

Physikalische Grundlagen der zahnärztlichen Materialkunde

4^{te} Vorlesung
 Strukturuntersuchungsmethoden
 4. Oktober 2018.
 Gergely Agócs

Lehrbuch:
 8. Kapitel

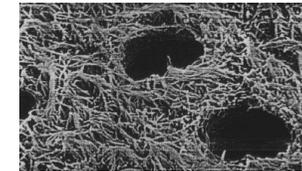
Hausaufgaben:
 2. Kap.: 1-7, 10, 12

Was bedeutet "Struktur"?

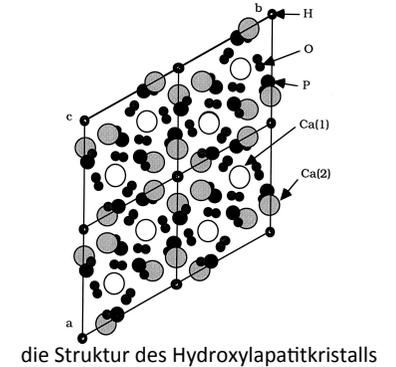
Die **Lage** der Elemente eines komplexen Systems und die **Beziehungen** zwischen ihnen.



die schematische Anatomie eines Molars

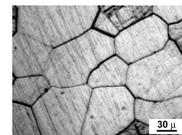
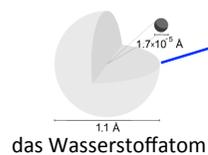
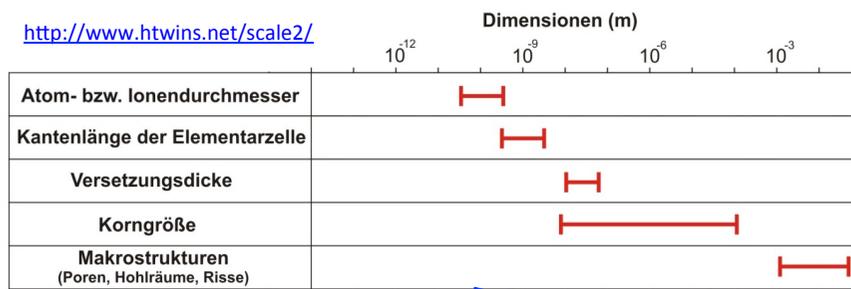


die Feinstruktur des Dentins



Dimensionen der Strukturuntersuchungen

<http://www.htwins.net/scale2/>



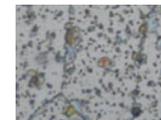
Metallkörner



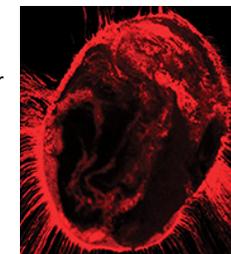
ein Zahnbruch₃

Was ist das Wesen der Bildgebung?

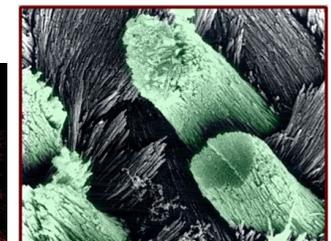
Wir ordnen Intensitätswerte zu den einzelnen Bildpunkten aufgrund irgendwelcher Eigenschaften der Gegenstandspunkte zu



die Struktur der Metallkörner im Metallmikroskop



eine Wurzelfüllung aus Guttapercha im konfokalen Mikroskop

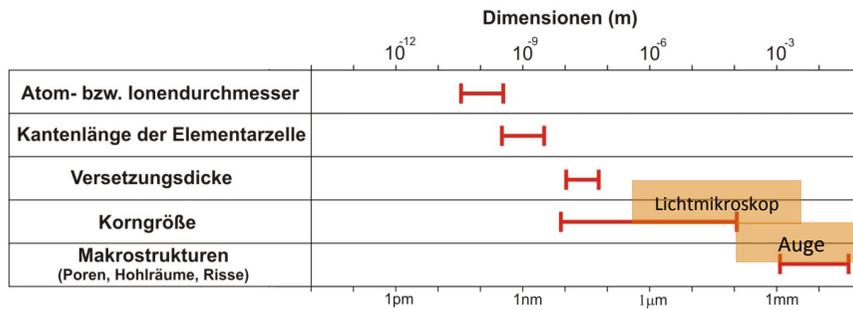


die Apatitkristalle des Zahnschmelzes im Elektronenmikroskop



die Dentinkanälchen in Rasterkraftmikroskop

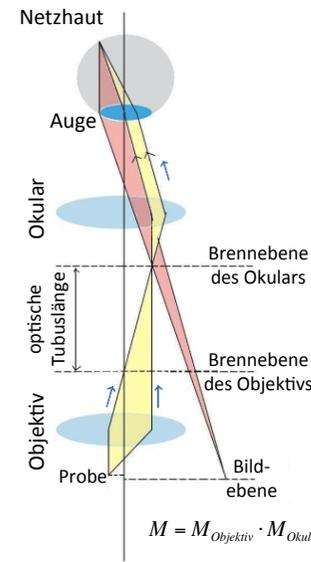
Dimensionen der Strukturbauelemente



• **Auge** Auflösungsgrenze: ung. 1 Bogenminute ⇒ bei der deutlichen Sehweite = 25 cm

• **Lichtmikroskop** Auflösungsgrenze: ≈ 200 nm
 (s. Biophysik, Vorlesung und Praktikum)
 $d = 0,61 \cdot \frac{\lambda}{n \cdot \sin \omega} \approx \lambda$
 $n \cdot \sin \omega \approx 1$

Lichtmikroskop



$$M = M_{\text{Objektiv}} \cdot M_{\text{Okular}} = - \frac{a \cdot d}{f_{\text{Objektiv}} \cdot f_{\text{Okular}}}$$

einfaches Lichtmikroskop

Lichtmikroskop

Entwicklungsmöglichkeiten:

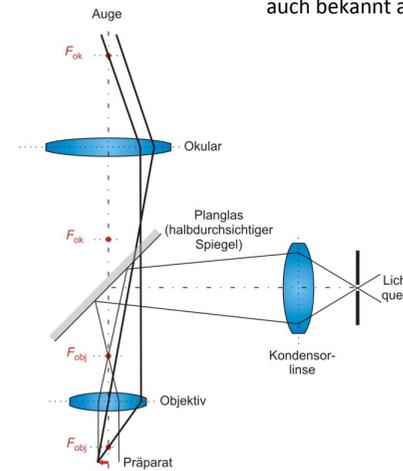
Verbesserung des Kontrastes

Verbesserung der Auflösung

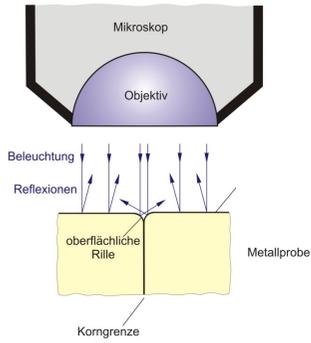


Metallmikroskop

auch bekannt als: Auflichtmikroskop

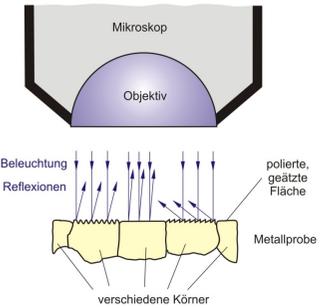
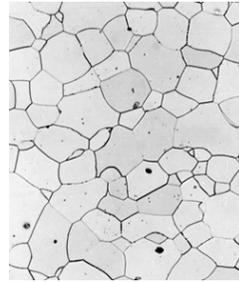


stehendes Metallmikroskop



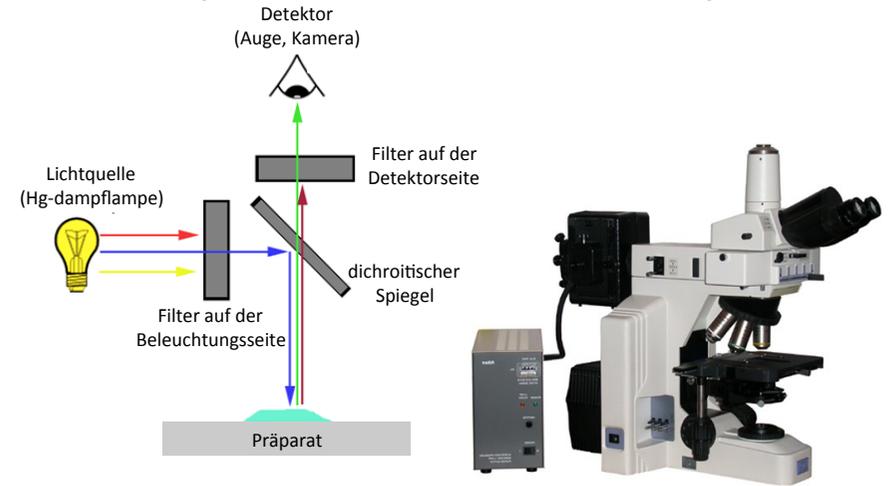
Vorbereitung :

- **Probenahme (Prüfkörper oder Abdruck)**
- **Schleifen oder Polieren**
- **Ätzen**



9

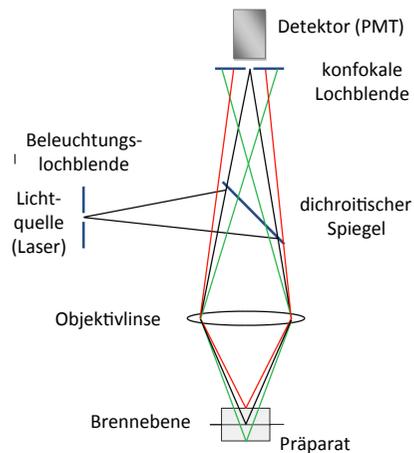
Epifluoreszenzmikroskop



Vorteil im Vergleich zum einfachen Lichtmikroskop:

10

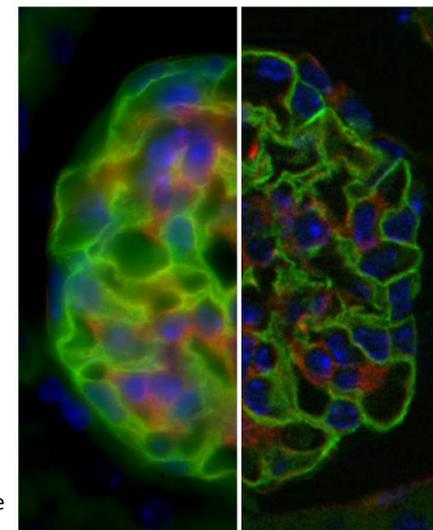
Konfokalmikroskop



Vorteil im Vergleich zum Epifluoreszenzmikroskop:

11

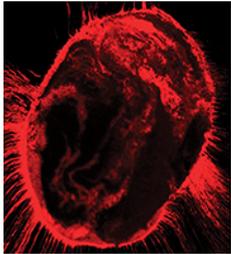
Epifluoreszenz vs. Konfokal



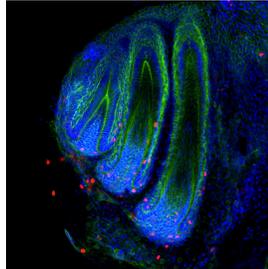
Nierenscheibe

12

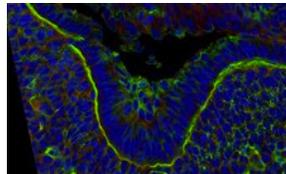
Konfokalmikroskop



Wurzelfüllung aus Guttapercha



ein funktionierender Zahn und zwei "Ersatzzähne" einer Schlange



Einstülpung einer Zahnknospe

Elektronenmikroskop

Grundlage: Elektronenbündel als Materiewelle

theoretische Hypothese – de Broglie-Wellenlänge (1923):

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

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

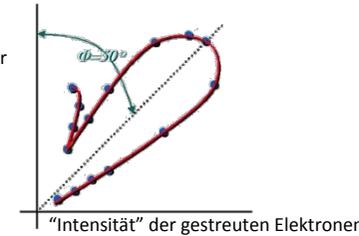
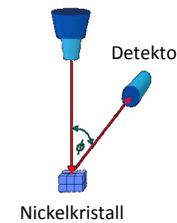
Impuls des Elektrons



Louis de Broglie
(1892-1987)
Physiker

experimenteller Beweis – Elektronenbeugung (1927):

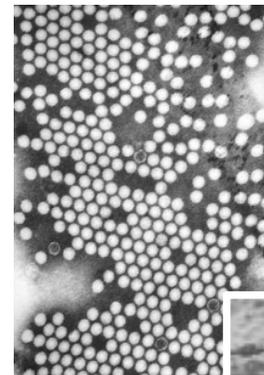
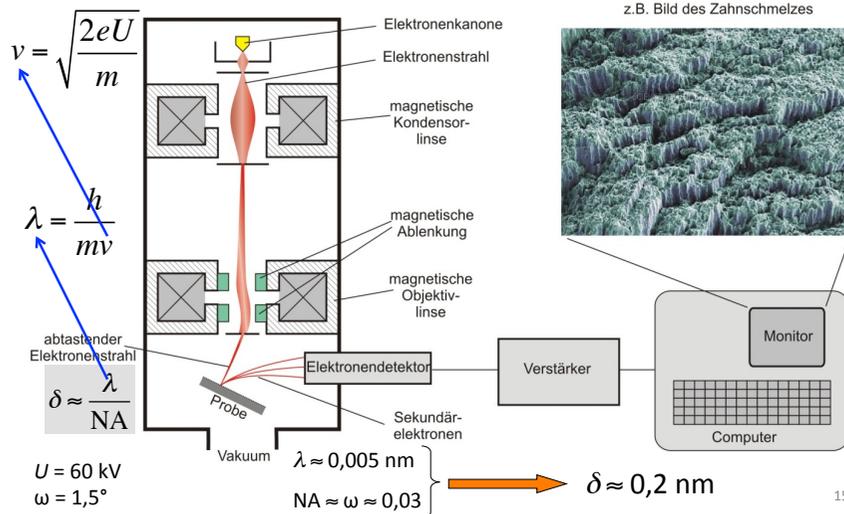
Elektronenkanone



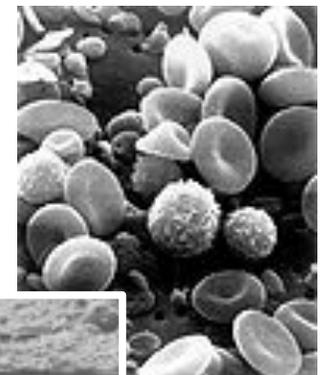
Clinton Davisson
(1881-1958)
Lester Germer
(1896-1971)
Physiker

Transmissionselektronenmikroskop (transmission electron microscope – TEM)

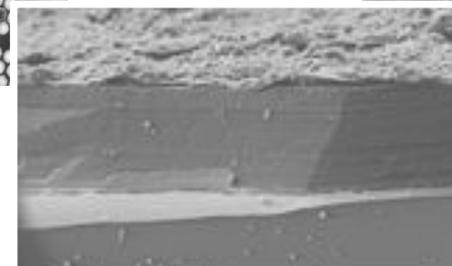
Rasterelektronenmikroskop (scanning electron microscope – SEM)



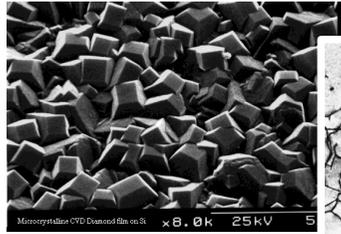
Viren der Kinderlähmung (TEM)



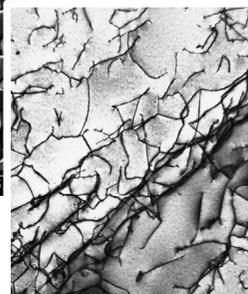
Humanblut (SEM)



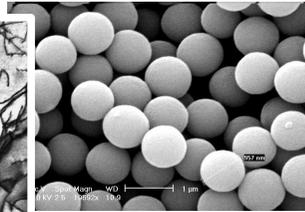
Korrosionsschicht auf einem antiken Glasstück (SEM)



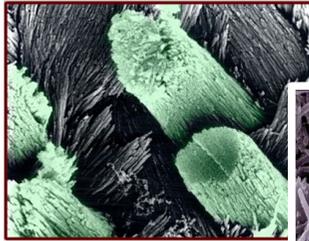
Diamant-Mikrokristalle (SEM)



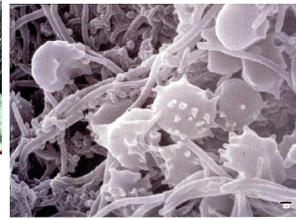
Versetzungen in Titan (SEM)



TiO-Kugelchen (SEM)



Apatit-Kristallite in dem Zahnschmelz (SEM)

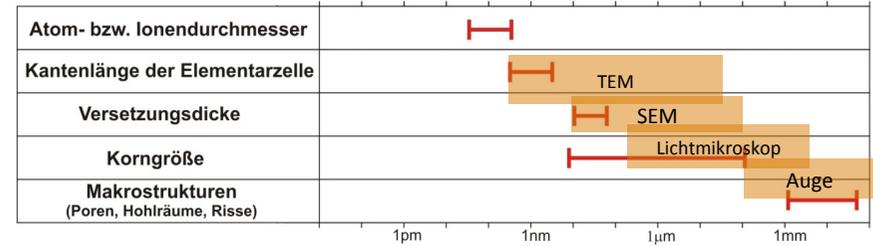


Plaques auf der Zahnoberfläche (SEM)



Dentinkanälchen mit den Odontoblastzellen (SEM)

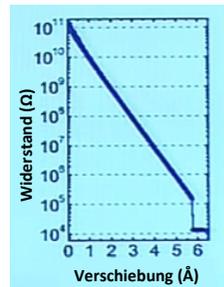
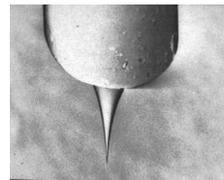
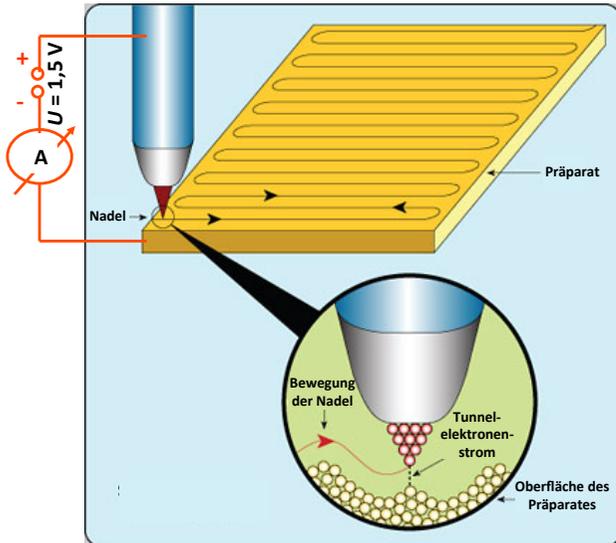
Dimensionen (m)



(Engl. scanning probe microscopes – SPM)

Rastersondenmikroskope

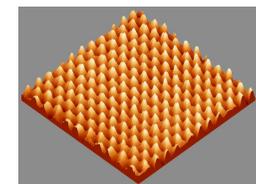
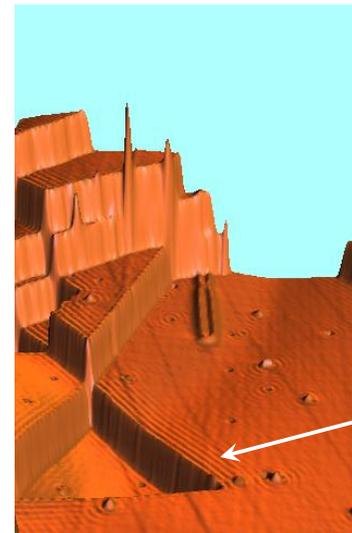
Rastertunnelmikroskop (Engl. scanning tunneling microscope – STM)



(Engl. scanning probe microscopes – SPM)

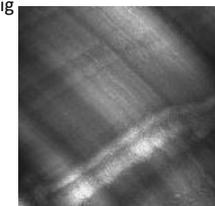
Rastersondenmikroskope

Rastertunnelmikroskop (Engl. scanning tunneling microscope – STM)



Graphit

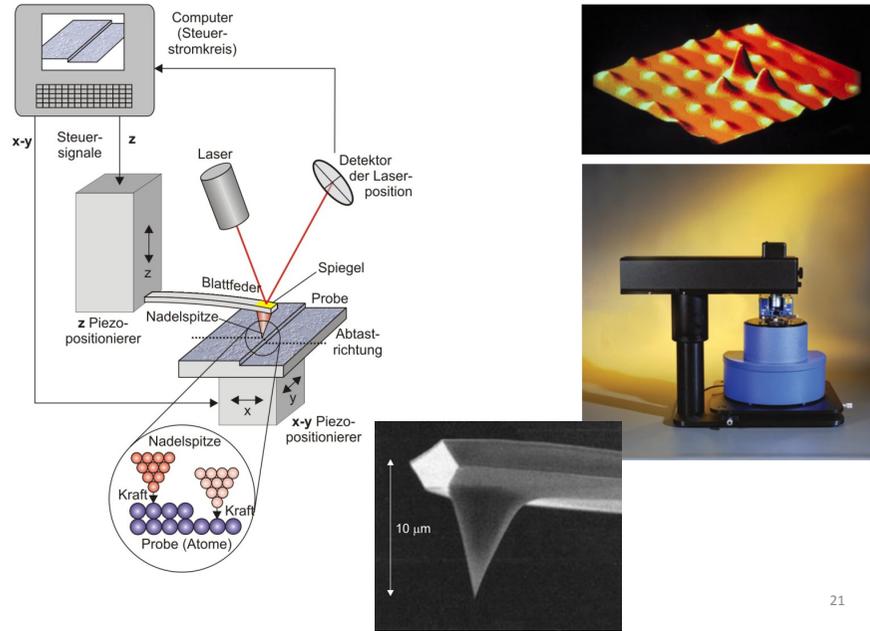
Kupferoberfläche (in der Richtung z unverhältnismäßig vergrößert)



Kollagen

Was ist das?

Rasterkraftmikroskop (Engl. atomic force microscope – AFM)



Umweg: Piezoelektrizität

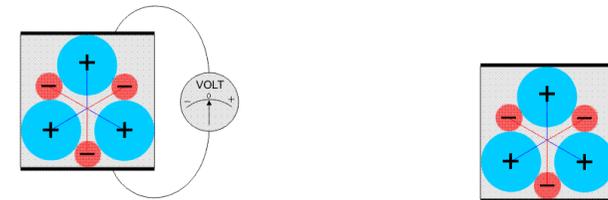
Z.B.: Quarz



1880 P. Curie (*piezein* = gr. zusammendrücken)

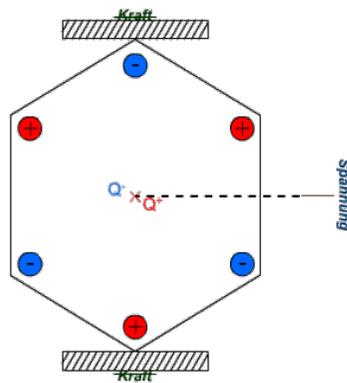
(direkter) piezoelektrischer Effekt:
Deformation ⇒ elektrische Spannung

inverser piezoelektrischer Effekt:
elektrische Spannung ⇒ Deformation

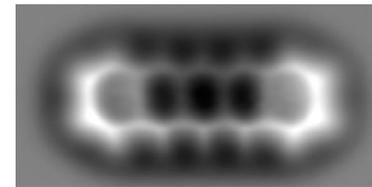


$$U = \delta \cdot \Delta x$$

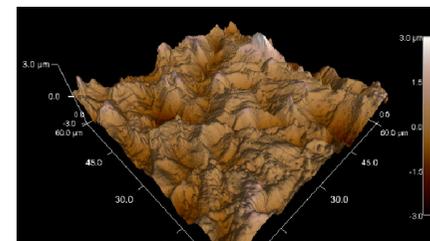
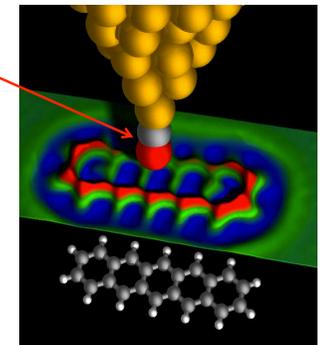
z.B für Quarz: $\delta \approx 10^{12}$ V/m



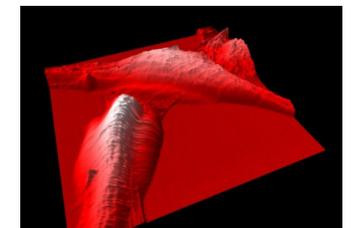
ein Kohlenstoffmonoxid-Molekül (CO)
auf der Messspitze



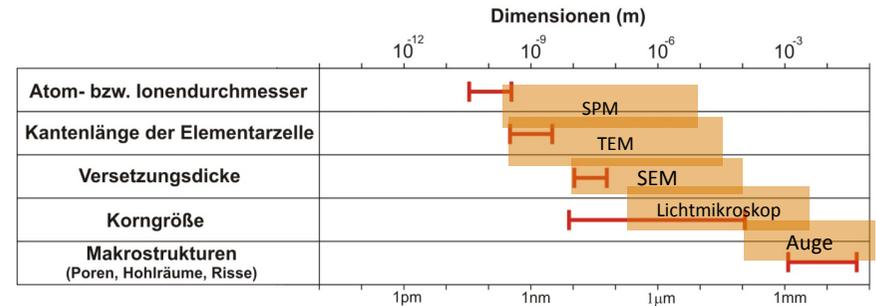
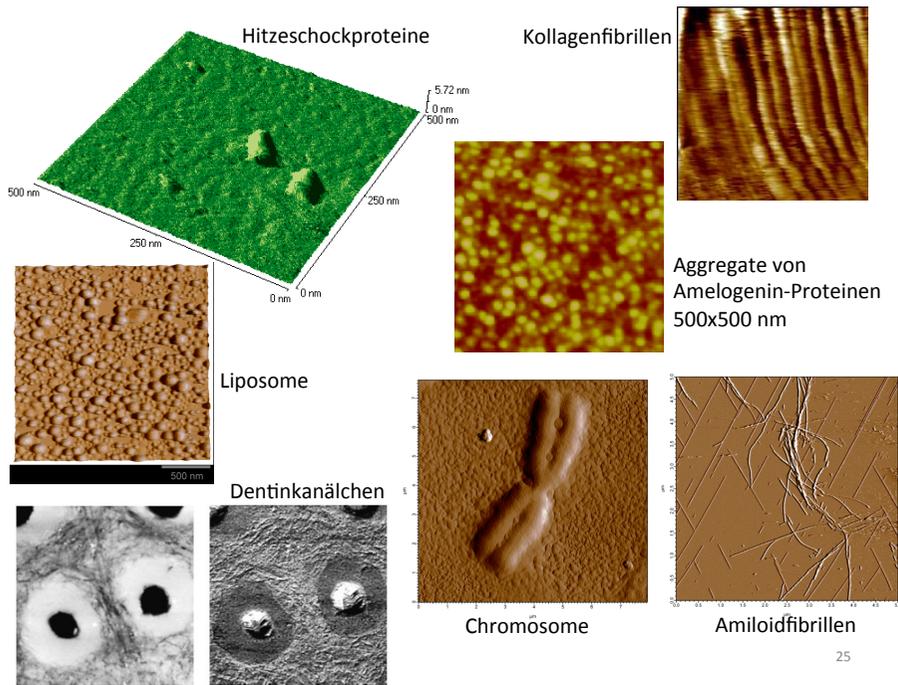
Pentacen (C₂₂H₁₄) –Molekül (2009)



raue Ti-Oberfläche



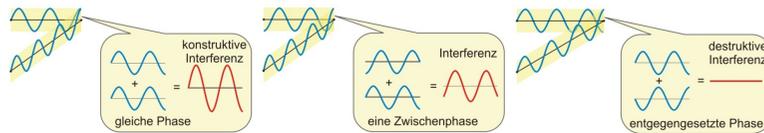
Knochenzellen auf einer Ti-Oberfläche



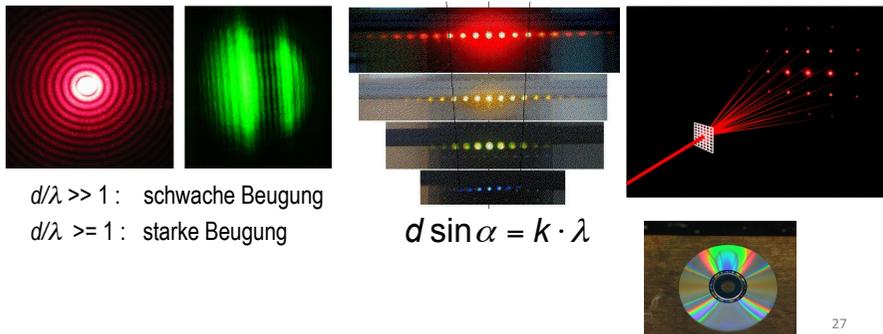
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Interferenz und Diffraktion (Beugung)

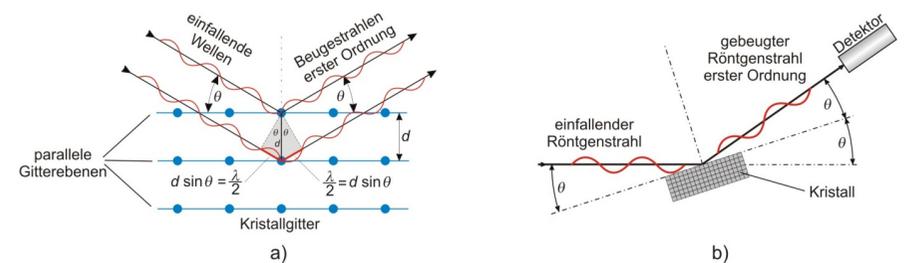
Interferenz



Diffraktion

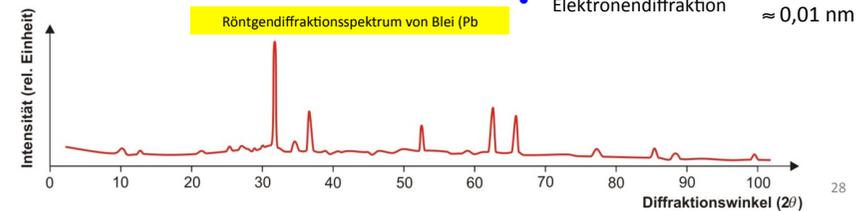


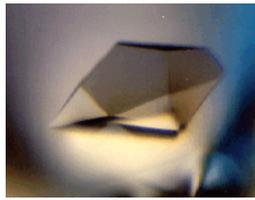
Diffraktionsmethoden



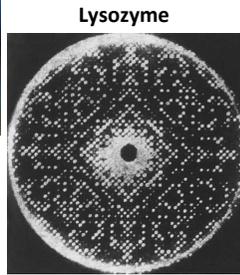
Bragg-Gleichung: $2d \sin \theta = n \cdot \lambda$

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

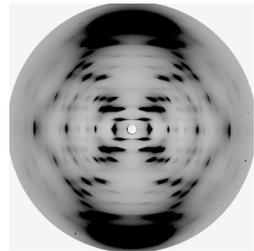
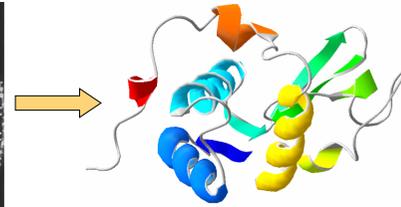




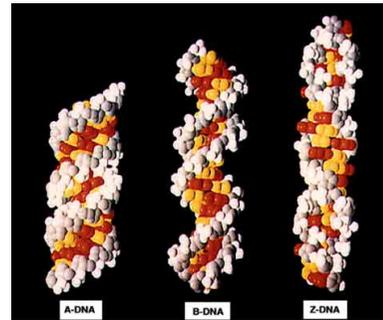
Protein-Kristall



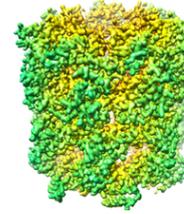
Lysozyme



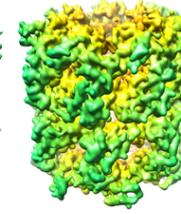
DNA



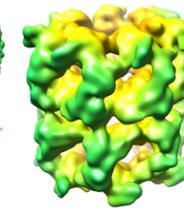
GroEL (Chaperon Protein in Bakterien)
bei verschiedenen Auflösungen:



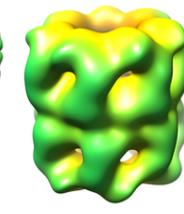
0,4 nm



0,8 nm

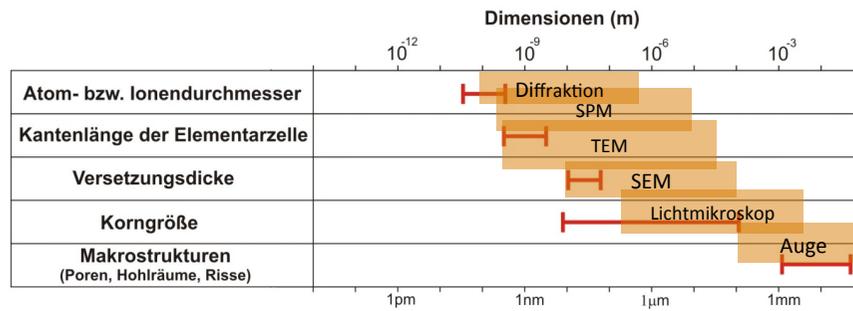
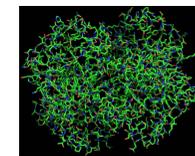
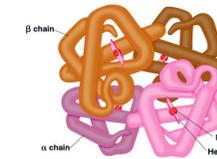
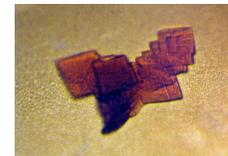


1,6 nm



3,2 nm

Hämoglobin:



Nächste Vorlesung:
Kapitel 9-13