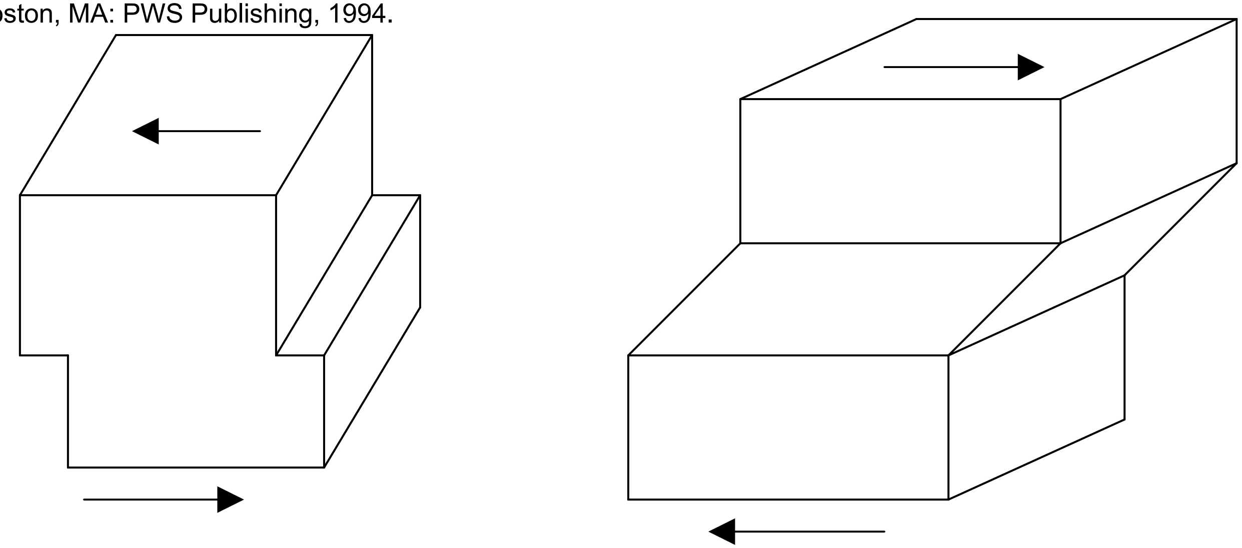
Lecture Summary 10/07/09 “Twinning”

Glide vs Twinning Comparison

	Glide	Twinning
Atomic movement	Atoms move a whole number of atomic spacing on a single plane.	Planes of atoms move fractional atomic spacing. Distributed over entire volume.
Microscopic appearance	Thin lines	Wide bands or broad lines
Lattice orientation	No change in lattice orientation. The steps are only visible on the surface of the crystal and can be removed by polishing. After polishing there is no evidence of slip.	Lattice orientation changes. Surface polishing will not destroy the evidence of twinning.



http://info.lu.farmingdale.edu/depts/met/met205/plasticdeformation.html

Characteristics of Twinning

- Distributed over entire volume and not confined to a single plane
- Happens very quickly (speed of sound in material)
- Cooperative motion of many planes of atoms with each plane moving only a small distance

- Lattice is rotated not distorted » <u>NOT</u> a phase transformation

Rules for Twinning

- Fundamental Rule: crystal orientation is rotated but crystal is not distorted -Crystal structure is unchanged as a result of twinning
  - Basis vectors maintain same mutual angles and length
  - Solving for the vector combinations that follow the above rules yields the twinning system

Rule Development

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Reed-Hill, Physical Metallurgy Principles 3rd Edition, PWS Publishing Company, 1994

Rules for Twinning

- Twin is completely defined when K_1, K_2, η_1, η_2 are all known

- η_1 and η_2 must lie in the same plane

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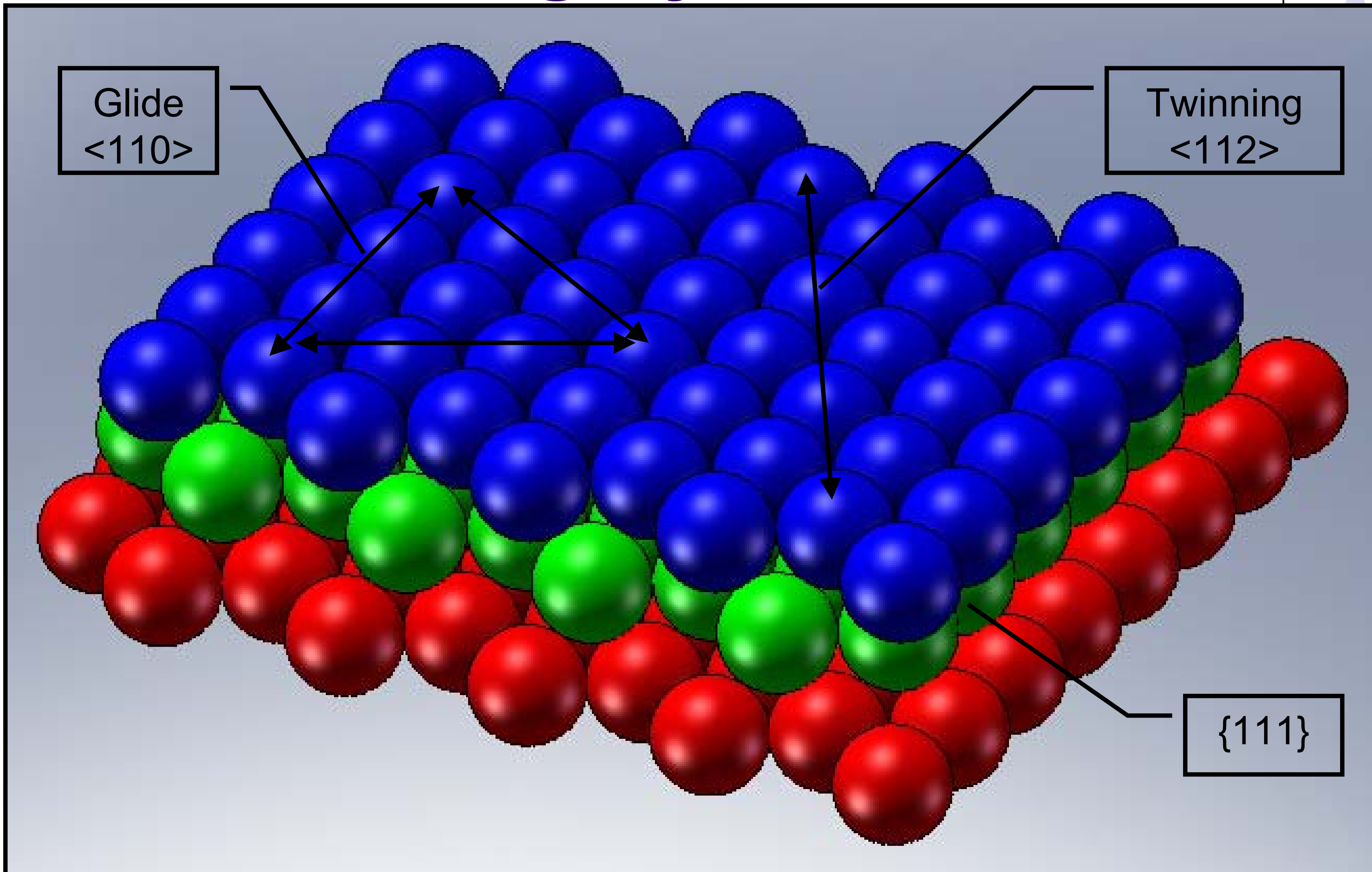
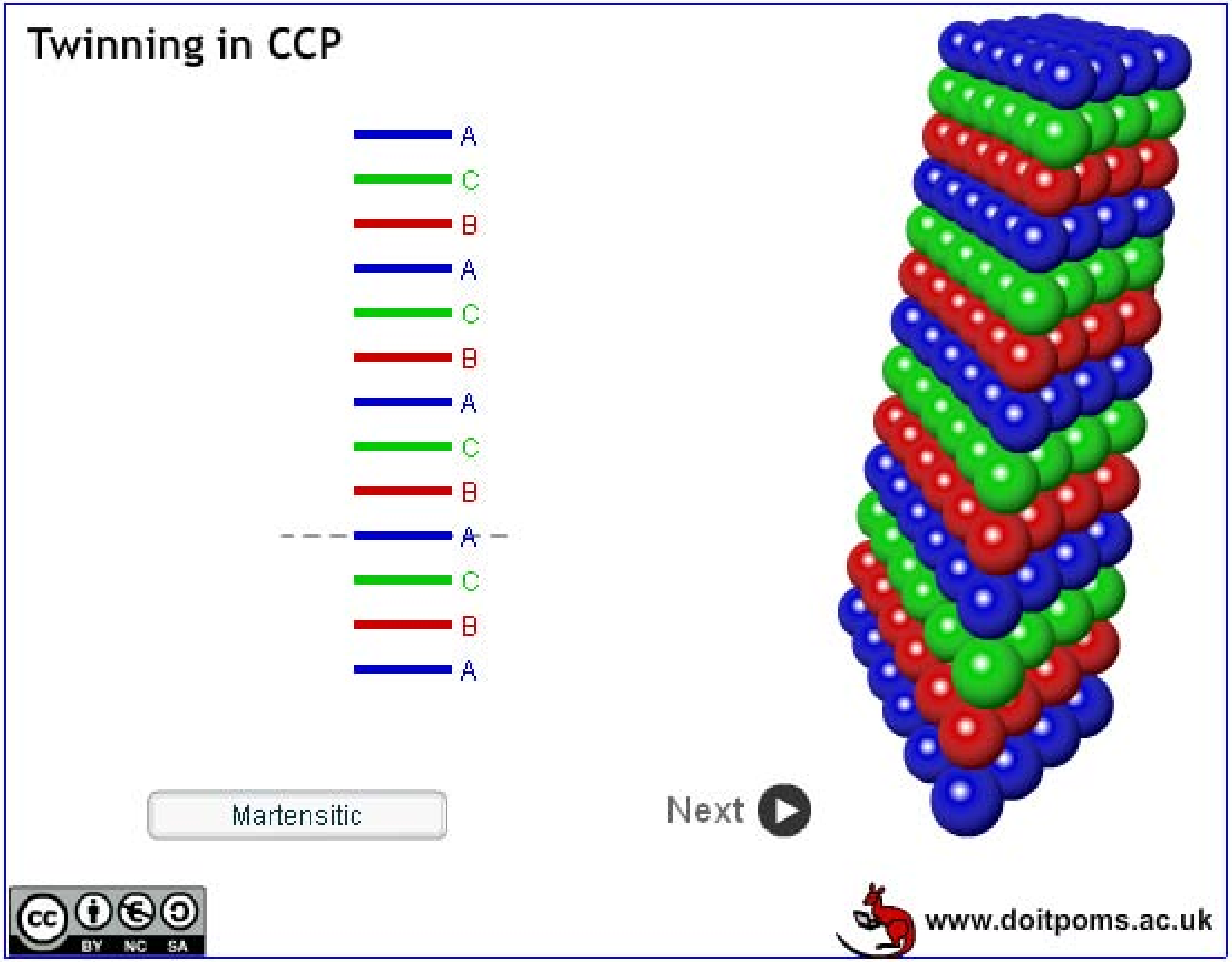
- η_1 and η_2 must be perpendicular to the intersection of the K_1 and K_2 planes

FCC Twinning System



Cubic Close Packed Twinning



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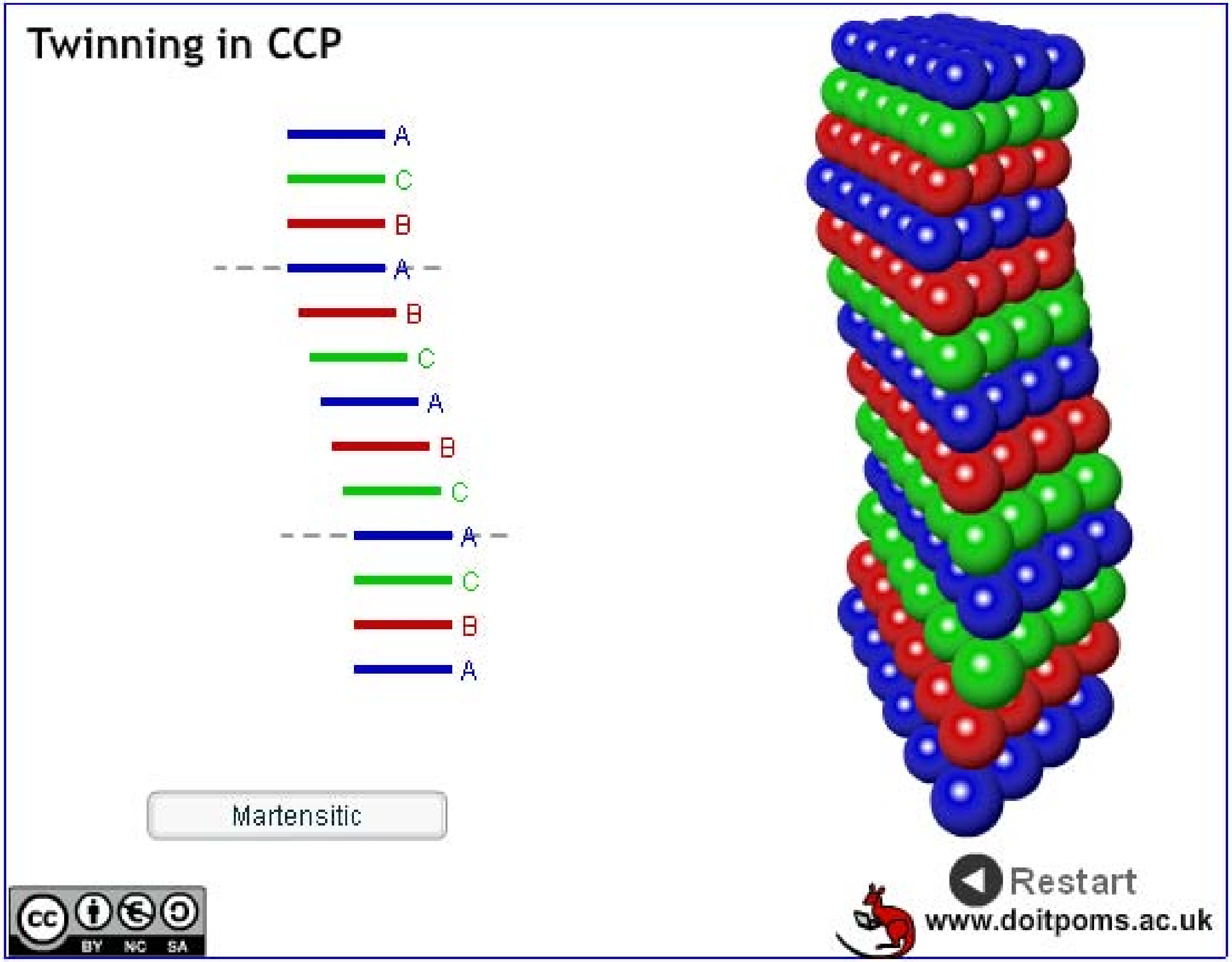
Cubic Close Packed Twinning



Courtesy of DoITPoMS, University of Cambridge. (Online)

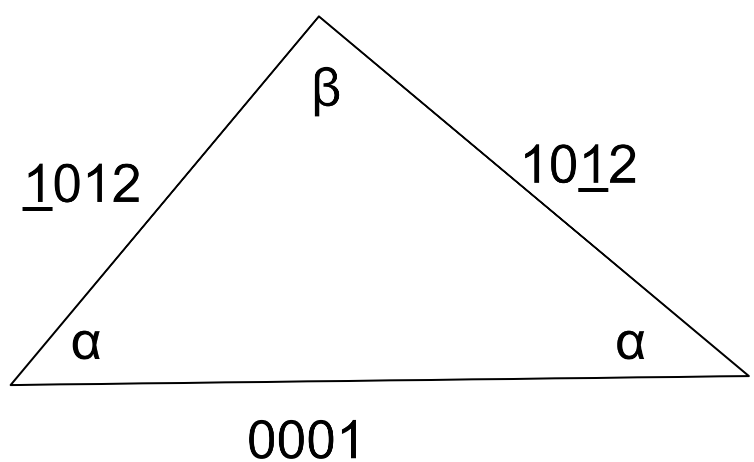
Twinning Systems

Type of Metal	**K_1**	**η_1**	**K_2**	**η_2**
BCC	{112}	<11$\underline{1}$>	{11$\underline{2}$}	<111>
FCC	{111}	<11$\underline{2}$>	{11$\underline{1}$}	<112>
HCP *(Mg, Ti)*	{10$\underline{1}$1}	<10$\underline{12}$>	{10$\underline{13}$}	<30$\underline{3}$2>
(Be, Cd, Hf, Mg, Ti, Zn, Zr)	{10$\underline{1}$2}	<10$\underline{11}$>	{10$\underline{12}$}	<10$\underline{11}$>
(Mg)	{10$\underline{1}$3}	<30$\underline{32}$>	{10$\underline{11}$}	<10$\underline{1}$2>
(Hf, Ti, Zr)	{11$\underline{2}$1}	<11$\underline{26}$>	{0002}	<11$\underline{2}$0>
(Ti, Zr)	{11$\underline{2}$2}	<11$\underline{23}$>	{11$\underline{24}$}	<22$\underline{4}$3>

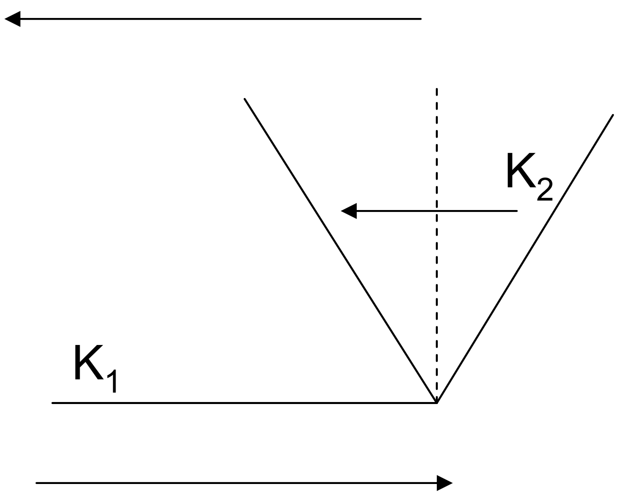
"Physical Metallurgy Principles" Appendix E

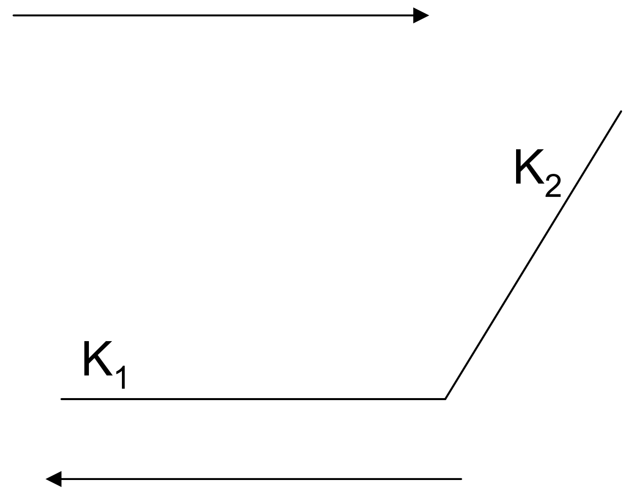
Hexagonal Metals

- Twinning system is often $\{10\underline{1}2\}$ $\langle\underline{1}011\rangle$, corresponding to $K_1=(10\underline{1}2)$, $K_2=(\underline{1}012)$
- Zn: c/a=1.86, β=86°
- Mg: c/a=1.62, β=94°



Twinning & Stress Sign
Obtuse β





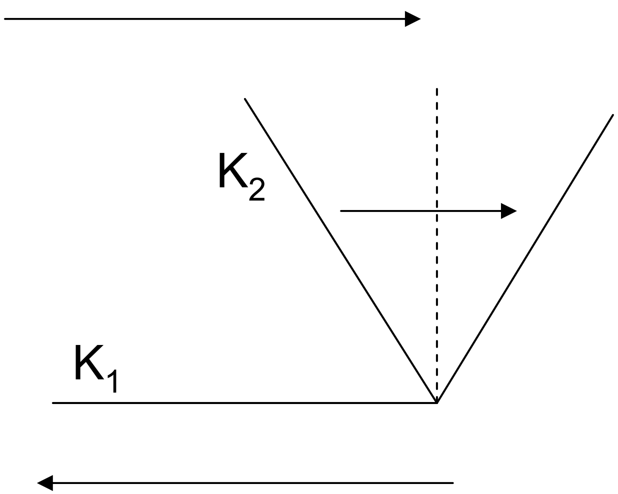
Twinning **will** occur

•Mg in compression

Twinning will **not** occur → fracture

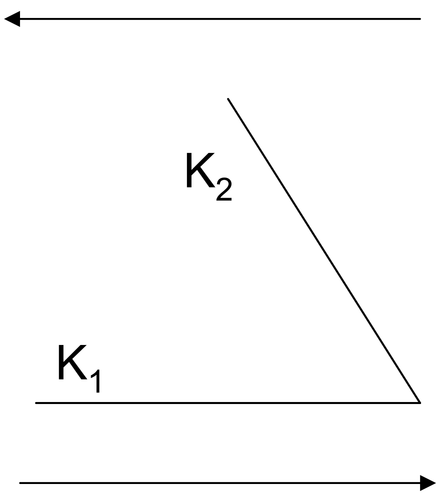
•Mg in tension

Twinning & Stress Sign Acute β



Twinning **will** occur

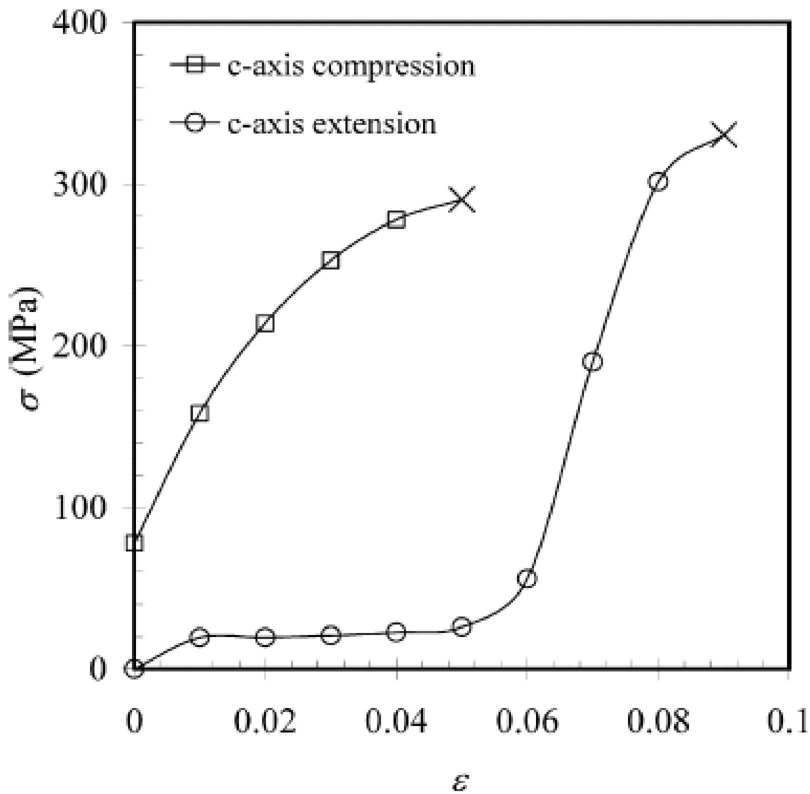
•Zn in tension



Twinning will **not** occur → fracture

•Zn in compression

Magnesium Twinning



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M. R. Barnett, 2007

Titanium Twinning

Please see Fig. 9 in Zhong, Yong, Fuxing Yin, and Kotobu Nagai. "Role of deformation twin on texture evolution in cold-rolled commercial-purity Ti." *Journal of Materials Research* 23 (November 2008): 2954-2966.

Zhong et al., 2008

Questions?