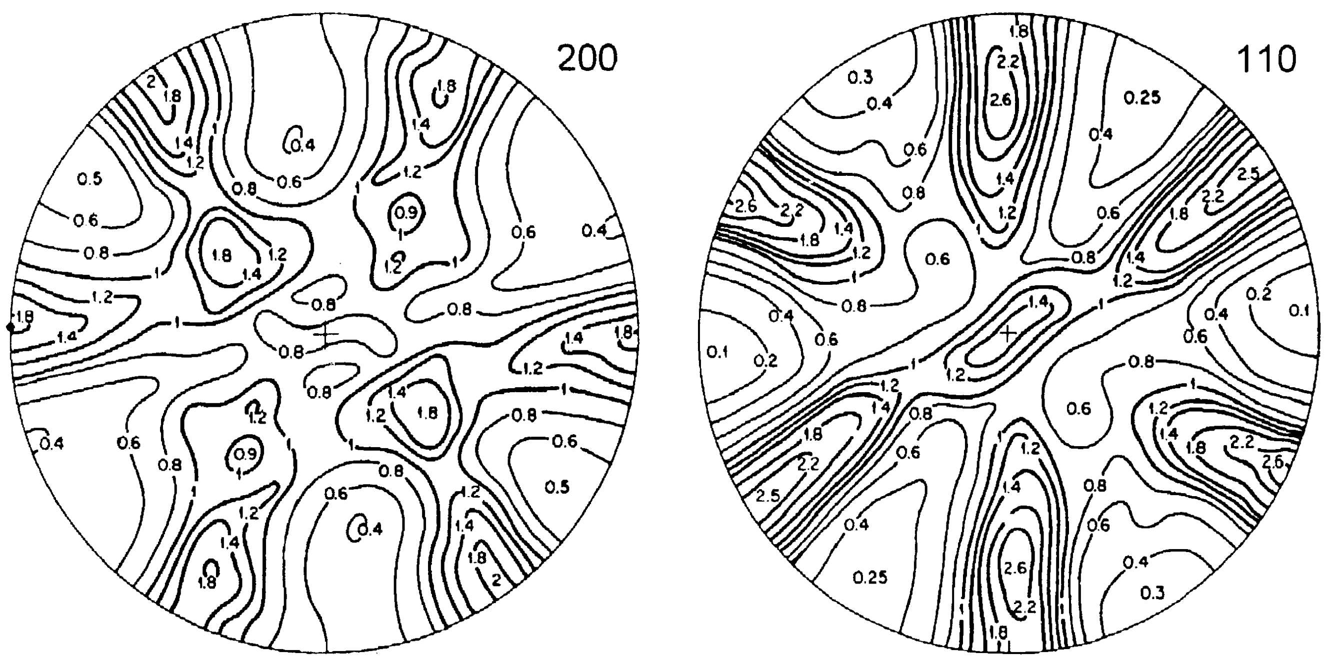
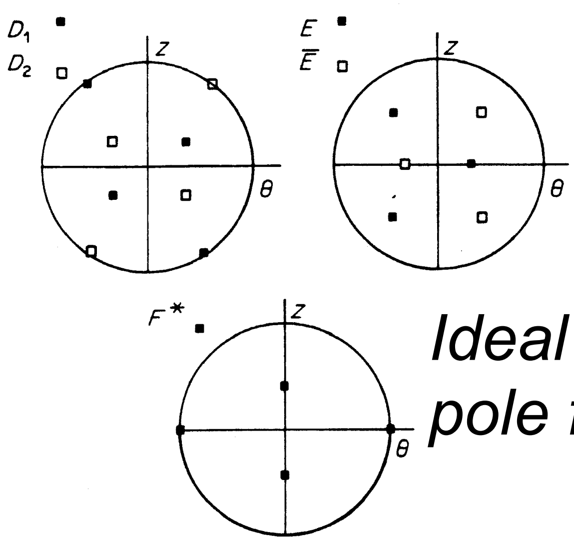


Fig. 18. Experimental 200 and 110 pole figures for Armco iron sheared to γ=2.1 (ε_{vM}=1.2) [WILLIAMS 1962] (Stereographic projection.) The shear direction points right on top.

BCC torsion textures: Ta

(a) initial texture from swaged rod;
(b) torsion texture



Ideal |{100} pole figures

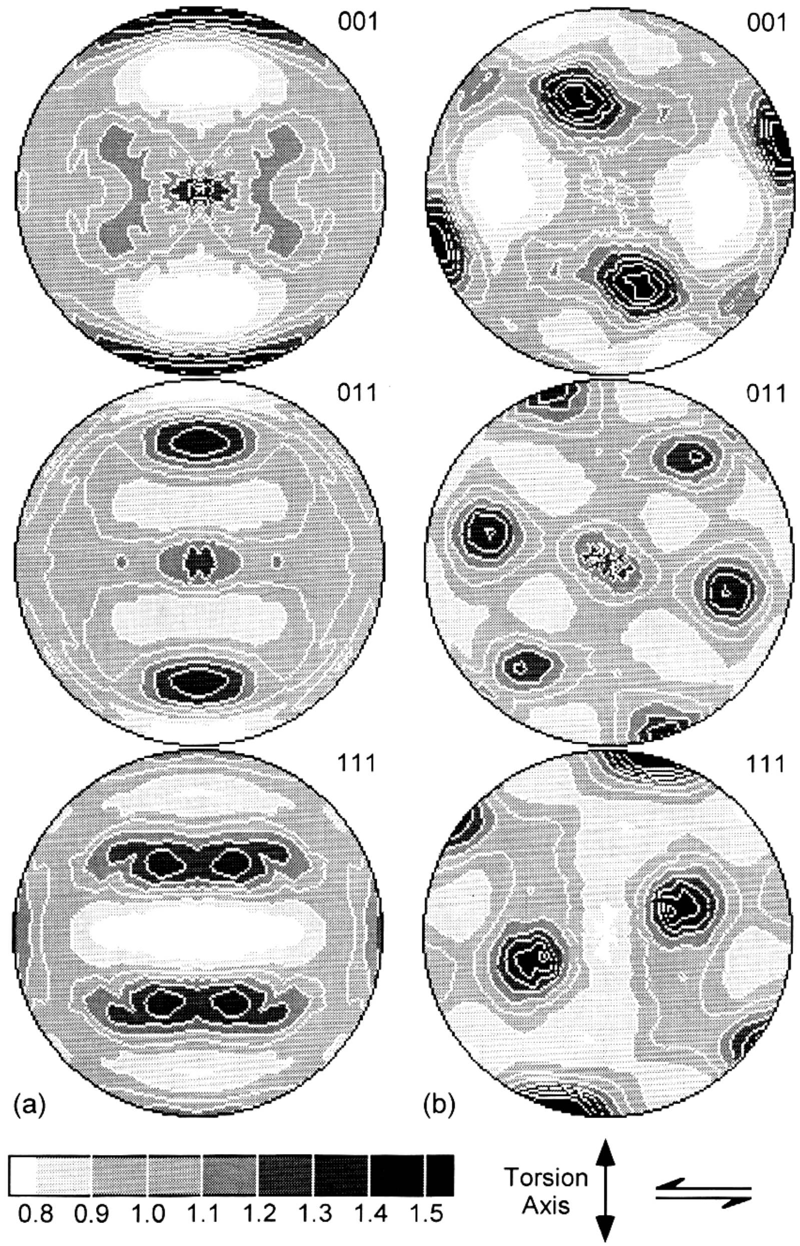


Fig. 19. Recalculated 111, 100 and 110 pole figures for tantalum: (a) initial texture; (b) tested in torsion to ε_{vM}=1.4. Equal-area projection.

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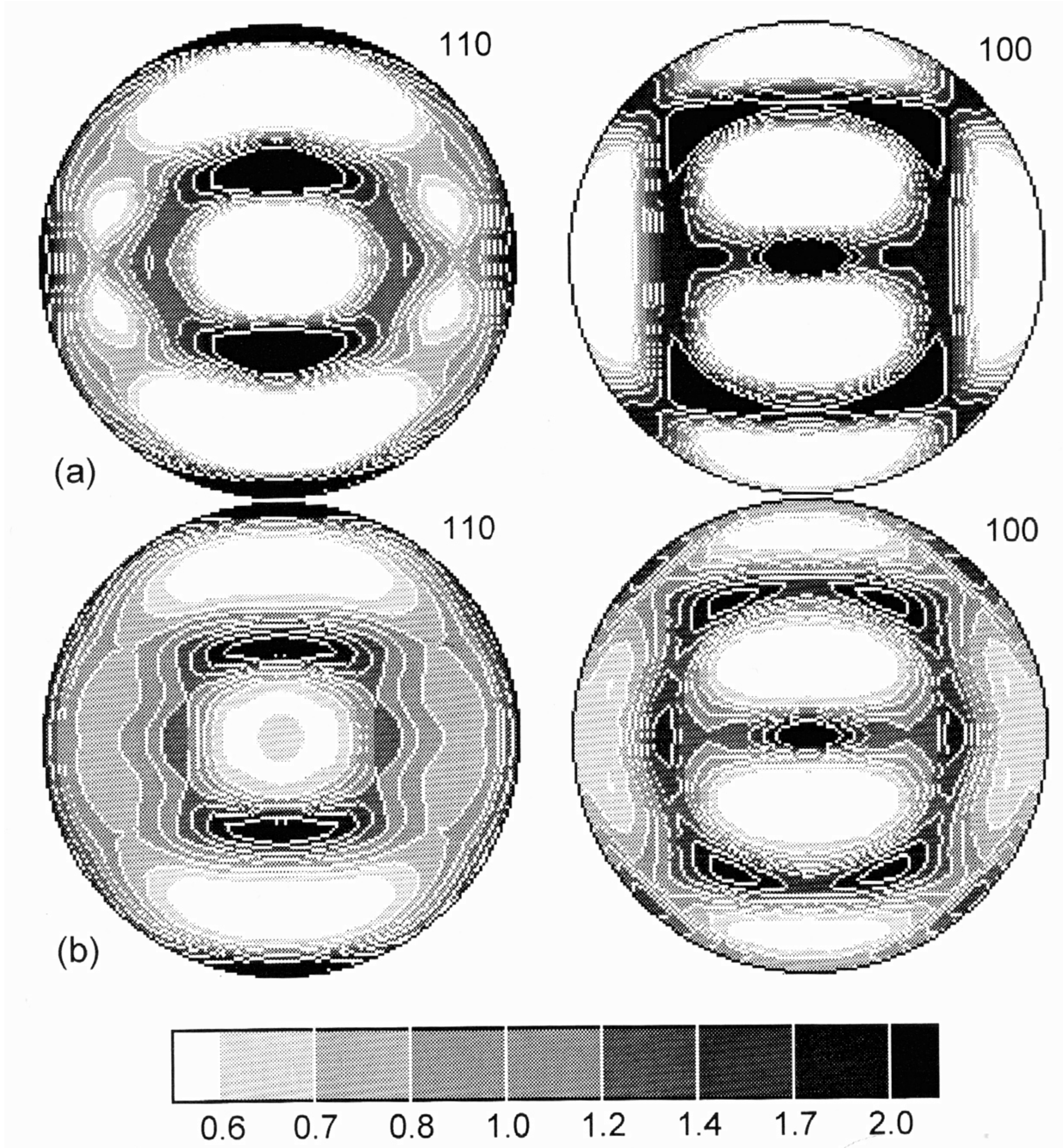
Rolling Textures BCC



{110} and {100} pole figures (equal area projection; rolling direction vertical) for (a) low-carbon steel cold rolled to a reduction in thickness of 80% (approximate equivalent strain of 2); (b) tantalum, unidirectionally rolled at room temperature to a reduction in thickness of 91%.

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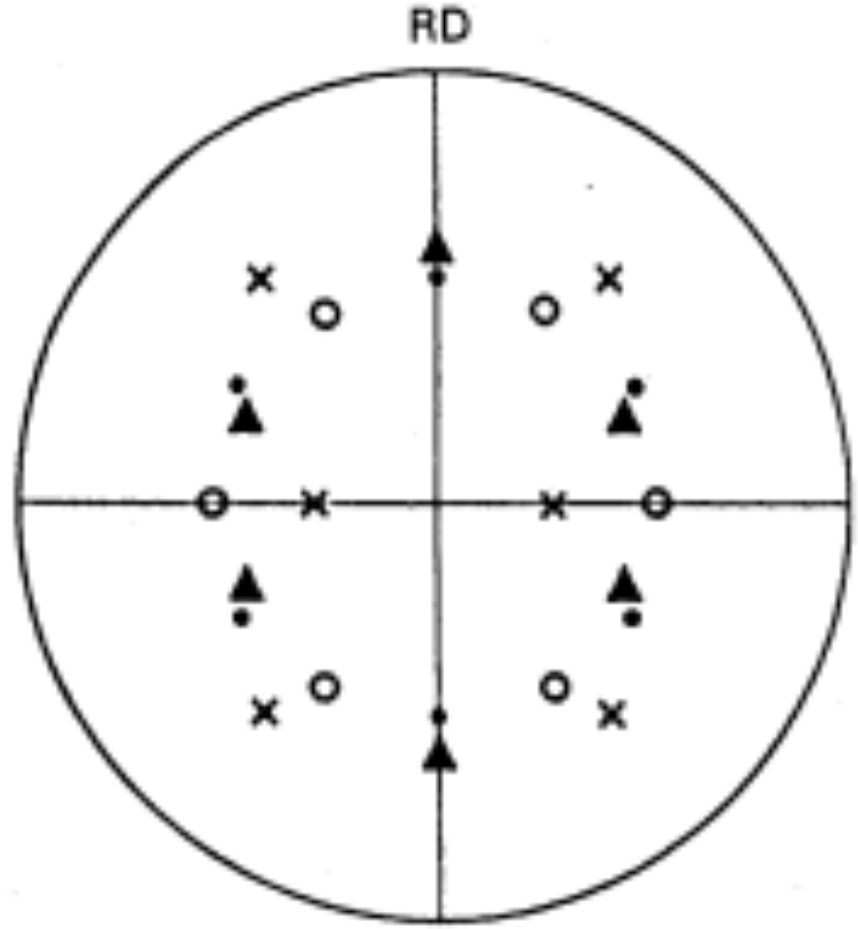
{100} Pole figure for certain components of rolled BCC metals



Note how very different components tend to overlap in a pole figure.

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BCC fibers: the $\phi_2 = 45°$ section

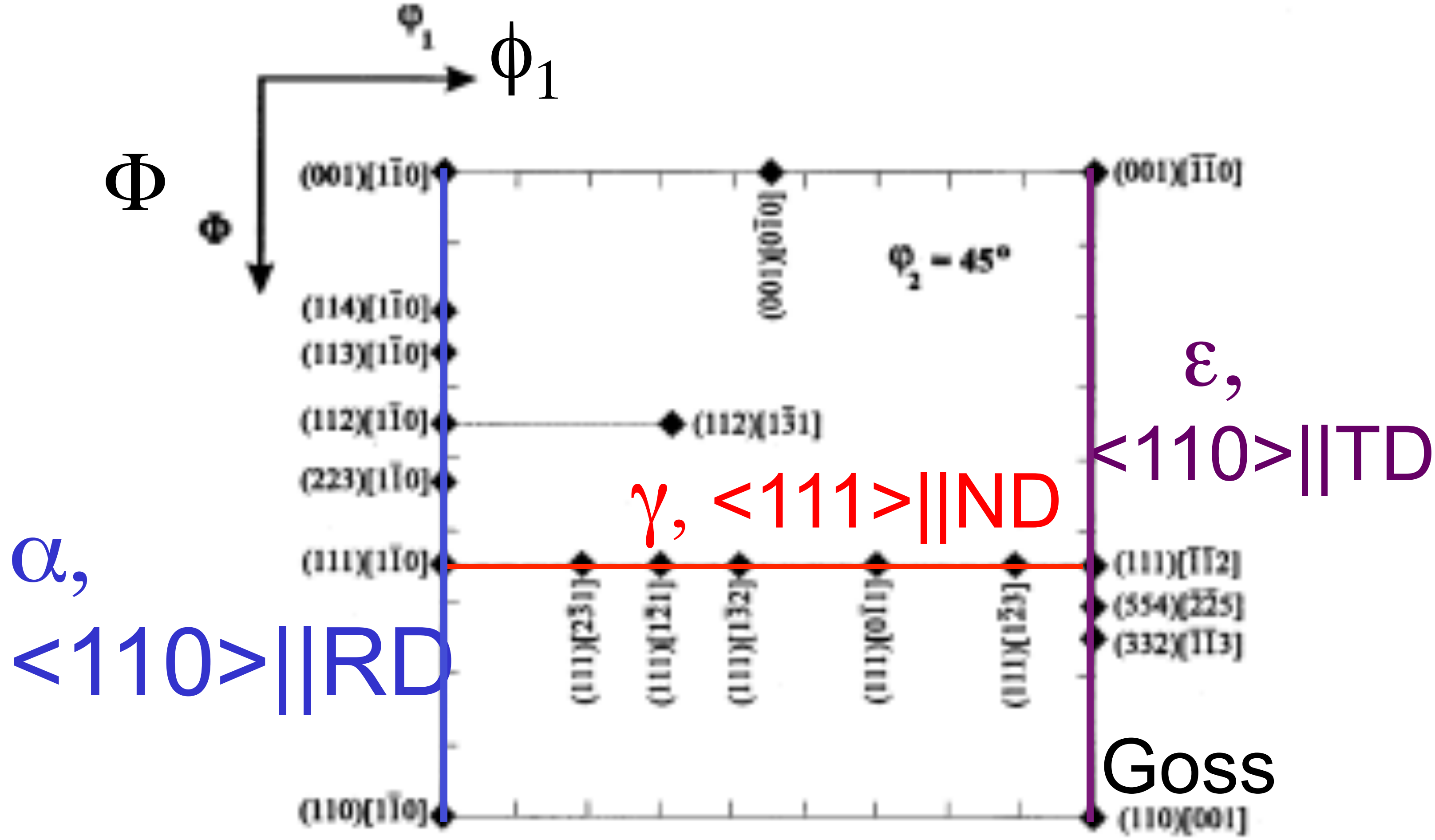

Fig. 6. Exact positions of important orientations in the $\varphi_2 = 45°$ section.

Ta,Fe rolling textures

Note: Euler angles are Roe angles: axes transposed with Θ horiz., ψ vertical.

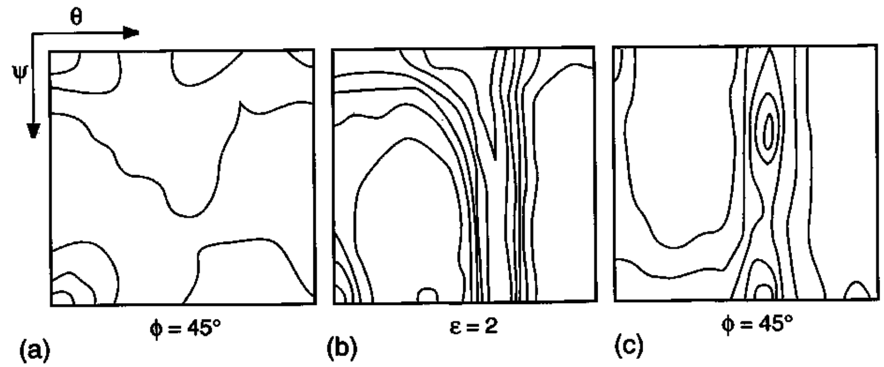

Fig. 15. Plot of the 45° sections (ϕ_2=45°, Roe angles) for the same steel and tantalum textures shown in Fig. 13: (a) low-carbon steel prior to cold rolling; (b) low-carbon steel cold rolled to a reduction in thickness of 80% (approximate equivalent strain of 2); (c) tantalum, unidirectionally rolled at room temperature to a reduction of 91%. The contours are drawn at multiples of the random intensity of 1,2,3...7. Note the weaker intensities in the tantalum, and the stronger α fiber in the steel.

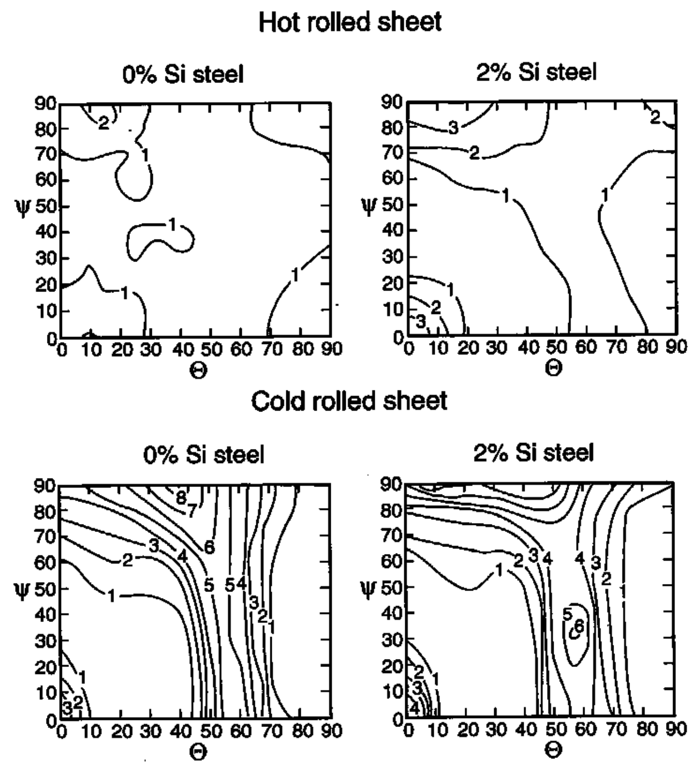

Fig. 16. Plot of the 45° sections (ϕ_2=45°, Roe angles, origin in lower left corner) for steels with 0% and 2% Si, both as hot-rolled (initial condition) and after 75% reduction cold rolling. The strongest intensity is at the {112}⟨110⟩ position in the 0% Si-steel, whereas it is at the {111}⟨110⟩ position in the 2% Si-steel. Note that a weak RD||⟨110⟩ fiber is already present in the hot rolled 2% Si-steel.

Fe,Fe-Si rolling fiber plots

Note the marked alloy dependence in the alpha fiber; smaller variations in the gamma fiber.

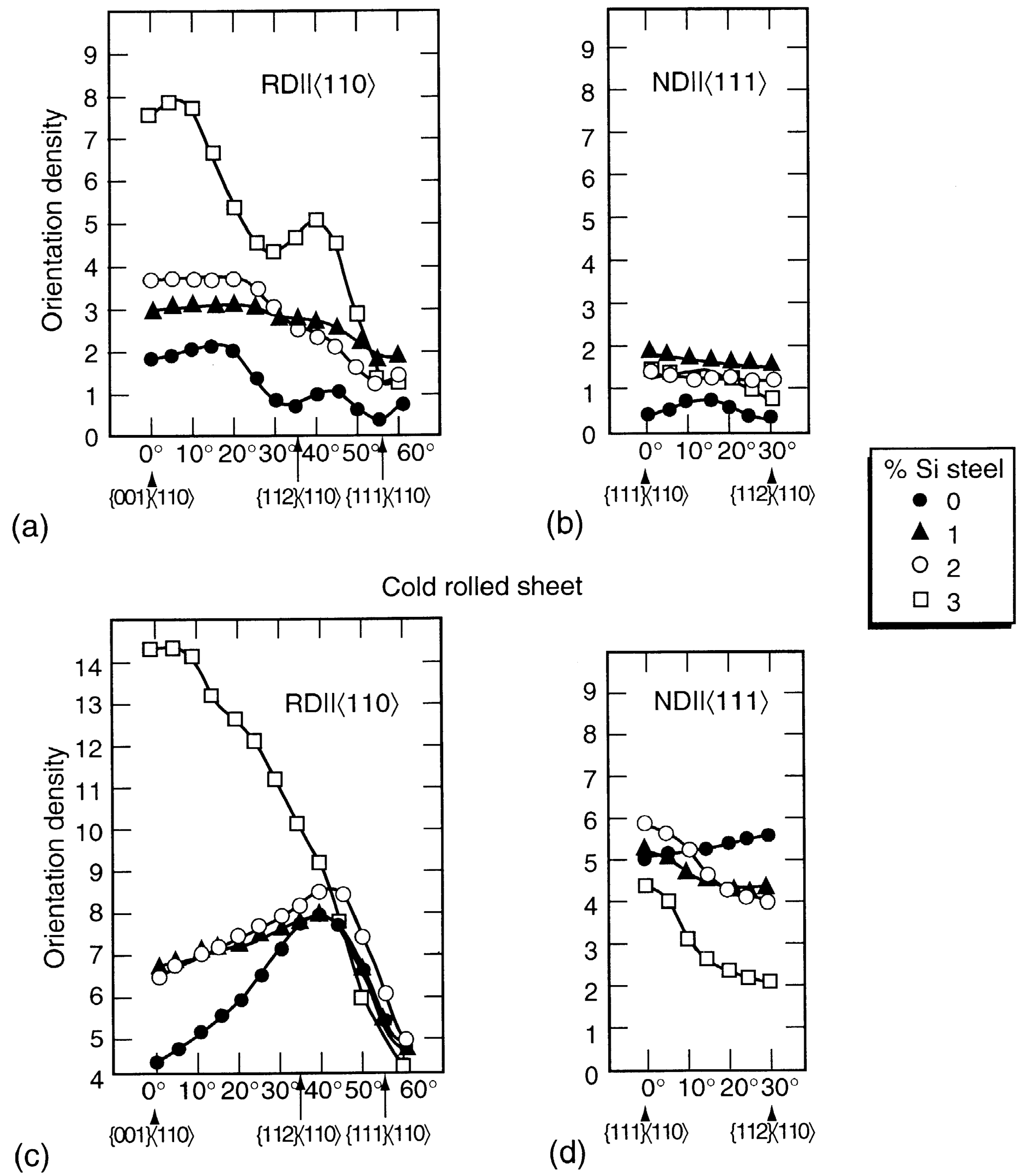

Fig. 17. Plot of the α and γ fibers for a range of iron-Si alloys, including 0, 1, 2, & 3% Si. Increasing silicon leads to stronger α fibers in both the hot-rolled (initial) condition and the cold-rolled condition.

Summary: part 2

- Typical textures illustrated for shear textures and for *bcc* metals.
- Pole figures are recognizable for standard deformation histories but orientation distributions provide much more detailed information.