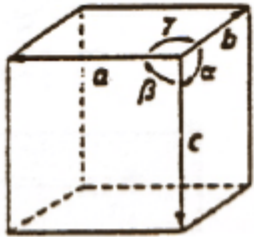


7 Kristallsysteme

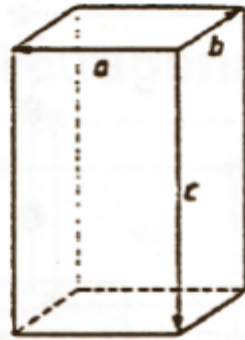
Kubisch



$$a = b = c$$

$$\alpha = \beta = \gamma = 90^\circ$$

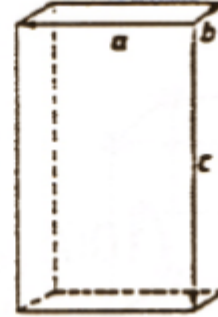
Tetragonal



$$a \neq b \neq c$$

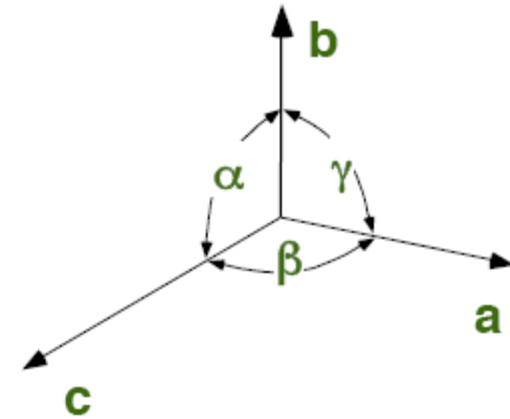
$$\alpha \neq \beta \neq \gamma \neq 90^\circ$$

Orthorhombisch

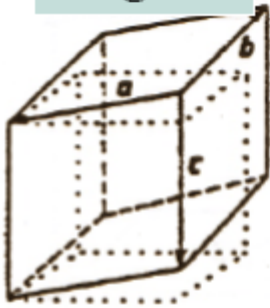


$$a \neq b \neq c$$

$$\alpha = \beta = \gamma = 90^\circ$$



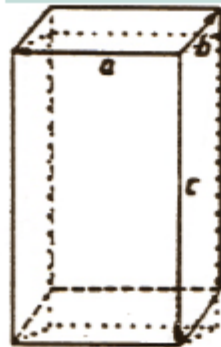
Trigonal



$$a = b = c$$

$$\alpha = \beta = \gamma \neq 90^\circ$$

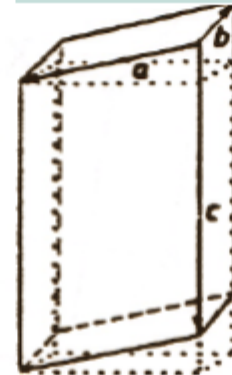
Monoklin



$$a \neq b \neq c$$

$$\alpha = \gamma = 90^\circ, \beta \neq 90^\circ$$

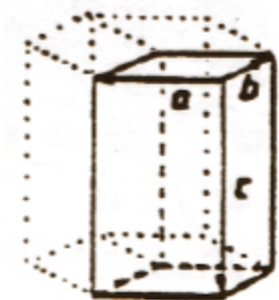
Triklin



$$a \neq b \neq c$$

$$\alpha \neq \beta \neq \gamma \neq 90^\circ$$

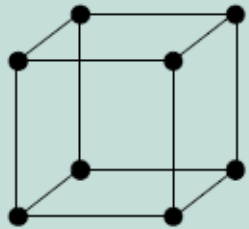
Hexagonal



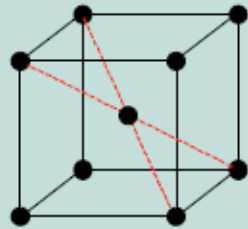
$$a = b \neq c$$

$$\alpha = \beta = 90^\circ, \gamma = 120^\circ$$

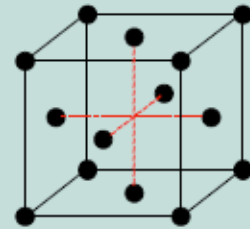
Die 14 Bravaisgitter



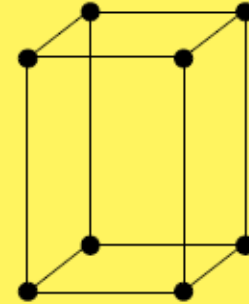
Kubisch *P*



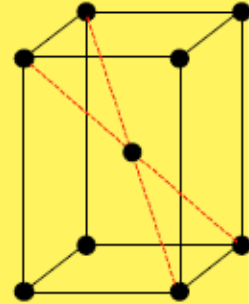
Kubisch *I*



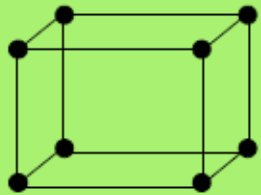
Kubisch *F*



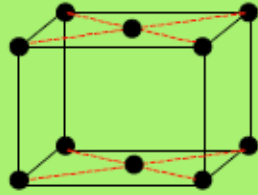
Tetragonal *P*



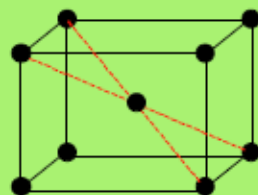
Tetragonal *I*



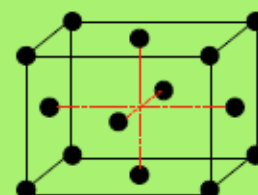
Ortho-
Rhombisch *P*



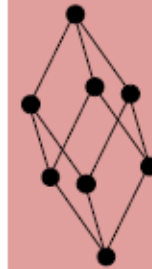
Ortho-
Rhombisch *C*



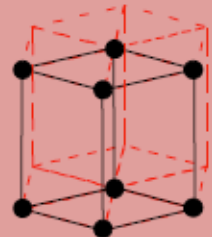
Ortho-
Rhombisch *I*



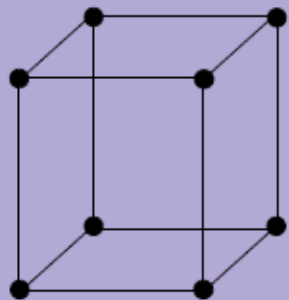
Ortho-
Rhombisch *F*



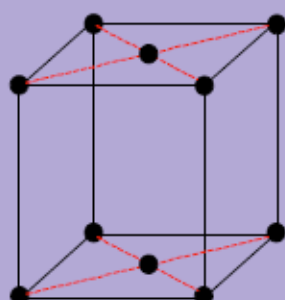
Rhombo-
edrisch *R*



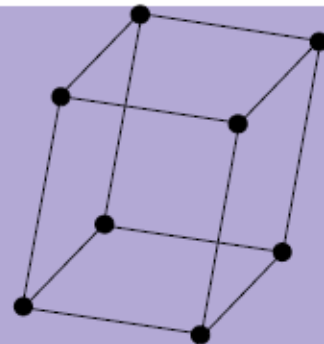
Hexa-
gonal *P*



Monoklin *P*



Monoklin *C*



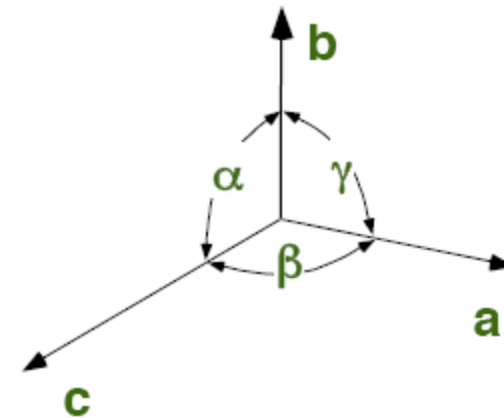
Triklin

Erweiterung der Kristallklassen
durch Hinzufügen weiterer
Gitterpunkte

➔ 14 Bravais-Gitter

**Einschränkungen
für Achsen und
Winkel**

| Gittersystem | Anzahl | Symbol | Winkel |
|----------------------|---------------|--|--|
| Triklin | 1 | P | (keine) |
| Monoklin | 2 | P,C | $\alpha = \beta = 90^\circ$ |
| Orthorombisch | 4 | P,C,I,F | $\alpha = \beta = \gamma = 90^\circ$ |
| Tetragonal | 2 | P,I | $a = b$ $\alpha = \beta = \gamma = 90^\circ$ |
| Kubisch | 3 | P oder sc I oder bcc F oder fcc | $a = b = c$ $\alpha = \beta = \gamma = 90^\circ$ |
| Rhomboedrisch | 1 | R | $a = b$ $\alpha = \beta = \gamma \neq 90^\circ$ |
| Hexagonal | 1 | P | $a = b$ $\alpha = \beta = 90^\circ$ $\gamma = 120^\circ$ |



DLR



Anzahl der Atome in der Basis:

1 in Edelgaskristallen, 2 in Fe, 4 in SiF_4 , 12 in MoAl_{12}
 10^3 in Polymerkristallen, 10^6 in Viruskristallen

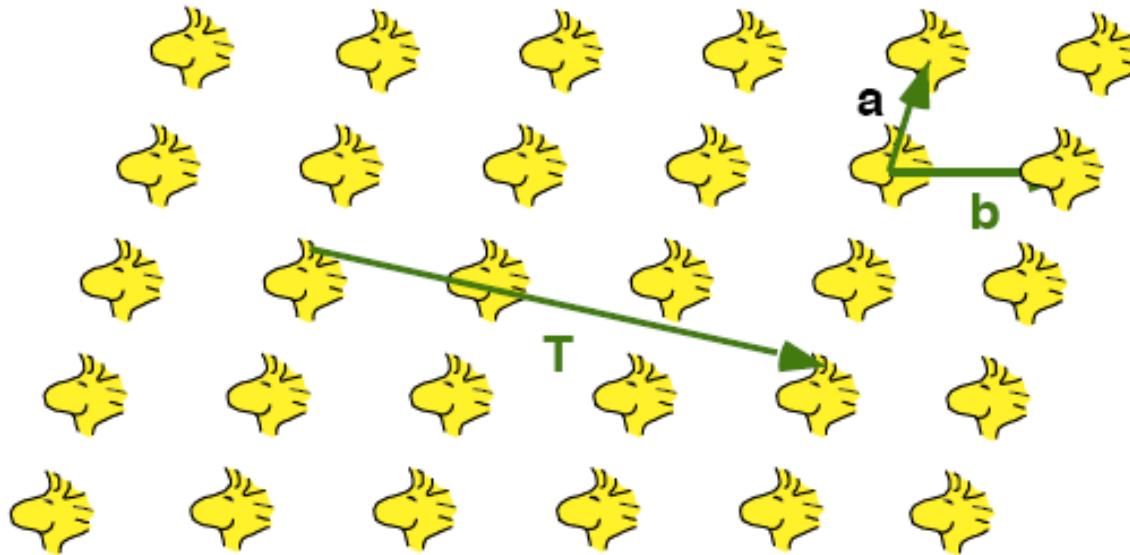
Gittertranslation:

$$\mathbf{T} = u \mathbf{a} + v \mathbf{b} + w \mathbf{c}$$

T: Translationsvektor

a, b, c: primitive Translationsvektoren

DLR



$$T = -a + 3b$$

Kristallstruktur:



Basis $f(r)$

Raumgitter $g(r)$

$$f(r) * g(r) = \int f(r - r'') g(r) dr''$$

(Faltung von Basis und Gitter)

Symmetrien

Drehung um eine Symmetrieachse, die durch einen Gitterpunkt führt, die den Kristall in sich selbst überführt.

Erlaubte Drehungen (Drehachsen)

2π (1-zählig)

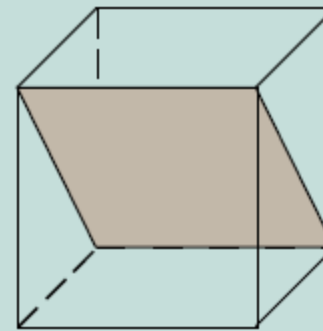
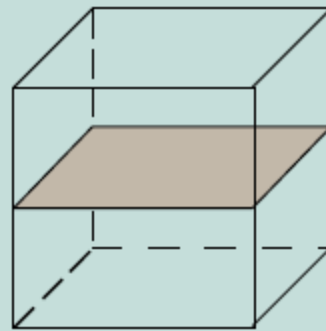
$2\pi/2$ (2-zählig)

$2\pi/3$ (3-zählig)

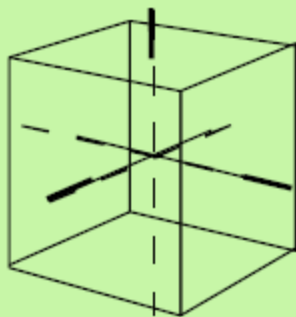
$2\pi/4$ (4-zählig)

$2\pi/6$ (6-zählig)

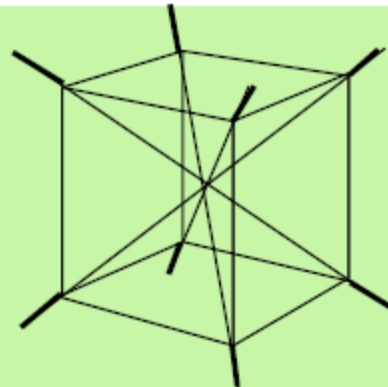
5-zählige Drehachsen sind in der Kristallographie verboten!
keine Translationsinvarianz, keine Raumfüllung!



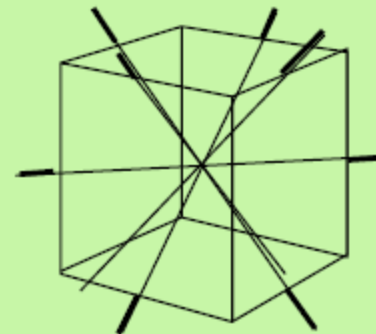
Symmetrieebenen



3 vierzählige



4 dreizählige



6 zweizählige

Drehachsen
eines
Würfels

Punktsymmetrien:

Spiegelung an einer Ebene: z. B. an der yz-Ebene: $y' = y, z' = z, x' = -x$

*Das Vorhandensein einer Spiegelebene wird durch das Symbol **m** angezeigt.*

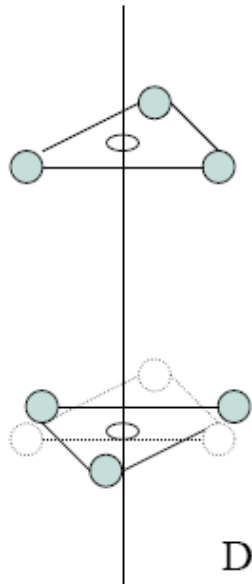
Inversion (Spiegelung an einem Punkt): $y' = -y, z' = -z, x' = -x$

Drehachsen, Deckungsgleichheit durch Rotation um einen Winkel, 2-, 3-, 4-, 6-zählig

Drehinversionsachsen: Drehung und gleichzeitige Inversion

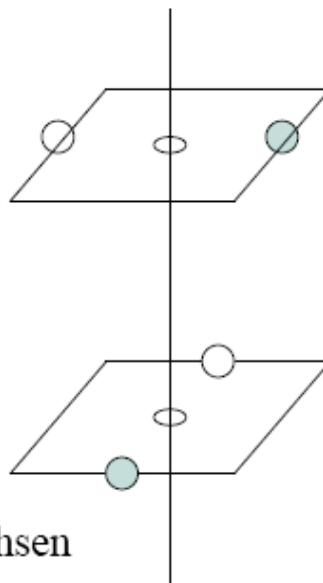
Bezeichnung durch $\bar{2}, \bar{3}, \bar{4}, \bar{6}$

$$\bar{3} = 3 + \bar{1}$$



dreizählig

$$\bar{4} = mm$$



vierzählig

Drehinversionsachsen

Bezeichnung von Ebenen im Kristallgitter

$$n_a = 4; \quad 1/n_a = 1/4$$

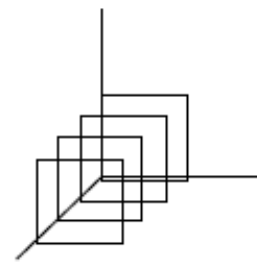
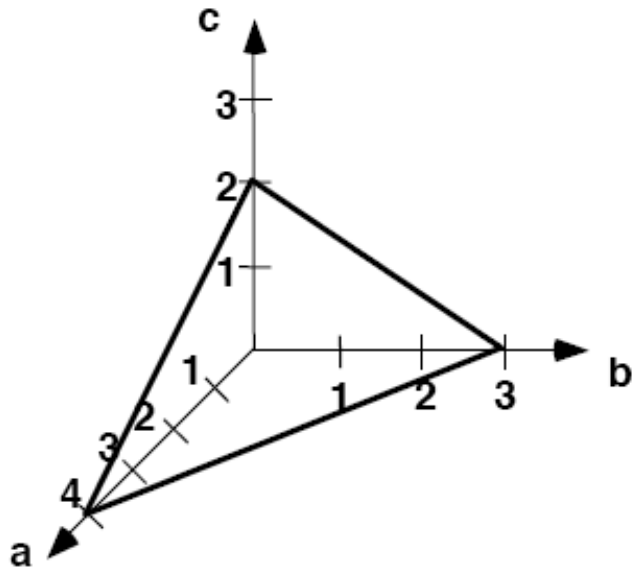
$$n_b = 3; \quad 1/n_b = 1/3$$

$$n_c = 2; \quad 1/n_c = 1/2$$

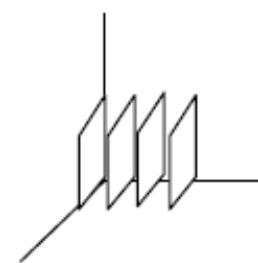
$$1/4 : 1/3 : 1/2 = 3 : 4 : 6;$$

$$(h,k,l) = (346)$$

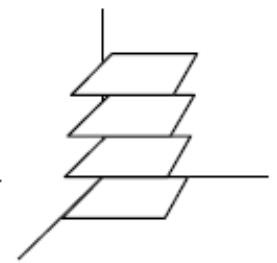
hkl: Miller-Indizes



(100)

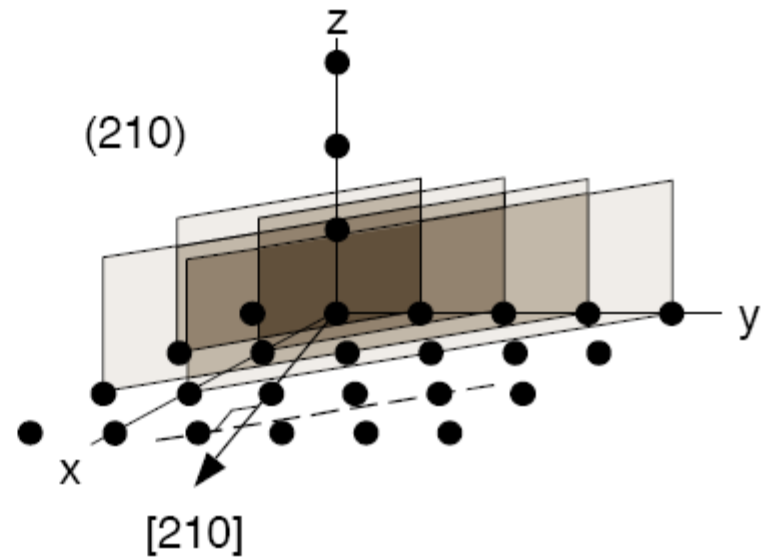
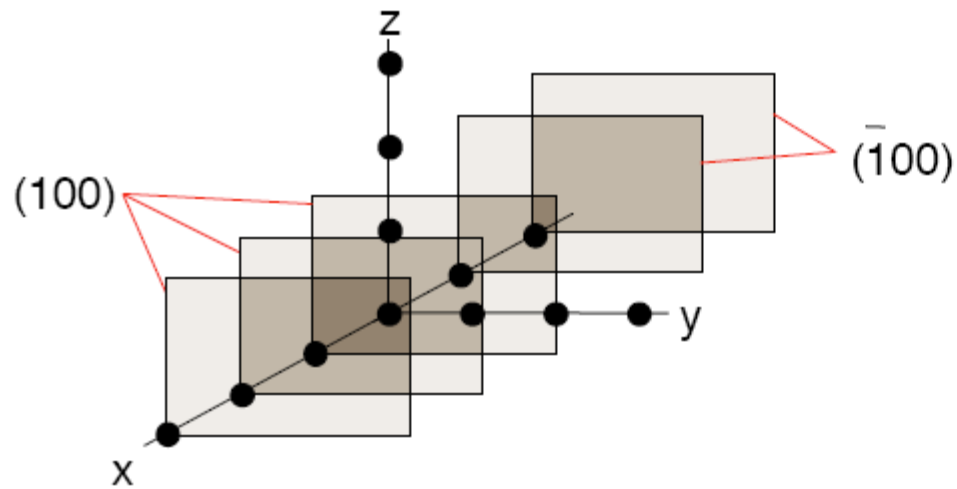
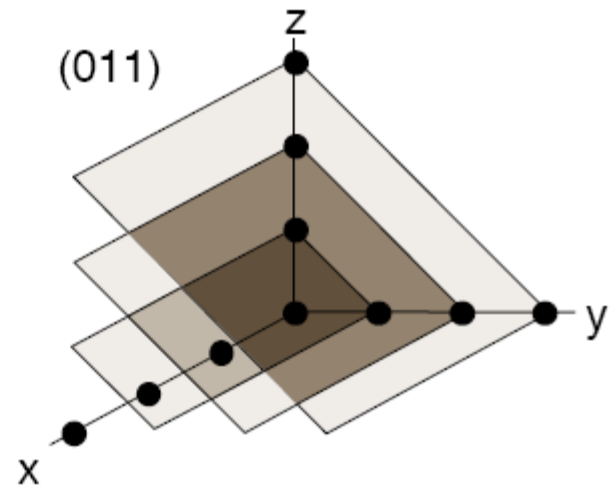
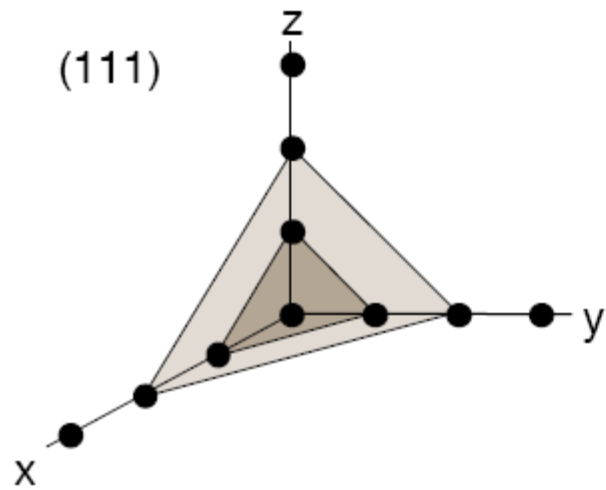


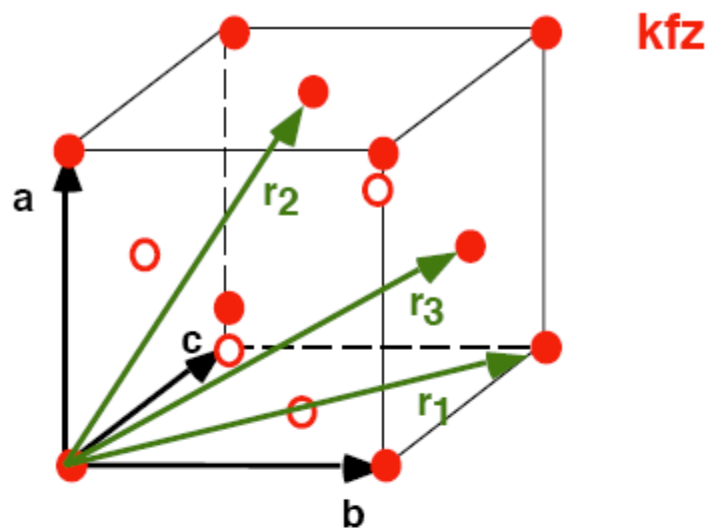
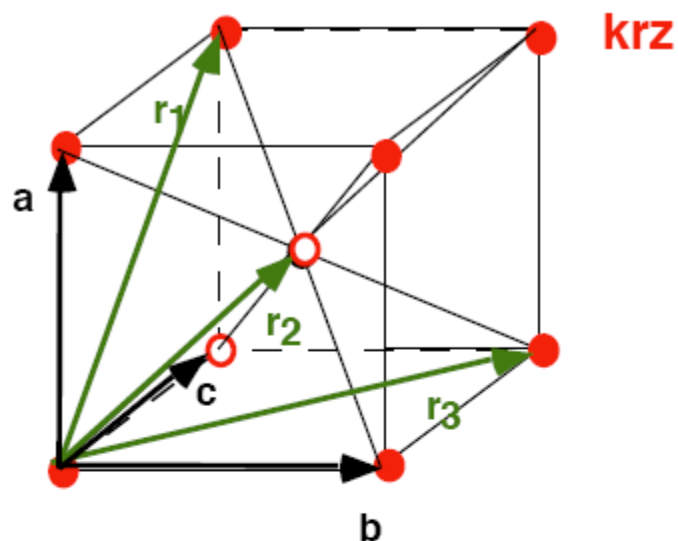
(010)



(001)

Gitternetzebenen





Ortsvektoren im Kristallgitter

$$\mathbf{r} = x \mathbf{a} + y \mathbf{b} + z \mathbf{c}$$

$$\mathbf{r}_1 = 1 \mathbf{a} + 0 \mathbf{b} + 1 \mathbf{c}$$

$$\mathbf{r}_2 = 1/2 \mathbf{a} + 1/2 \mathbf{b} + 1/2 \mathbf{c}$$

$$\mathbf{r}_3 = 1/2 \mathbf{a} + 1/2 \mathbf{b} + 1/2 \mathbf{c}$$

Die 6 äquivalenten Richtungen $\langle 100 \rangle$

$$x:y:z = 0:1:1$$

$$x:y:z = 1:1/2:1/2 = 2:1:1$$

$$x:y:z = 1/2:1:1/2 = 1:2:1$$

$$\begin{aligned} [u,v,w] &= [011] \\ [u,v,w] &= [211] \\ [u,v,w] &= [121] \end{aligned}$$

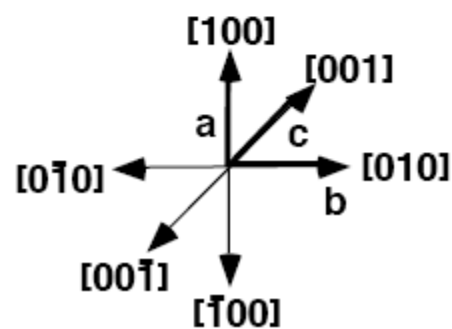
Richtungen im Kristallgitter

Richtungsindizes u, v, w

$$\mathbf{r}_1 = 0 \mathbf{a} + 1 \mathbf{b} + 1 \mathbf{c}$$

$$\mathbf{r}_2 = 1 \mathbf{a} + 1/2 \mathbf{b} + 1/2 \mathbf{c}$$

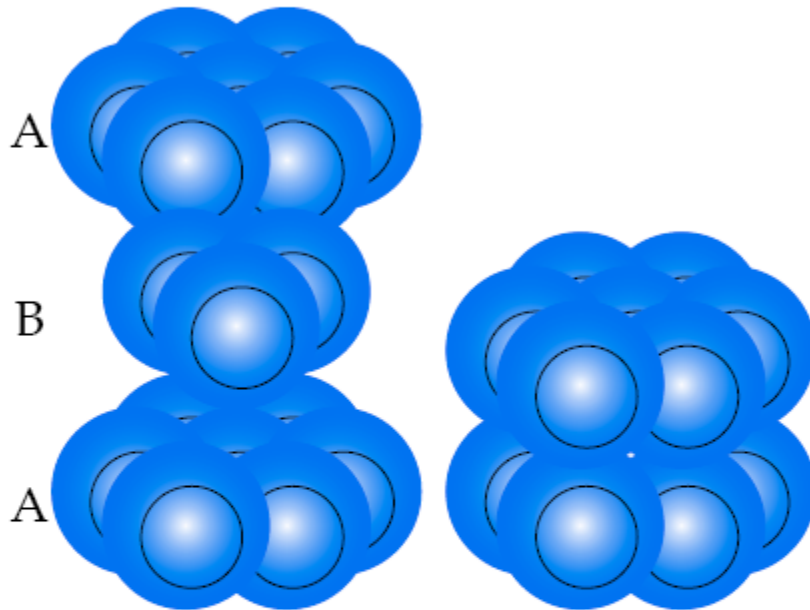
$$\mathbf{r}_3 = 1/2 \mathbf{a} + 1 \mathbf{b} + 1/2 \mathbf{c}$$



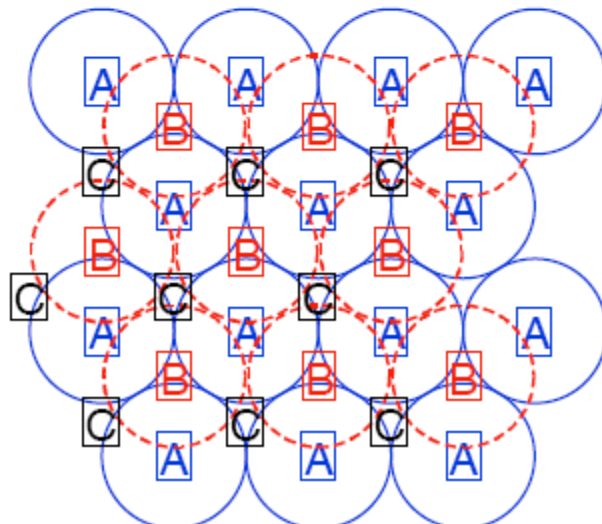
Dichteste Packung harter Kugeln

Metalle: Symmetrische Bindungsverhältnisse

➔ Modell harter Kugeln ➔ Energetisch begünstigt: Dichteste Packung

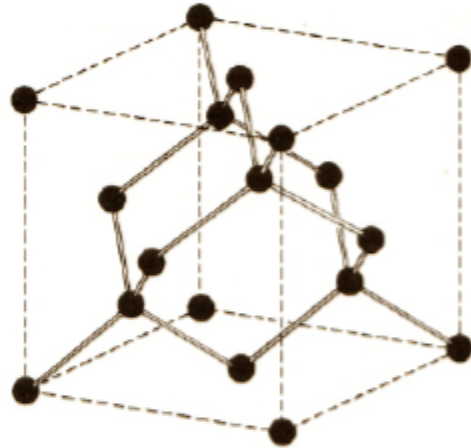


Hexagonal, kubisch-flächenzentrierte
dichteste Packung harter Kugeln

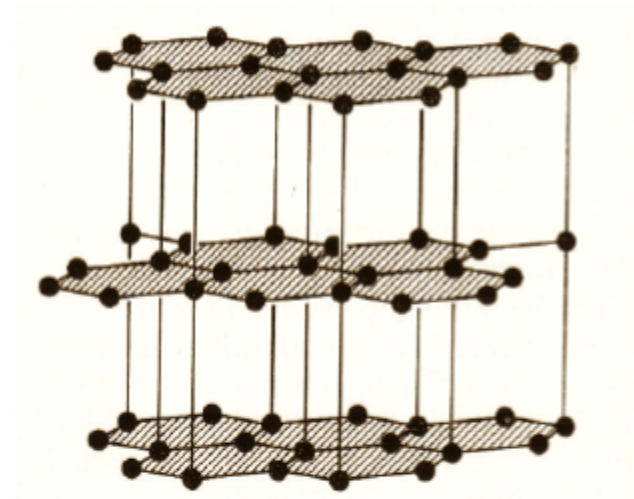


Schichtfolge: ABABABAB
Hexagonal dichtest gepackt
Schichtfolge: ABCABCABC
Kubisch-flächenzentriert
dichtest gepackt

Kristallstrukturen des Kohlenstoffs (C)



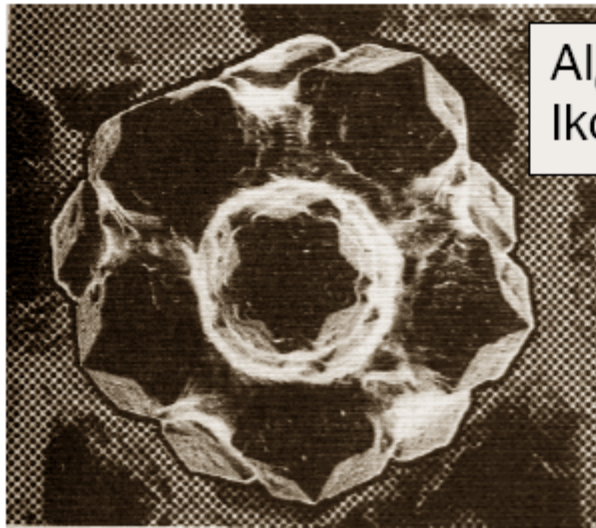
Diamant:
Tetraedrische Bindungen
Härtester Festkörper
Metastabile Hochdruckphase



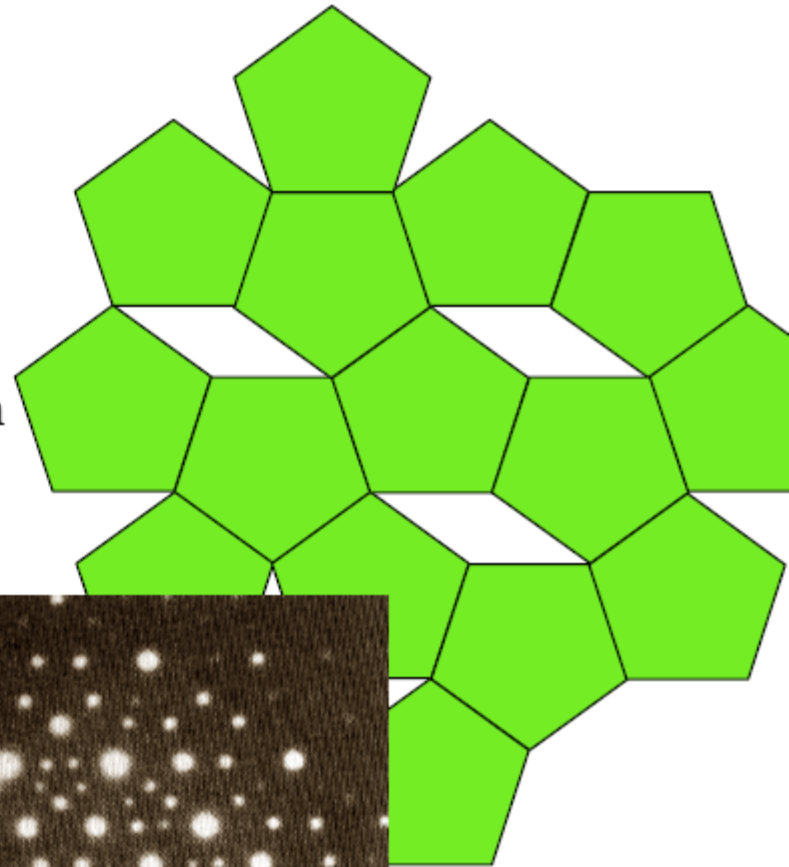
Graphit:
Schicht-Struktur
Weicher Festkörper
Stabile Phase
Anisotrope
Transporteigenschaften

Fünzfählige Symmetrie in Quasikristallen

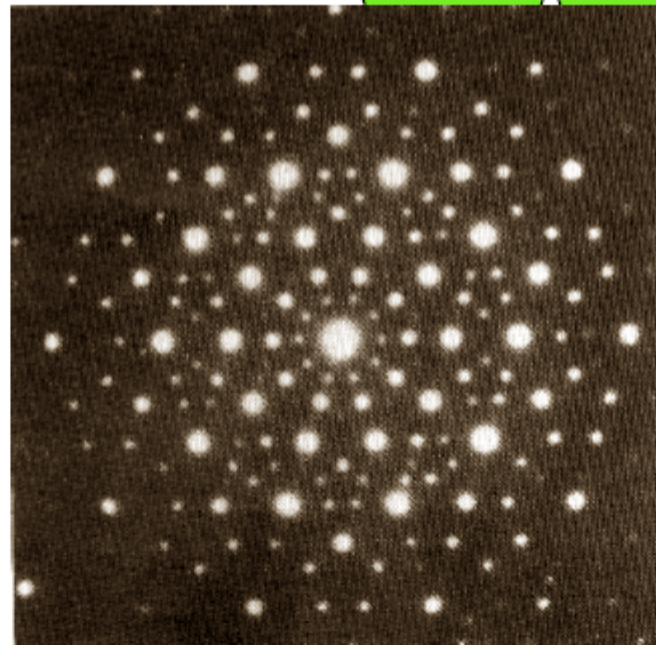
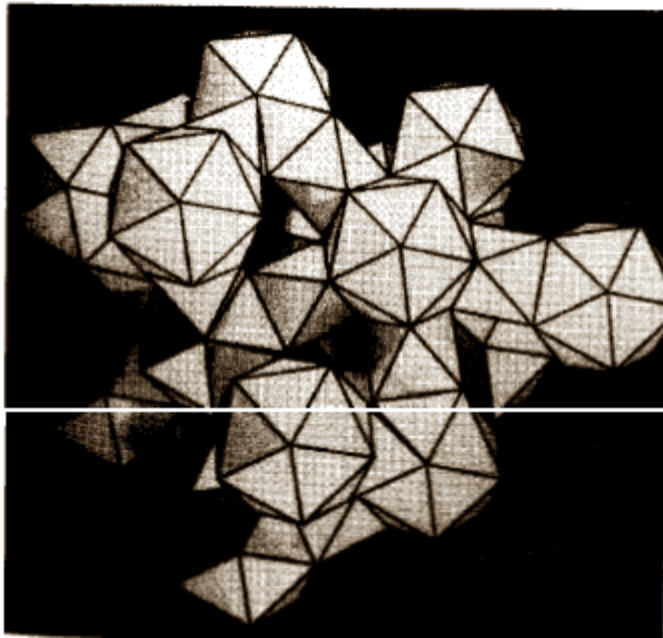
keine Translationsfernordnung, aber Orientierungsfernordnung



Al₆Li₃Cu
Ikosaederekristall

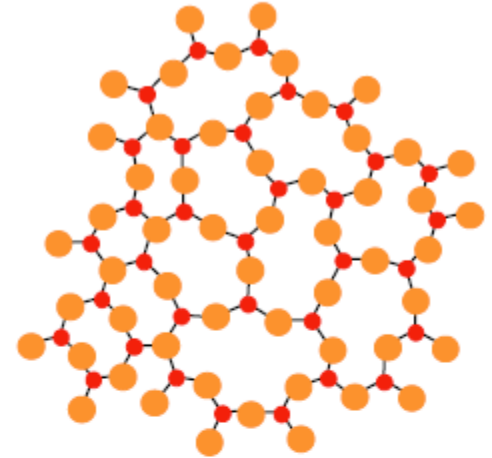
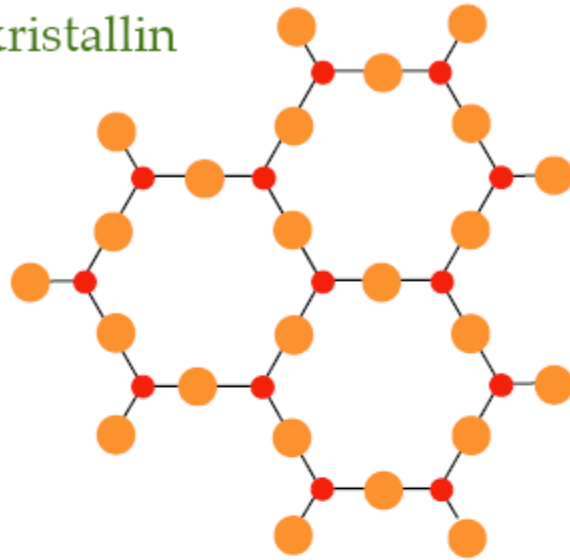


Pentagons füllen
nicht den Raum



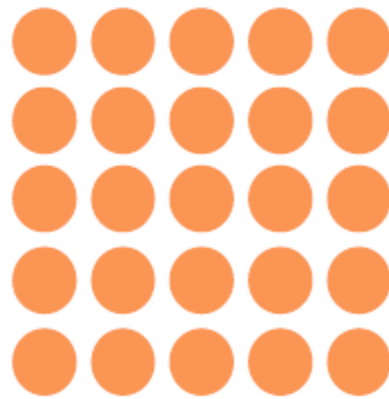
Systeme mit gerichteter atomarer Bindung: z. B. SiO_2

kristallin



amorph

Systeme mit symmetrischer atomarer Bindung: z. B. Metalle



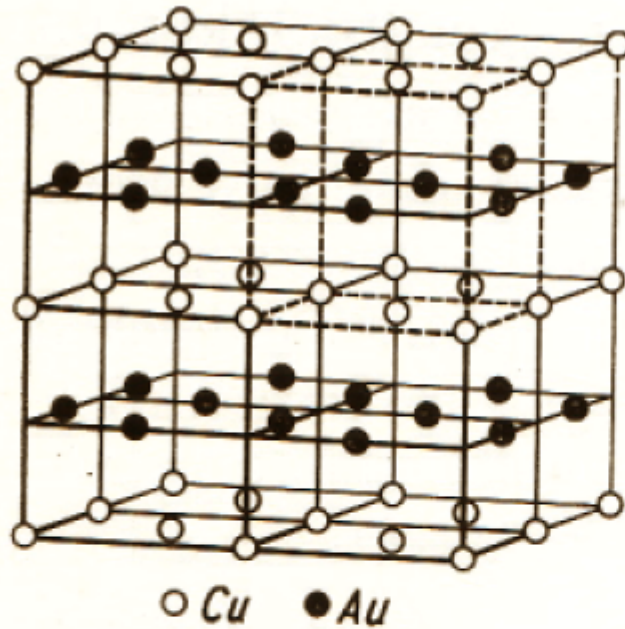
kristallin



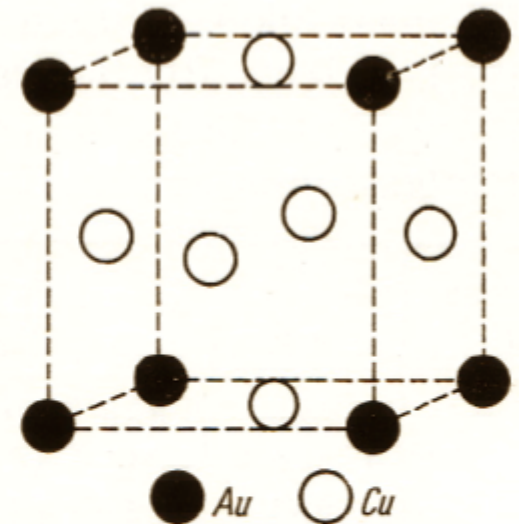
amorph

Überstrukturen in geordneten Mischkristallen

CuAu



Cu₃Au



$T > 793 \text{ K}$:

Ungeordnet

Hart und spröde

Kubische kfz Struktur

$T < 793 \text{ K}$:

Geordnet

Weich und duktil

Tetragonale Struktur

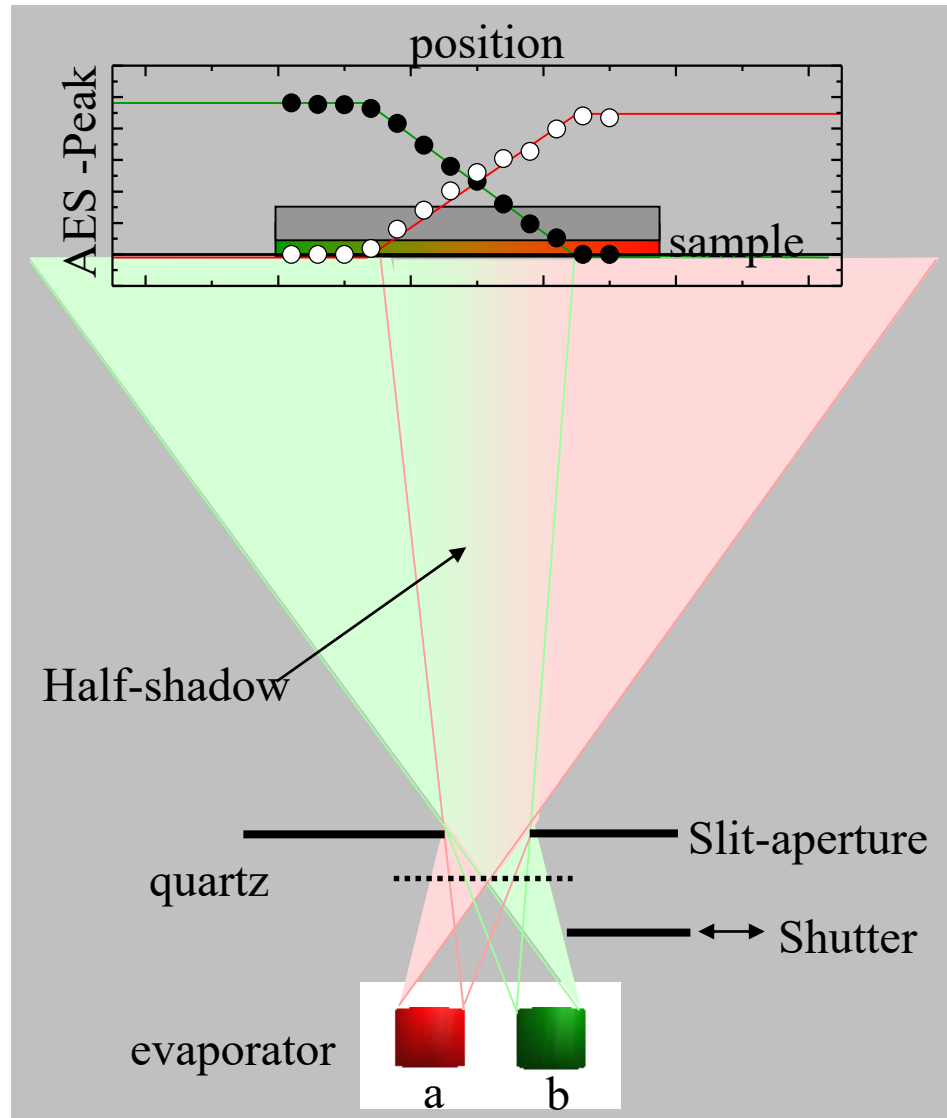
Geordnete Überstruktur
in Cu₃Au

Kubische Struktur

←
Härte, Zugfestigkeit und Streckgrenze

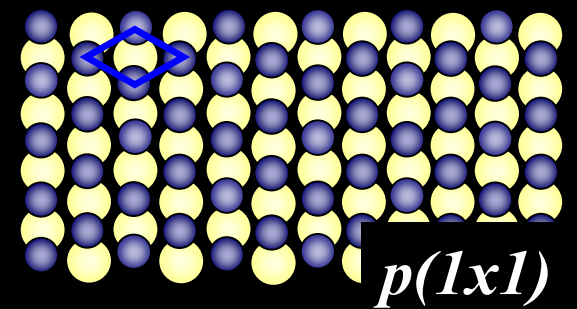
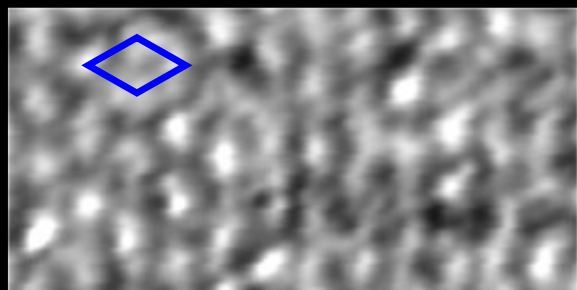
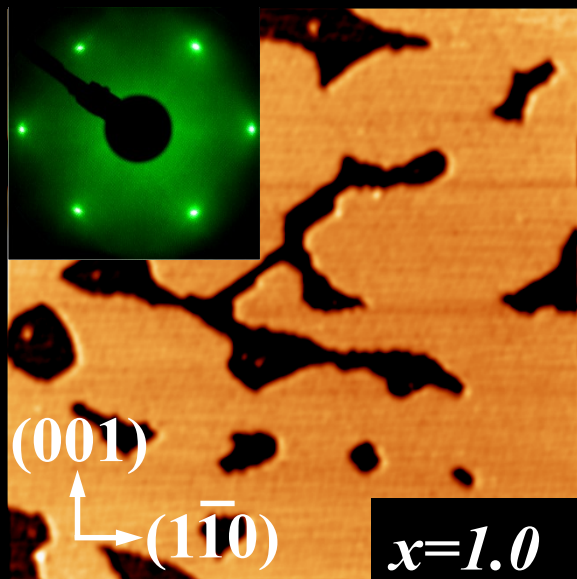
→
Elektrische Leitfähigkeit, magn. Suszeptibilität

Codeposition of Co and Fe:



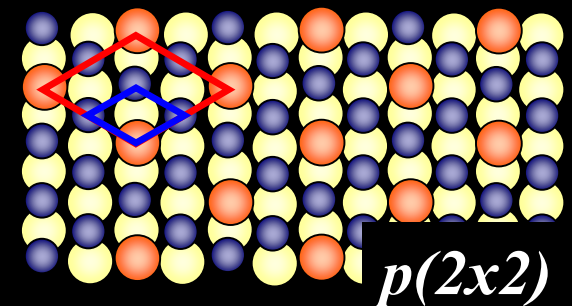
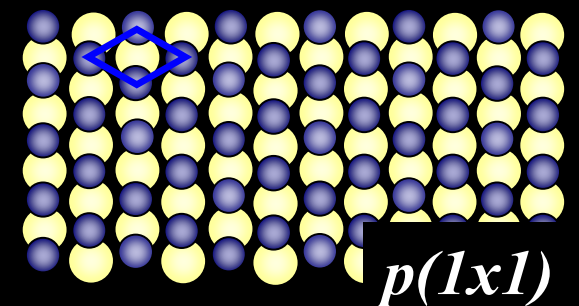
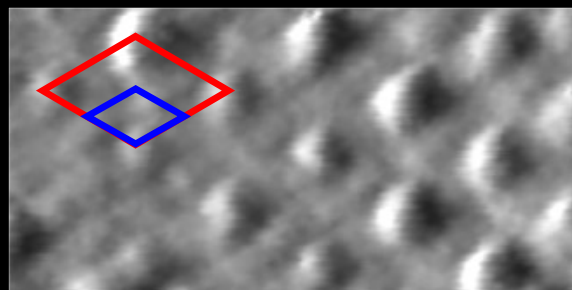
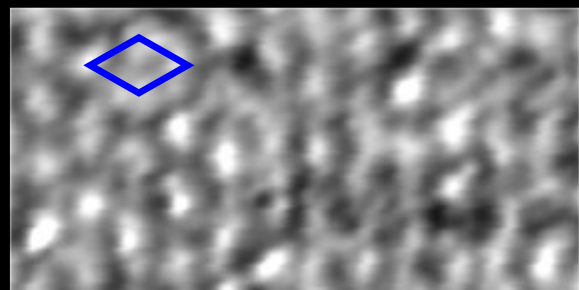
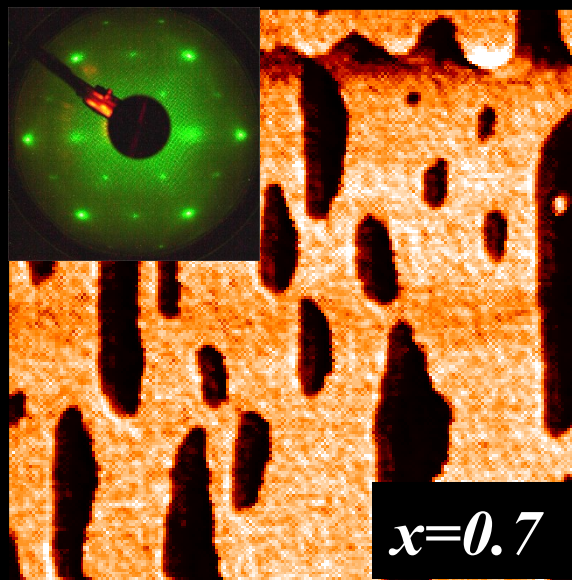
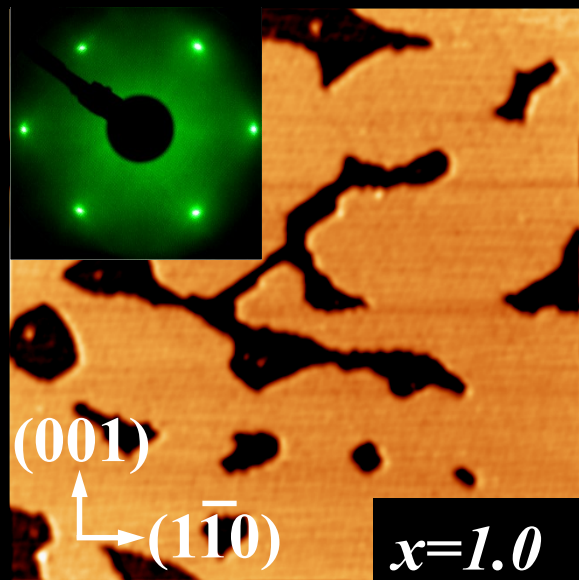
Structure of $\text{Co}_{1-x}\text{Fe}_x / \text{W}(110)$ monolayers

LEED, STM



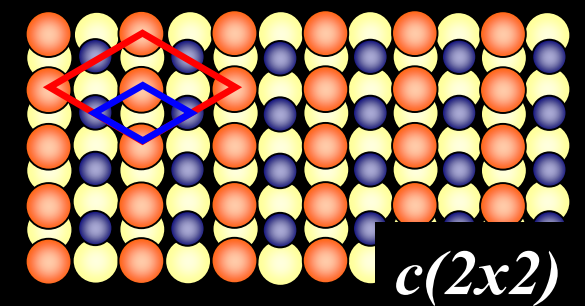
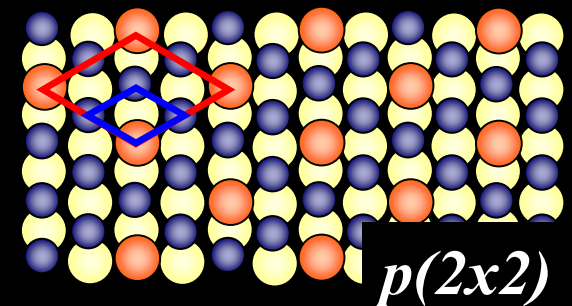
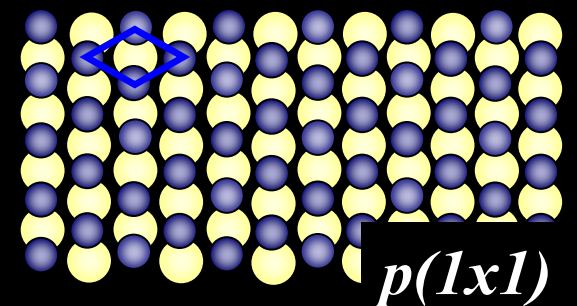
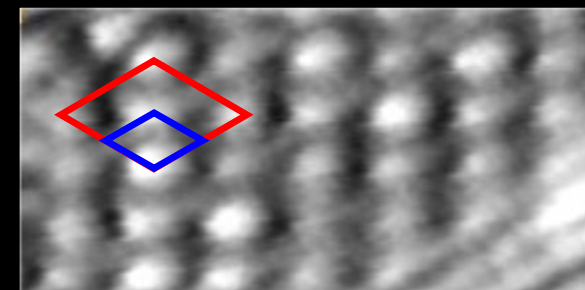
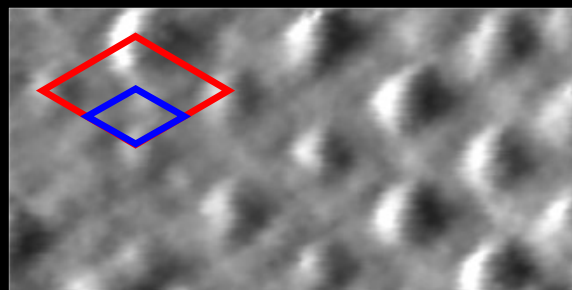
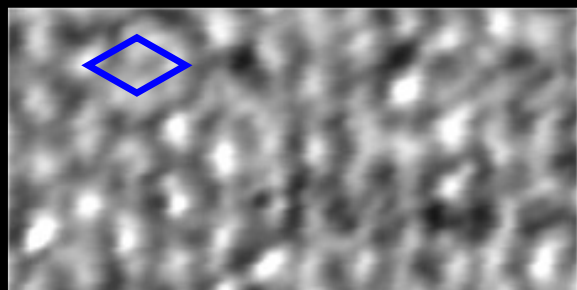
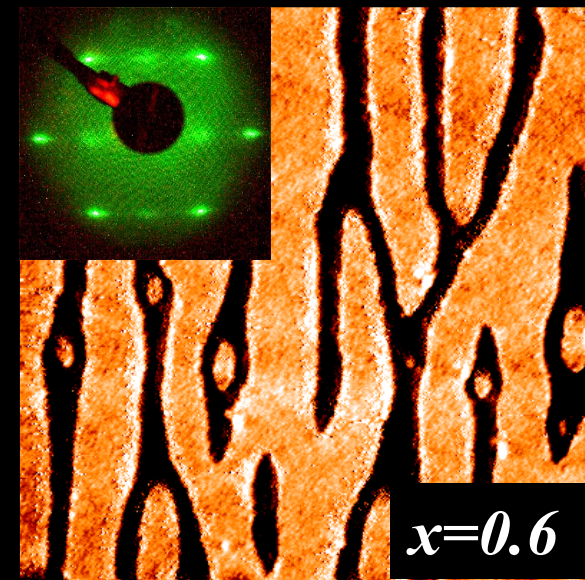
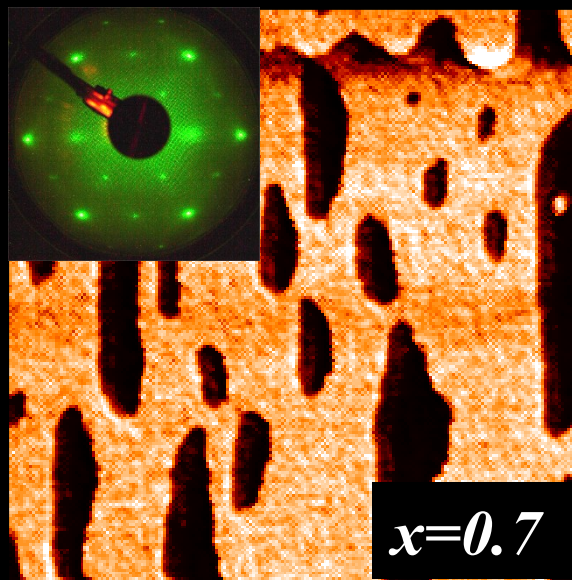
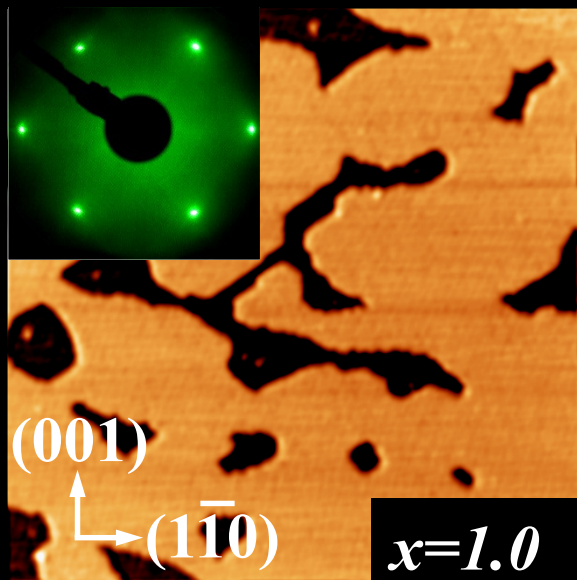
Structure of $\text{Co}_{1-x}\text{Fe}_x$ / $\text{W}(110)$ monolayers

LEED, STM

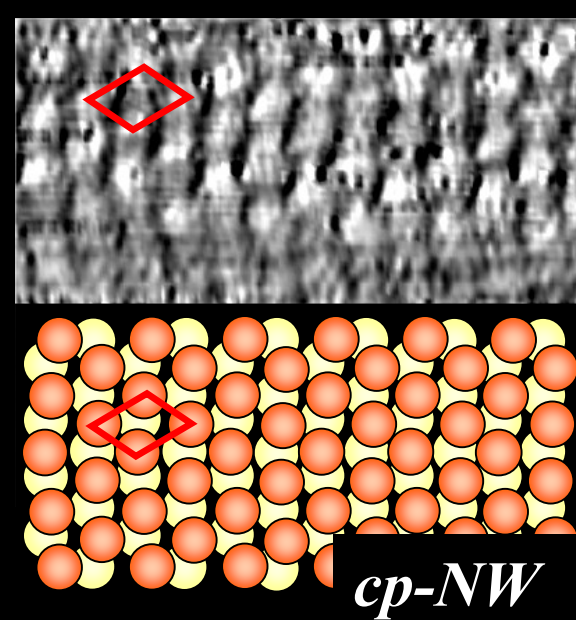
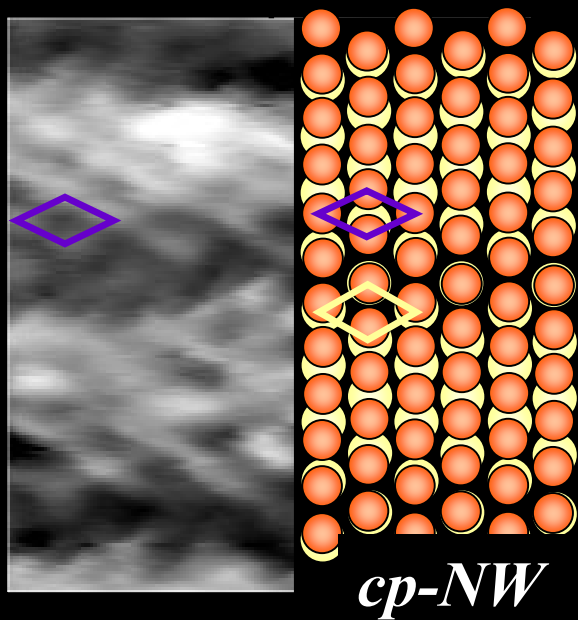
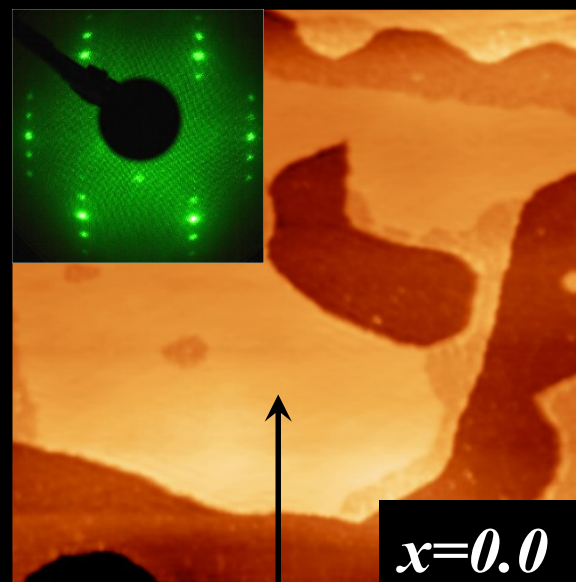
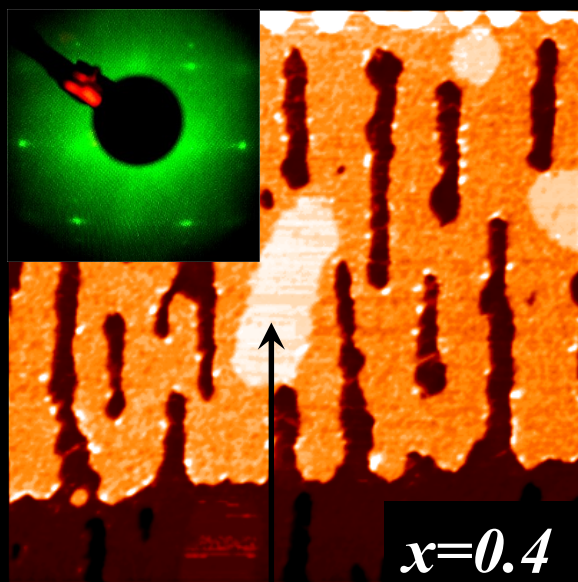


Structure of $\text{Co}_{1-x}\text{Fe}_x / \text{W}(110)$ monolayers

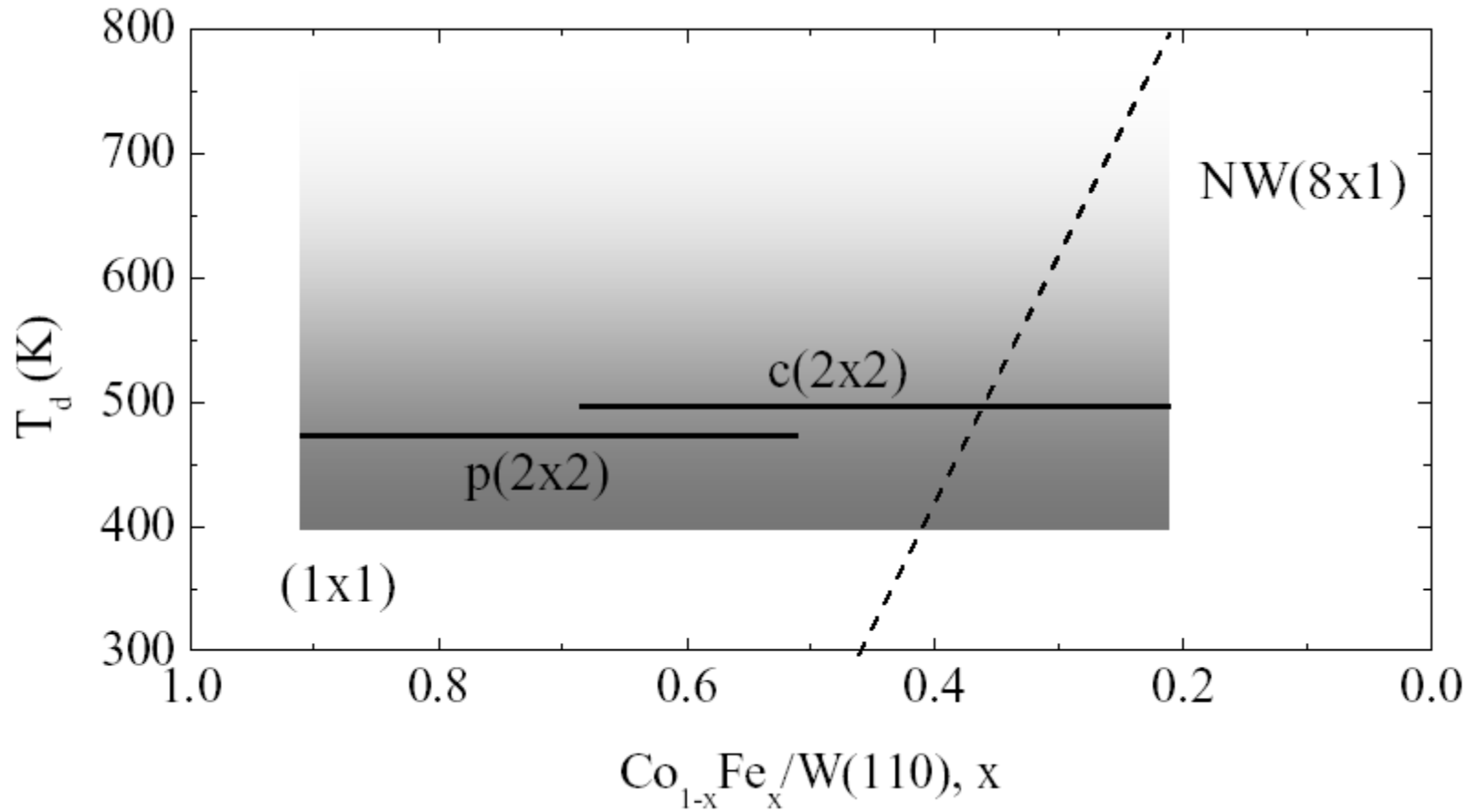
LEED, STM



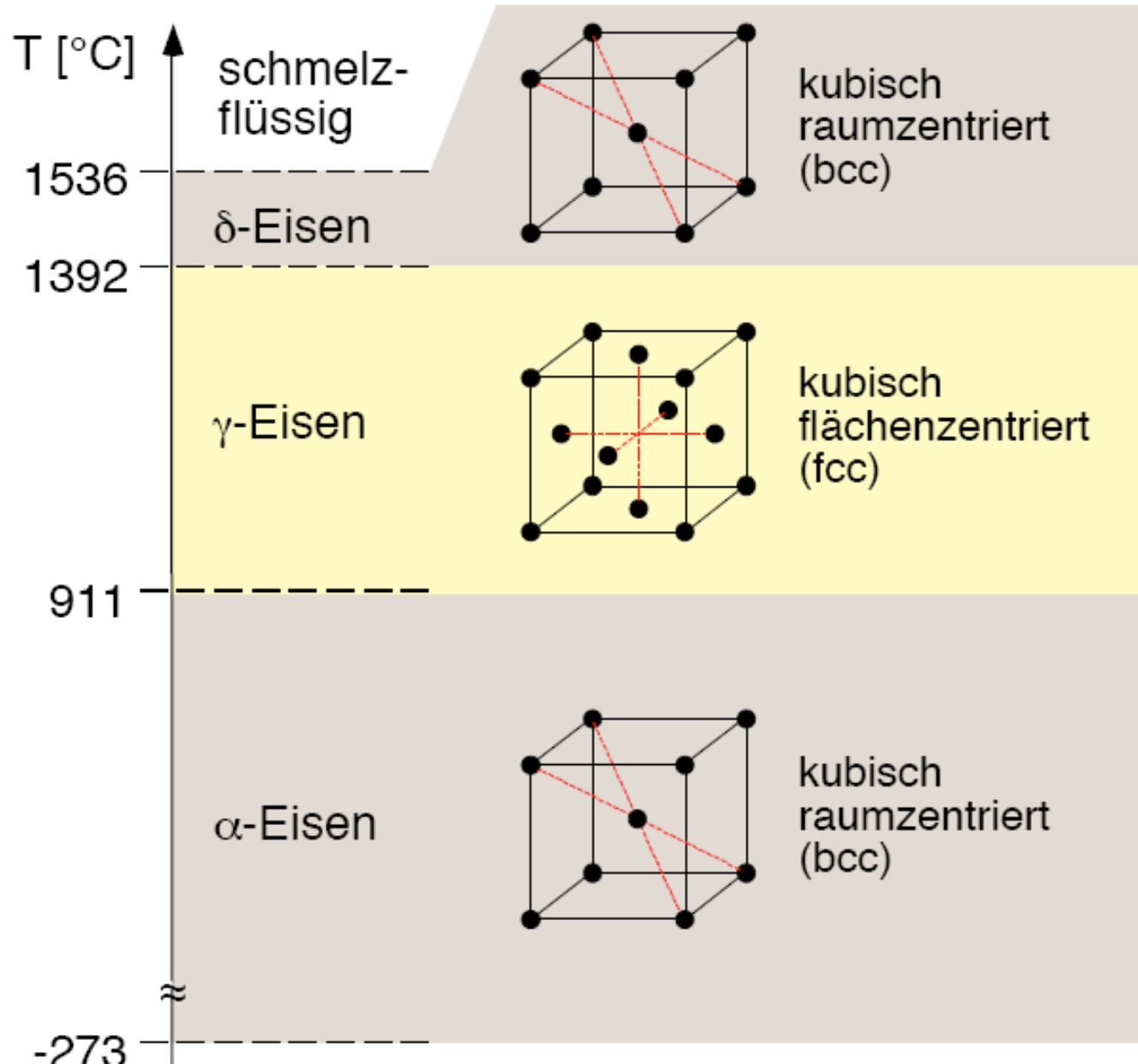
Structure of $\text{Co}_{1-x}\text{Fe}_x / \text{W}(110)$ monolayers LEED, STM



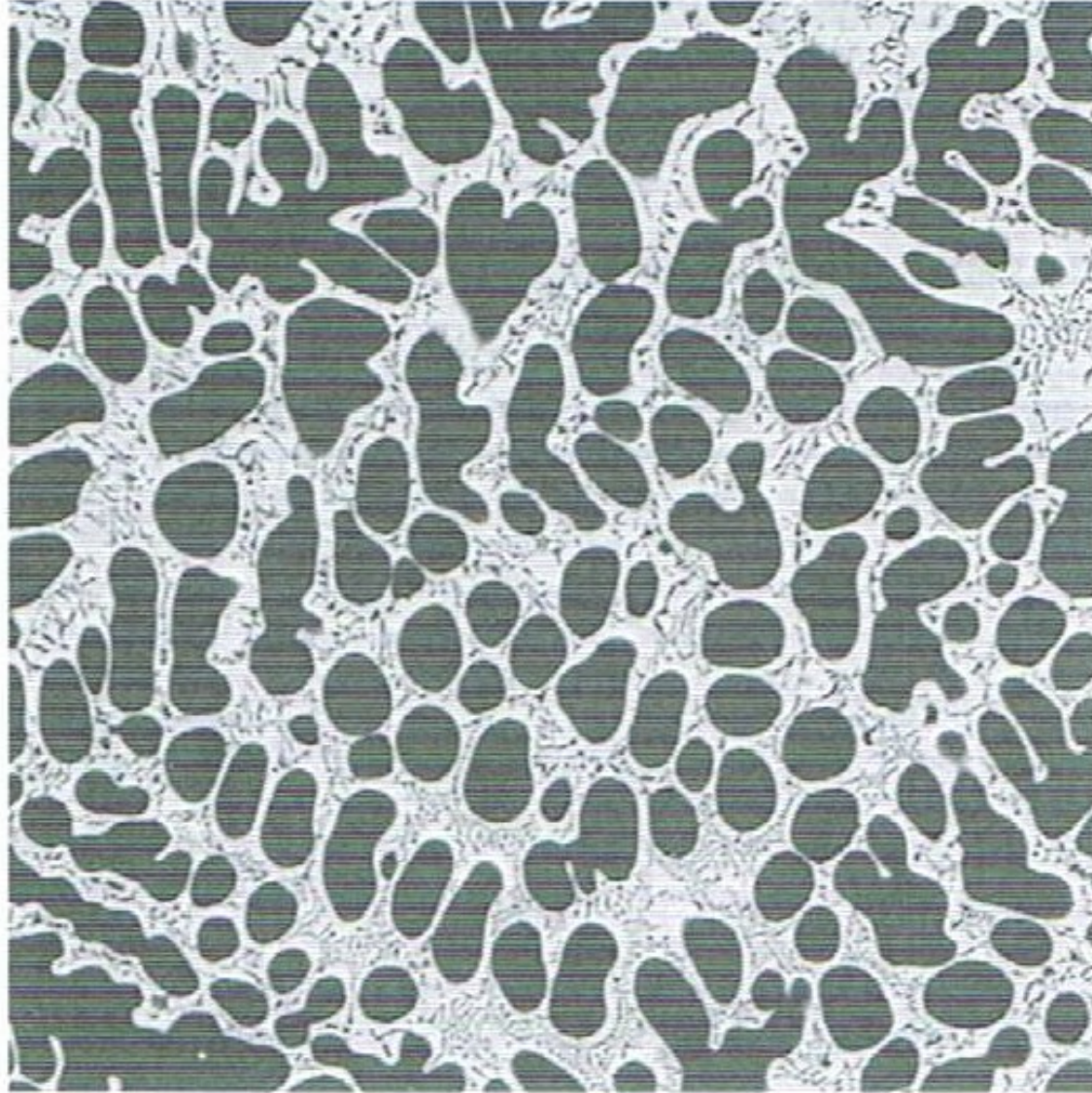
Structural Phase Diagram for $\text{Co}_{1-x}\text{Fe}_x / \text{W}(110)$



Änderung der Struktur

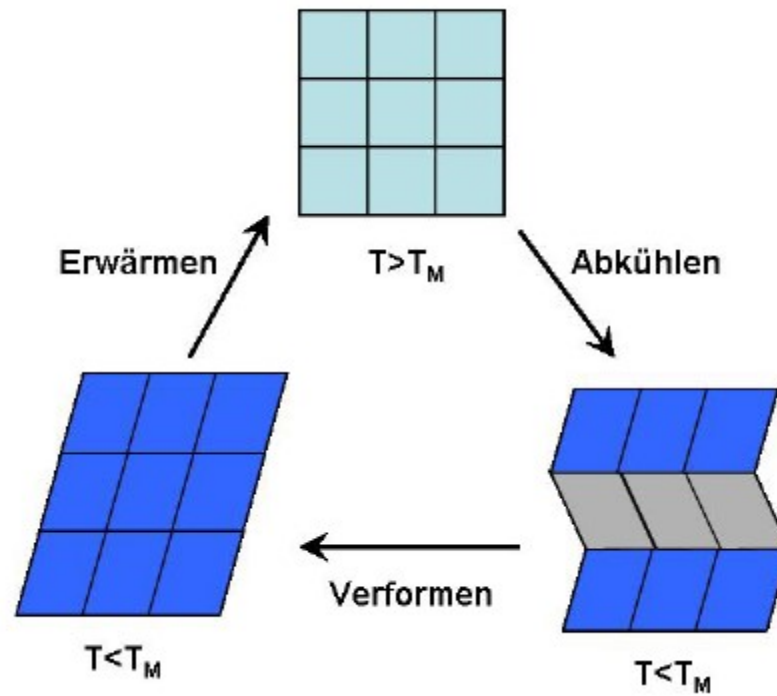


AgCu-Legierung



Quelle : Ibach/Lüth

Form-Gedächtnismetalle



Magnetischer Formgedächtnis-Effekt

(a)

