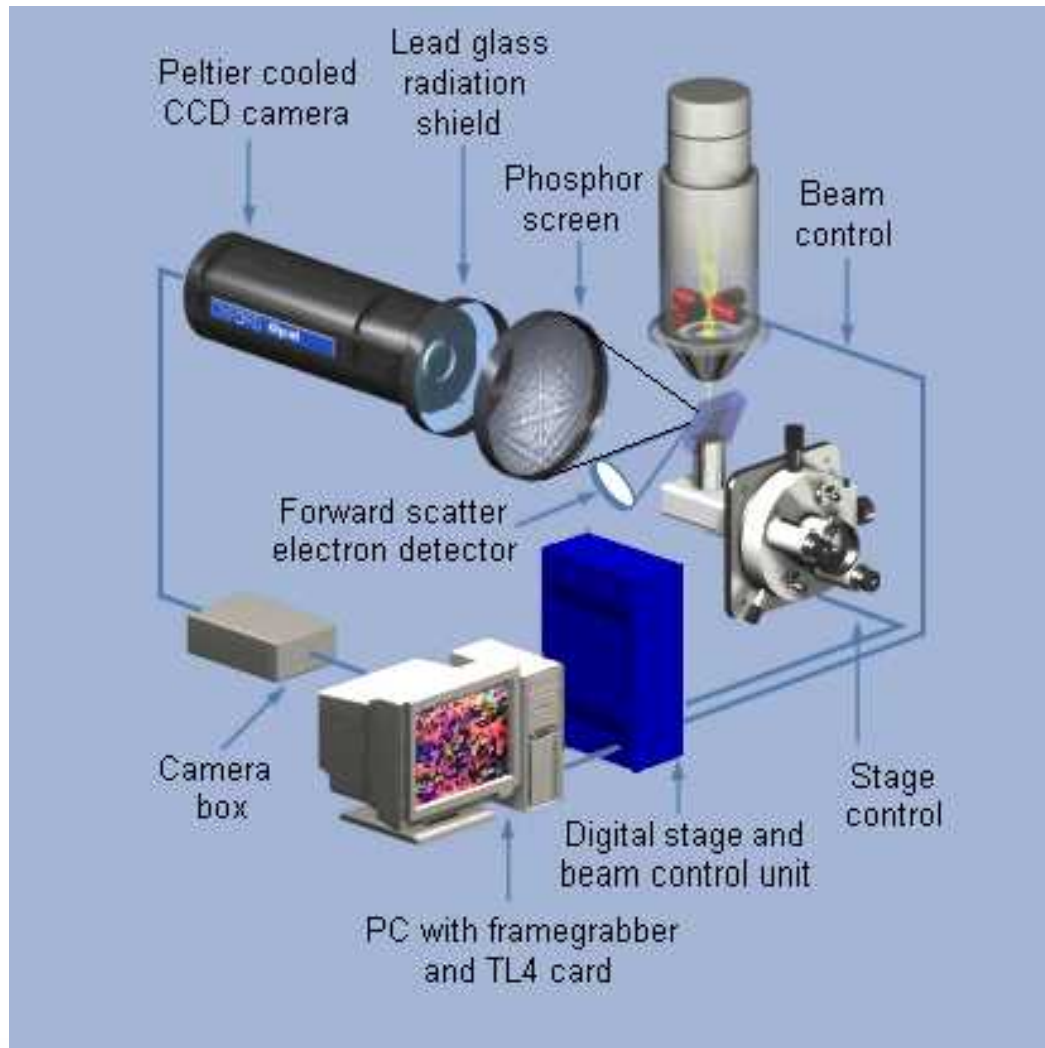
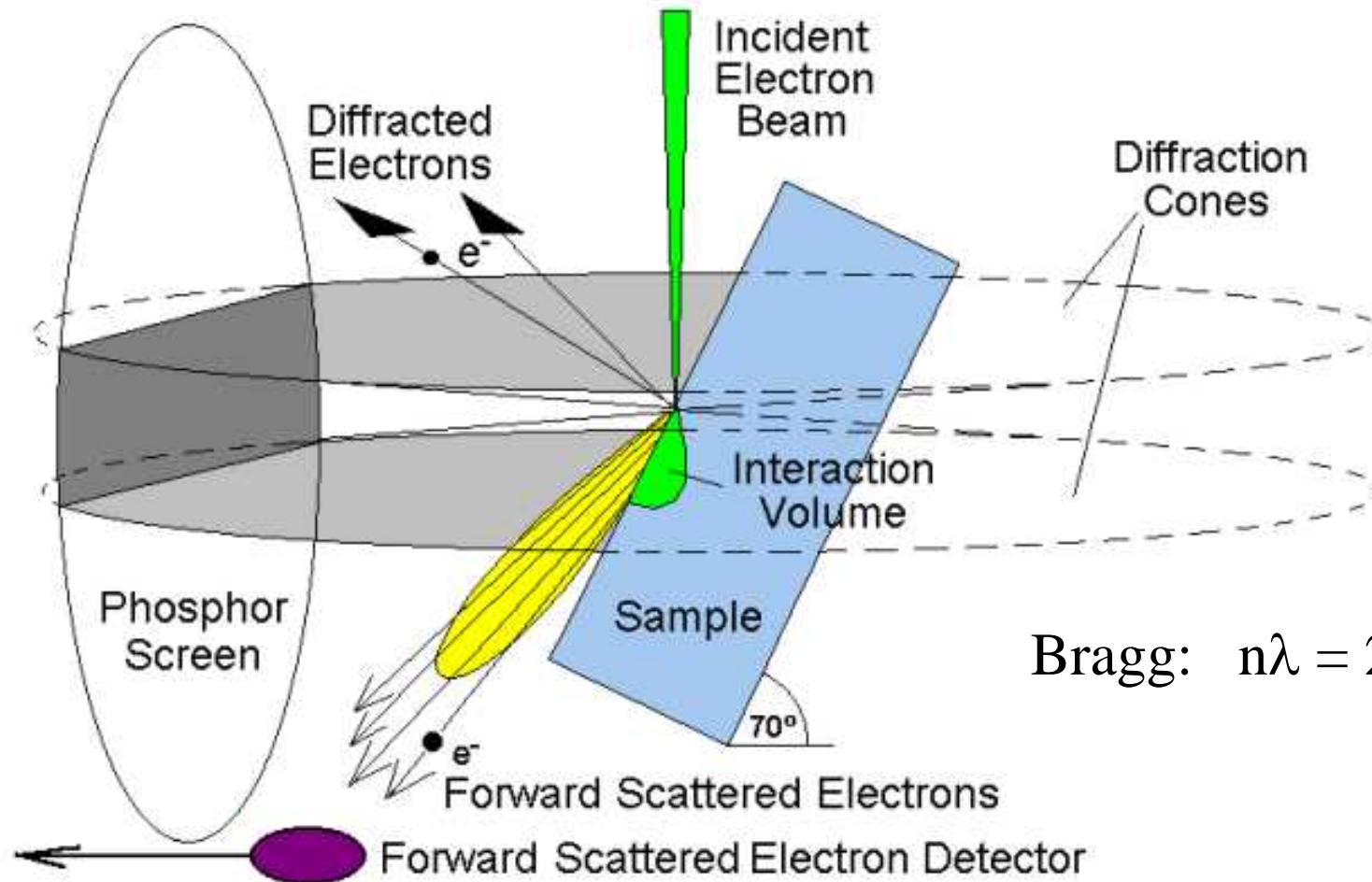


Electron Backscatter Diffraction EBSD

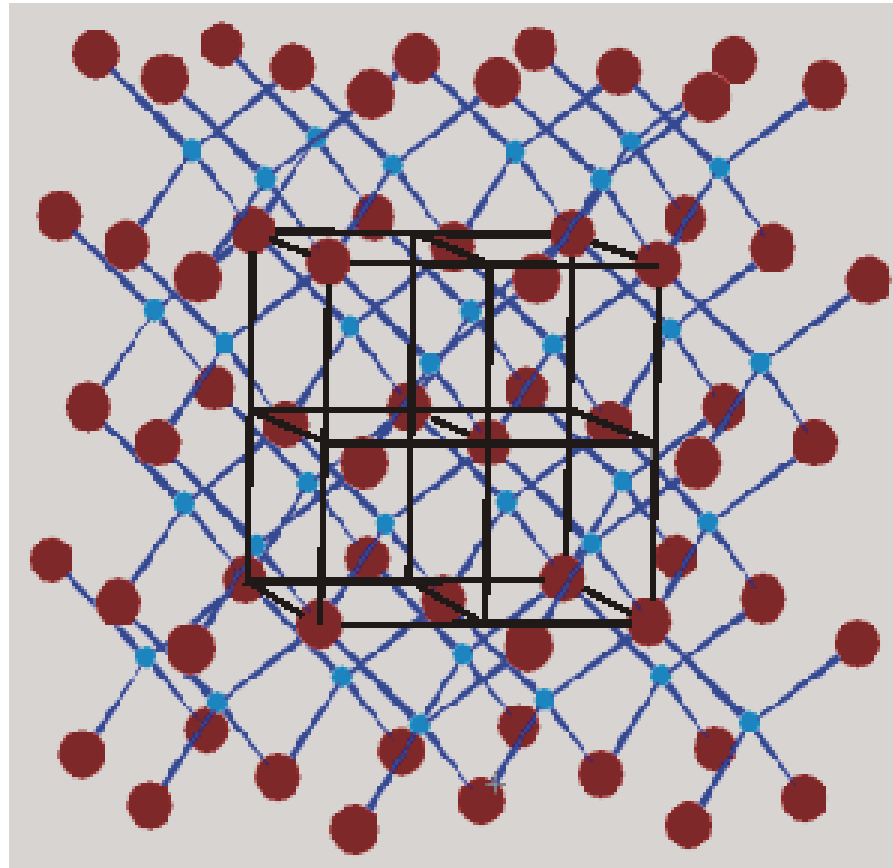
Oxford - Link System



Geometrie EBSD



Kristall

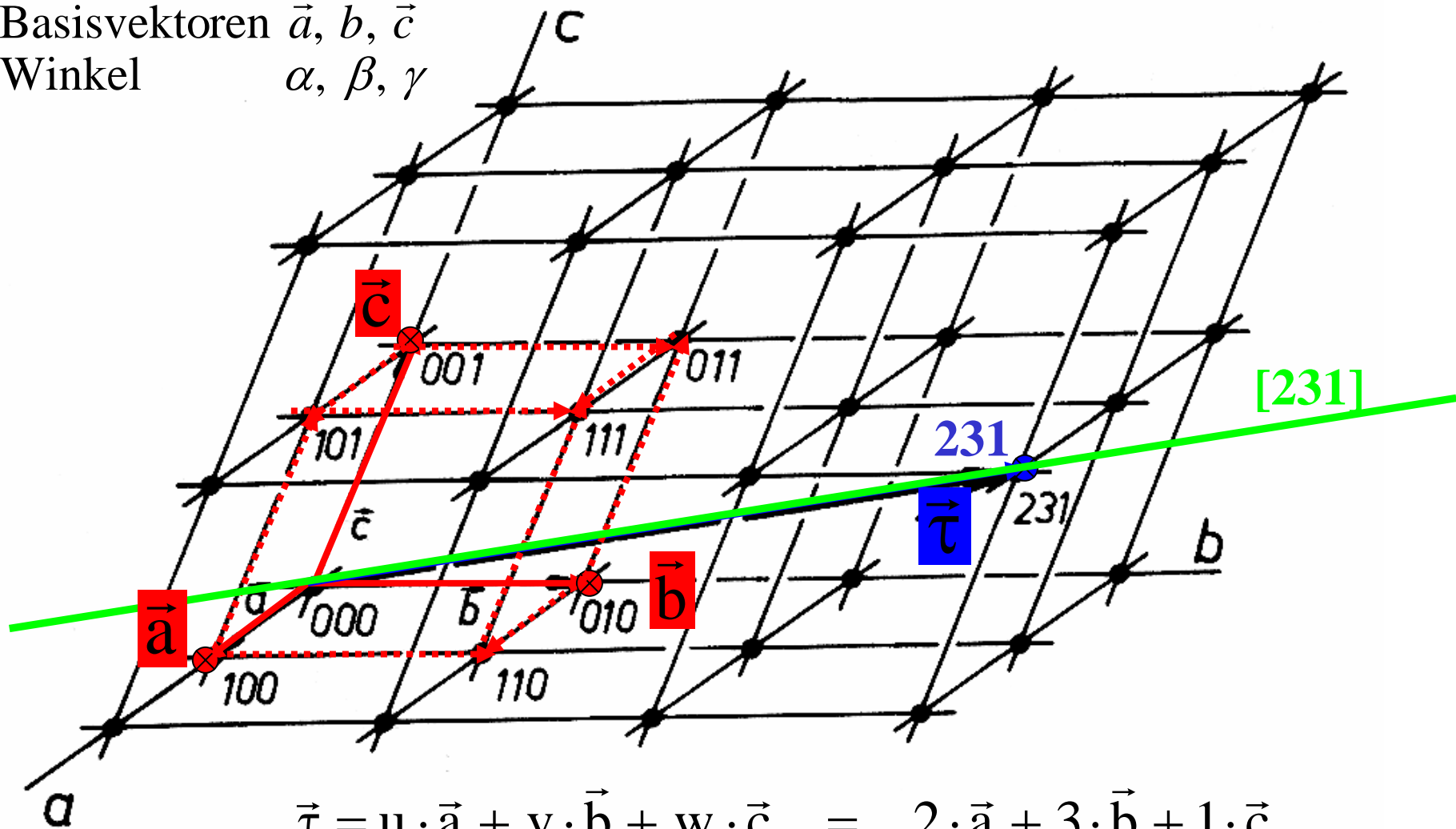


homogenes, anisotropes Diskontinuum mit dreidimensional
periodischer Anordnung von Gitterbausteinen



Raumgitter

Basisvektoren $\vec{a}, \vec{b}, \vec{c}$
 Winkel α, β, γ

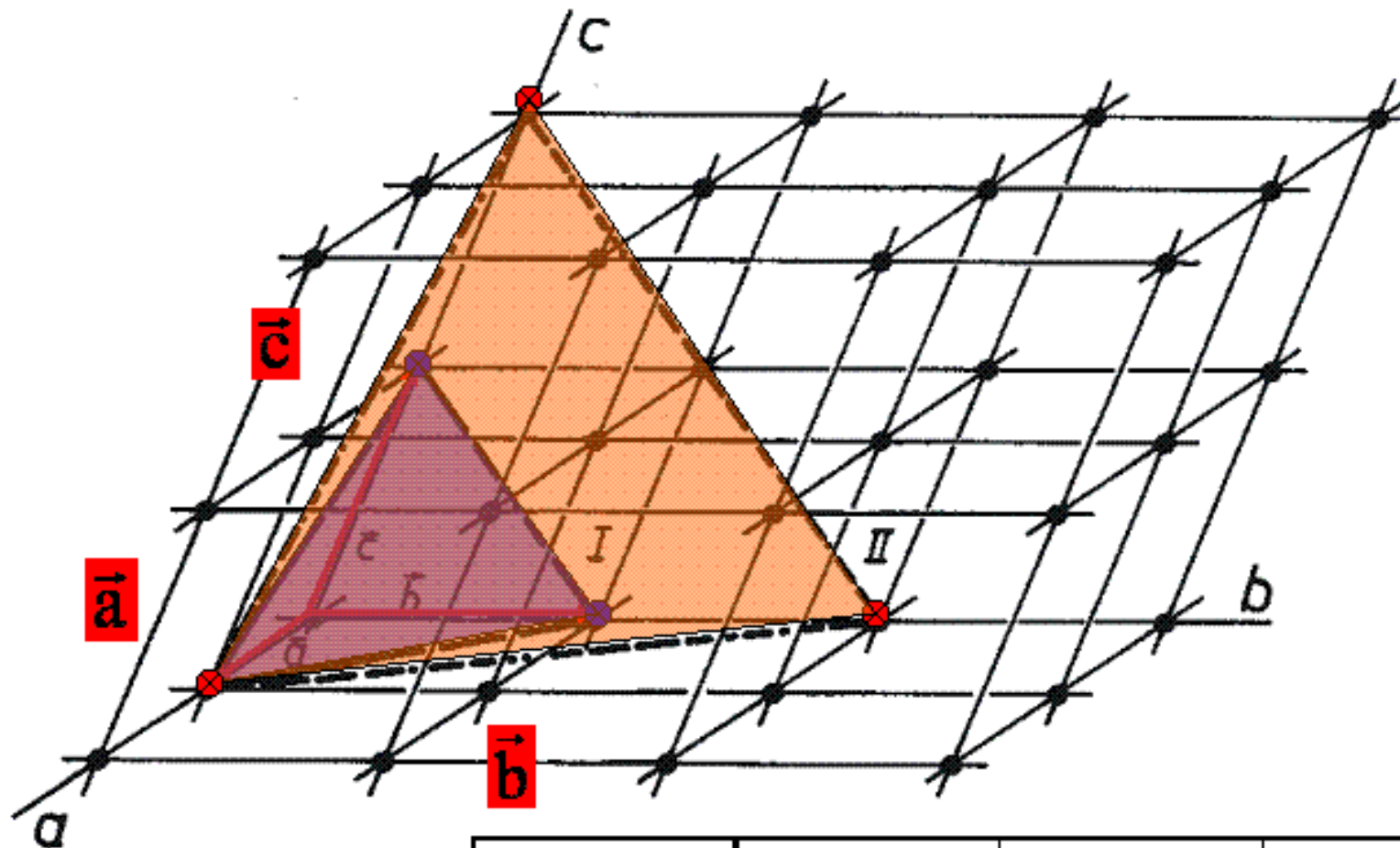


$$\vec{\tau} = u \cdot \vec{a} + v \cdot \vec{b} + w \cdot \vec{c} = 2 \cdot \vec{a} + 3 \cdot \vec{b} + 1 \cdot \vec{c}$$

Gerade durch die Punkte 000 und 231: [231]

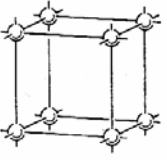
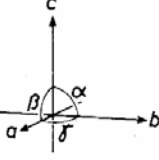
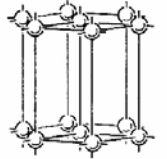
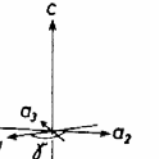
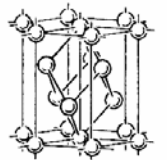
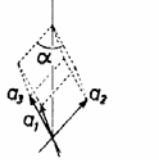
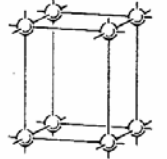
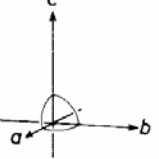
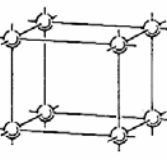
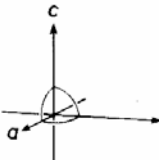
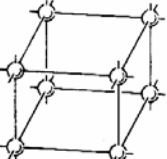
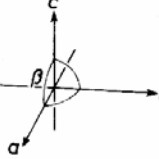
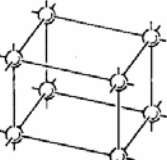
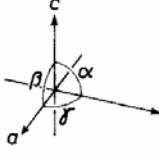


Netzebenen



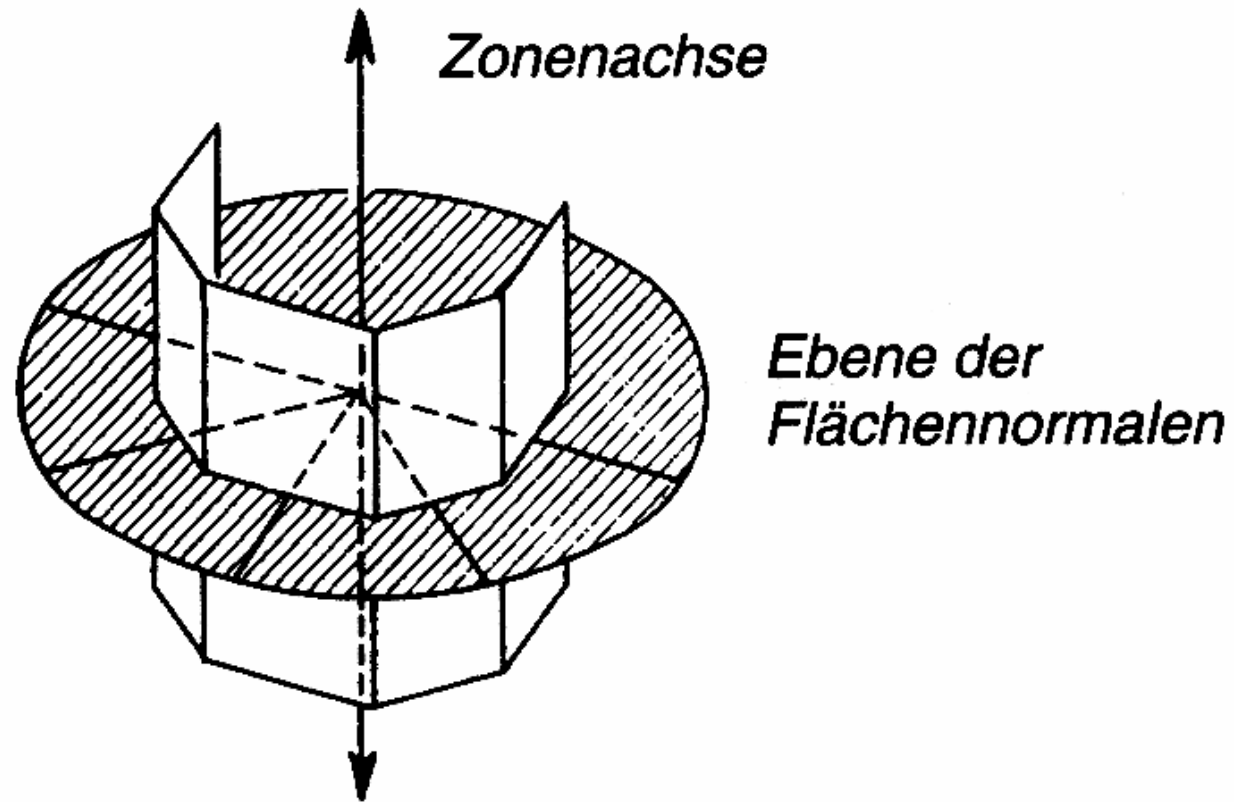
Indizes nach	Weiß	Kehrwert	Miller
Ebene I	111	111	(111)
Ebene II	122	$1 \frac{1}{2} \frac{1}{2}$	(211)

Kristallsysteme

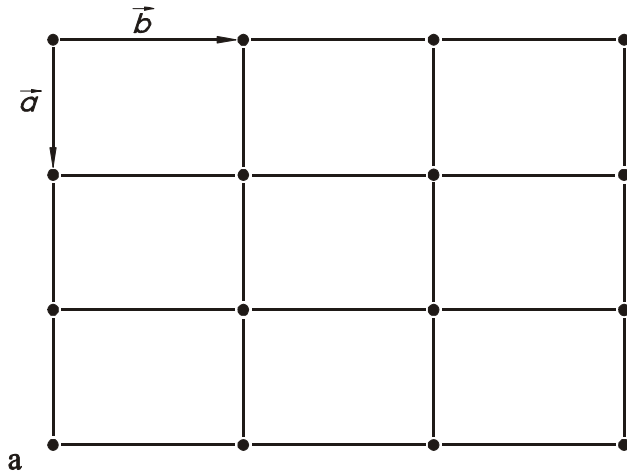
	 <p><i>Kubisch:</i> $a = b = c$ $\alpha = \beta = \gamma = 90^\circ$</p>
	 <p><i>Hexagonal:</i> $a_1 = a_2 = a_3 \neq c$ $\alpha = \beta = 90^\circ; \gamma = 120^\circ$</p>
	 <p><i>Rhomboedrisch:</i> $a_1 = a_2 = a_3$ $\alpha_1 = \alpha_2 = \alpha_3 \neq 90^\circ$</p>
	 <p><i>Tetragonal:</i> $a = b \neq c$ $\alpha = \beta = \gamma = 90^\circ$</p>
	 <p><i>Orthorhombisch:</i> $a \neq b \neq c$ $\alpha = \beta = \gamma = 90^\circ$</p>
	 <p><i>Monoklin:</i> $a \neq b \neq c$ $\alpha = \gamma = 90^\circ; \beta \neq 90^\circ$</p>
	 <p><i>Triklin:</i> $a \neq b \neq c$ $\alpha \neq \beta \neq \gamma \neq 90^\circ$</p>



Zonen und Zonenachsen

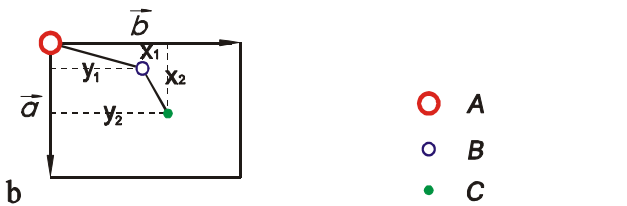


Kristallstruktur



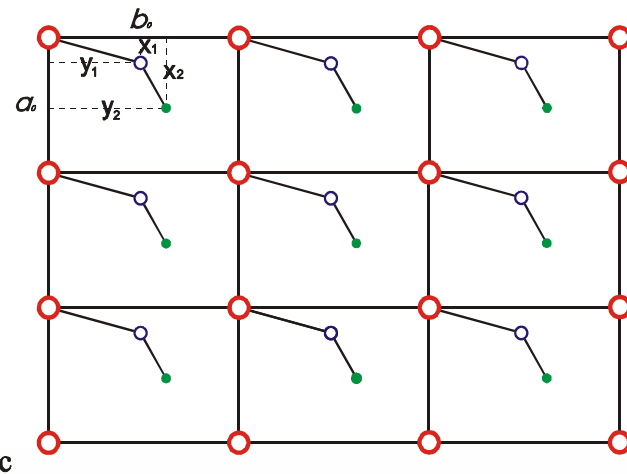
Gitter

+



Basis

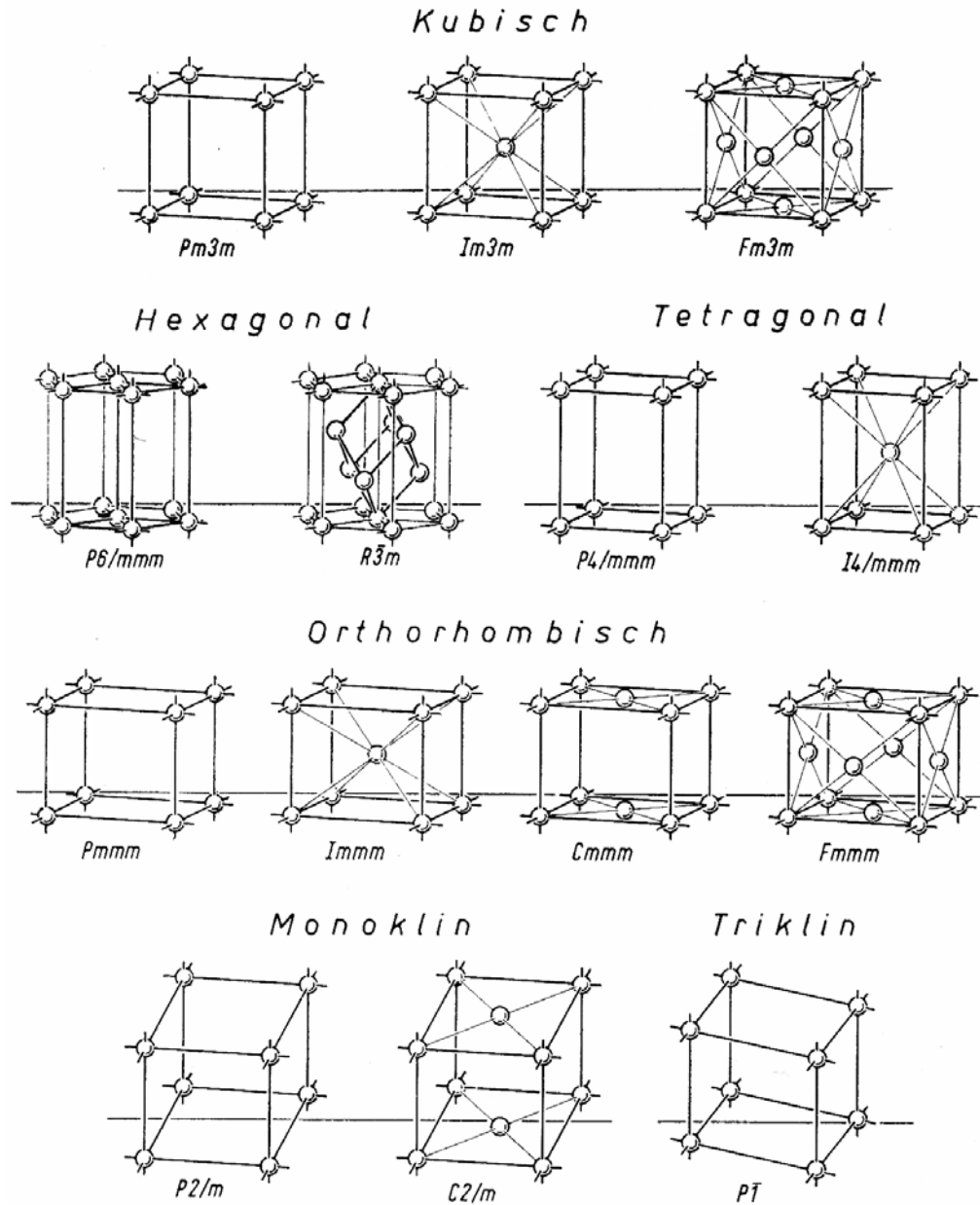
=



Kristall-
struktur

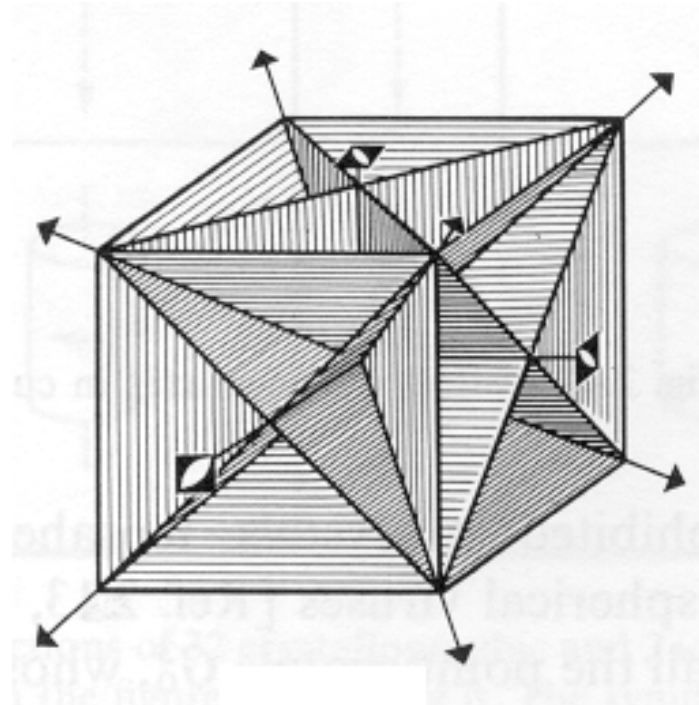
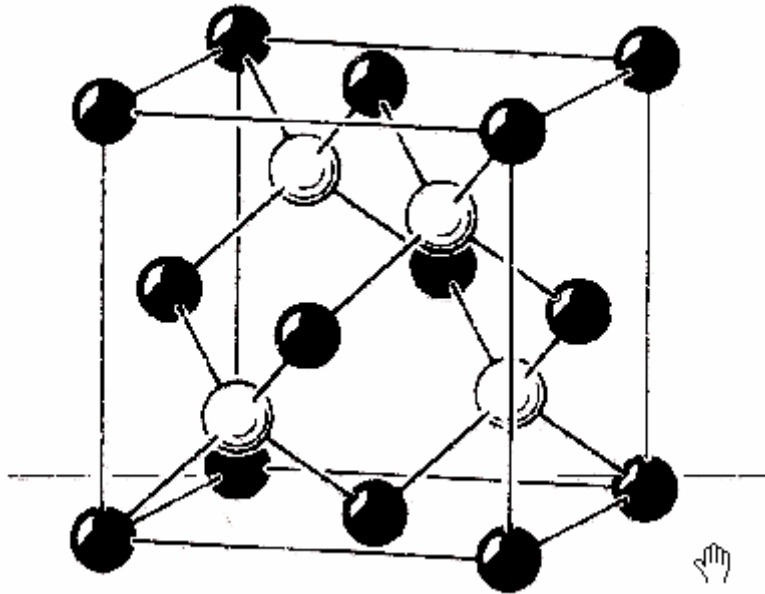


14 Bravaisgitter



Elementarzelle

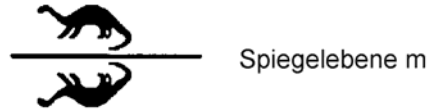
Kleinste Baueinheit, die die Metrik wiedergibt und
alle Symmetrieelemente enthält



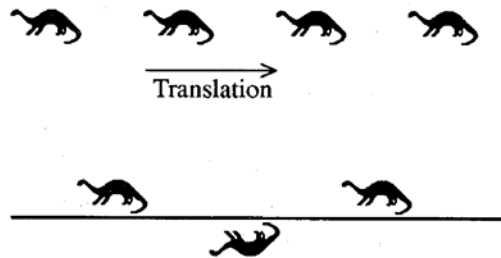
z.B.: $F\bar{4}3m$,
Zinkblendestruktur



Symmetrieelemente im Zweidimensionalen



Drehachsen



Gleitspiegelung g

Symmetrie

Deckoperationen im

Kontinuum

Diskontinuum



Symmetrieprinzip

10 Symmetrieelemente des Kontinuums:

- Drehachsen 1, 2, 3, 4, 6
- Drehinversionsachsen $\bar{3}$, $\bar{4}$, $\bar{6}$
- Inversion $\bar{1}$ oder i
- Spiegelebene m

=> 32 Kristallklassen

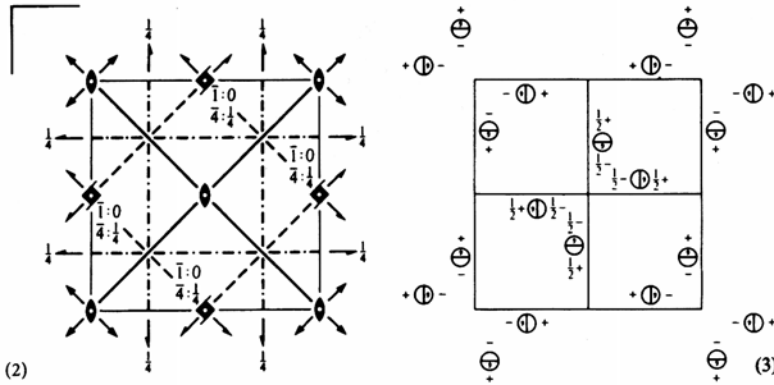
10 Symmetrieelemente des Kontinuums + Translation:

- Gleitspiegelebenen a , b , c , d
- Drehinversionsachsen, z. B.: 4_1 , 4_2 , 4_3

=> 230 Raumgruppen



(1) $P 4_2/m n m$ D_{4h}^{14} $4/m m m$ Tetragonal
No. 136 $P 4_2/m 2_1/n 2/m$



(4) Origin at centre ($m m m$) at $2/m 1 2/m$

(5) Asymmetric unit $0 \leq x \leq \frac{1}{2}$; $0 \leq y \leq \frac{1}{2}$; $0 \leq z \leq \frac{1}{2}$; $x \leq y$

(6) Symmetry operations

- | | | | |
|---|---|---|---|
| (1) 1 | (2) 2 0,0,z | (3) $4^+(0,0,\frac{1}{2})$ $0,\frac{1}{2},z$ | (4) $4^-(0,0,\frac{1}{2})$ $\frac{1}{2},0,z$ |
| (5) $2(0,\frac{1}{2},0)$ $\frac{1}{4},y,\frac{1}{4}$ | (6) $2(\frac{1}{2},0,0)$ $x,\frac{1}{4},\frac{1}{4}$ | (7) 2 x,x,0 | (8) 2 x, \bar{x} ,0 |
| (9) $\bar{1}$ 0,0,0 | (10) m x,y,0 | (11) $4^+(\frac{1}{2},0,z)$ $\frac{1}{2},0,\frac{1}{4}$ | (12) $4^-(\frac{1}{2},0,z)$ $0,\frac{1}{2},\frac{1}{4}$ |
| (13) $n(\frac{1}{2},0,\frac{1}{2})$ $x,\frac{1}{4},z$ | (14) $n(0,\frac{1}{2},\frac{1}{2})$ $\frac{1}{4},y,z$ | (15) m x, \bar{x} ,z | (16) m x,x,z |

(7) Positions

	Multiplicity, Wyckoff letter, Site symmetry	Coordinates
16	k 1	(1) x,y,z (2) \bar{x},\bar{y},z (3) $\bar{y}+\frac{1}{2},x+\frac{1}{2},z+\frac{1}{2}$ (4) $y+\frac{1}{2},\bar{x}+\frac{1}{2},z+\frac{1}{2}$ (5) $\bar{x}+\frac{1}{2},y+\frac{1}{2},z+\frac{1}{2}$ (6) $x+\frac{1}{2},\bar{y}+\frac{1}{2},z+\frac{1}{2}$ (7) y,x,z (8) \bar{y},\bar{x},z (9) \bar{x},\bar{y},z (10) x,y,z (11) $y+\frac{1}{2},\bar{x}+\frac{1}{2},z+\frac{1}{2}$ (12) $\bar{y}+\frac{1}{2},x+\frac{1}{2},z+\frac{1}{2}$ (13) $x+\frac{1}{2},\bar{y}+\frac{1}{2},z+\frac{1}{2}$ (14) $\bar{x}+\frac{1}{2},y+\frac{1}{2},z+\frac{1}{2}$ (15) \bar{y},\bar{x},z (16) y,x,z
8	j ..m	x,x,z \bar{x},\bar{x},z $\bar{x}+\frac{1}{2},x+\frac{1}{2},z+\frac{1}{2}$ $x+\frac{1}{2},\bar{x}+\frac{1}{2},z+\frac{1}{2}$ $\bar{x}+\frac{1}{2},x+\frac{1}{2},z+\frac{1}{2}$ $x+\frac{1}{2},\bar{x}+\frac{1}{2},z+\frac{1}{2}$ x,x,z \bar{x},\bar{x},z
8	i m..	x,y,0 $\bar{x},\bar{y},0$ $\bar{y}+\frac{1}{2},x+\frac{1}{2},z+\frac{1}{2}$ $y+\frac{1}{2},\bar{x}+\frac{1}{2},z+\frac{1}{2}$ $\bar{x}+\frac{1}{2},y+\frac{1}{2},z+\frac{1}{2}$ $x+\frac{1}{2},\bar{y}+\frac{1}{2},z+\frac{1}{2}$ y,x,0 $\bar{y},\bar{x},0$
8	h 2..	$0,\frac{1}{2},z$ $0,\frac{1}{2},z+\frac{1}{2}$ $0,\frac{1}{2},z+\frac{1}{2}$ $\frac{1}{2},0,z$ $0,\frac{1}{2},z$ $0,\frac{1}{2},z+\frac{1}{2}$ $0,\frac{1}{2},z+\frac{1}{2}$ $\frac{1}{2},0,z$
4	g m.2m	x, \bar{x} ,0 $\bar{x},x,0$ $x+\frac{1}{2},x+\frac{1}{2},z+\frac{1}{2}$ $\bar{x}+\frac{1}{2},\bar{x}+\frac{1}{2},z+\frac{1}{2}$
4	f m.2m	x,x,0 $\bar{x},\bar{x},0$ $\bar{x}+\frac{1}{2},x+\frac{1}{2},z+\frac{1}{2}$ $x+\frac{1}{2},\bar{x}+\frac{1}{2},z+\frac{1}{2}$
4	e 2.mm	0,0,z $\frac{1}{2},\frac{1}{2},z+\frac{1}{2}$ $\frac{1}{2},\frac{1}{2},z+\frac{1}{2}$ 0,0,z
4	d $\bar{4}$..	$0,\frac{1}{2},\frac{1}{4}$ $0,\frac{1}{2},\frac{3}{4}$ $\frac{1}{2},0,\frac{1}{4}$ $\frac{1}{2},0,\frac{3}{4}$
4	c 2/m..	$0,\frac{1}{2},0$ $0,\frac{1}{2},\frac{1}{2}$ $\frac{1}{2},0,\frac{1}{2}$ $\frac{1}{2},0,0$
2	b m.mm	$0,0,\frac{1}{2}$ $\frac{1}{2},\frac{1}{2},0$
2	a m.mm	0,0,0 $\frac{1}{2},\frac{1}{2},\frac{1}{2}$

Raumgruppen

tabelliert in:

International Tables for
Crystallography, Vol A

asymmetrische Einheit:

kleinster Volumenteil einer
Elementarzelle, der durch Einwirkung
aller Symmetrieeoperationen die
Elementarzelle als Ganzes ergibt



11 Laue - Gruppen

Aufgrund des Phasenproblems beinhalten Beugungsbilder immer ein Inversionszentrum

=> zentro- und nichtzentrosymmetrische Gruppen können nicht unterschieden werden

Kristallsystem	Laue - Gruppe	Azentrische Untergruppen
triklin	$\bar{1}$	1
monoklin	2/m	2, m
orthorhombisch	mmm	222, mm2
tetragonal	4/m 4/mmm	4, $\bar{4}$ 4mm, $\bar{4}m2$, 422
trigonal	$\bar{3}$ $\bar{3} m$	3 3m, 32
hexagonal	6/m 6/mmm	6, $\bar{6}$ 6mm, 6m2, 622
kubisch	$m\bar{3}$ $m\bar{3}m$	23 $\bar{4}3m$, 432



Strukturdaten

Creating a crystal database

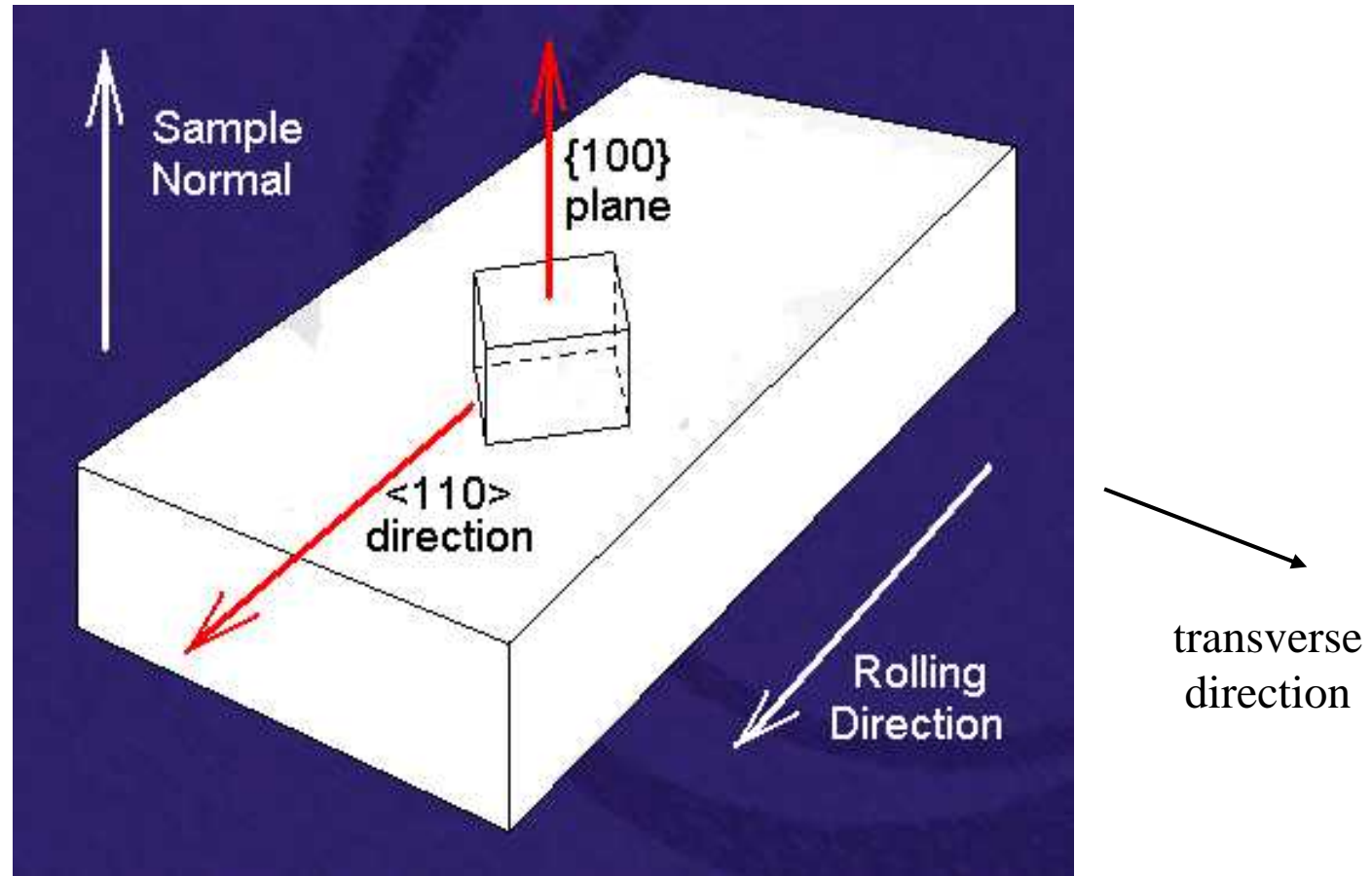
1. Select a crystal e.g. aluminium
2. Input lattice parameters e.g. $a = b = c = 0.405\text{nm}$
 $\alpha = \beta = \gamma = 90^\circ$
3. Input crystal symmetry e.g. cubic
Laue group = $m\bar{3}m$
Space group = $Fm\bar{3}m$
or $Fm\bar{3}m$
4. Input crystal unit cell e.g.

<u>Atom</u>	<u>x</u>	<u>y</u>	<u>z</u>	<u>Occ</u>
Al	0	0	0	1
Al	0	0.5	0.5	1
Al	0.5	0	0.5	1
Al	0.5	0.5	0	1

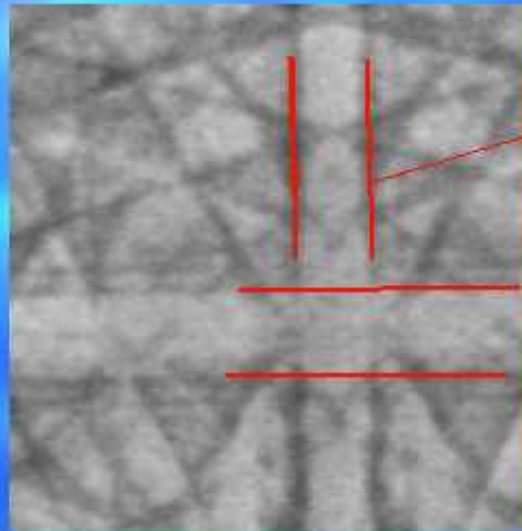
symmetry indicates
4 atomic positions



Probenorientierung und Referenzsystem



Informationen im EBSD - Bild



Bright 'Kikuchi' bands correspond to planes in the crystal lattice

Width of bands is dependent upon electron wavelength and lattice plane spacing

Relationship is given by the Bragg equation
 $\lambda = 2d \times \sin\theta$

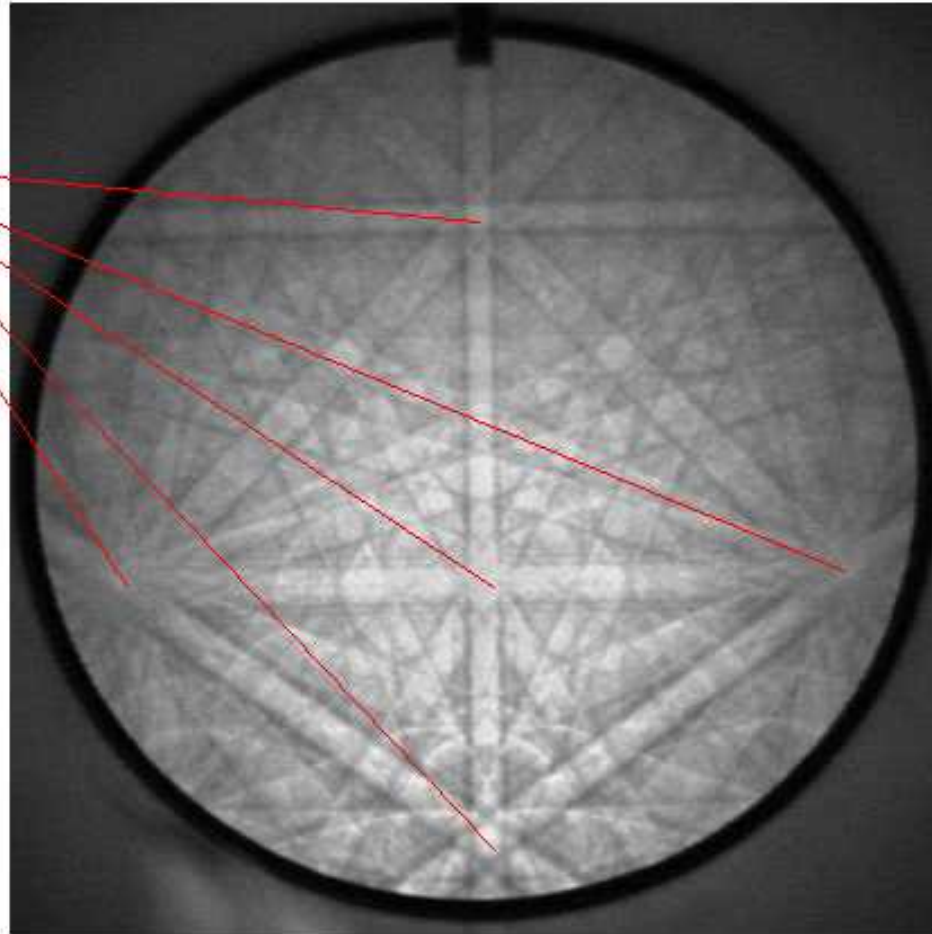
The EBSP contains the angular relationship between the planes, the symmetry of the crystal and orientation information.



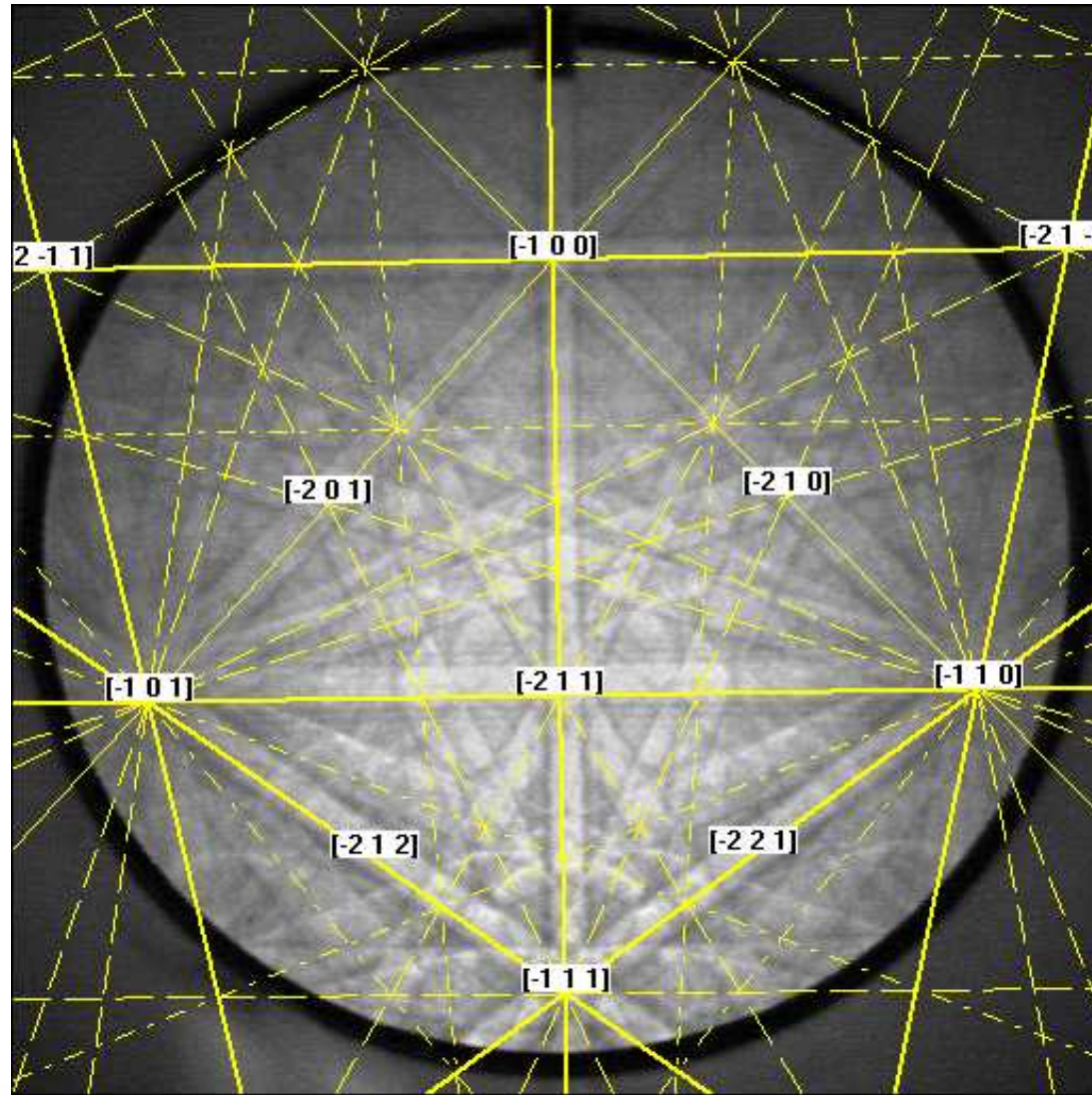
EBSD von Ge

'EBSP' Ge single crystal at 20keV

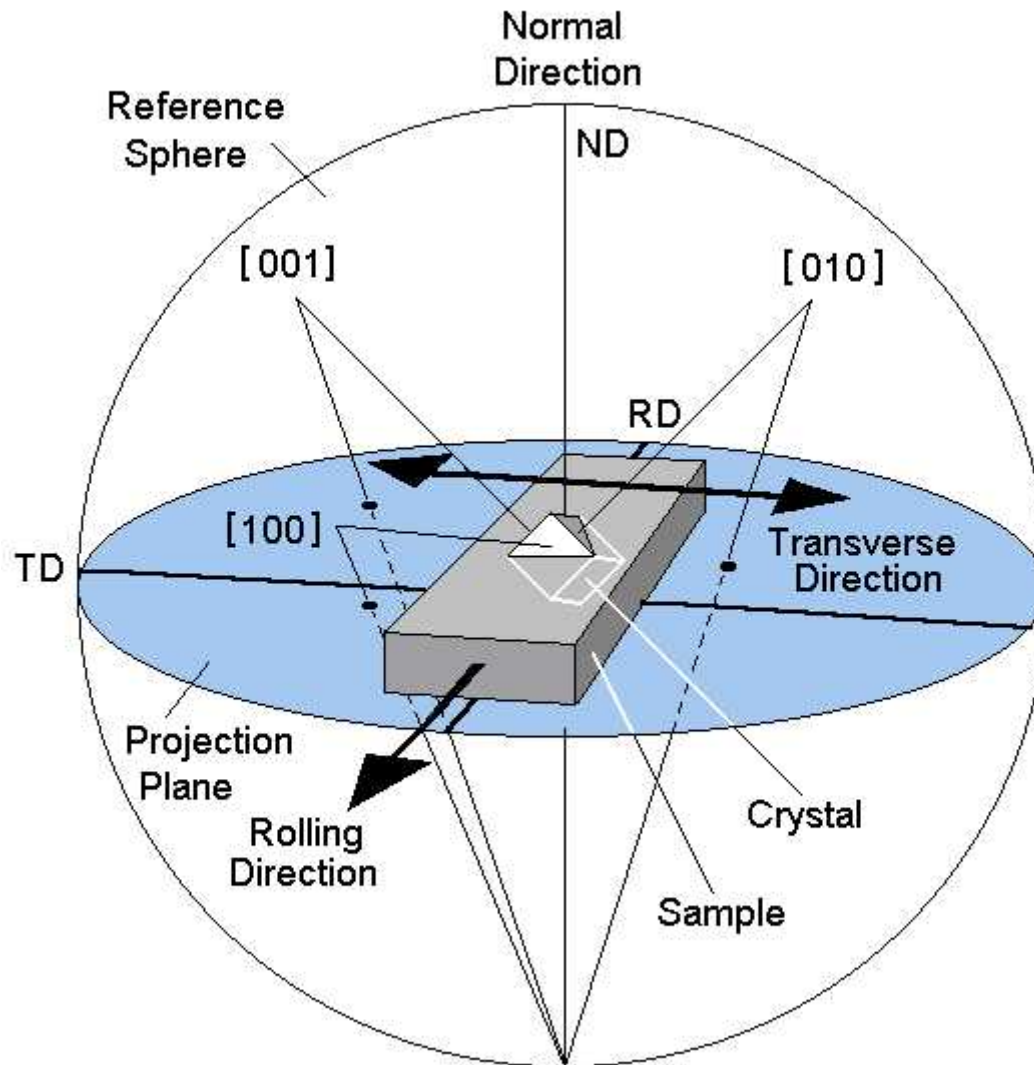
Some 'Zones'



EBSD von Ge indiziert

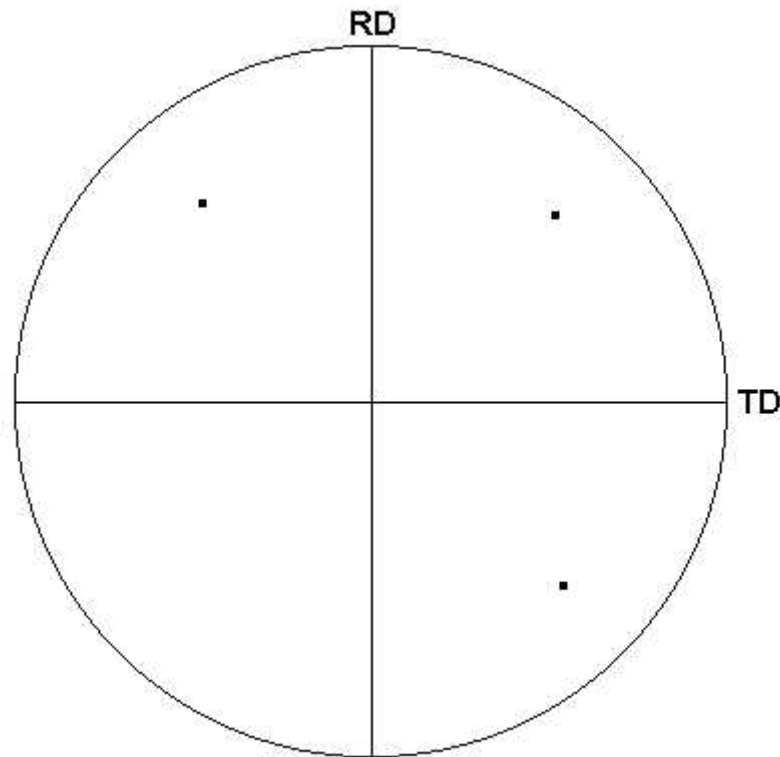


Darstellung der Probenorientierung

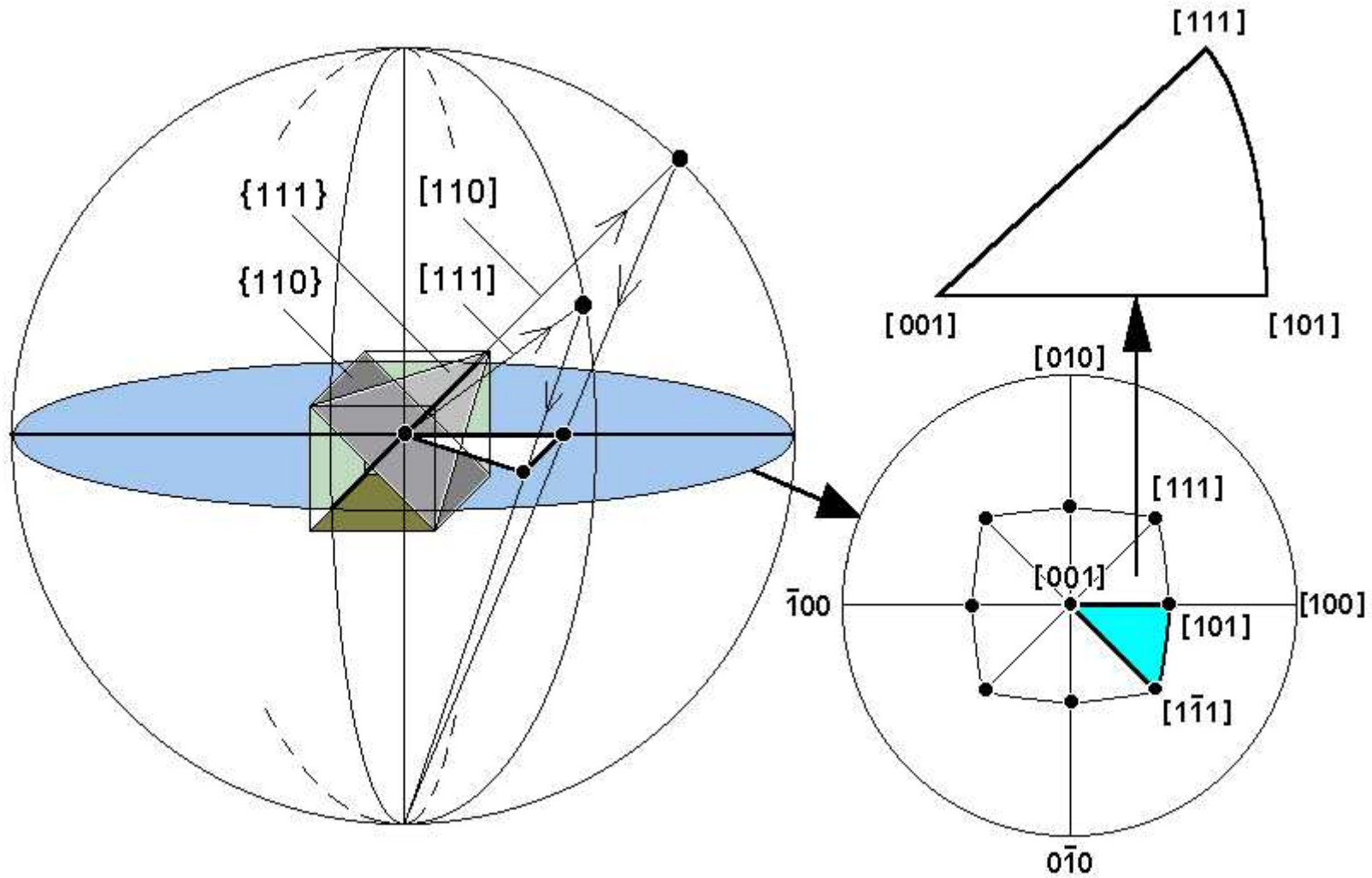


Projektion der
Flächennormalen in
eine
zweidimensionale
Ebene erfolgt analog
der
Stereographischen
Projektion:
=> Polfigur

Polfigur nach $\sim [111]$ mit leichter Verkippung und Drehung

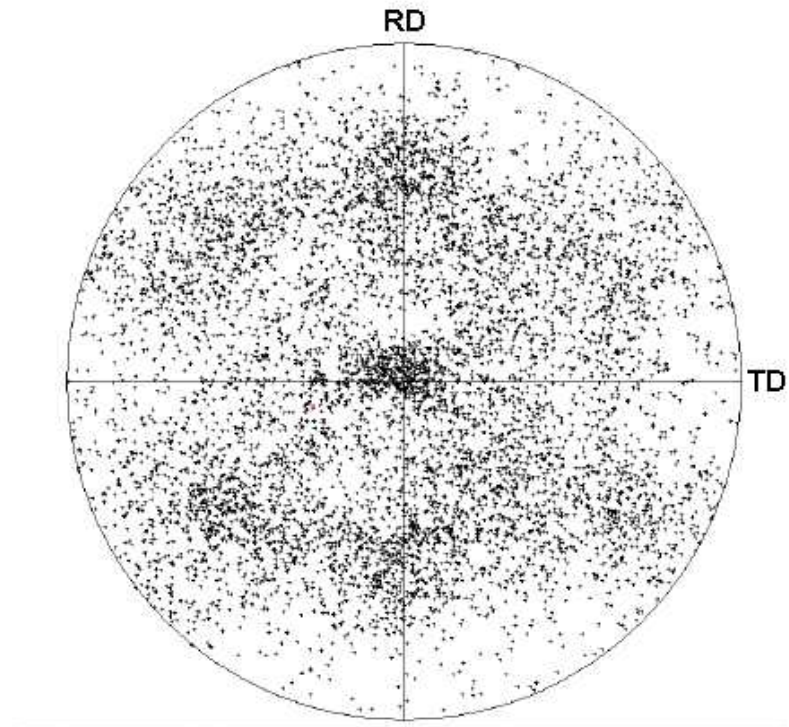
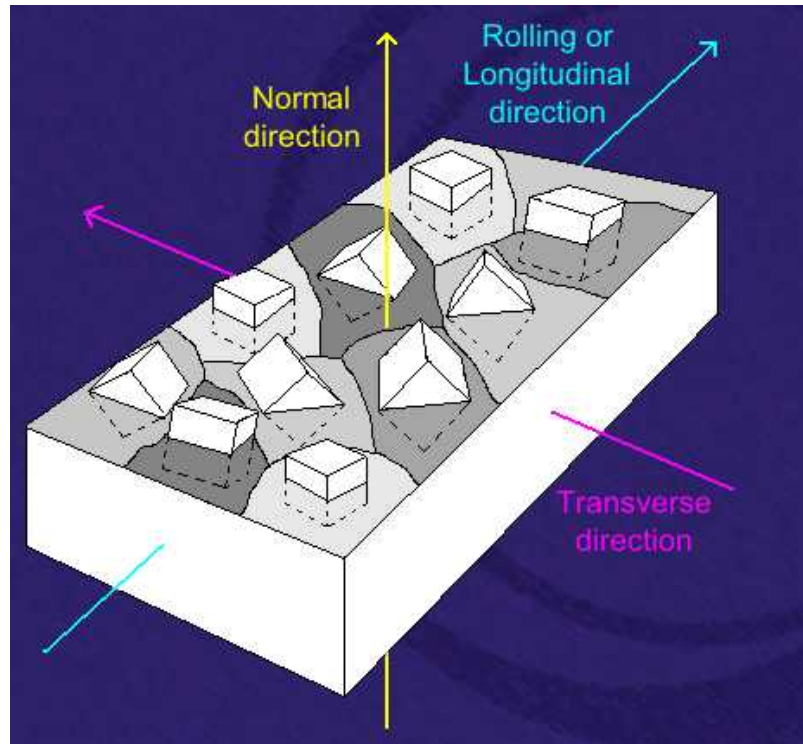


Inverse Polfigur



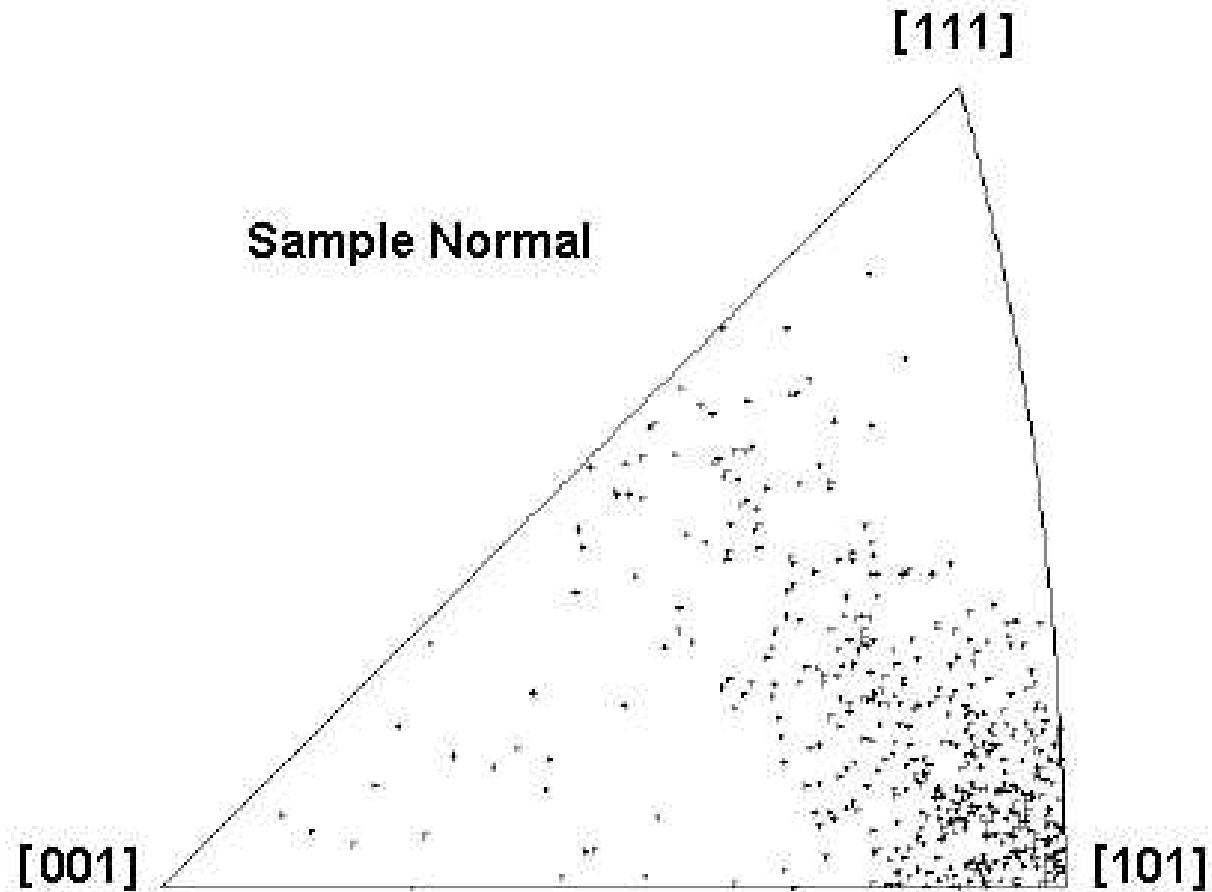
Polykristalline Probe

geringe Einregelung der Kristallite



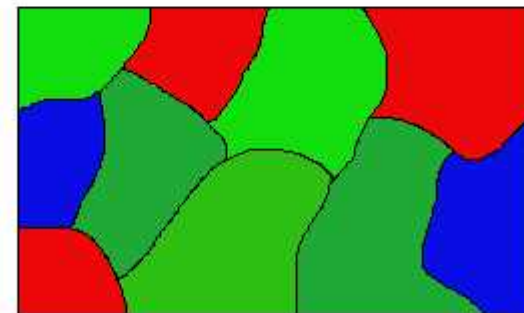
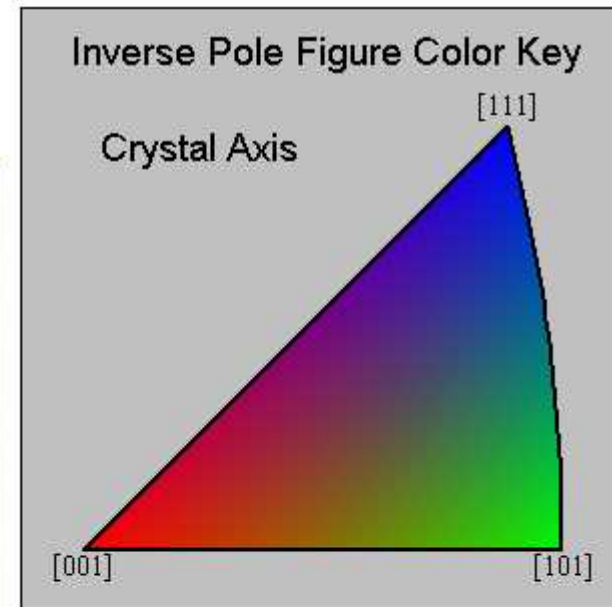
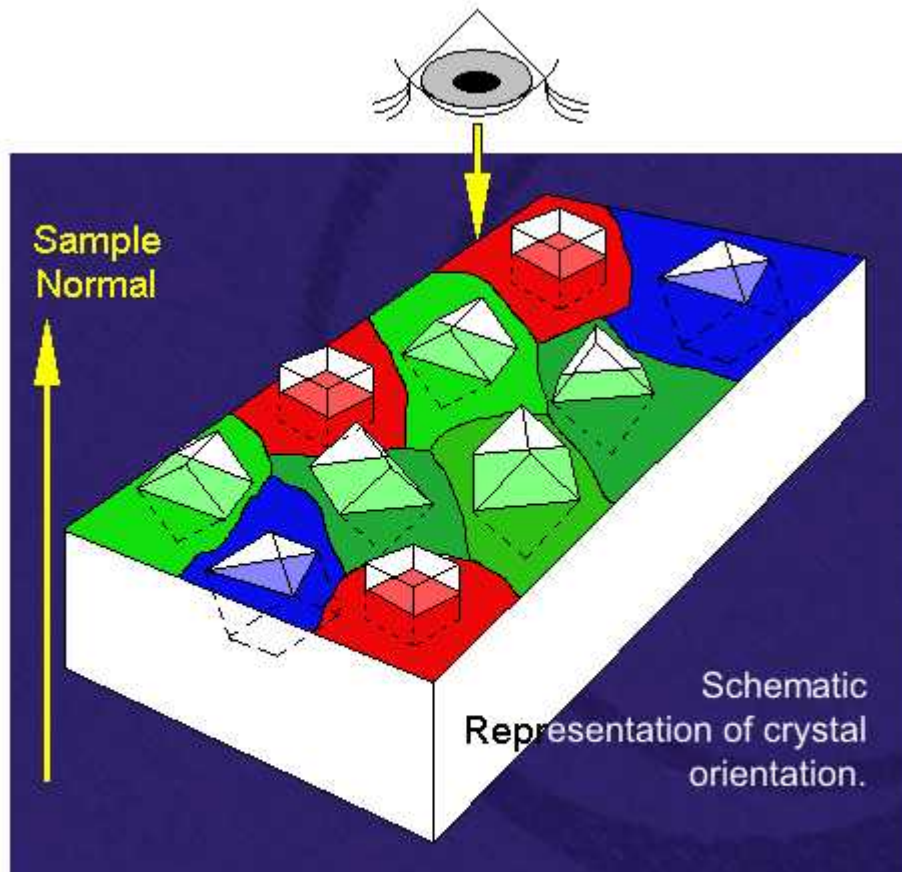
Polykristalline Probe

Einregelung der Kristallite nach [101], inverse Polfigur



Polykristalline Probe

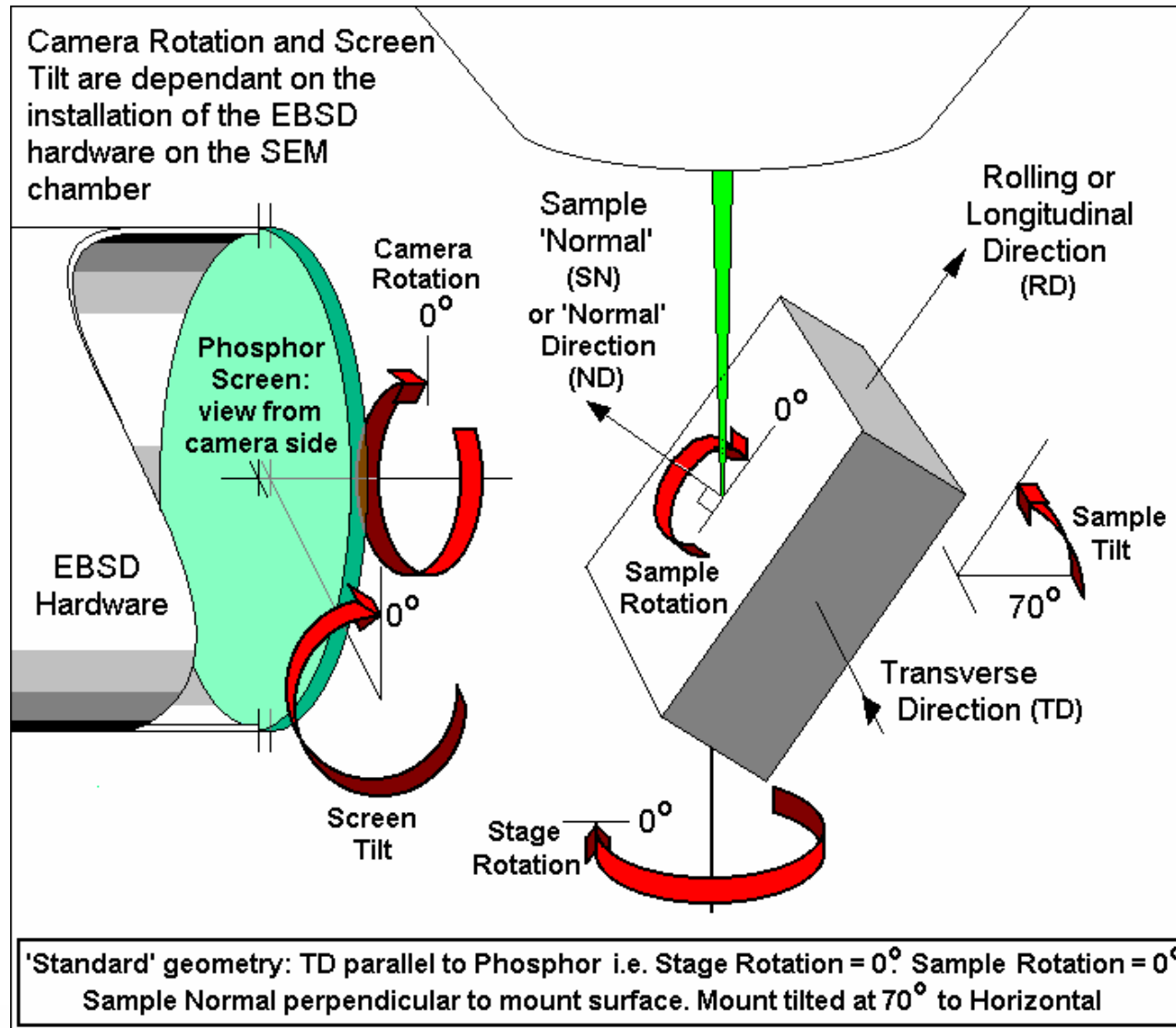
Einregelung der Kristallite, inverse Polfigur



Schematic Representation
of Sample Normal COM



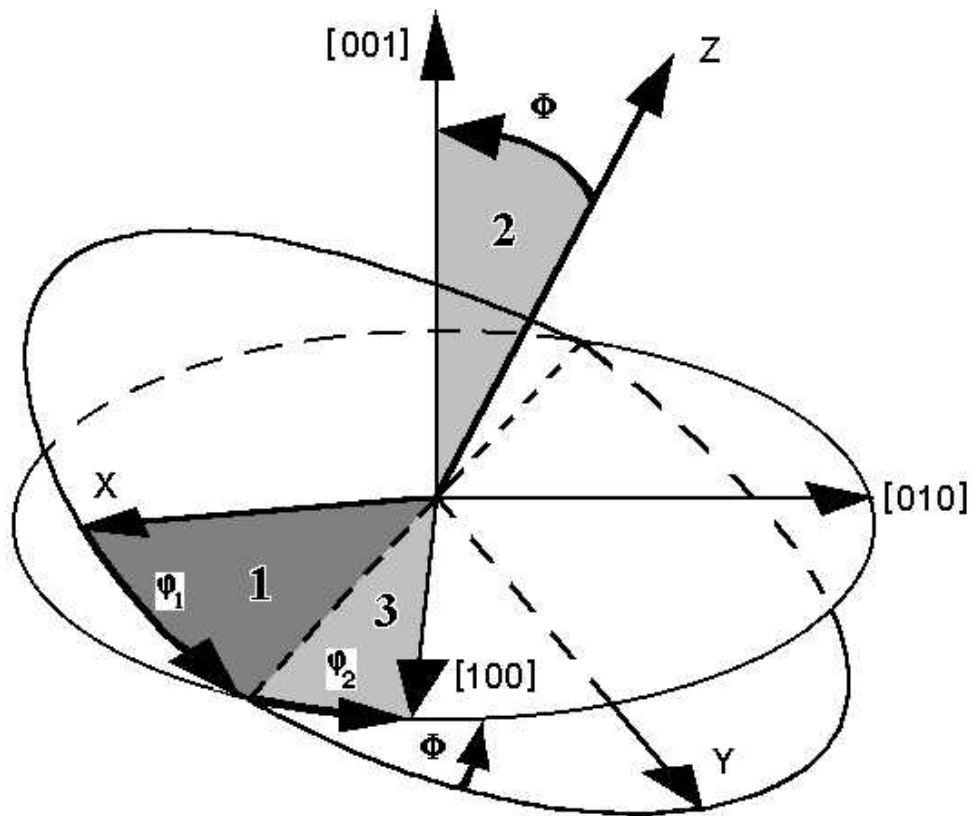
Referenzsystem



Orientierungsdarstellung - Eulerwinkel

Orientierung:

Drehung des probenfesten Koordinatensystems (kartesisch !)
in das kristallfeste System des einzelnen Kristalliten



Konvention nach Bunge:

a) Probenorientierung

φ_1 - Rotation um Normalenrichtung

Φ - Rotation um longitudinale Richtung

φ_2 - Rotation um transversale Richtung

b) Kristallorientierung

φ_1 - Rotation in (001)

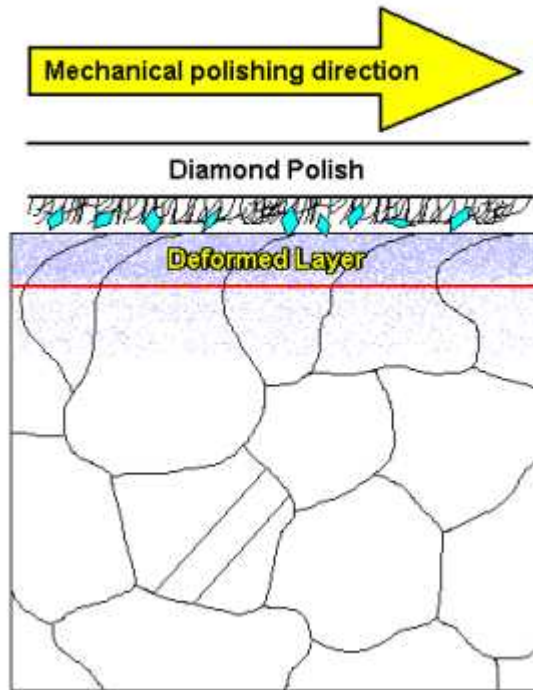
Φ - Rotation um [100]

φ_2 - Rotation in (001)

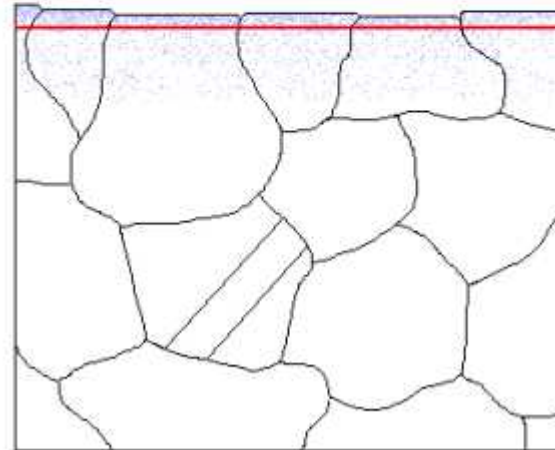


Mechanische Probenpräparation

Polishing is an extension of grinding i.e., the abrasives are held by the cloth and not free to rotate (lapping)



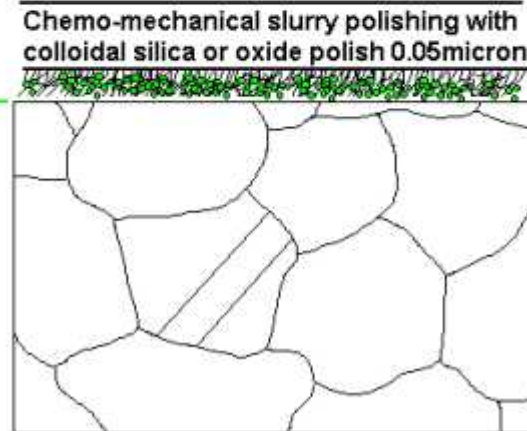
Diamond polishing may leave residual strain or damage after etching



Mechano-chemische Probenpräparation



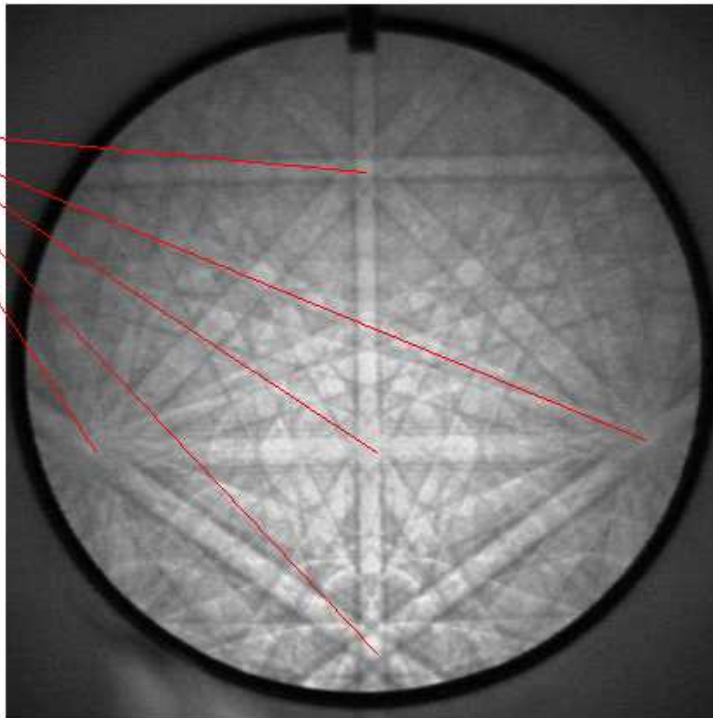
- Surface damage residual from diamond polishing can be removed using chemo-mechanical polishing
- Colloidal Silica is ideal



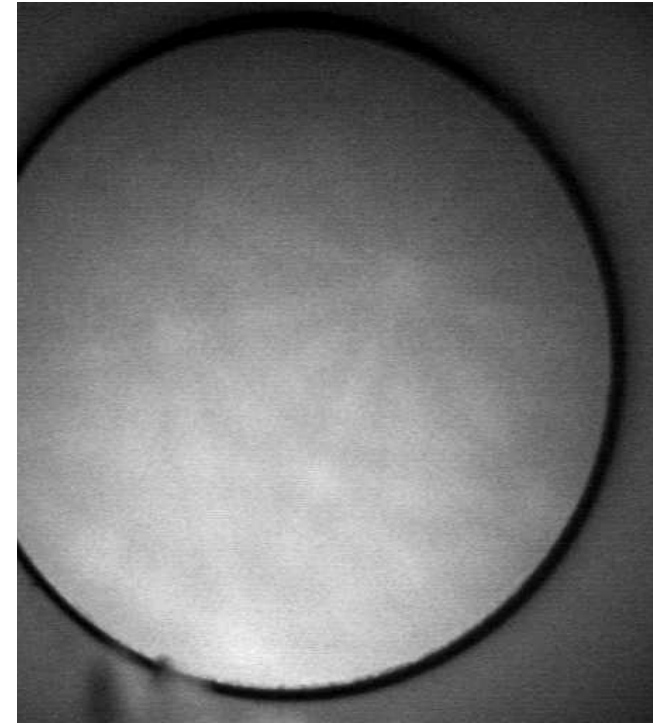
Probenpräparation

Eindringtiefe 10 - 100 nm

Some 'Zones'



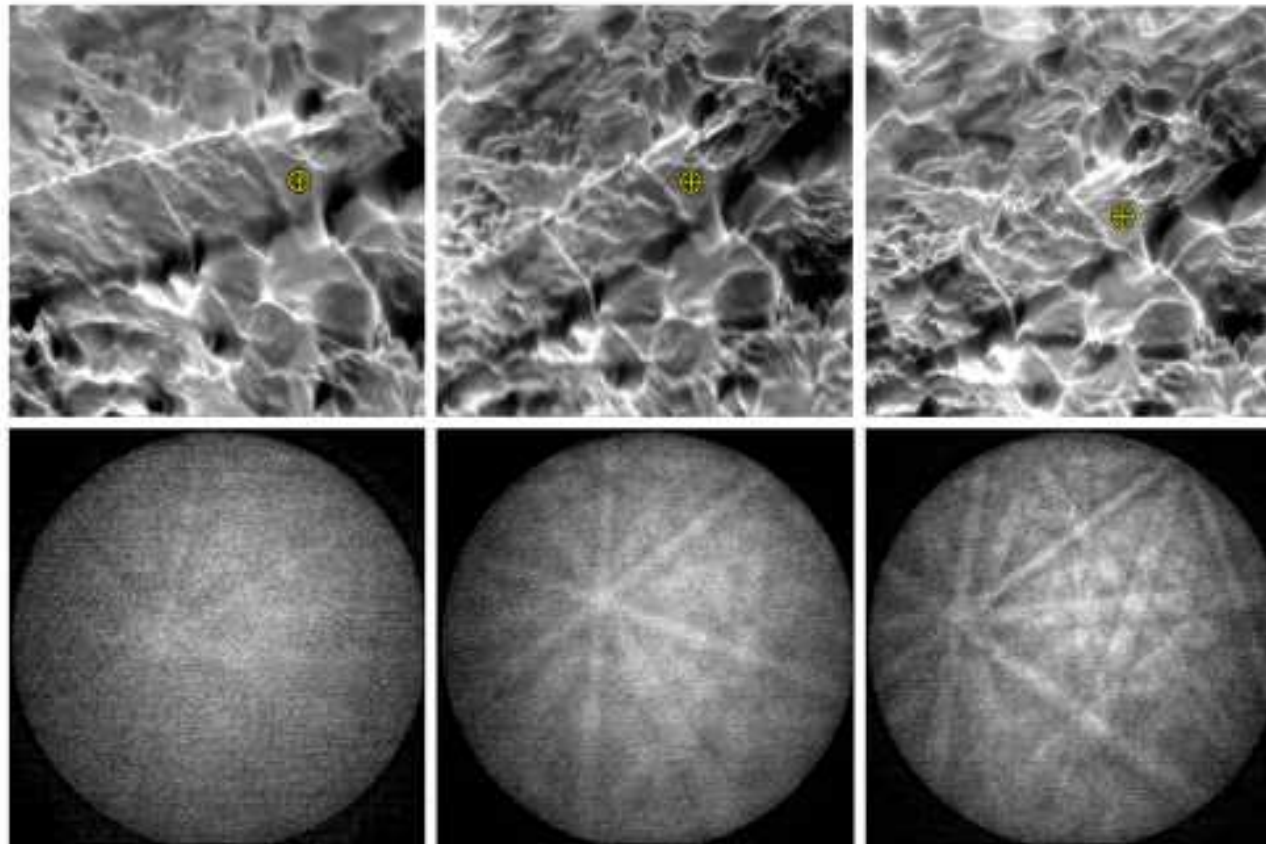
gute Politur



schlechte Politur



Probenpräparation durch Ionenabtrag



Zero ion milling

5 minutes

15minutes



Literatur zur Rasterelektronenmikroskopie

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