



## Physikalische Grundlagen der zahnärztlichen Materialkunde

### 4. Struktur der Materie Strukturuntersuchungsmethoden

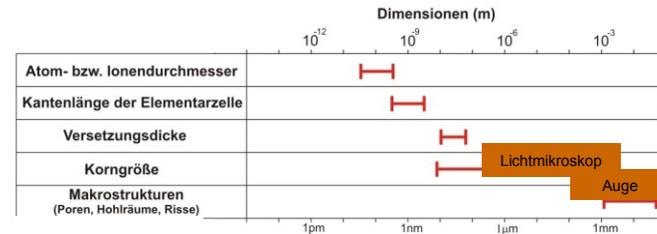
- Schwerpunkte:
- ❖ Elektronenmikroskope
  - ❖ Rastersondenmikroskope
  - ❖ Röntgendiffraktion

Kapitel des Lehrbuches:  
8

Aufgaben:  
2. Kapitel:  
1-7,10

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## Dimensionen der Strukturbauelemente



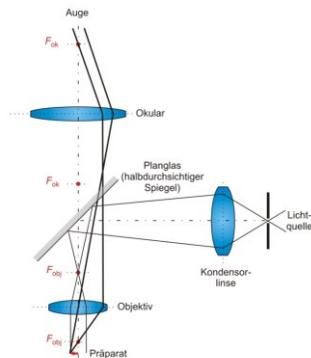
• **Auge** Auflösungsgrenze:  $\approx 1'$   $\Rightarrow$  bei der deutlichen Sehweite (25 cm)  $\approx 0,1$  mm

• **Lichtmikroskop** (s. Biophysik) Auflösungsgrenze:  $\approx 200$  nm

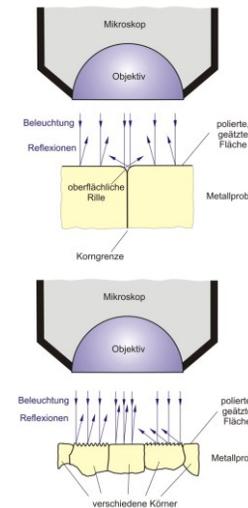
$$\delta \approx \frac{\lambda}{NA}$$

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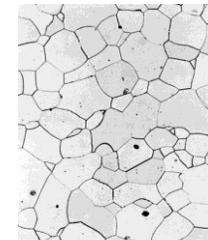
## Metallmikroskop (Auflichtmikroskop)



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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):

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

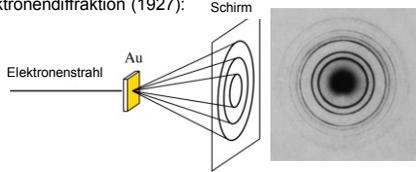
Planck-Konstante  
( $h = 6,63 \cdot 10^{-34} \text{ J/s}$ )

Impuls des Elektrons



Louis de Broglie  
(1892-1987)  
Physiker

Experimenteller Beweis – Elektronendiffraktion (1927):



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

$$NA \approx 0,03 \quad \longrightarrow \quad \delta \approx 0,2 \text{ nm}$$

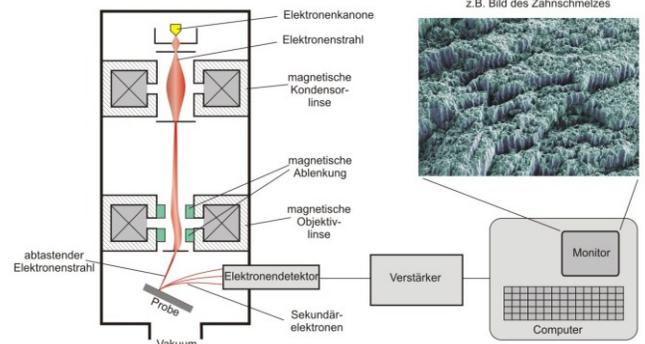


Clinton Davisson  
(1881-1958)  
Lester Germer  
(1896-1971)  
Physiker

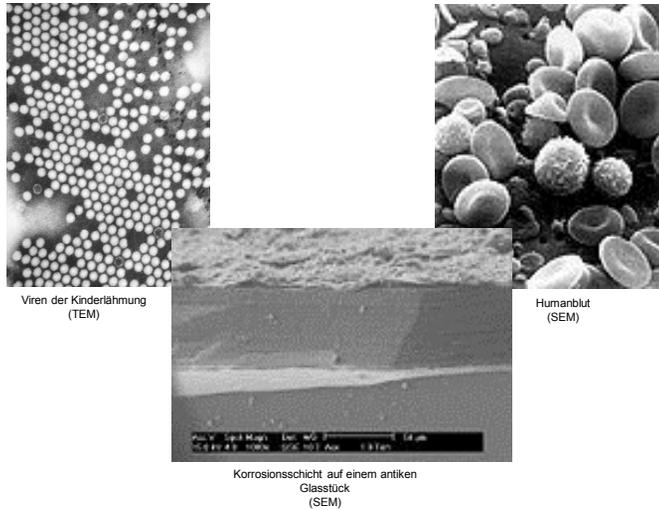
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# Transmissionselektronenmikroskop (transmission electron microscope – TEM)

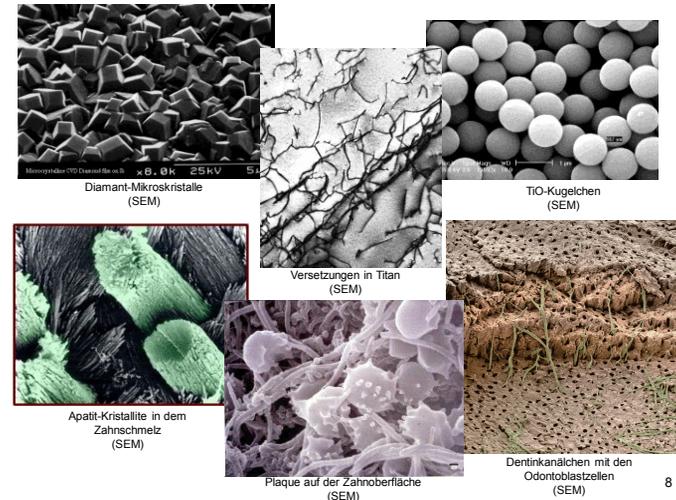
# Rasterelektronenmikroskop (scanning electron microscope – SEM)



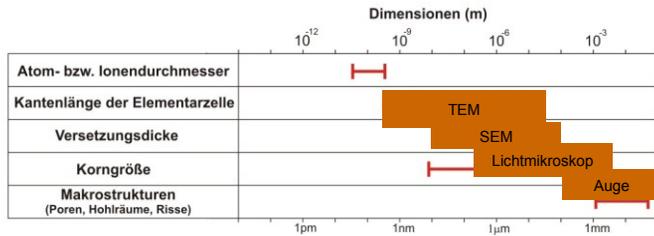
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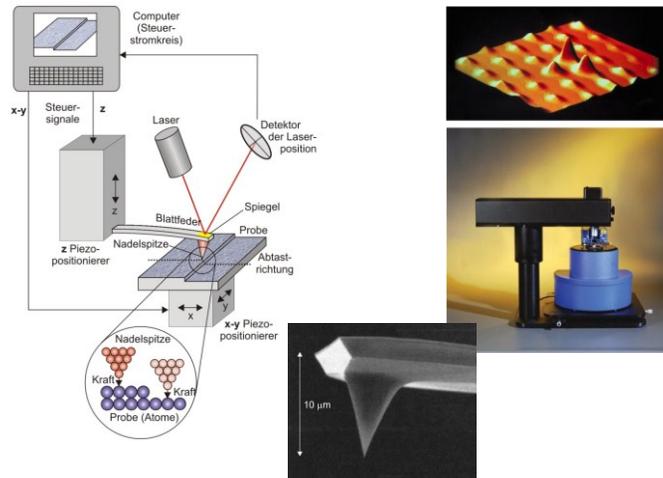


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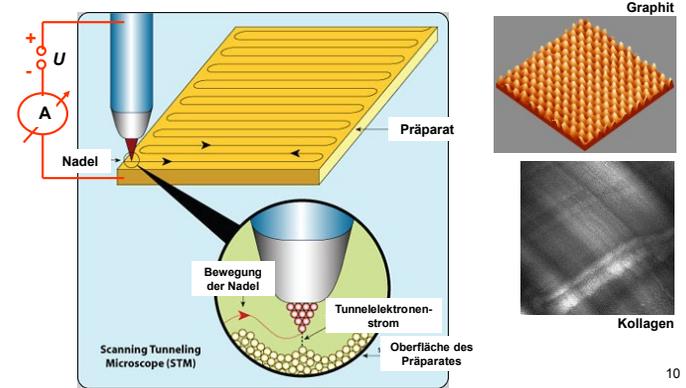
### Rasterkraftmikroskop (atomic force microscope – AFM)



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### Rastersondenmikroskope (scanning probe microscopes – SPM)

#### Rastertunnelmikroskop (scanning tunneling microscope – STM)



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### Umweg: Piezoelektrizität

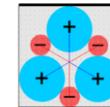
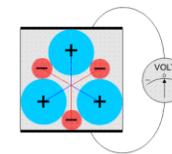
1880 P. Curie (piezein = gr. zusammendrücken)

Z.B.: Quarz



**Piezoelektrischer Effekt:**  
Deformation  $\Rightarrow$  elektrische Spannung

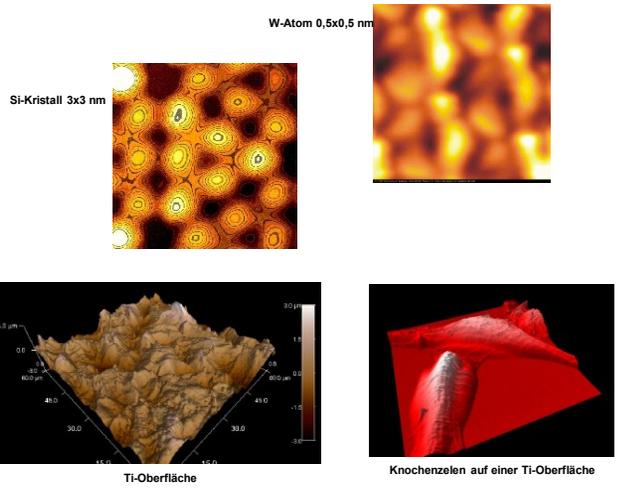
**Inverser piezoelektrischer Effekt:**  
elektrische Spannung  $\Rightarrow$  Deformation



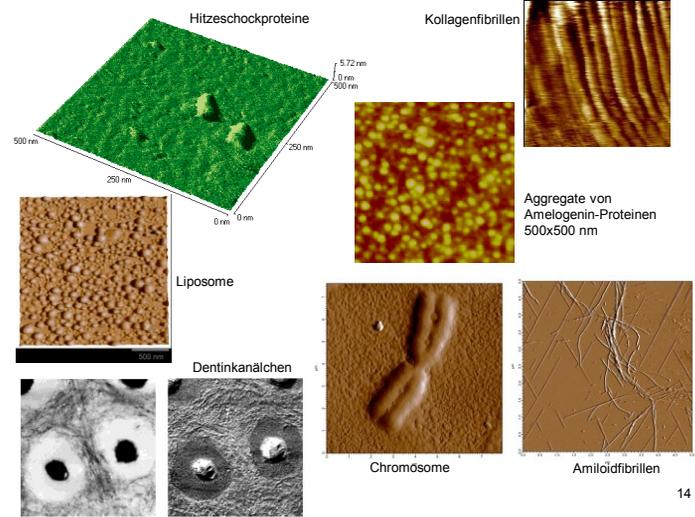
$$U = \delta \cdot \Delta x$$

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

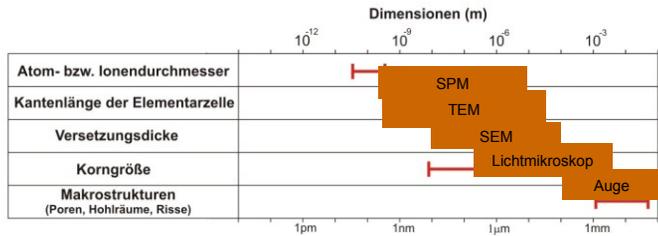
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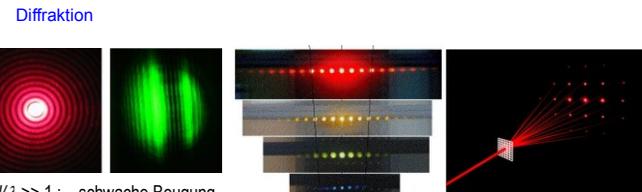
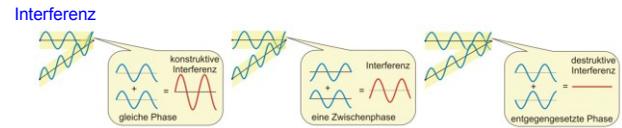


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## Interferenz, Diffraction (Beugung)



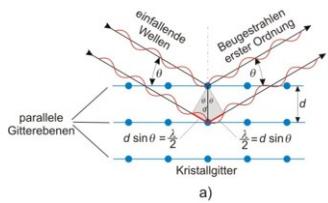
$d/\lambda \gg 1$ : schwache Beugung

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

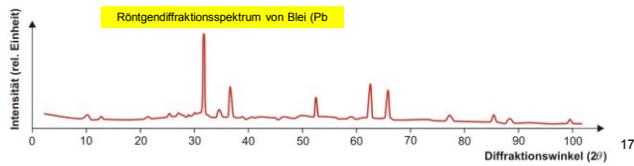
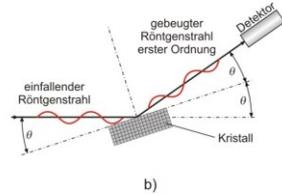
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# Diffractionsmethoden

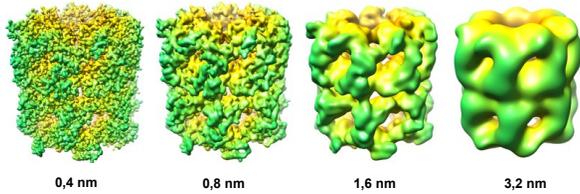
- Röntgendiffraktion  $\lambda \approx 0,01-0,1 \text{ nm}$
- Neutronendiffraktion  $\approx 0,1 \text{ nm}$
- Elektronendiffraktion  $\approx 0,01 \text{ nm}$



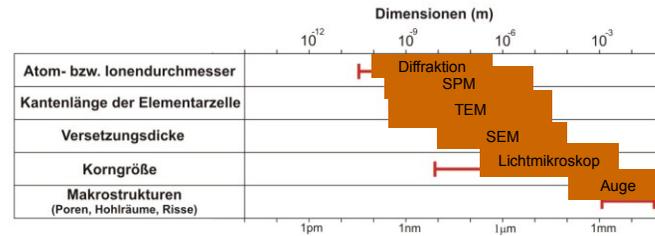
Bragg-Gleichung:  $2d \sin \theta = n \cdot \lambda$



## GroEL bei verschiedenen Auflösungen:



## Hämoglobin:



Nächste Vorlesung:  
Kapitel 9, 10, 11