Mechanical Behaviour of Materials

PII. Crystal plasticity (2):

Twin-Induced Deformation

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However, already 40 years ago Wassermann reported [1] that mechanical twinning may have an important influence on the deformation texture of several face-centred cubic (f.c.c.) metals. Later on Wagner et al. [2] and Paul et al. [3] have shown experimentally that single crystals of fcc metals show intense mechanical twinning during channel-die compression.

Deformation twinning often coexists with dislocation glide, but becomes particularly important when dislocation glide is difficult. Such a situation is relevant for intermetallic titanium aluminides based on γ (TiAl), which are currently being developed as high temperature structural materials [4].

1. G. Wassermann, Z. Metallkd. 54, 61-65 (1963)
2. P. Wagner, O. Engler and K. Lücke, Acta metall. mater. 43, 3799-3812 (1995)
3. H. Paul, J.H. Driver, C. Maurice and Z. JasieĚski, Mat. Sci. Engng. A A359, 178-191 (2003)
4. Y.W. Kim, H. Clemens and A.H. Rosenberger (Eds), Gamma Titanium Aluminides 2003, TMS , Warrendale, PA, USA (2003).

Introduction to deformation twinning

What is the difference between slip and twinning?

Dislocation glide and deformation twinning are the two major plastic deformation modes in metals and alloys.

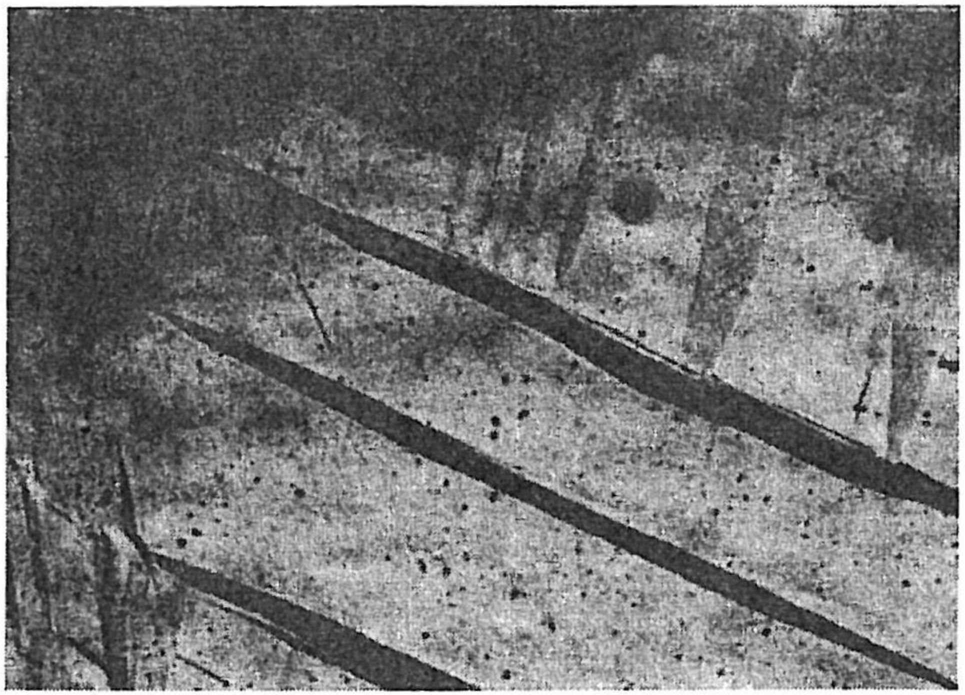
Experiments with single crystals reveal that some structures in f.c.c. metals do not normally twin (delayed twinning) until appreciable plastic deformation by slip has been recorded, whilst in b.c.c. metals, twins (immediate twinning) often form in the elastic region of the stress vs strain curve before macroscopic yielding. Delayed twinning has a rather small effect on the actual stress vs strain curve, whereas immediate twinning is characterized by very rapid formation of twinned regions, giving large load drops. Immediate twinning is very sensitive to temperature of deformation and to strain rate. The relative contribution of twinning to the overall strain increases as the temperature is lowered or the strain rate increased.

Introduction to deformation twinning-cont.

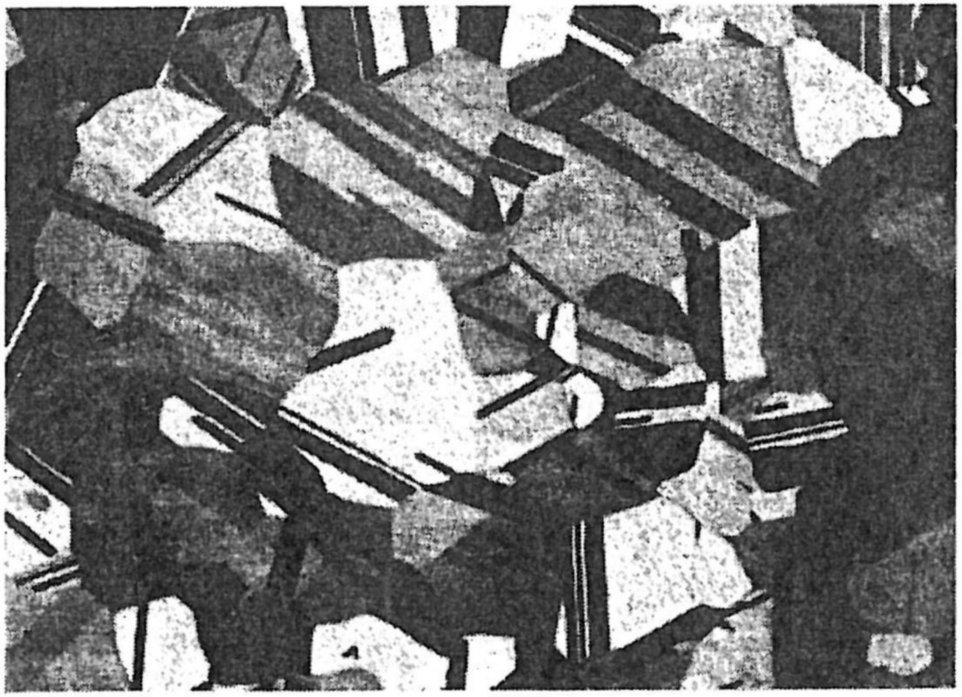
Energy:
1. Surface energy (twin boundary)
2. Strain energy (plastic shear)
3. Accommodation energy (mismatch between the twins and the matrix)

Surface energy:
fat twin

Surface energy:
high aspect ratio (lens shape)



(a)
Deformation twin

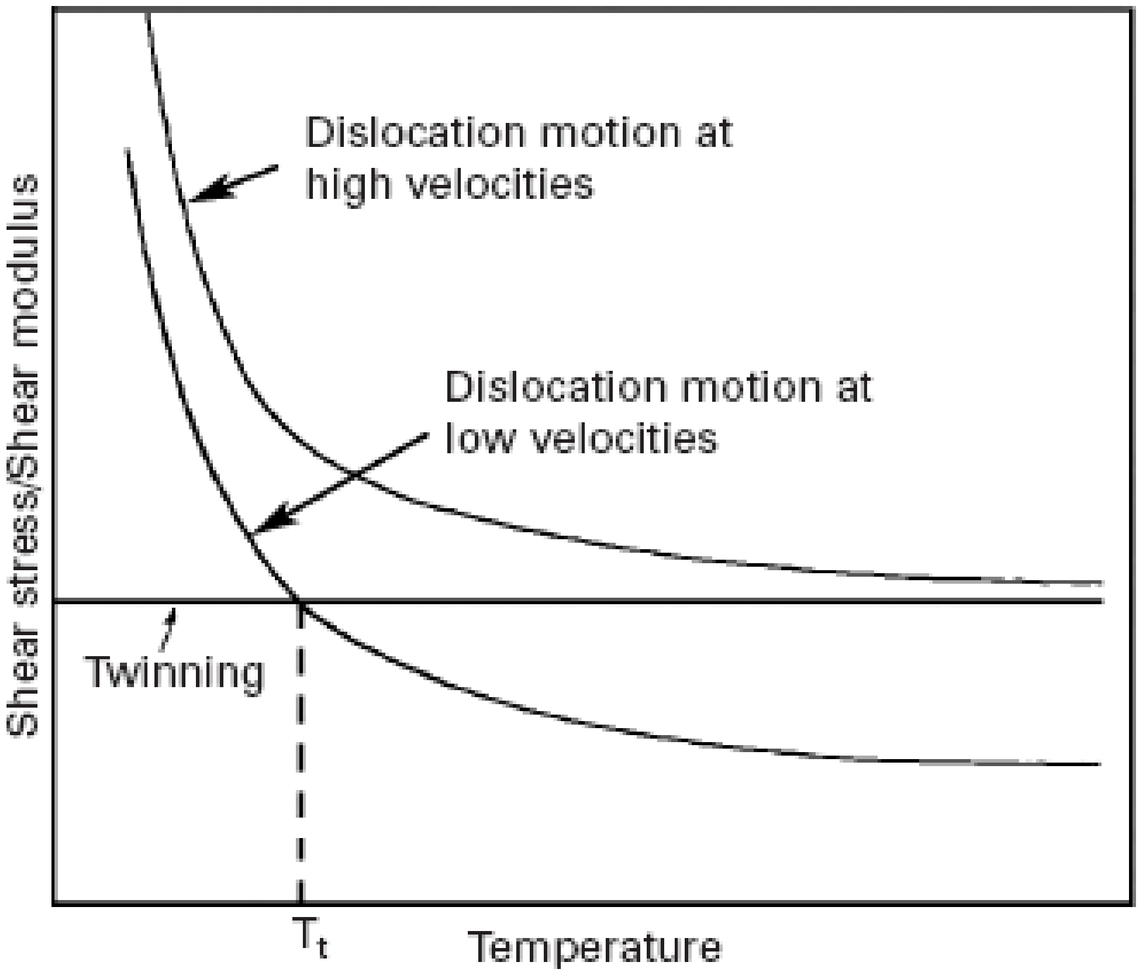


(b)
Annealing twin

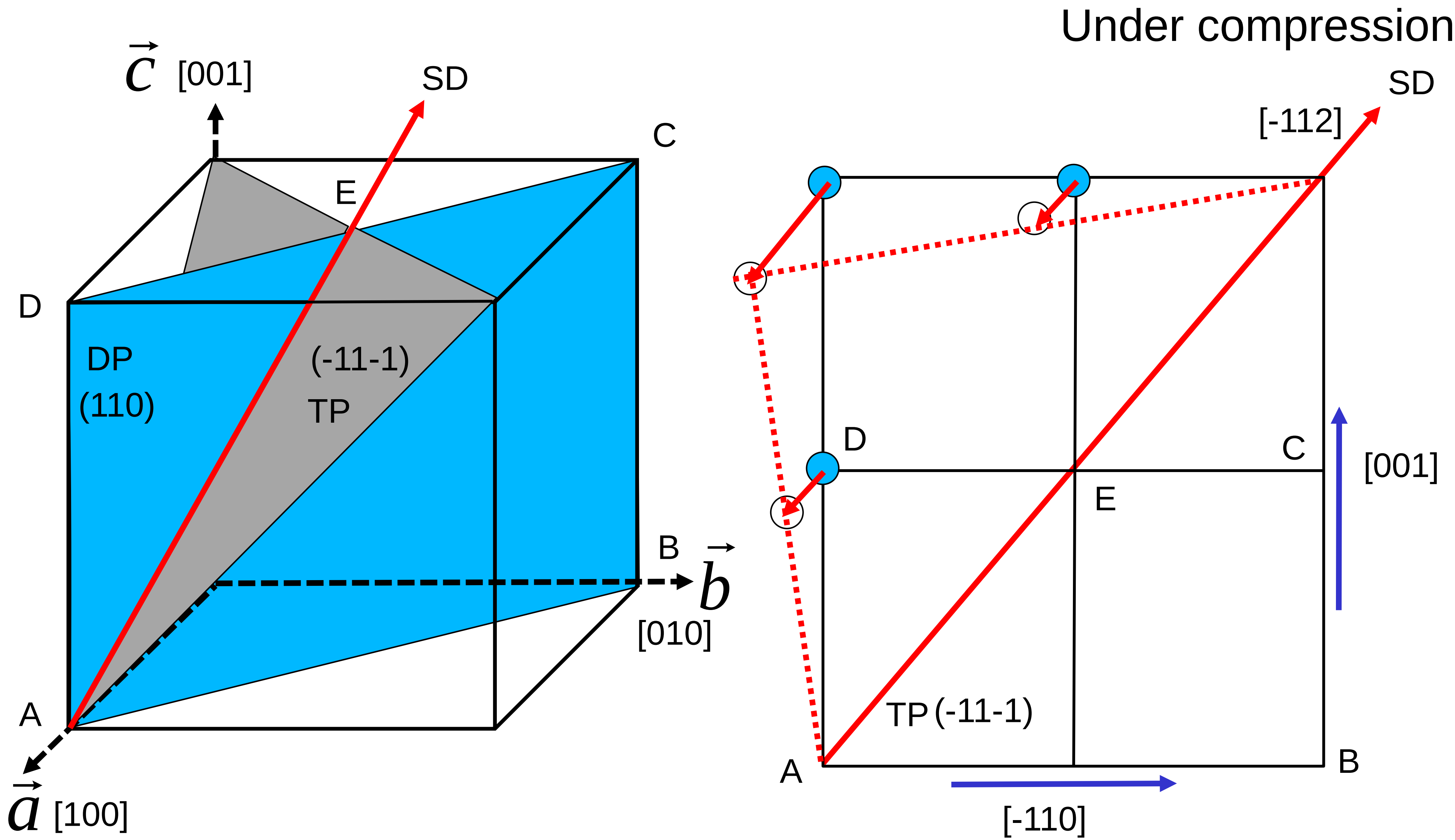
Types of twin

Twinning is not a thermally activated mechanism.

Dislocation motion is a thermally activated mechanism.



Deformation slip and twin in terms of temperature



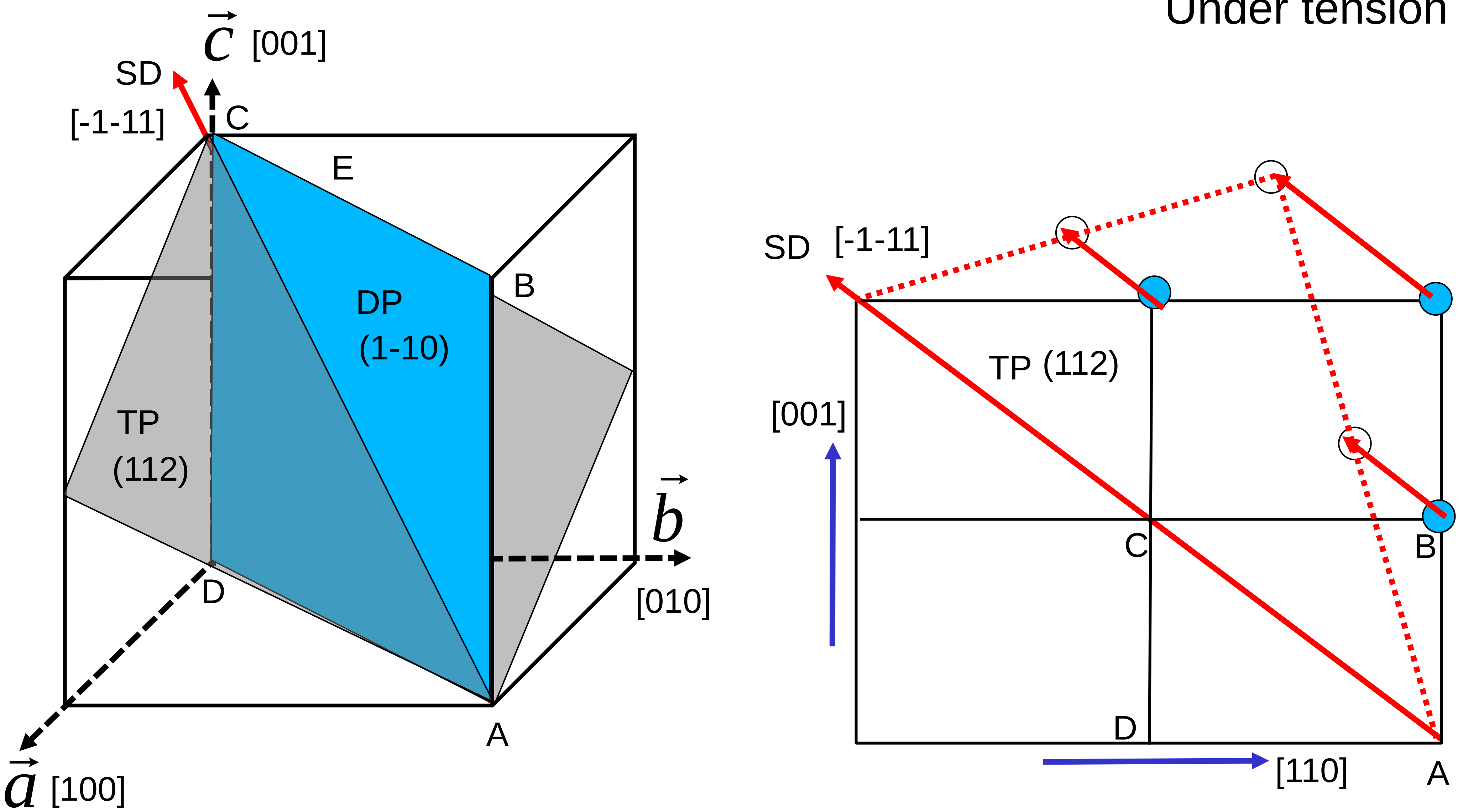
Twinning plane (TP) {111}

Shear direction (SD) <112>

Displacement plane (DP) {110}

Twinning system of fcc metals

Under tension

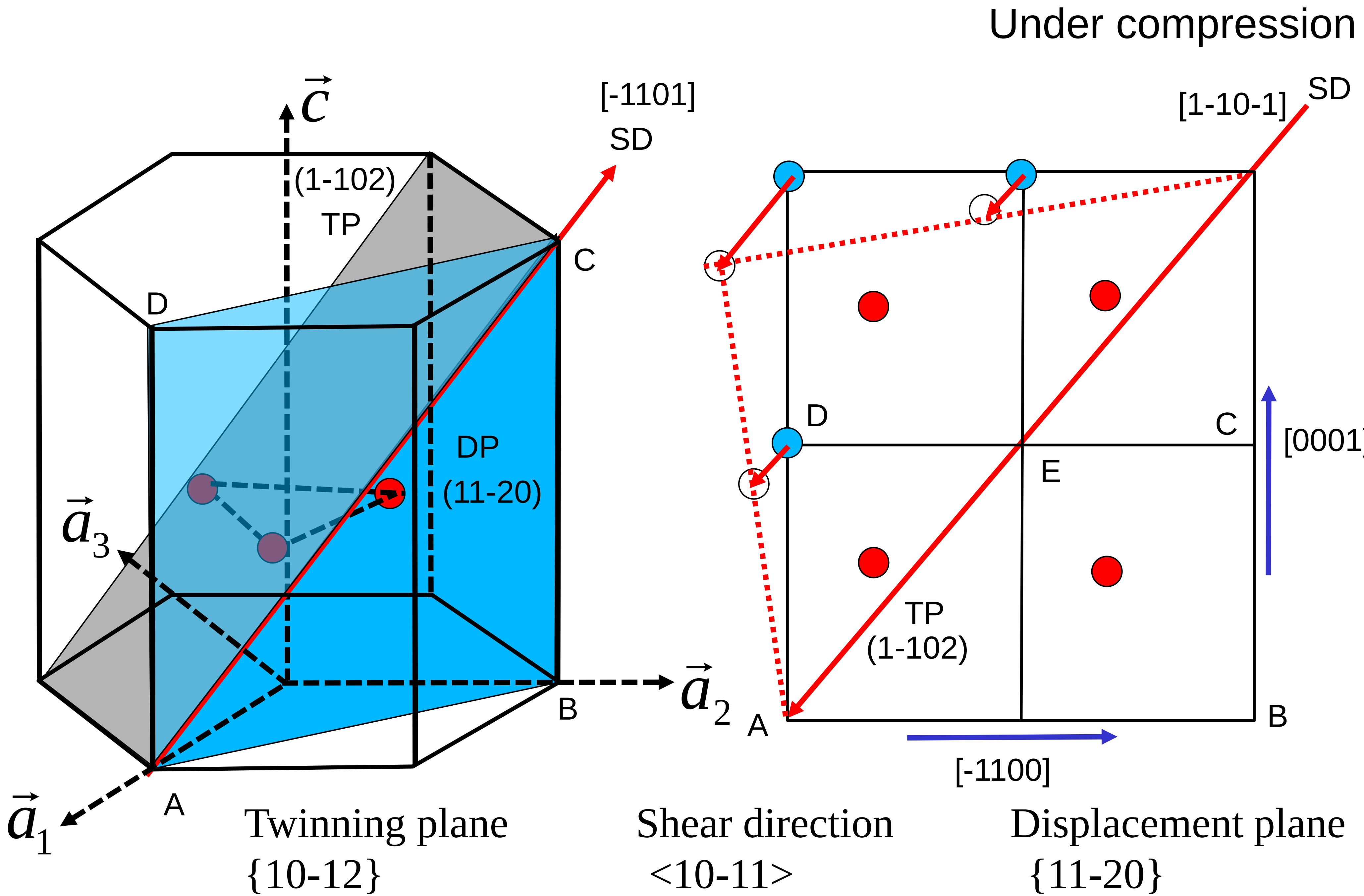


Twinning plane {112}

Shear direction <111>

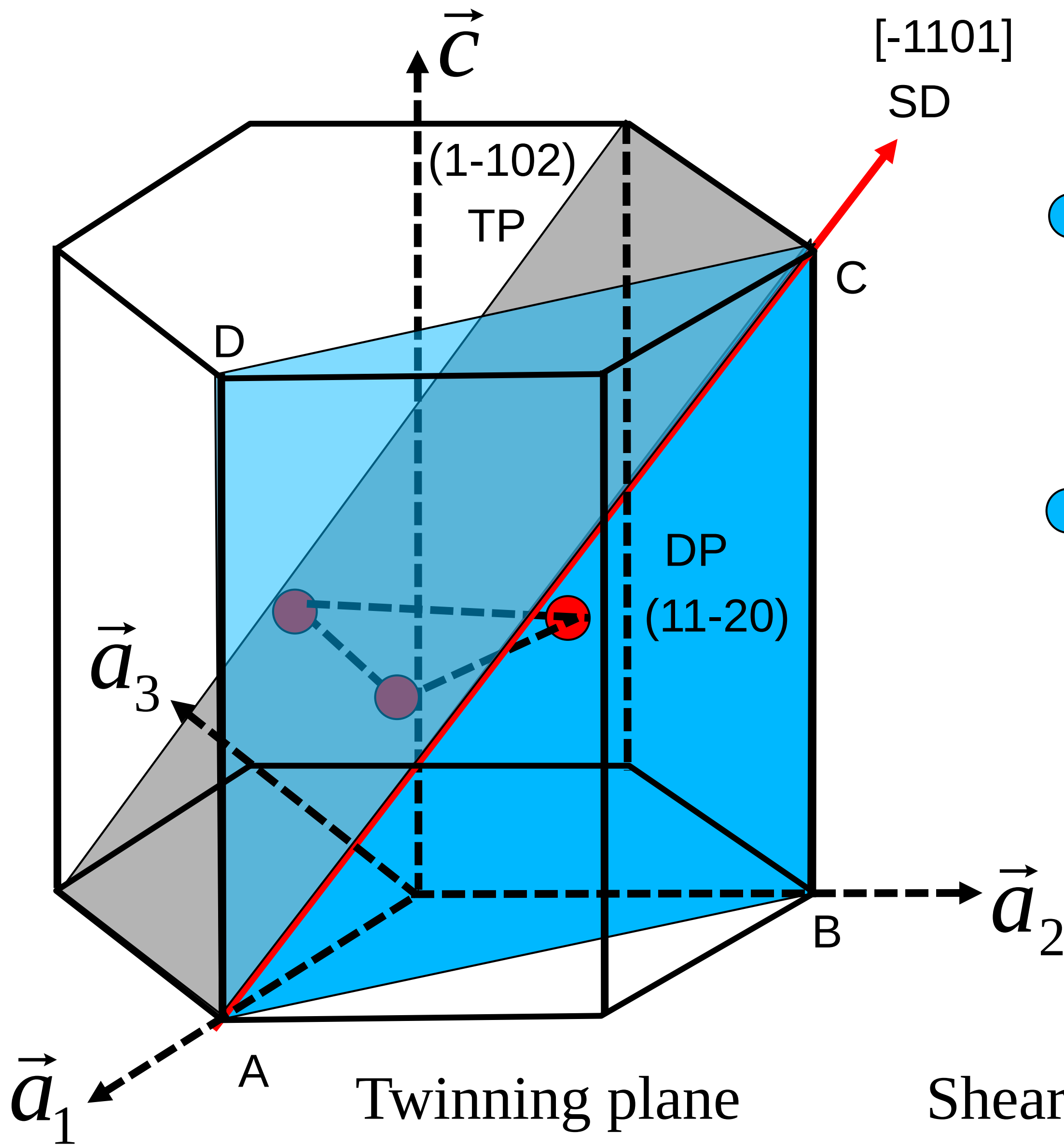
Displacement plane {110}

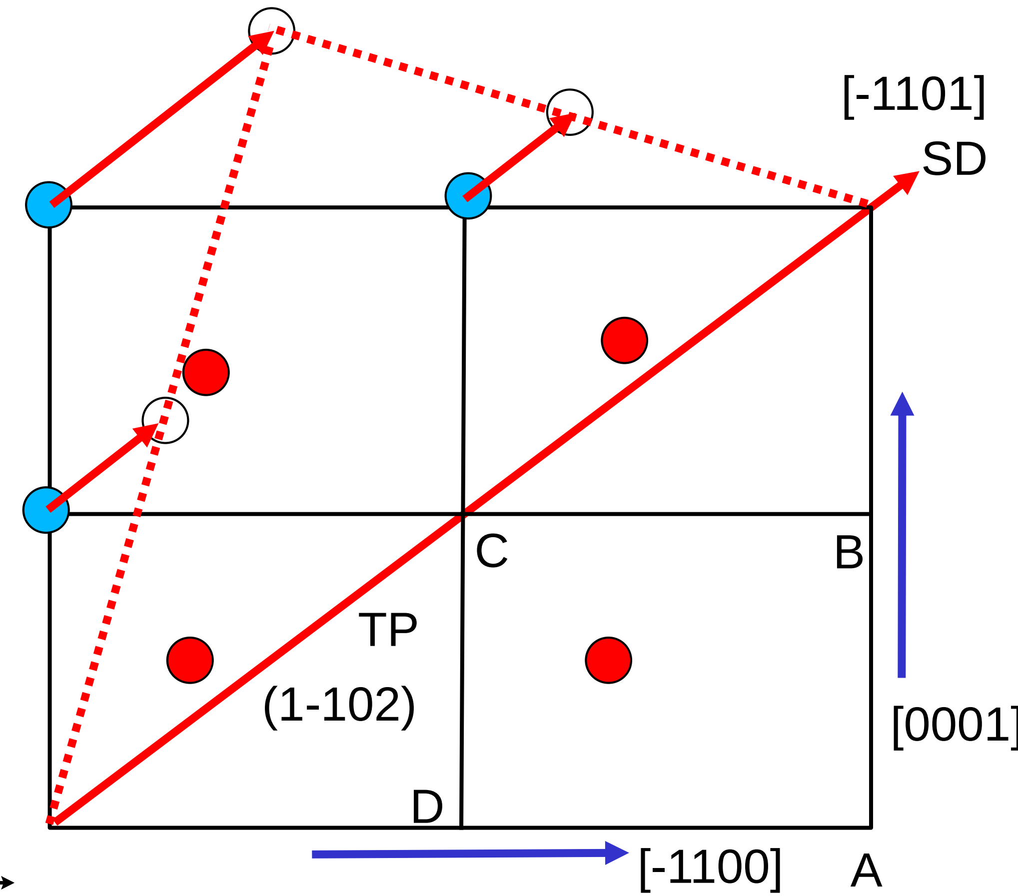
Twinning system of bcc metals



Twinning system of hcp metals in c/a > 1.63

Under tension



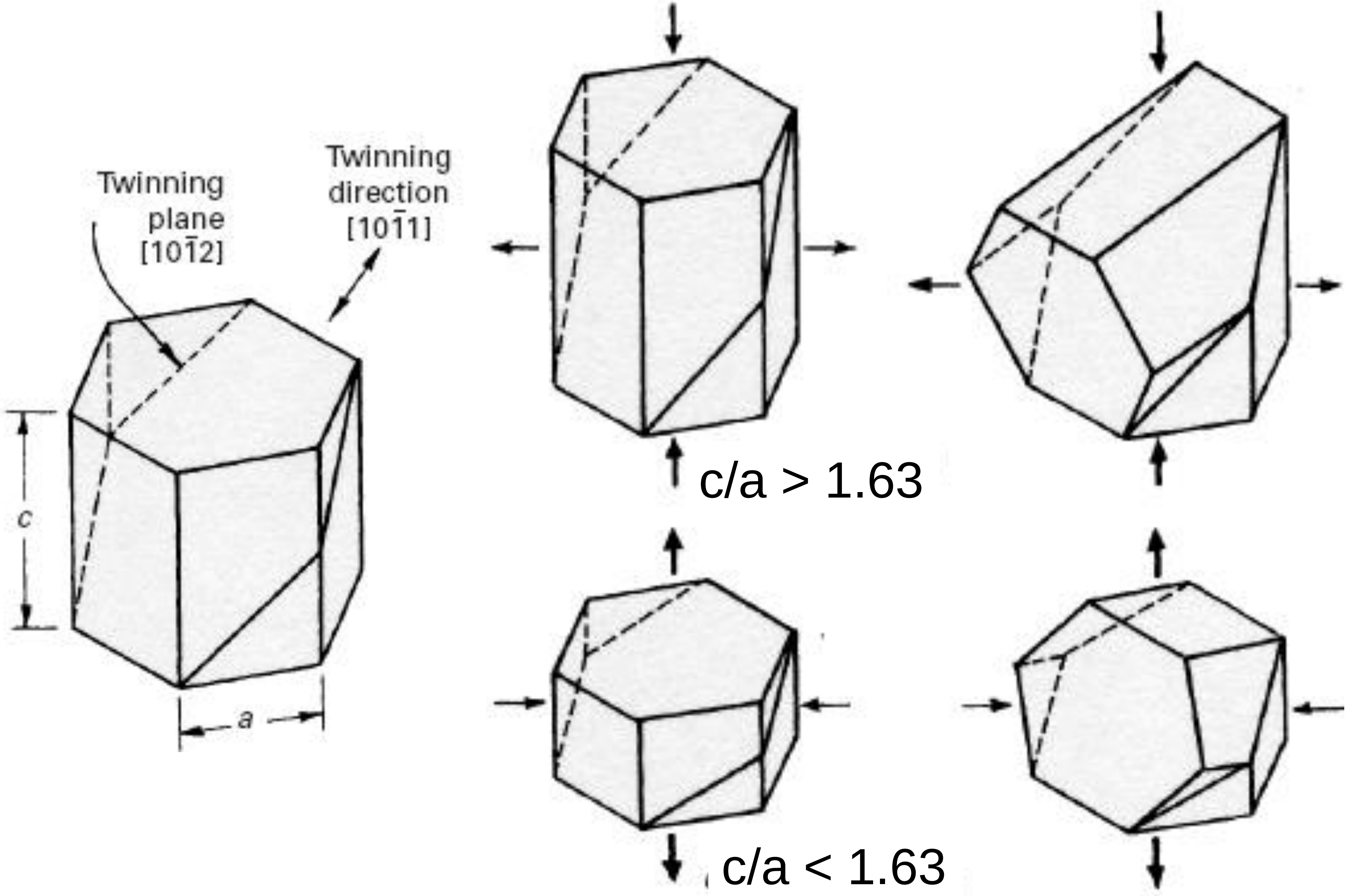


Twinning plane {10-12} | Shear direction <10-11> | Displacement plane {11-20}

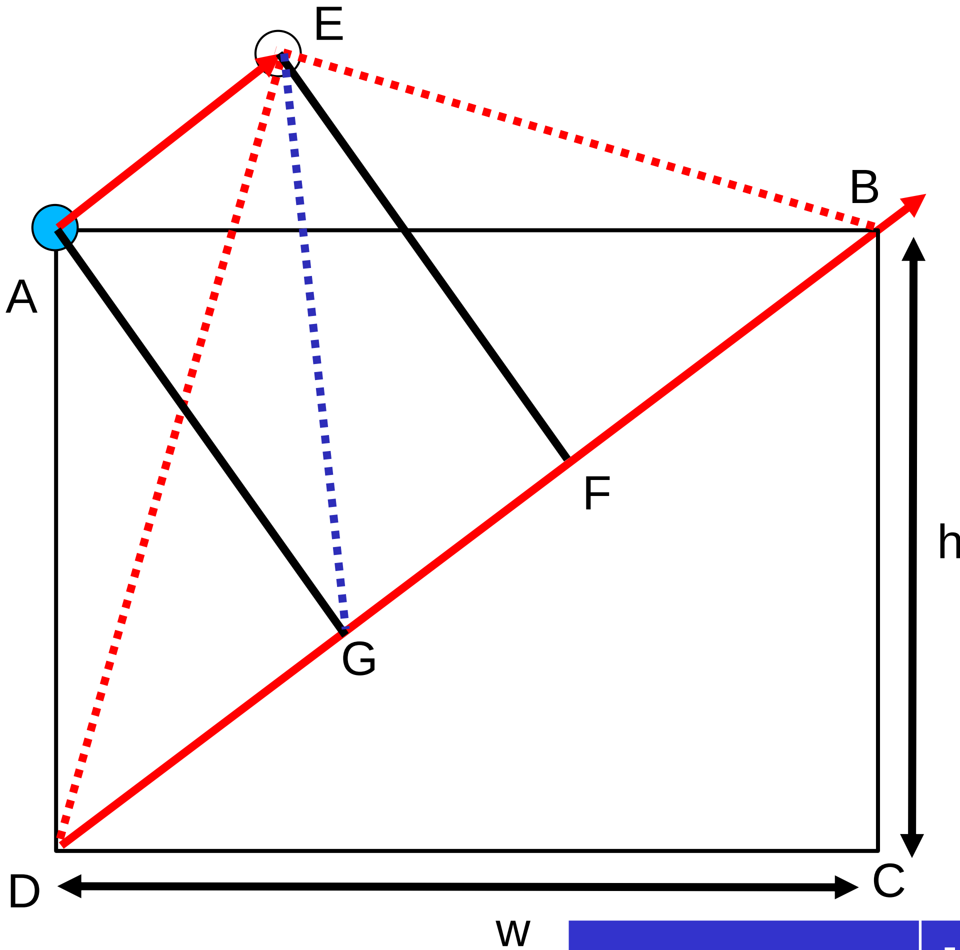
Twinning system of hcp metals in c/a < 1.63

HCP metals	c (nm)	a (nm)	c/a ratio
Be	0.3584	0.2286	1.568
Hf	0.5042	0.3188	1.582
Ti	0.4683	0.2590	1.587
Zr	0.5148	0.3231	1.593
Mg	0.5210	0.3209	1.624
Zn	0.4947	0.2665	1.856
Cd	0.5617	0.2979	1.886

Ratio of c/a in hcp metals



Twinning deformation in hcp metals



$$\gamma = \frac{\overline{AE}}{\overline{EF}} = \frac{\sqrt{\left(w^2+h^2\right)} - \frac{2h^2}{\sqrt{w^2+h^2}}}{\frac{wh}{\sqrt{w^2+h^2}}}$$

$$= \frac{w}{h} - \frac{h}{w}$$

$$\gamma = \frac{\overline{AE}}{\overline{EF}} \qquad \frac{\overline{EF}}{\overline{EB}} = \frac{\overline{DC}}{\overline{DB}} \qquad \overline{EF} = \frac{wh}{\sqrt{\left(w^2+h^2\right)}}$$

	h	w	γ
fcc	a	$a\sqrt{2}$	$\sqrt{2}/2$
bcc	a	$a/\sqrt{2}$	$\sqrt{2}/2$
hcp	c	$a\sqrt{3}$	$c\sqrt{3}a - \sqrt{3}a/c$

Calculation of twinning shear