



Physikalische Grundlagen der zahnärztlichen Materialkunde

4.

Struktur der Materie

Strukturuntersuchungsmethoden

Schwerpunkte:

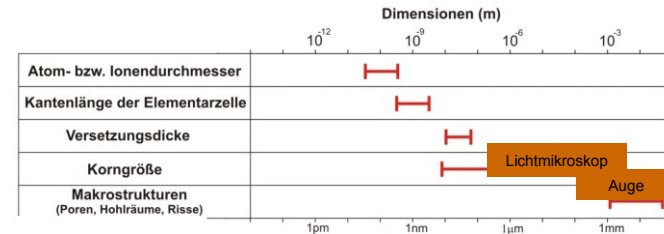
- ❖ Elektronenmikroskope
- ❖ Rastersondenmikroskope
- ❖ Röntgendiffraktion

Kapitel des Lehrbuches:
8

Aufgaben:
2. Kapitel:
1-7,10

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Dimensionen der Strukturbaulemente



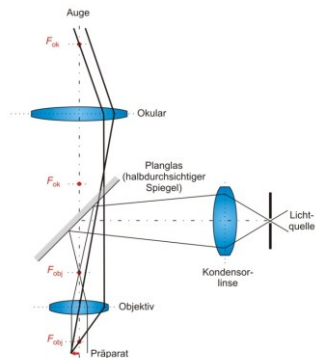
• **Auge** Auflösungsgrenze: ≈1' ⇒ bei der deutlichen Sehweite (25 cm) ≈0,1 mm

• **Lichtmikroskop** Auflösungsgrenze: ≈200 nm
(s. Biophysik)

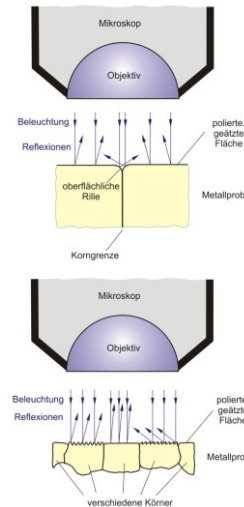
$$\delta \approx \frac{\lambda}{NA}$$

2

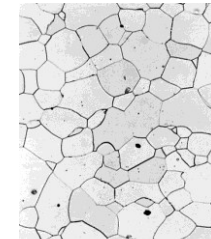
Metallmikroskop (Auflichtmikroskop)



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Vorbereitung :
• Schleifen
• Polieren
• Ätzen



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Elektronenmikroskop

$$\delta \approx \frac{\lambda}{NA}!$$

Grundlage: Elektronenbündel als Materiewelle

Theoretische Hypothese
— de Broglie-Wellenlänge
(1923):

$$\lambda = \frac{h \cdot v}{mv}$$

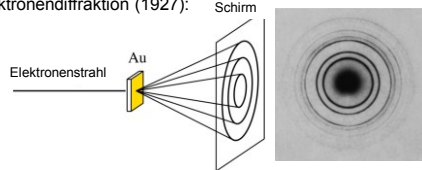
Planck-Konstante
($h = 6,63 \cdot 10^{-34} \text{ J/s}$)

Impuls des
Elektrons



Louis de Broglie
(1892-1987)
Physiker

Experimenteller Beweis —
Elektronendiffraktion (1927):



$$\lambda \approx 0,005 \text{ nm}$$

$$NA \approx 0,03$$

$$\delta \approx 0,2 \text{ nm}$$

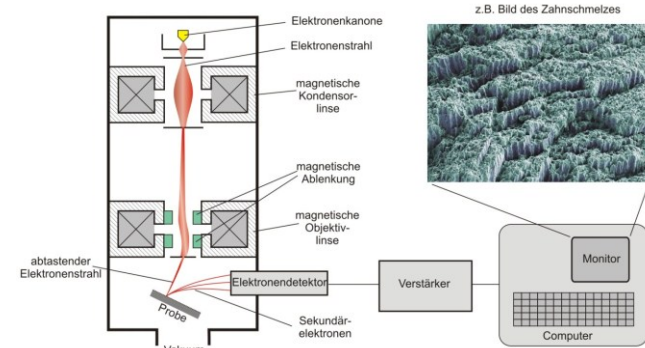


Clinton Davisson
(1881-1958)
Lester Germer
(1896-1971)
Physiker

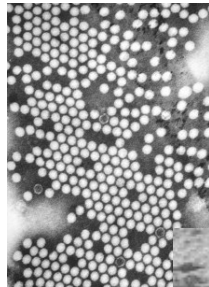
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Transmissionselektronenmikroskop (transmission electron microscope — **TEM**)

Rasterelektronenmikroskop (scanning electron microscope — **SEM**)



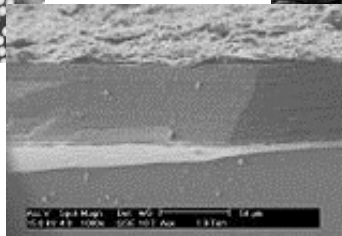
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Viren der Kinderlähmung
(TEM)

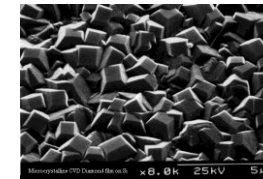


Humanblut
(SEM)

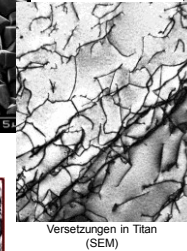


Korrosionsschicht auf einem antiken
Glasstück
(SEM)

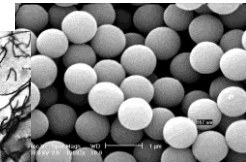
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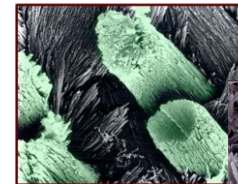
Diamant-Mikrokristalle
(SEM)



Versetzungen in Titan
(SEM)



TiO-Kugelnchen
(SEM)



Apatit-Kristallite in dem
Zahnschmelz
(SEM)

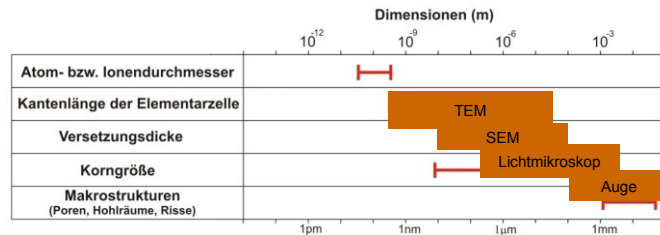


Plaques auf der Zahnoberfläche
(SEM)



Dentinkanäle mit den
Odontoblastzellen
(SEM)

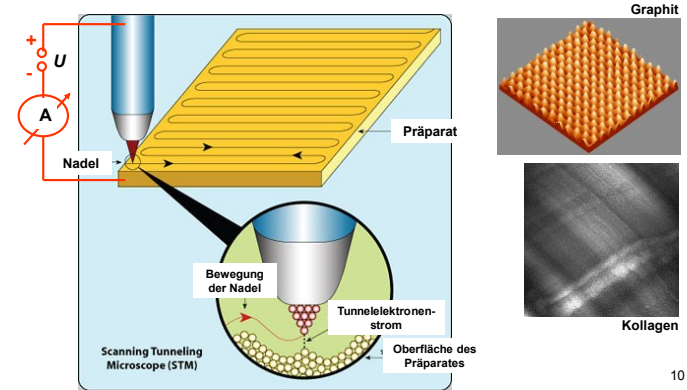
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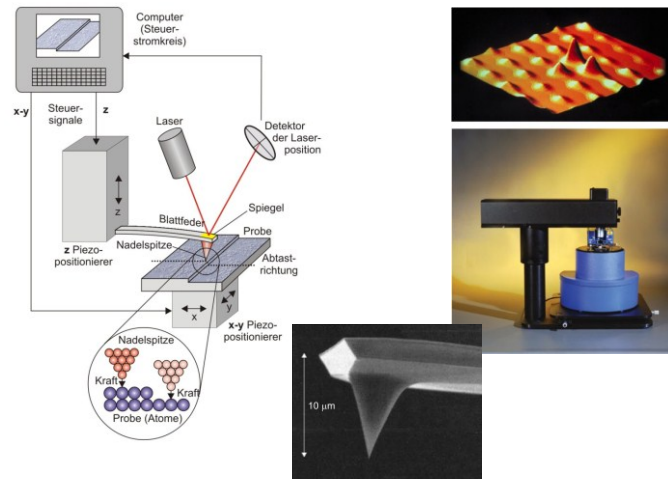
Rastersondenmikroskope (scanning probe microscopes – SPM)

Rastertunnelmikroskop (scanning tunneling microscope – STM)



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Rasterkraftmikroskop (atomic force microscope – AFM)



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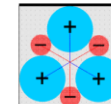
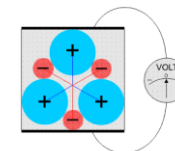
Umweg: Piezoelektrizität

1880 P. Curie (piezein = gr. zusammendrücken)



Piezoelektrischer Effekt:
Deformation \Rightarrow elektrische Spannung

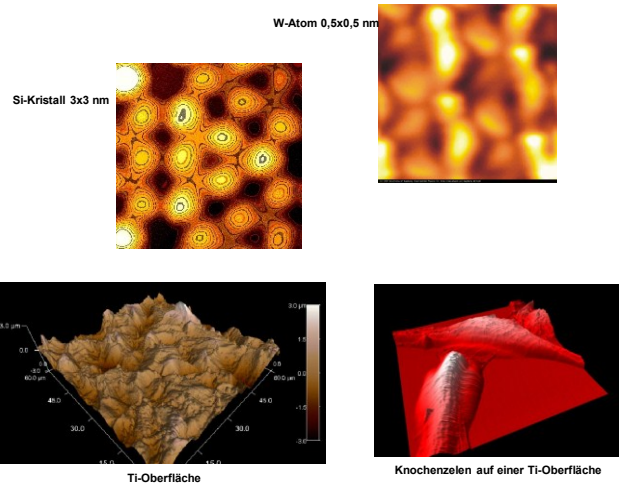
Inverser piezoelektrischer Effekt:
elektrische Spannung \Rightarrow Deformation



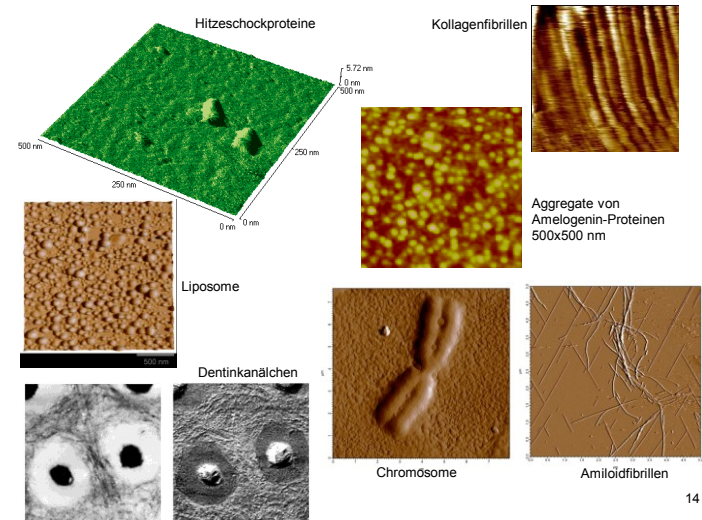
$$U = \delta \cdot \Delta x$$

z.B. für Quartz: $\delta \approx 10^{12}$ V/m

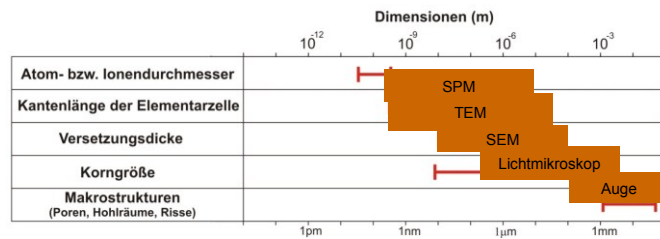
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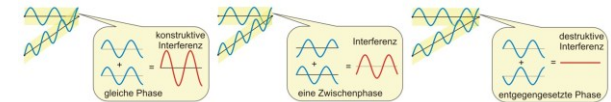
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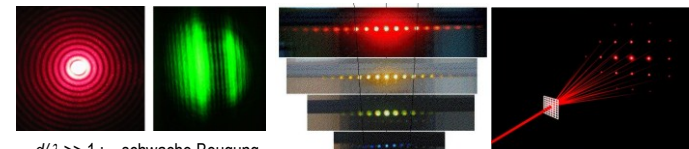
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Interferenz, Diffraction (Beugung)

Interferenz



Diffraction



$d/\lambda \gg 1$: schwache Beugung
 $d/\lambda \approx 1$: starke Beugung

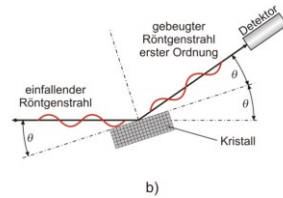
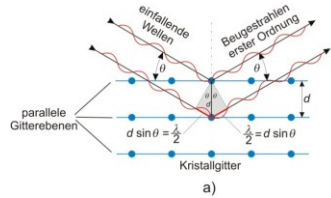
$$d \sin \alpha = k \cdot \lambda$$



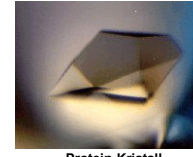
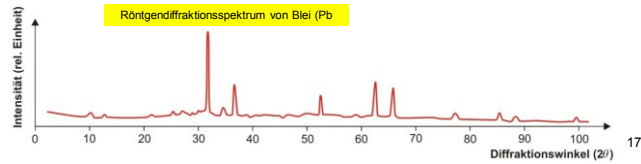
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Diffractionsmethoden

- Röntgendiffraktion $\lambda \approx 0,01\text{-}0,1 \text{ nm}$
- Neutronendiffraktion $\approx 0,1 \text{ nm}$
- Elektronendiffraktion $\approx 0,01 \text{ nm}$

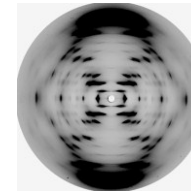
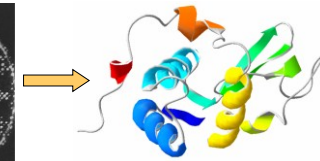
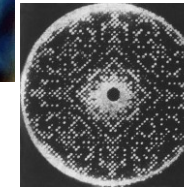


Bragg-Gleichung: $2d \sin \theta = n \cdot \lambda$

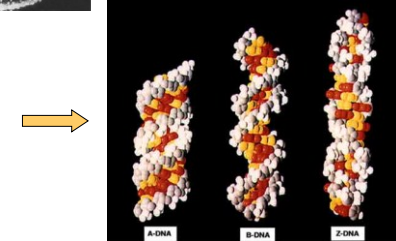


Protein-Kristall

Lysozyme

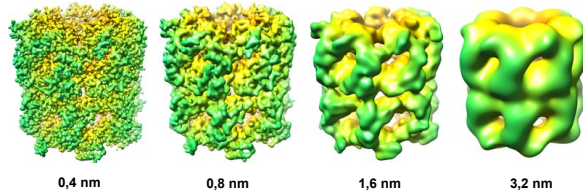


DNS



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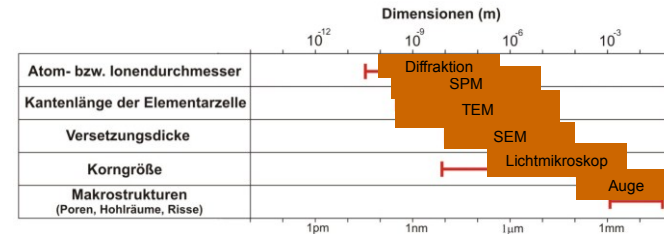
GroEL bei verschiedenen Auflösungen:



Hämoglobin:



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Nächste Vorlesung:
Kapitel 9-13

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