Einblicke in die Nanowissenschaft / Nanotechnologie

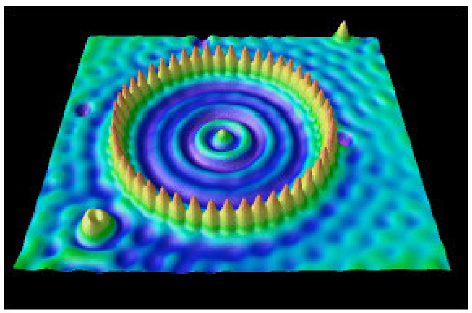
Eigenschaften und Technische Bedeutung

Ausgewählte Beispiele

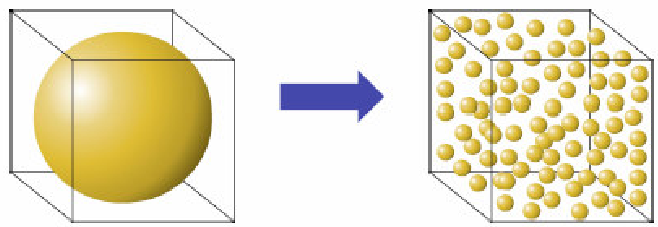
Eigenschaften von Nano-Materialien

What is Nanotechnology ?

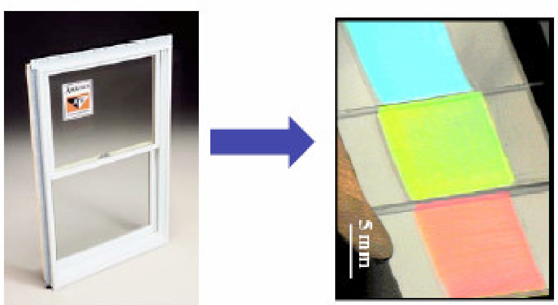
Nanomaterials will display or use new phenomena



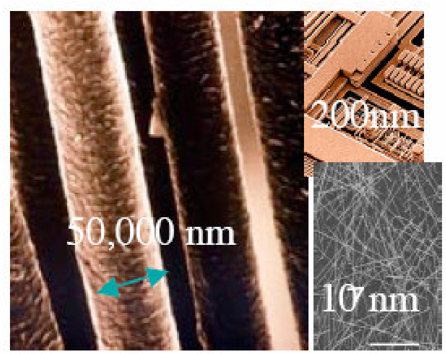
Quantum effects



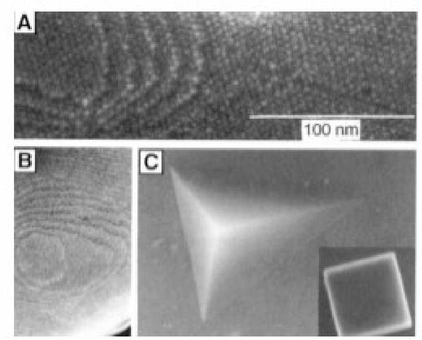
Interfacial properties – Surface Area : Volume



Molecular, aggregate, and structural properties

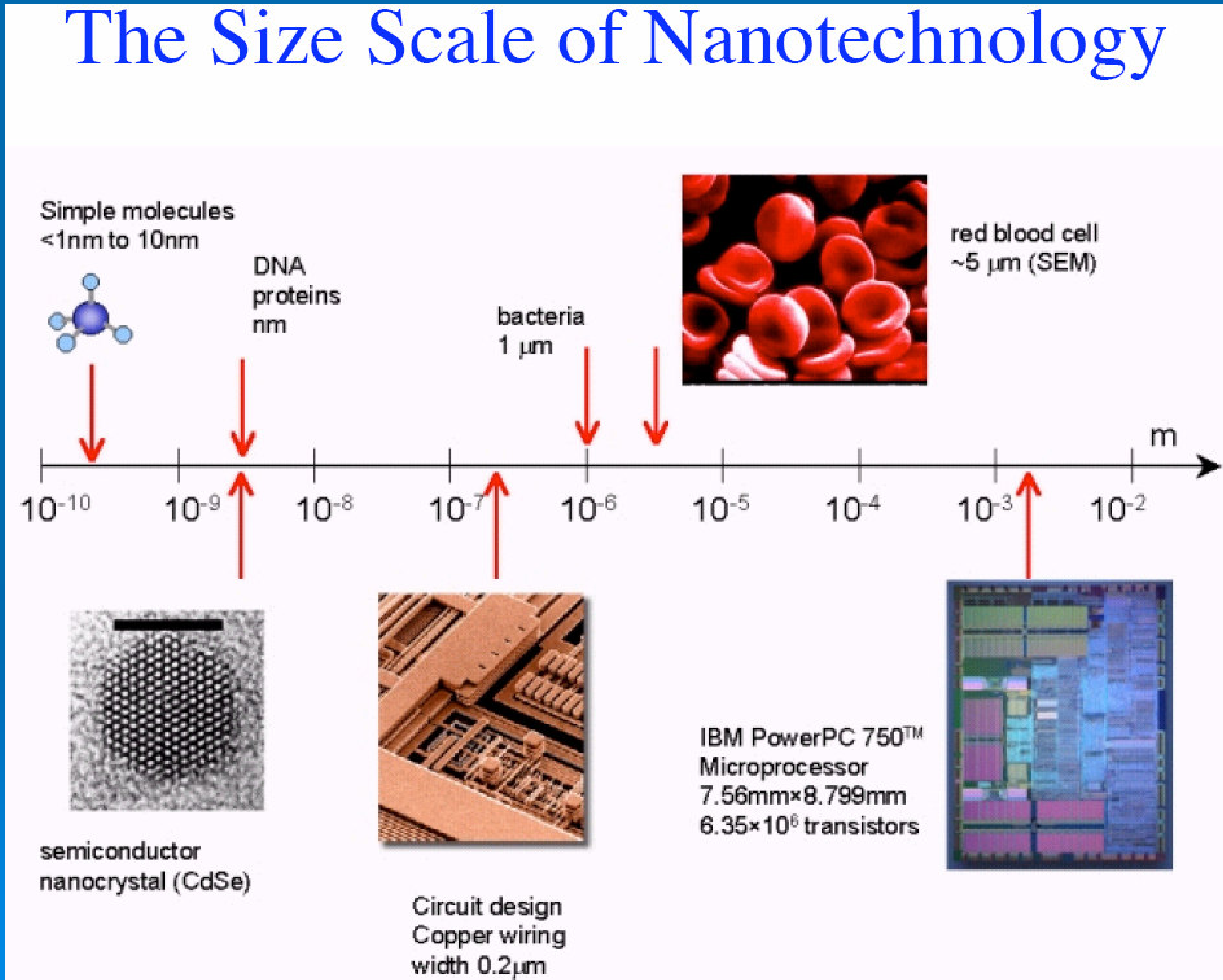


Massive Integration

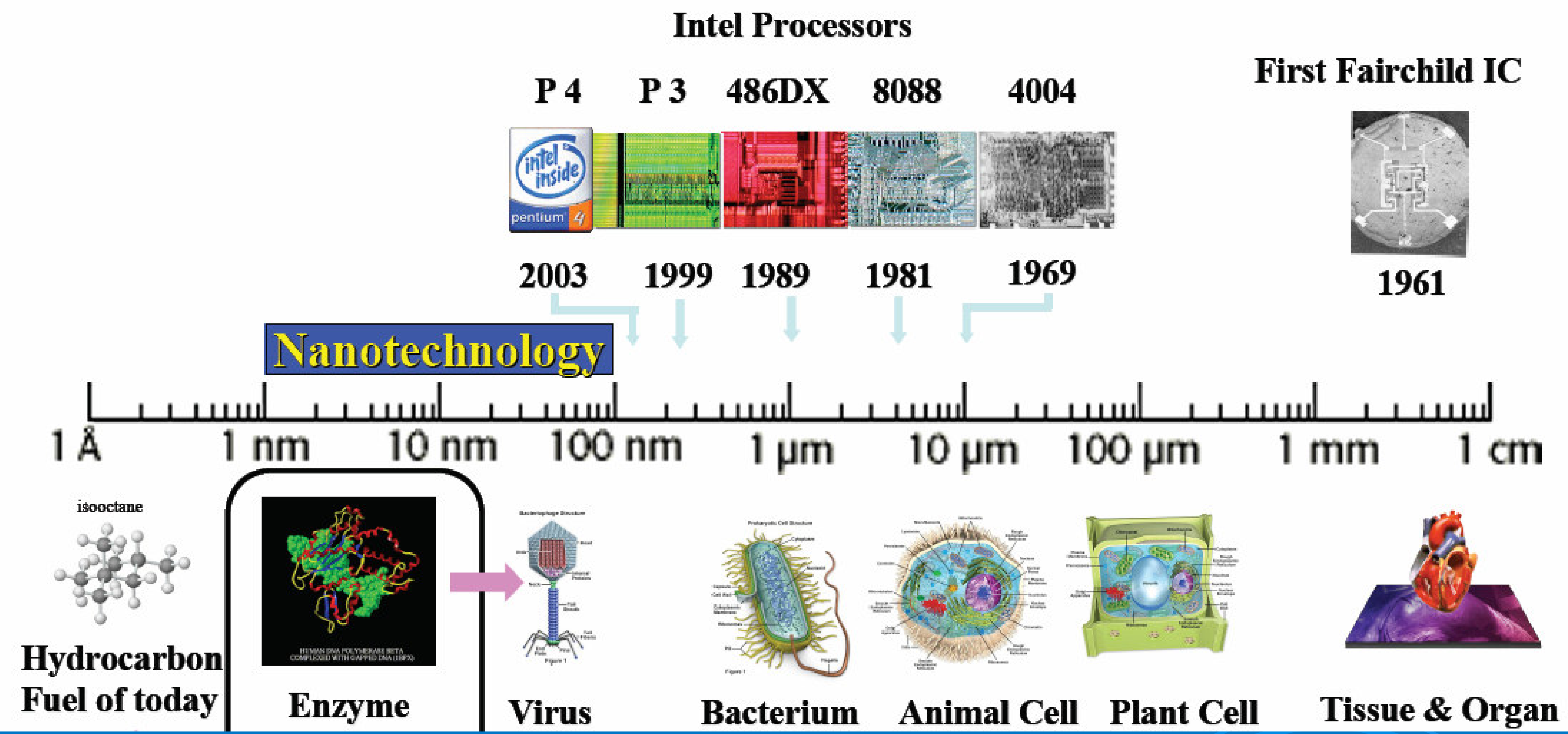


Self-Assembly

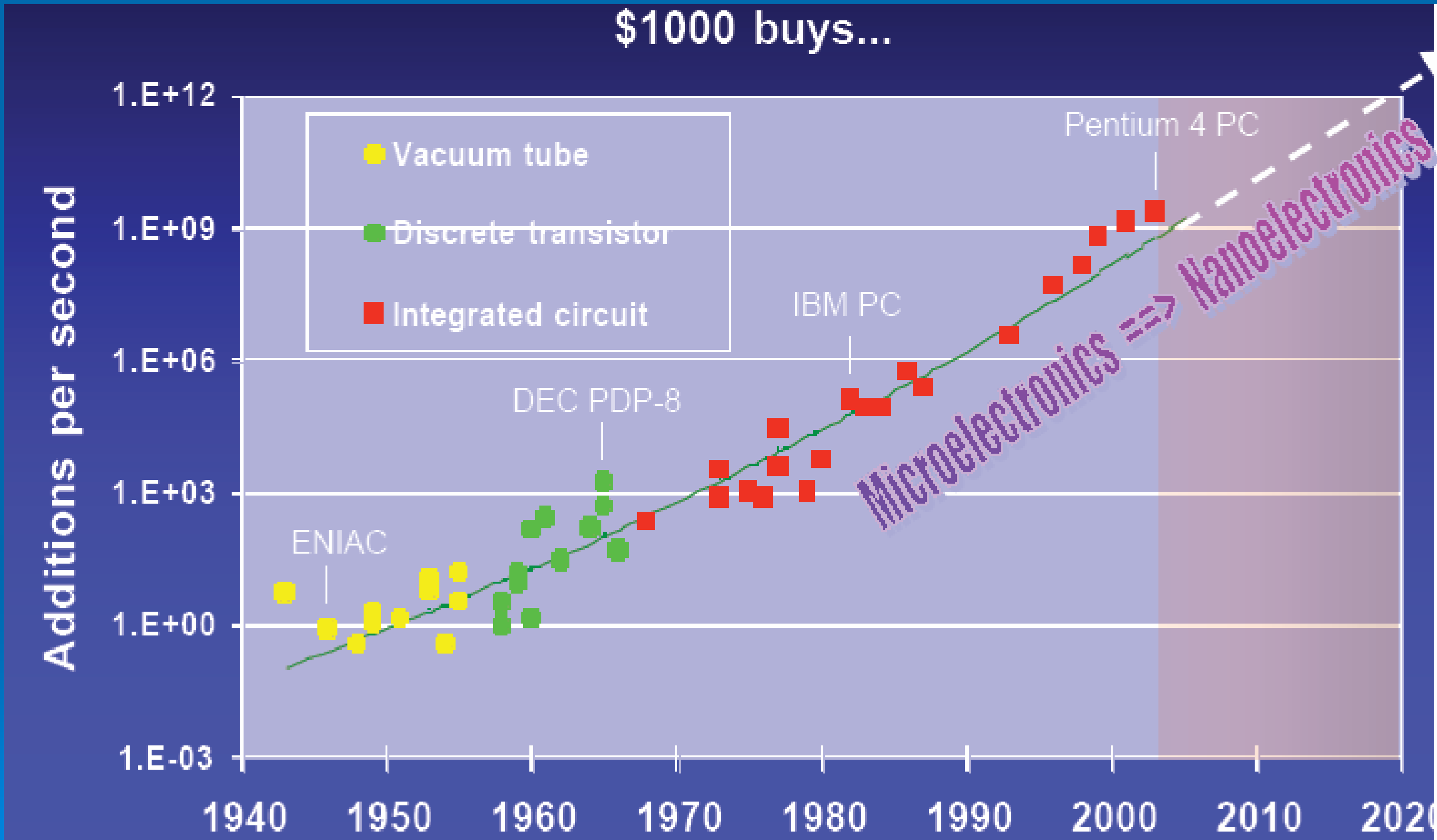
Eigenschaften von Nano-Materialien



Eigenschaften von Nano-Materialien



Technische Perspektiven / Computer

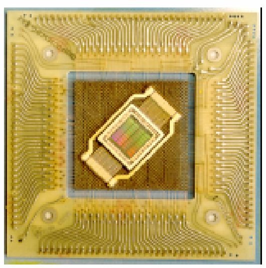


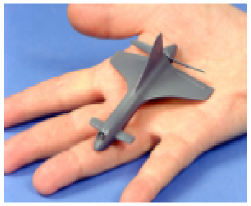
Technische Perspektiven / Consumer

Technische Perspektiven / Pentagon

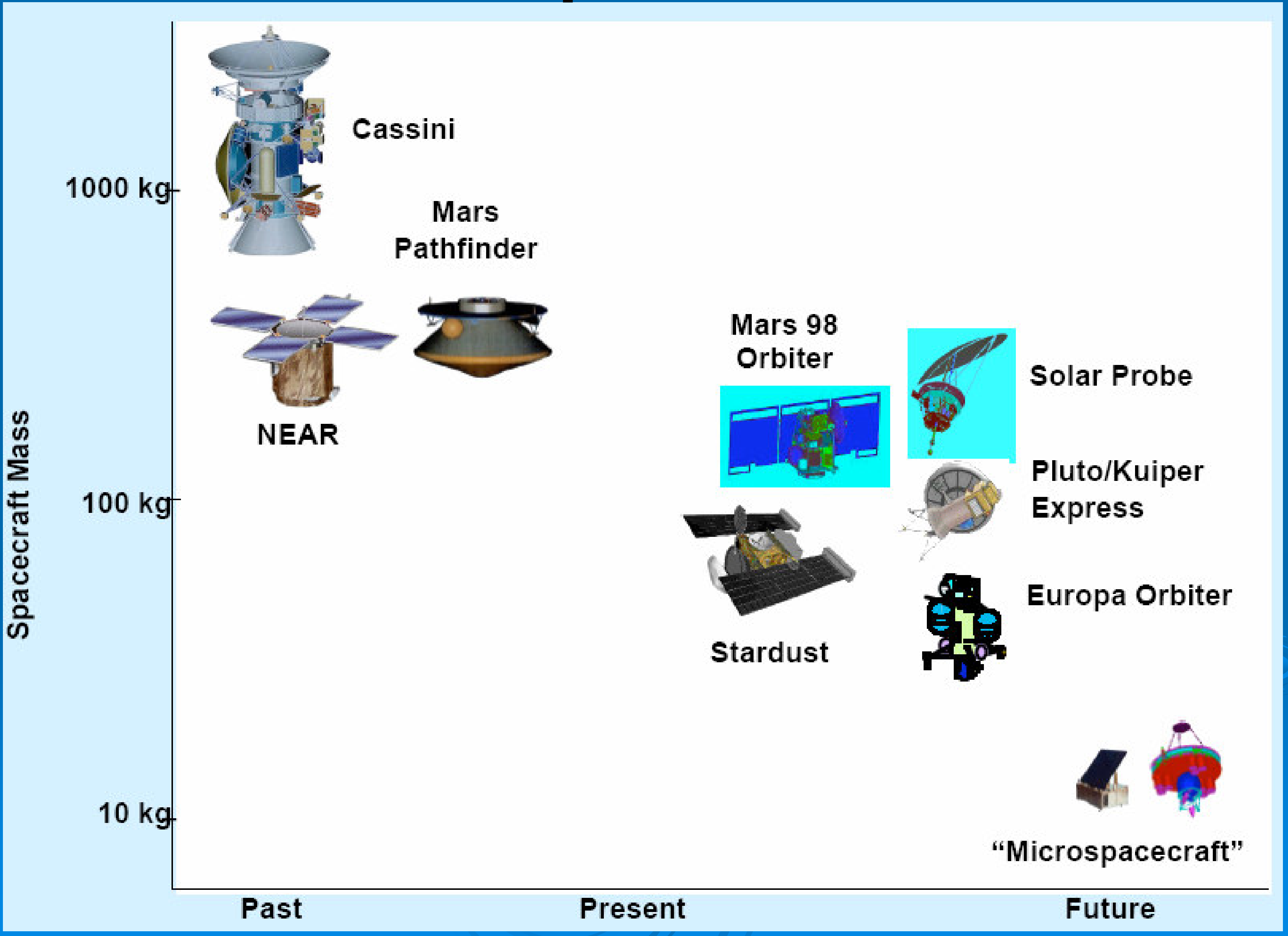
Enhanced warfighting capabilities

* Chem-bio warfare defense
  Sensors with improved detection sensitivity and selectivity, decontamination
* Protective armors for the warrior
  Strong, light-weight bullet-stopping armors
* Reduction in weight of warfighting equipment
  Miniaturization of sensors, computers, comm devices, and power supplies
* High performance platforms and weapons
  Greater stealth, higher strength light-weight materials and structures
* High performance information technology
  Nanoelectronics for computers, memory, and information systems
* Energy and energetic materials
  Energetic nano-particles for fast release explosives and slow release propellants
* Uninhabited vehicles, miniature satellites
  Miniaturization to reduce payload, increased endurance and range





Technische Perspektiven / NASA



Ausgewählte Beispiele

aus der Literatur und

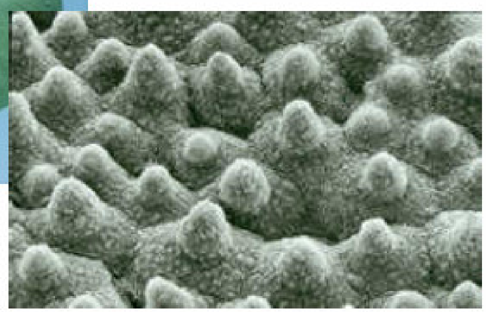
der eigenen Forschungspraxis

(Univ.Mainz, Physikalische Chemie, 1998 – 2005)

Schmutz-abweisende Oberflächen

Lotus-Effekt

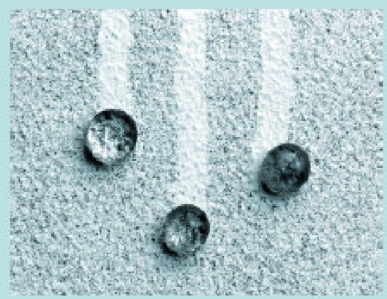
Oberflächenbeschichtung:
Adhaesionsreduktion



Minimierung des Oberflächenkontaktes durch die doppelt strukturierte Oberfläche:

Mikrostrukturierung - Zellen
Nanostrukturierung - Wachskristalle

Fassadenfarbe „Lotusan“

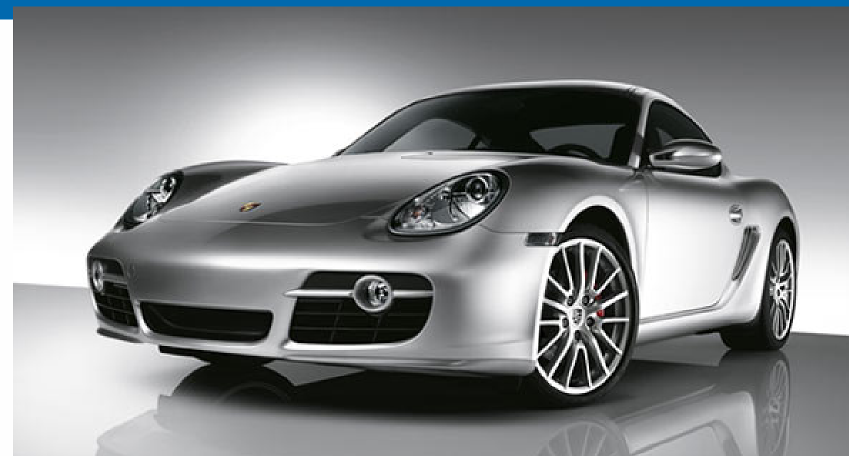


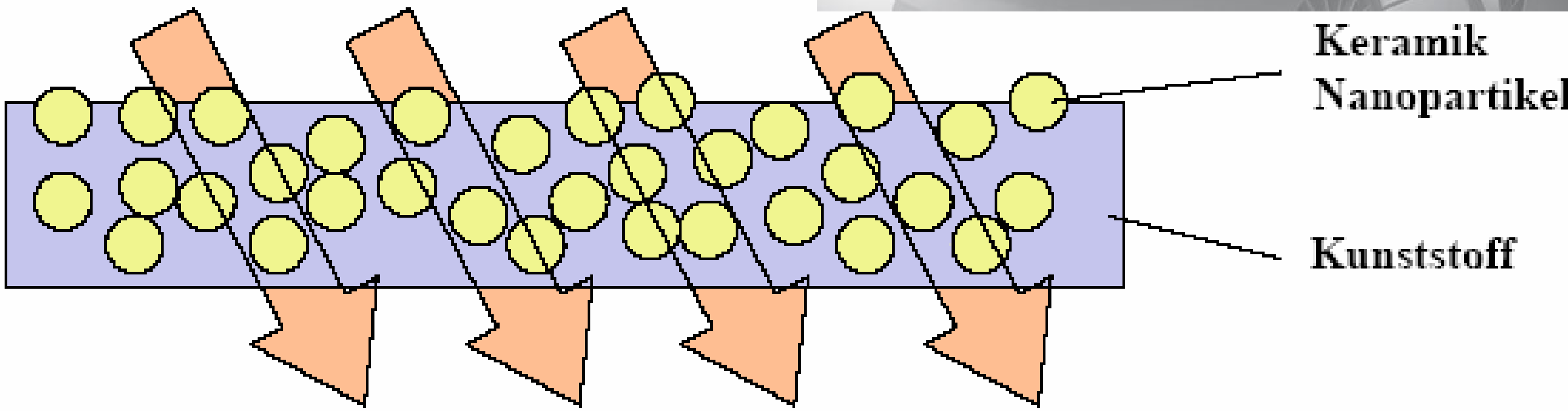
Windschutzscheiben Beschichtung

Kratzfeste Lackierungen

Kompositwerkstoffe

Oberflächenbeschichtung:
Kratzfestigkeit

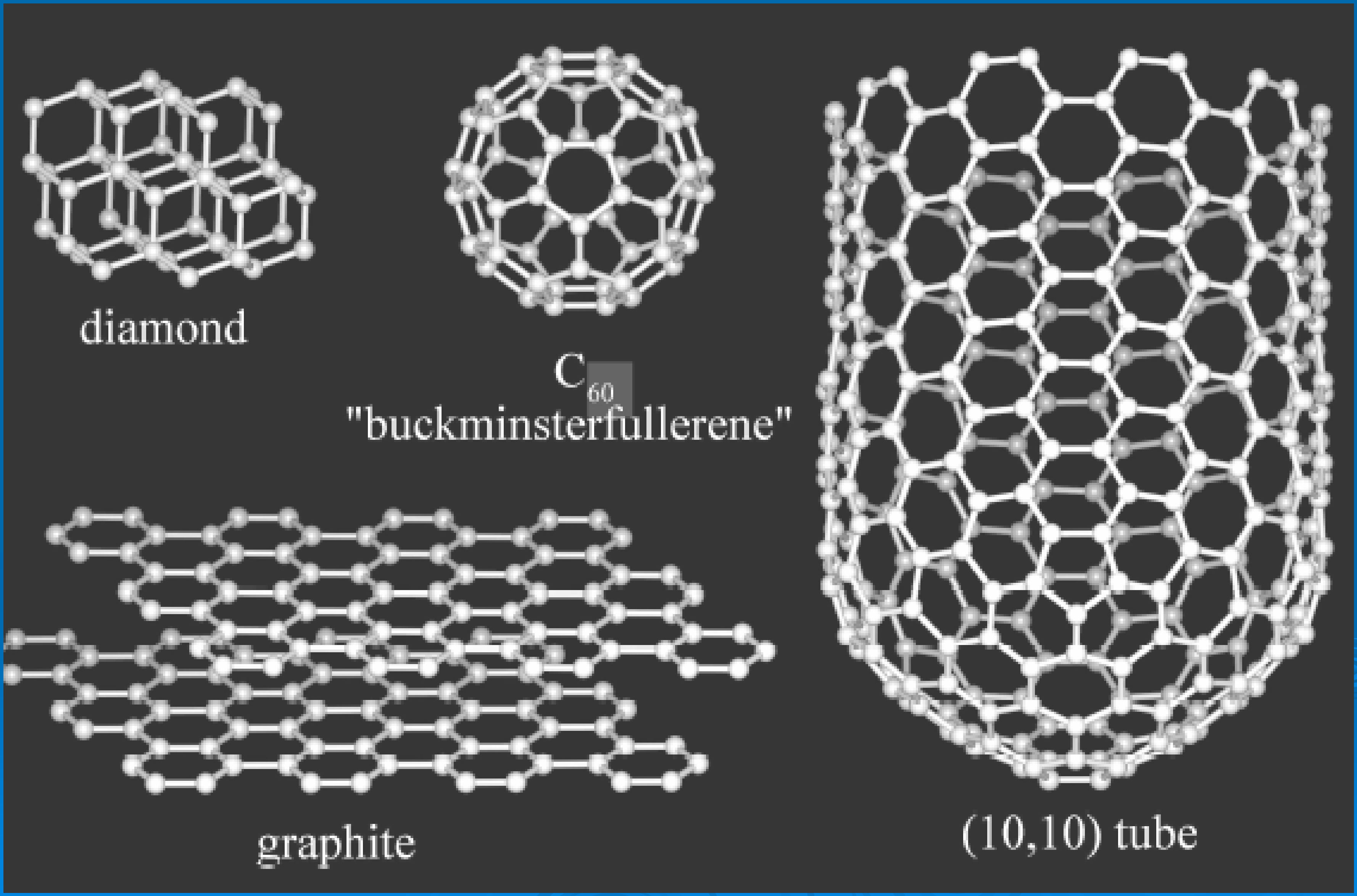




Nanopartikel streuen kein Licht!

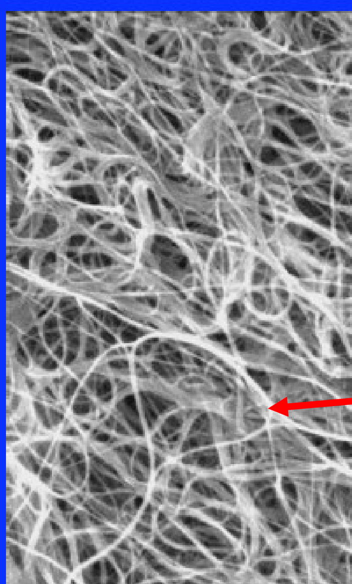
→ Elastizität und Bruchsicherheit des Kunststoffs mit Kratzfestigkeit von Keramik

Kohlenstoff-Nanotubes

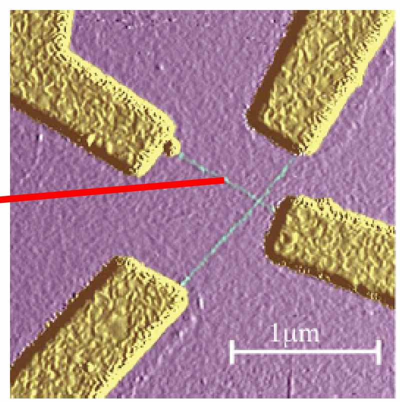


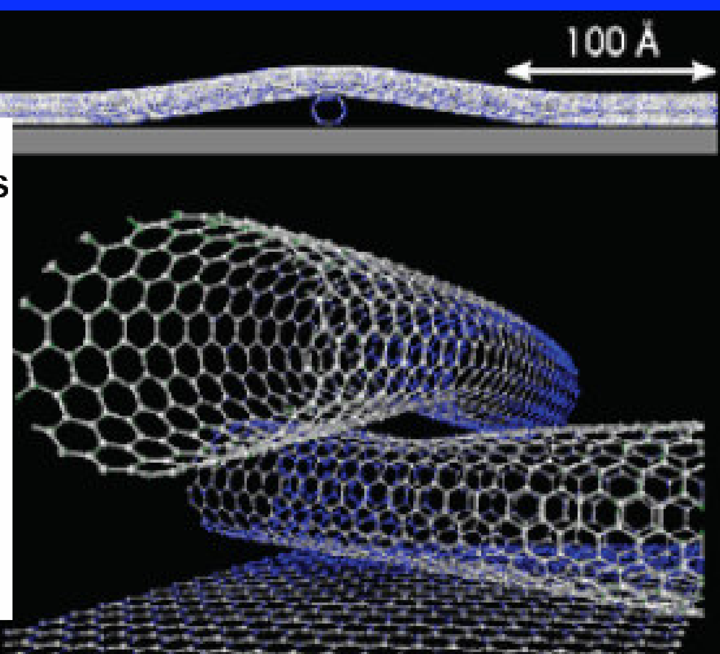
Kohlenstoff-Nanotubes

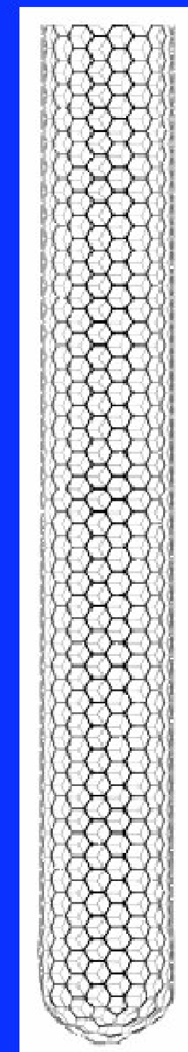
- The Strongest fiber that will ever be made.
- Electrical Conductivity of Copper or Silicon.
- Thermal Conductivity of Diamond.
- The Chemistry of Carbon.
- The size and perfection of DNA.



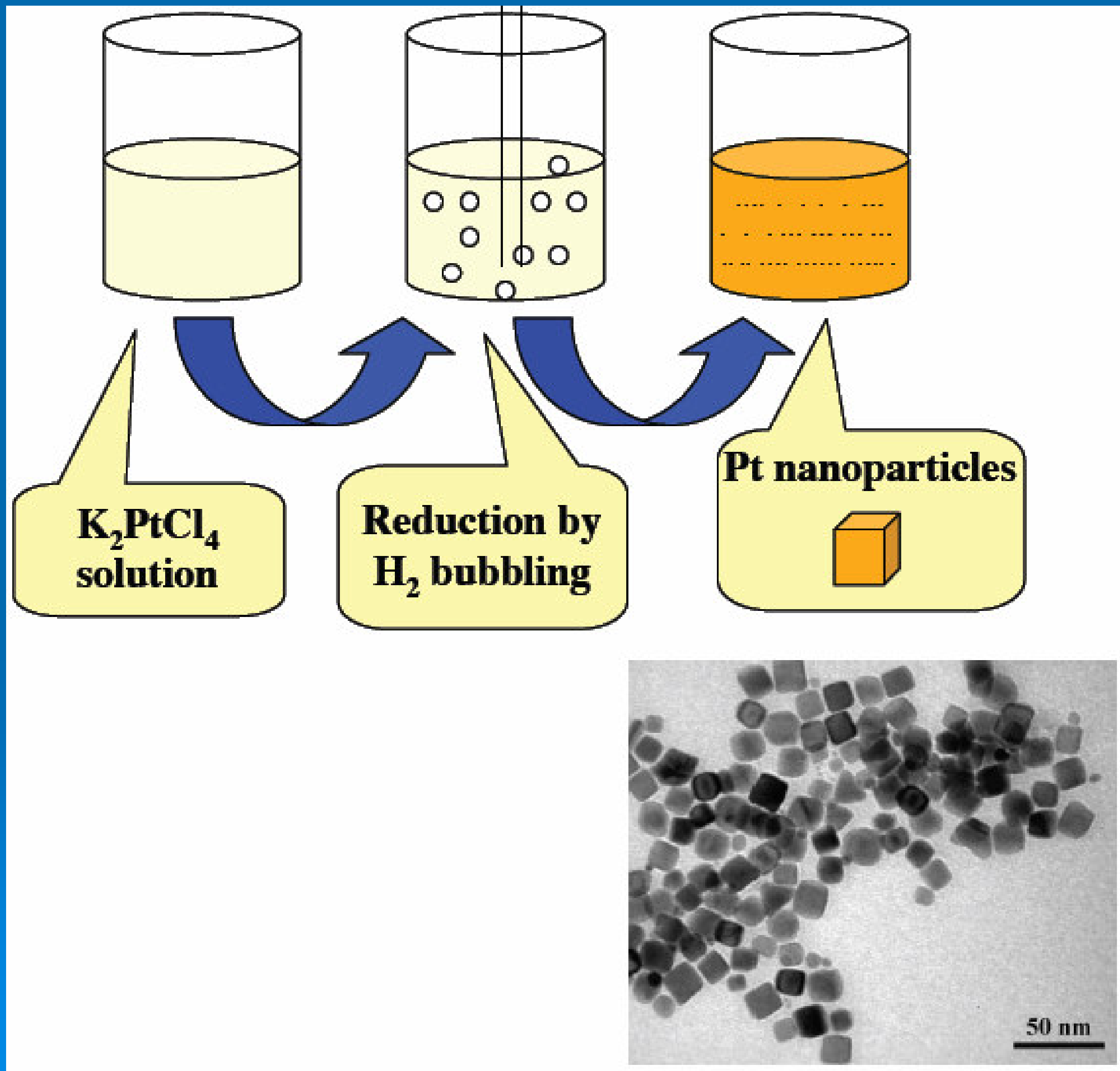
Electrical sensors -
Nanowires and nanotubes



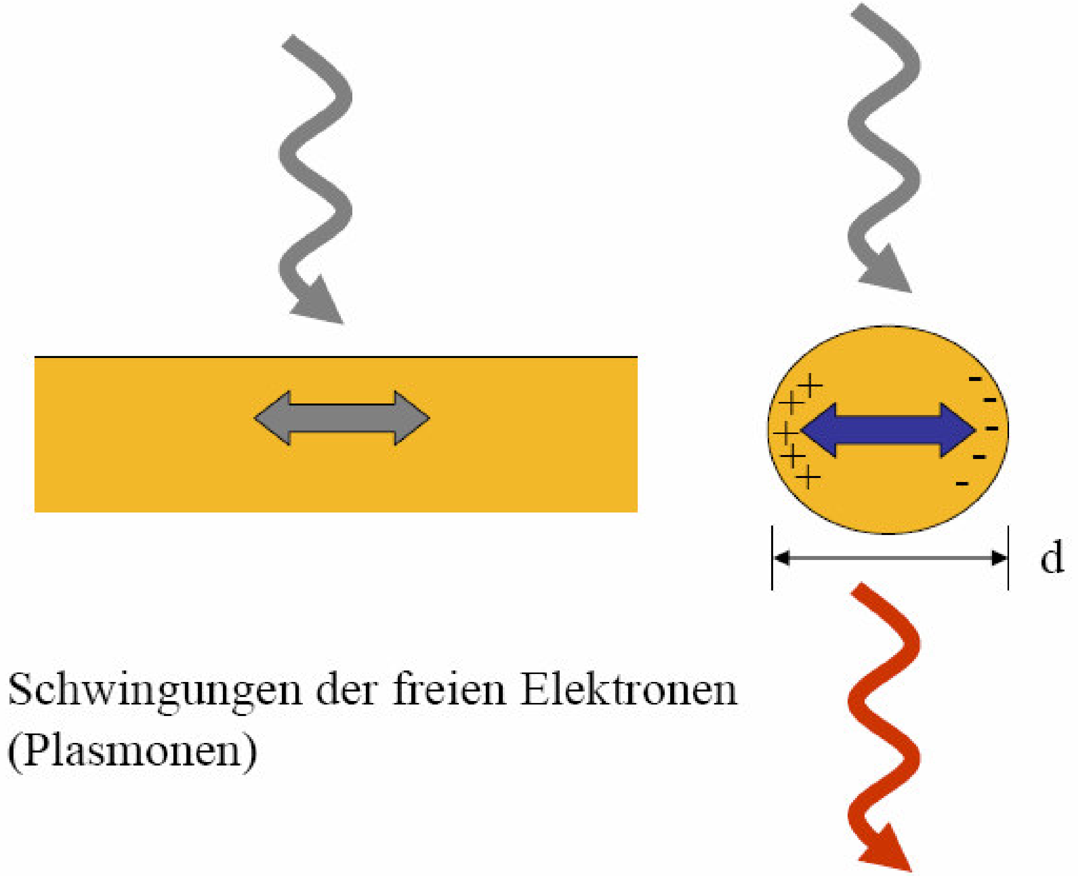




Metallische Nanopartikel - Platin



Metallische Nanopartikel - Gold



Größe der Nanopartikel bestimmt deren Farbe !

Metallische Nanopartikel - Gold

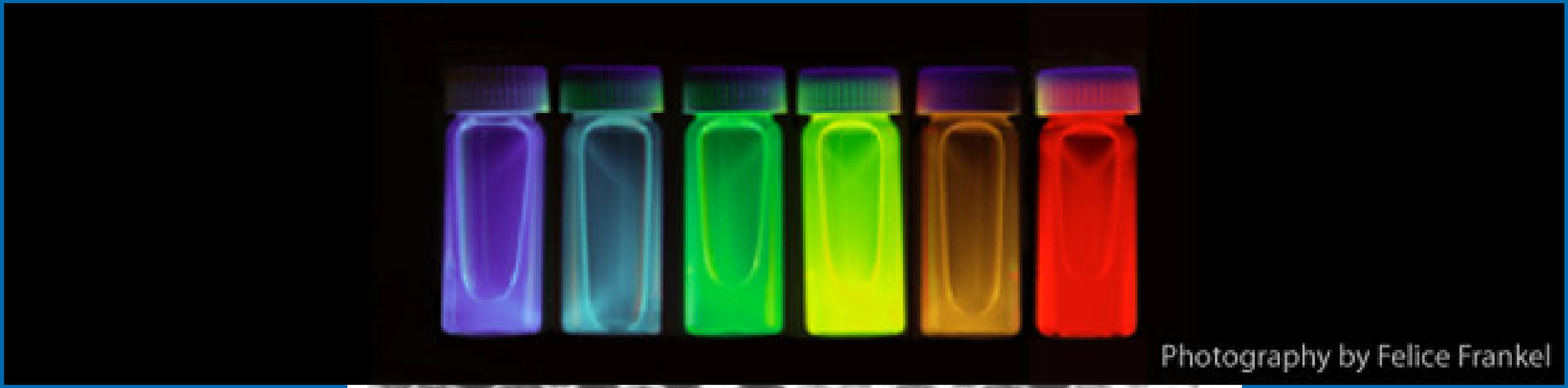
(einfache Synthese aus Goldsäure + Citrat)

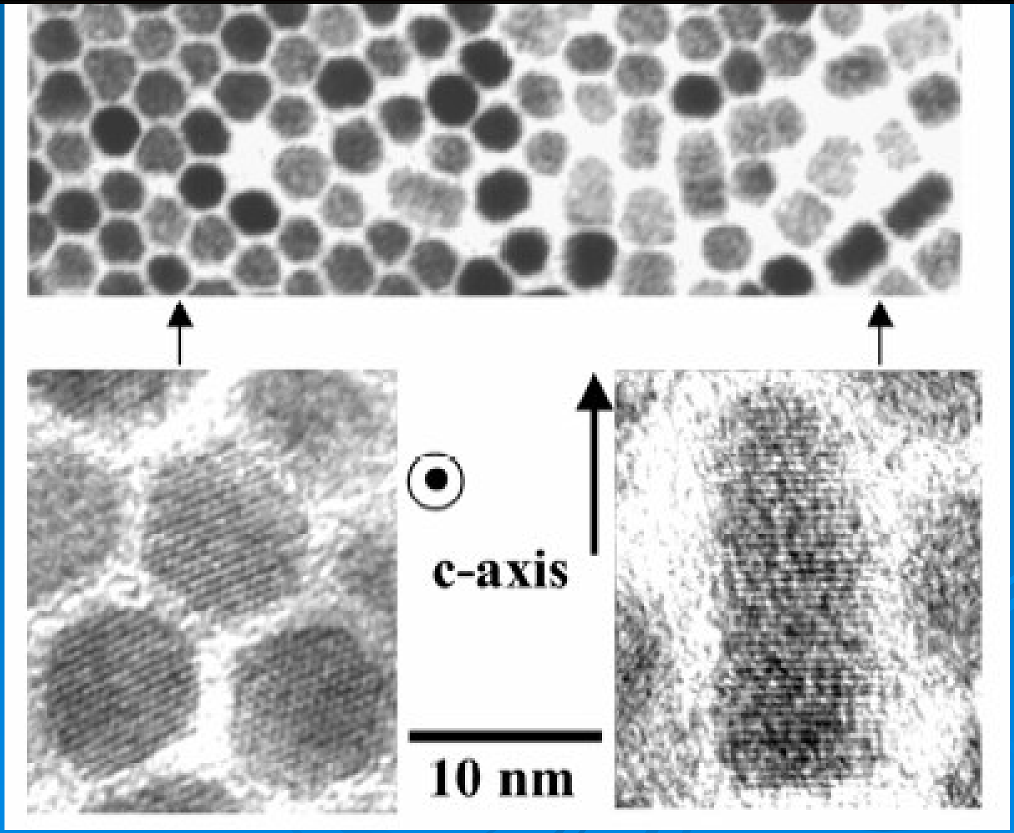
Add 20 mL of 1.0 mM HAuCl4 to a 50 mL Erlenmeyer flask on a stirring hot plate. Add a magnetic stir bar and bring the solution to a boil.

To the boiling solution, add 2 mL of a 1% solution of trisodium citrate dihydrate. Gold sol gradually forms as the citrate reduces the gold(III). Stop heating when a deep red color is obtained.

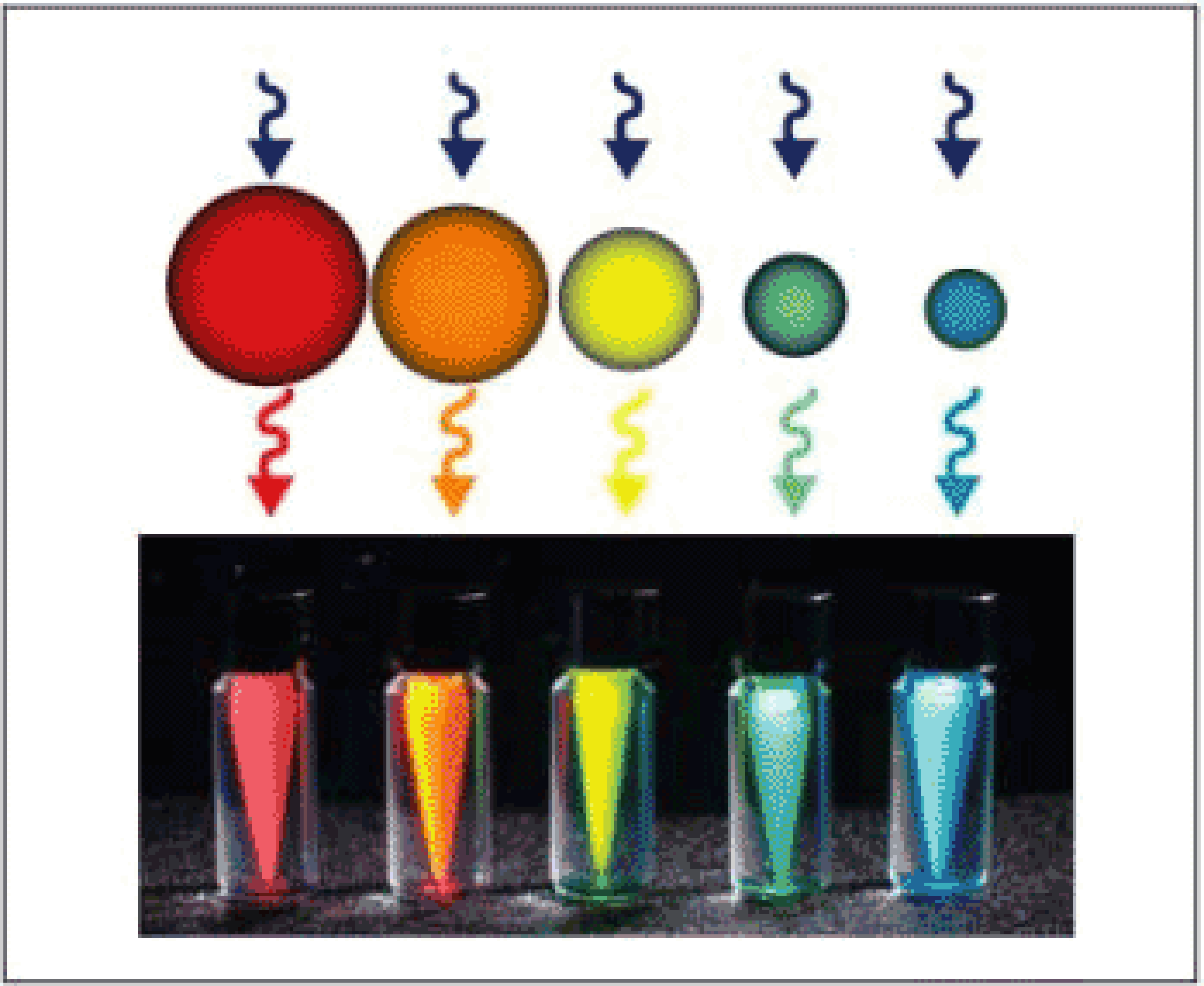
Stock Solutions for 25 batches
1.0 mM hydrogen tetrachloroaurate: Dissolve 0.1 g HAuCl4 in 500 mL distilled water. This stock solution of gold(III) ions can be prepared in advance if stored in a brown bottle.
1% trisodium citrate: Dissolve 0.5 g Na3C6H5O7.2H2O (sodium citrate) in 50 mL distilled water. 1 M NaCl: Dissolve 0.5 g of NaCl in 10 mL distilled water.

CdSe-Nanopartikel ("Quantum Dots")

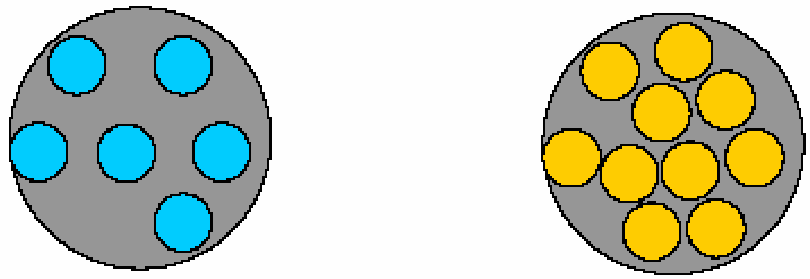




CdSe-Nanopartikel ("Quantum Dots")



“Superfluoreszente“ Nanopartikel auf Silikonbasis



motivation:

- increased photostability compared to single dye molecules
- higher quantumyield
- adjustment of emitted wavelength
  (e.g.. excimer-fluorescence)

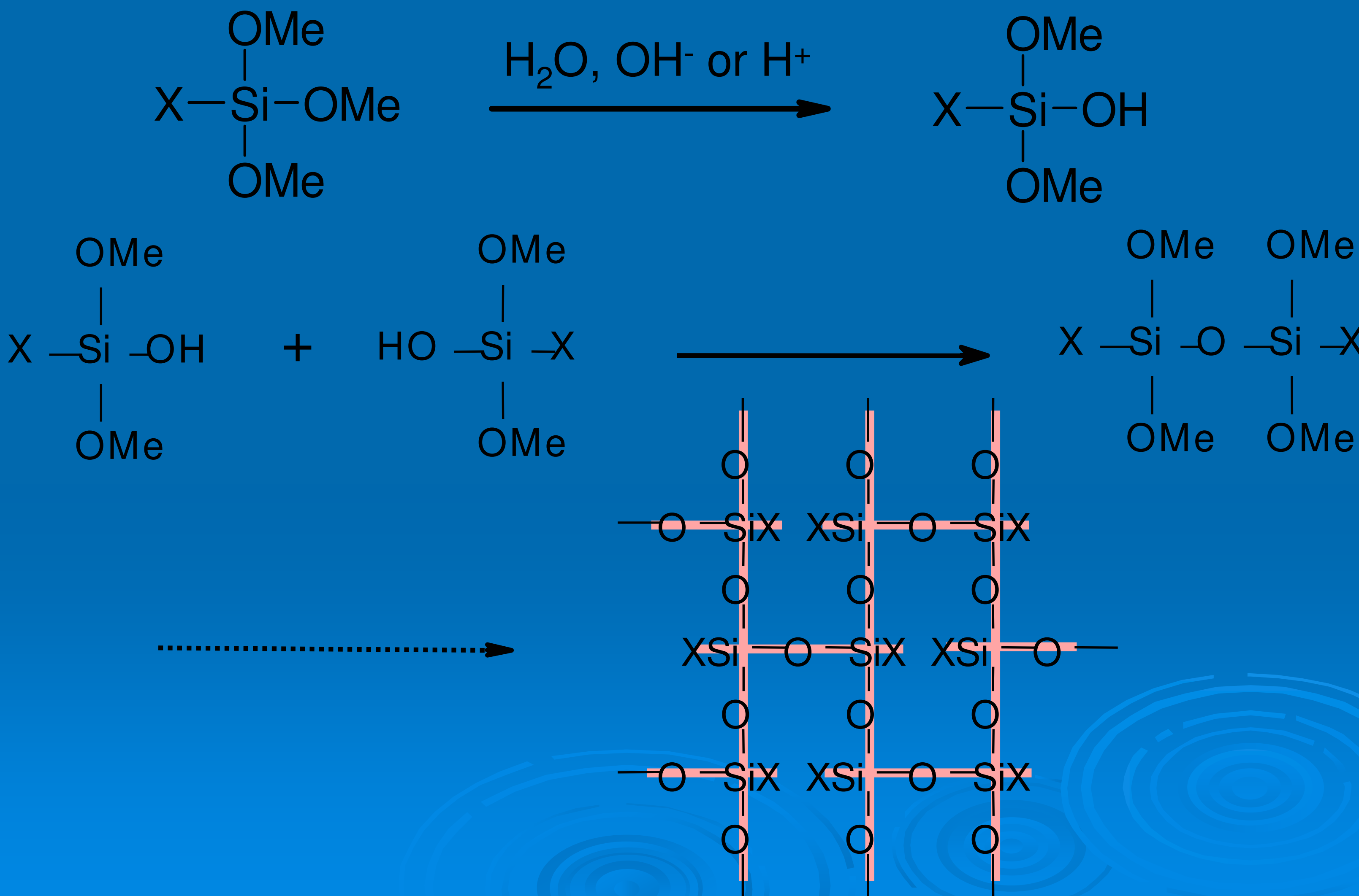
possible areas of application:

- tracers for diffusion measurements
- “biomarkers“

Doktorarbeit von Frau Christina Graf, Mainz 1999

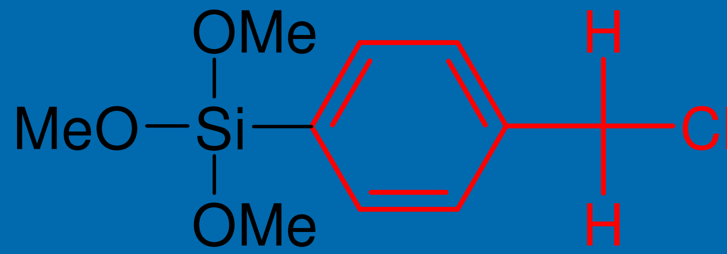
Fluoreszierende Silikon-Nanopartikel

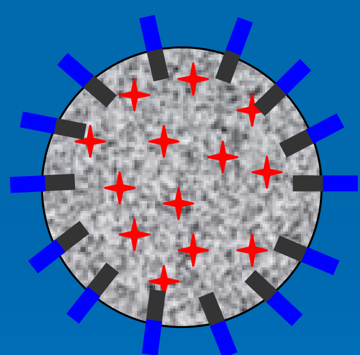
Polykondensation von Trimethoxysilanen in wässriger Emulsion zu hochvernetzten sphärischen Nanopartikeln



Fluoreszierende Silikon-Nanopartikel - I

$(CH_3O)_3Si\text{-}CH_3$ / $(CH_3O)_3Si\text{-}X$ in
H_2O / OH^- or H^+ / surfactant

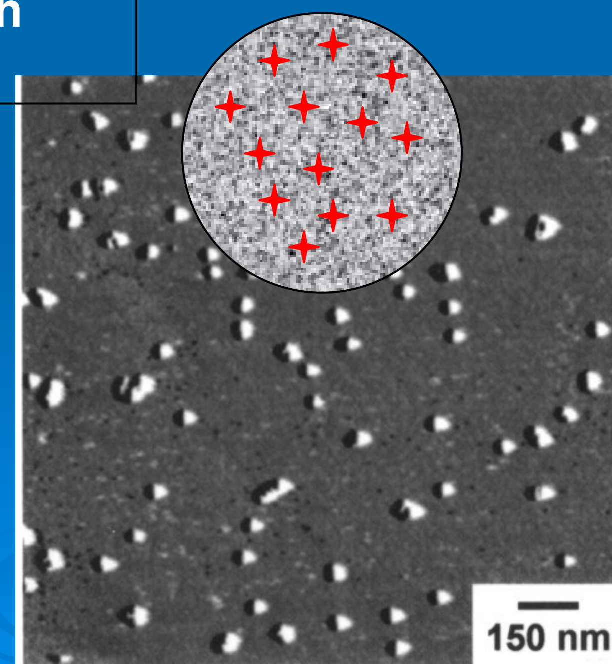




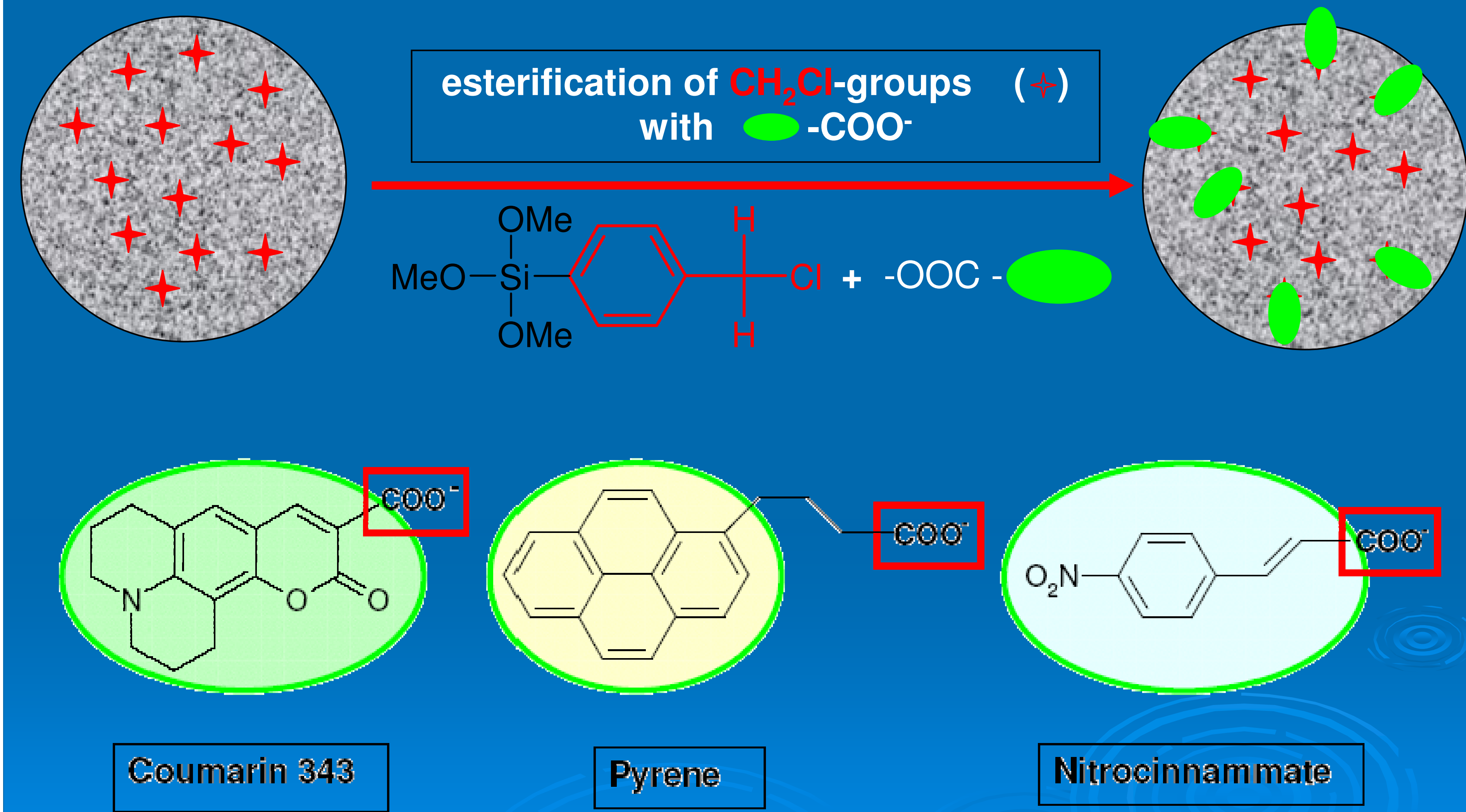
= X

= surfactant

hydrophobisation/passivation of
SiOH-surface groups with
$(CH_3)_3Si\text{-}OC_2H_5$

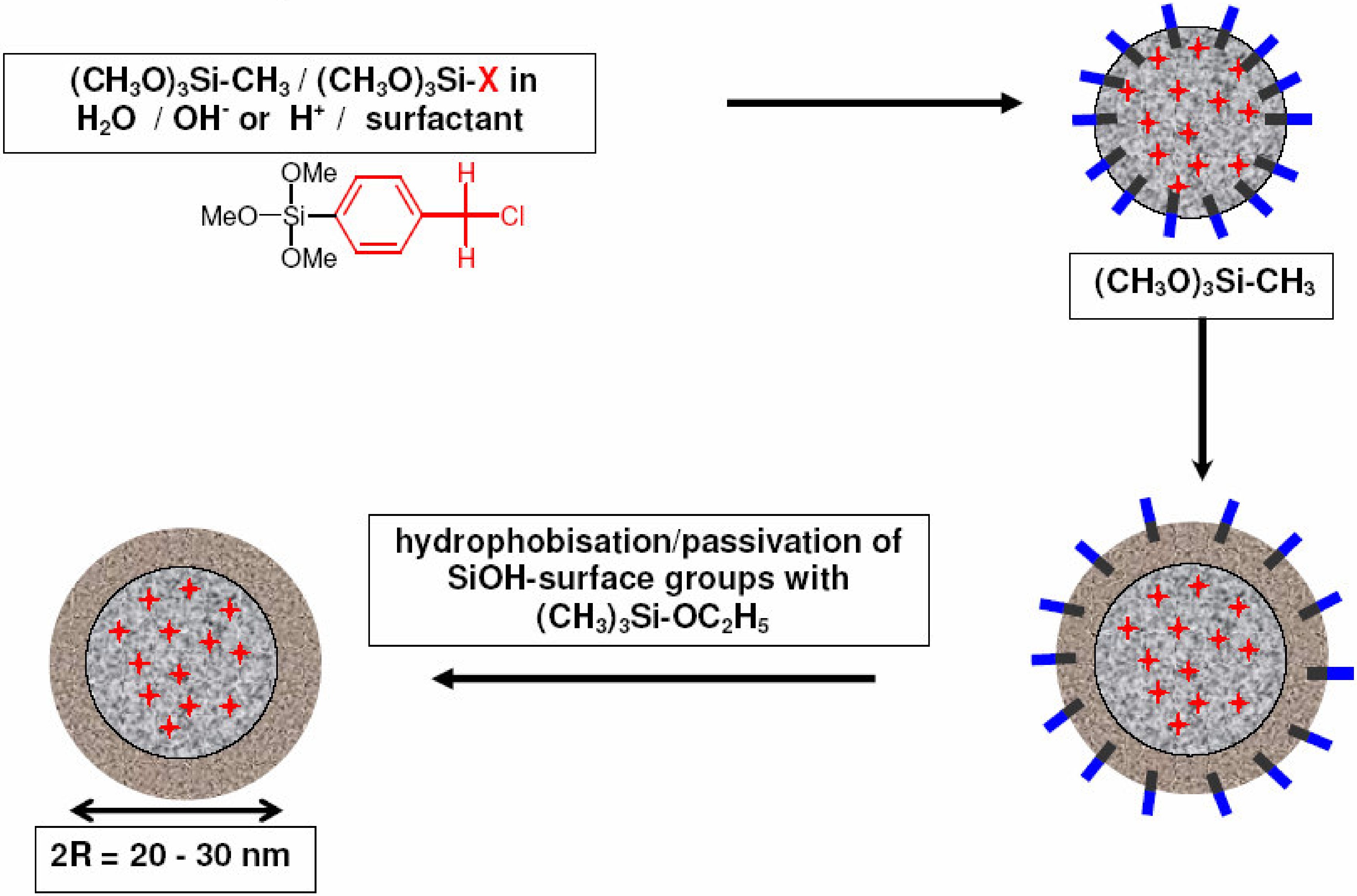


Fluoreszierende Silikon-Nanopartikel - I

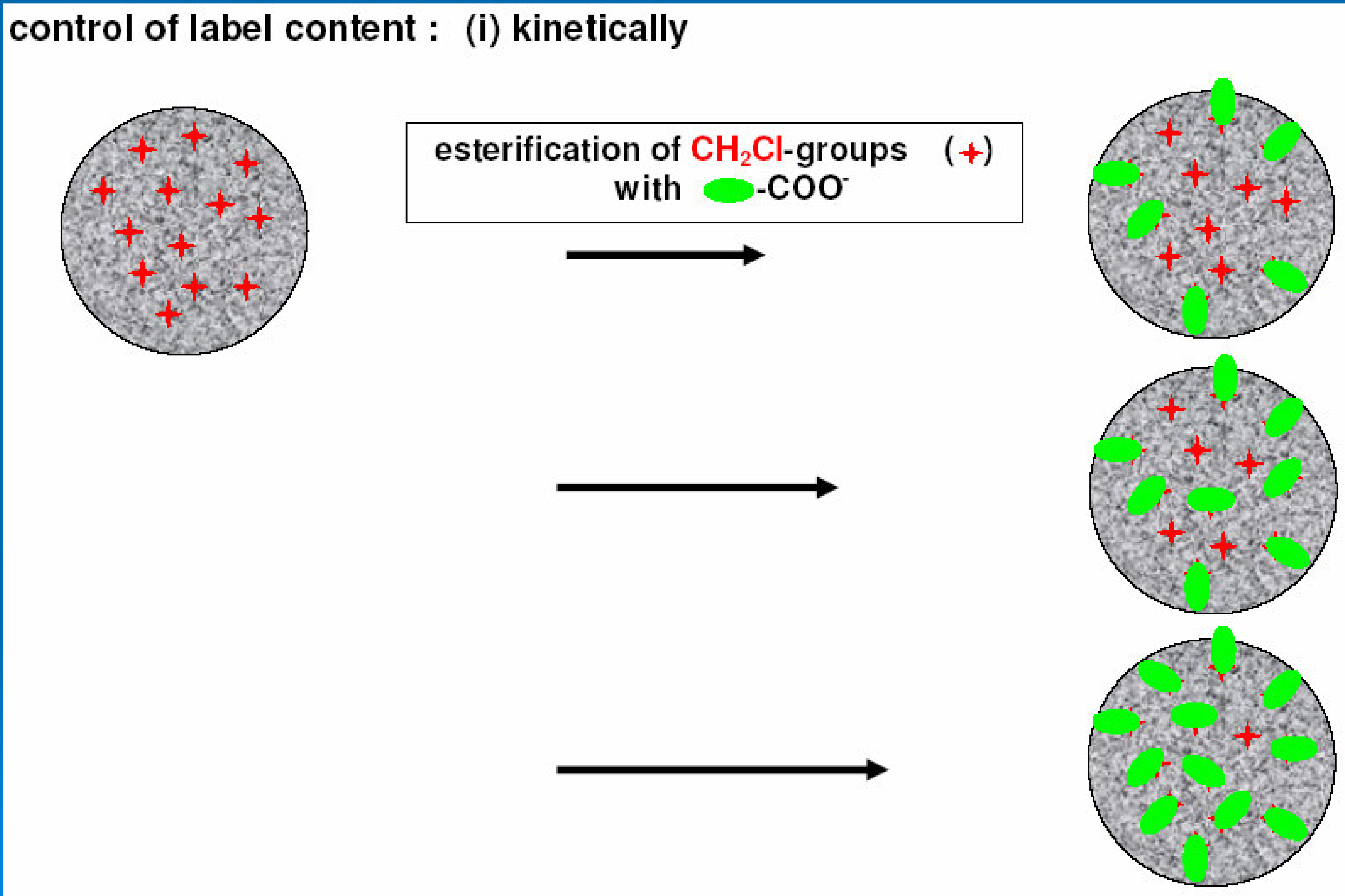


Fluoreszierende Silikon-Nanopartikel - II

core-shell-nanoparticles

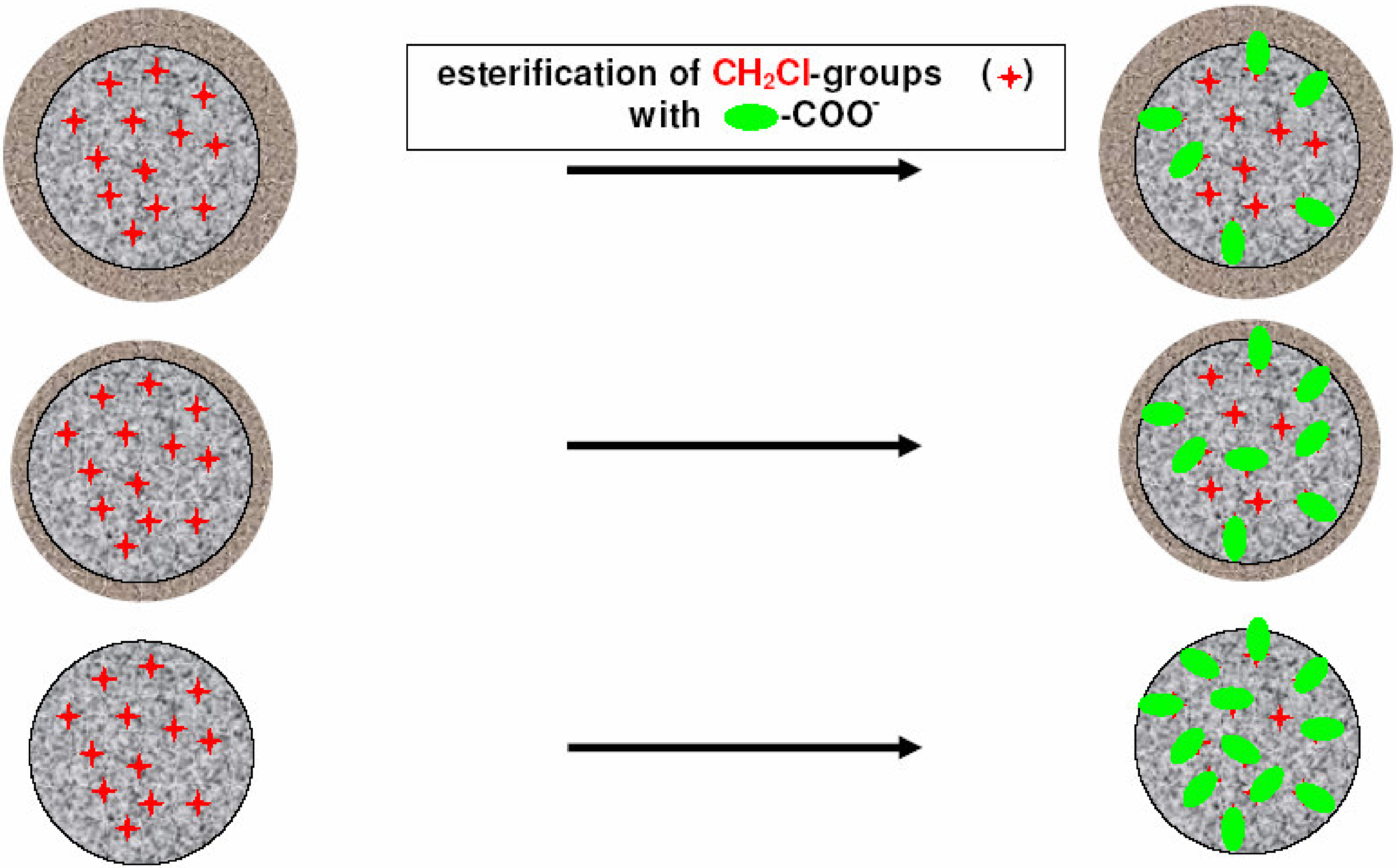


Fluoreszierende Silikon-Nanopartikel - I



Fluoreszierende Silikon-Nanopartikel - II

control of label content : (ii) topologically (thickness of shell)

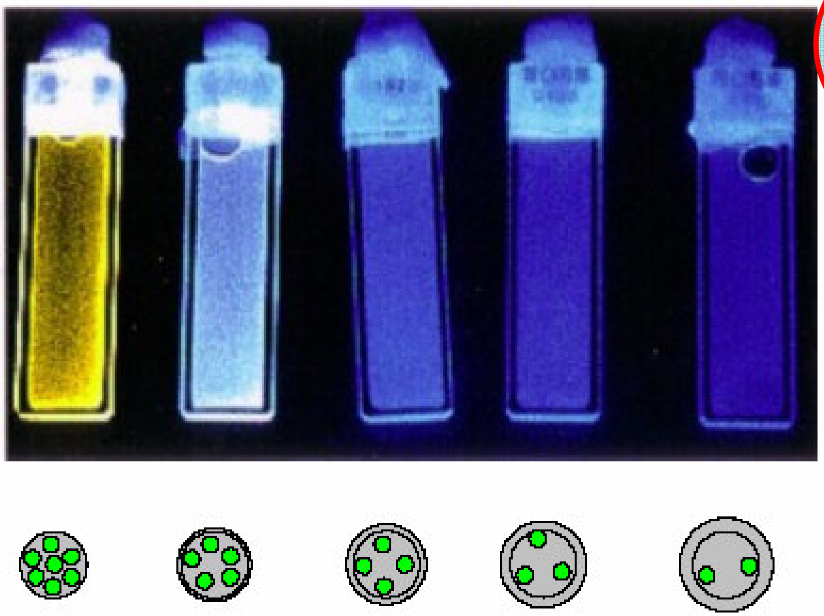


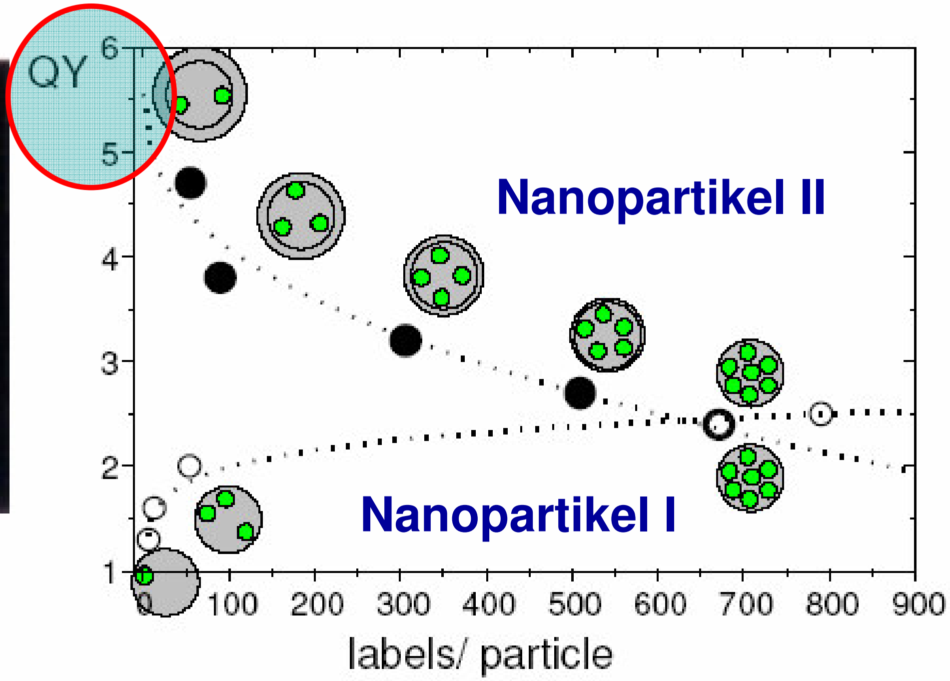
Fluoreszierende Silikon-Nanopartikel – I,II

optical properties (fluorescence): pyrene-labeled nanoparticles

wavelength of emitted light

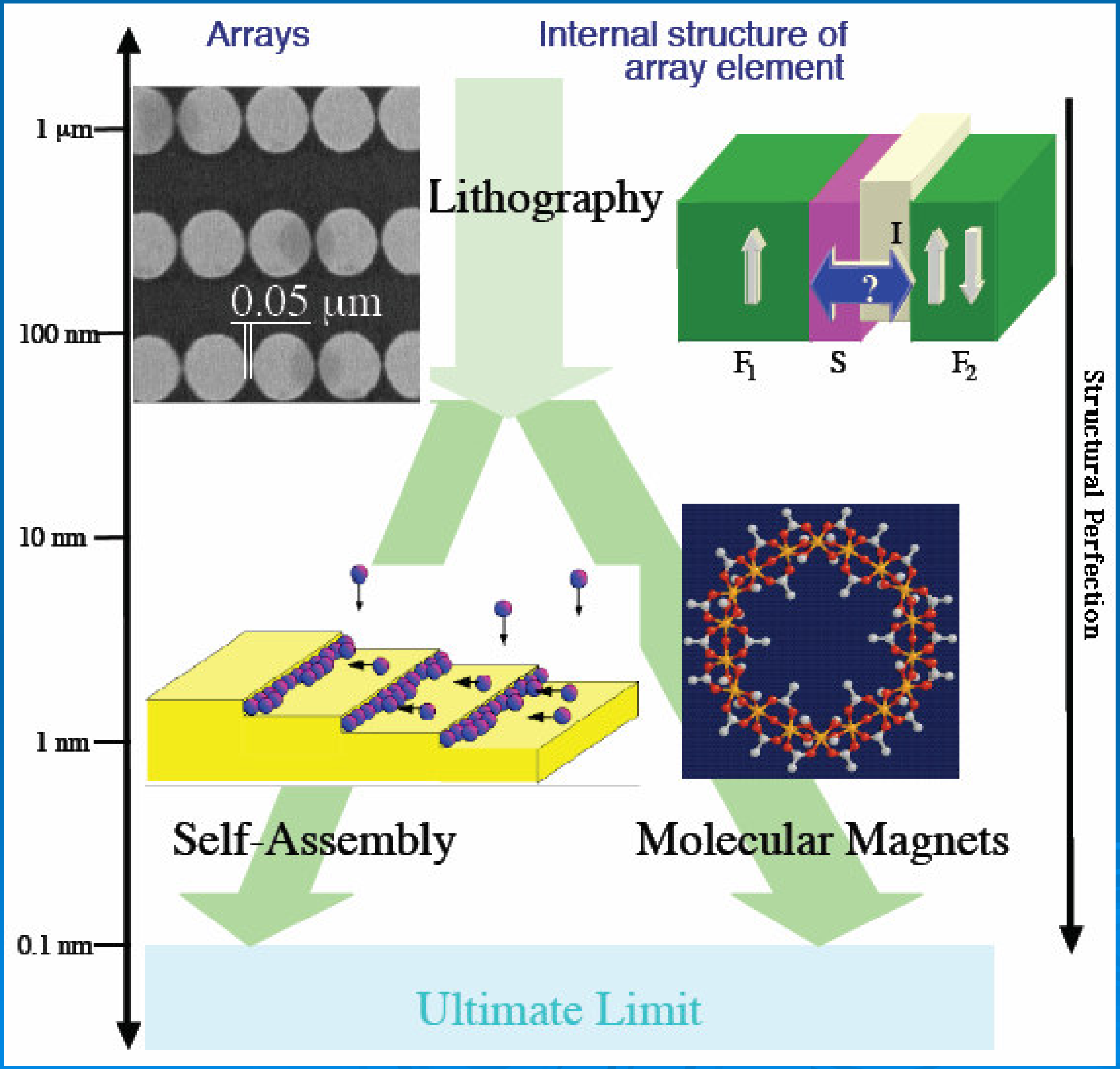
quantum yield (1 = molecular dye)





explanation :
- fraction of excimers (yellow fluoresc.) increases with label conc.
- quantum yield increases with immobilisation of labels

Magnetische Nanopartikel (Speicher)



Magnetische Nanopartikel (Speicher)

Technische Anwendungen des Magnetismus:

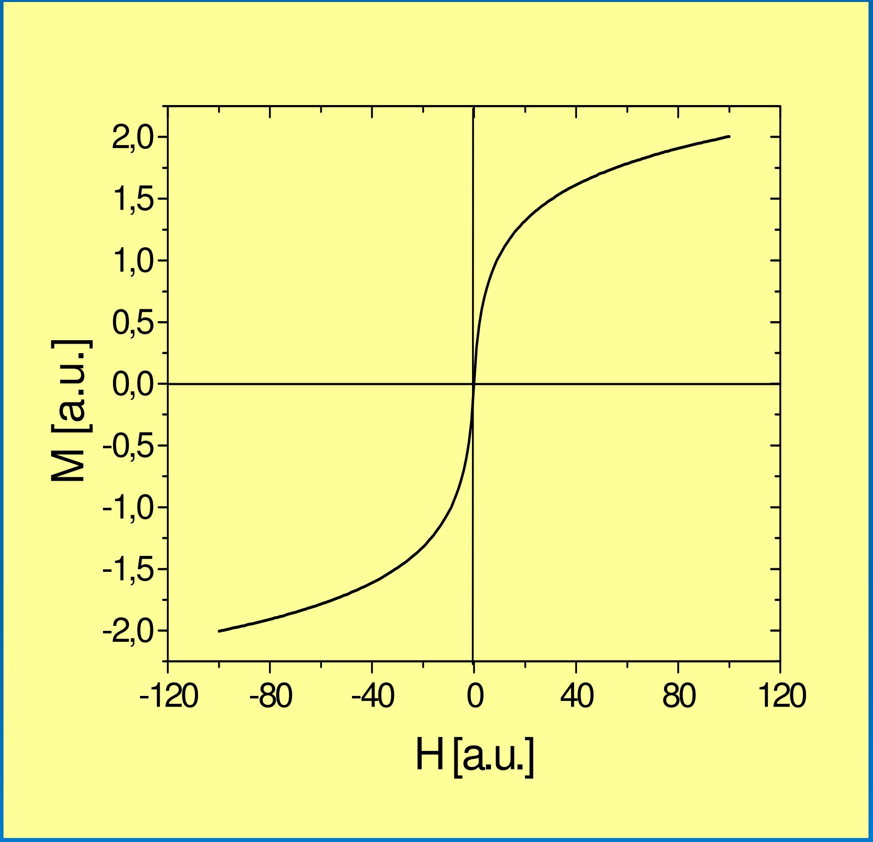
- Kompass
- Elektromagnet => Elektromotor, Transformator
- Speichermedien : Ton- und Videobänder,
  Computer-Festplatten, Arbeitsspeicher

Möglichst hohe Speicherdichte

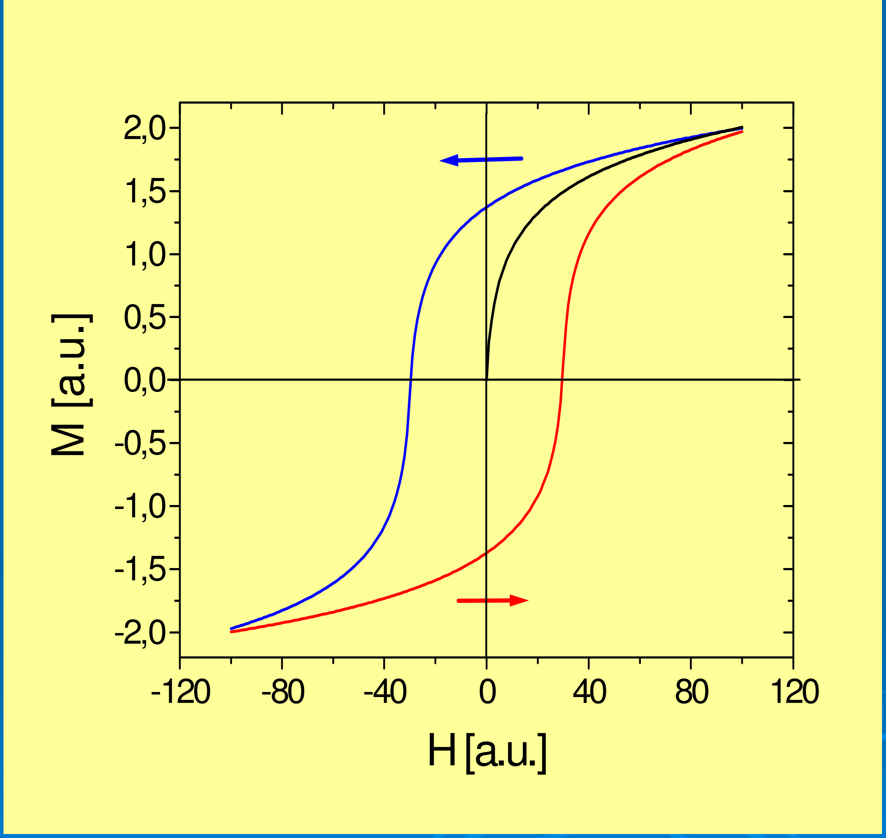
(z.Z.: 1 Bit = $(180\ nm)^2$ Magnet. Domäne,
jährlicher Zuwachs Bit/mm^2 seit 1990 : 60 % !!!)

Magnetische Nanopartikel (Speicher)

T > Tx



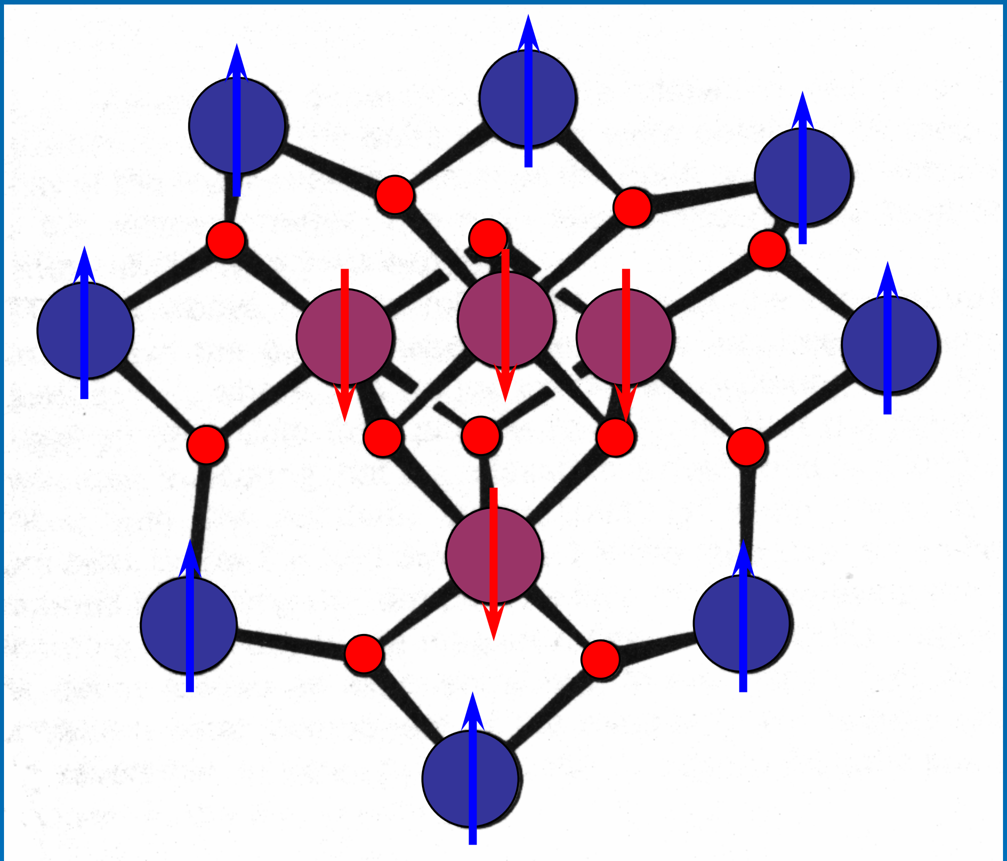
T < Tx => Hysterese



Hysterese => Bistabiler Zustand, Datenspeicher

Magnetische Nanopartikel (Speicher)

Mn12:



$[Mn^{4+}_4\ Mn^{3+}_8\ (CH_3COO)_{16}(H_2O)_4O_{12}]$

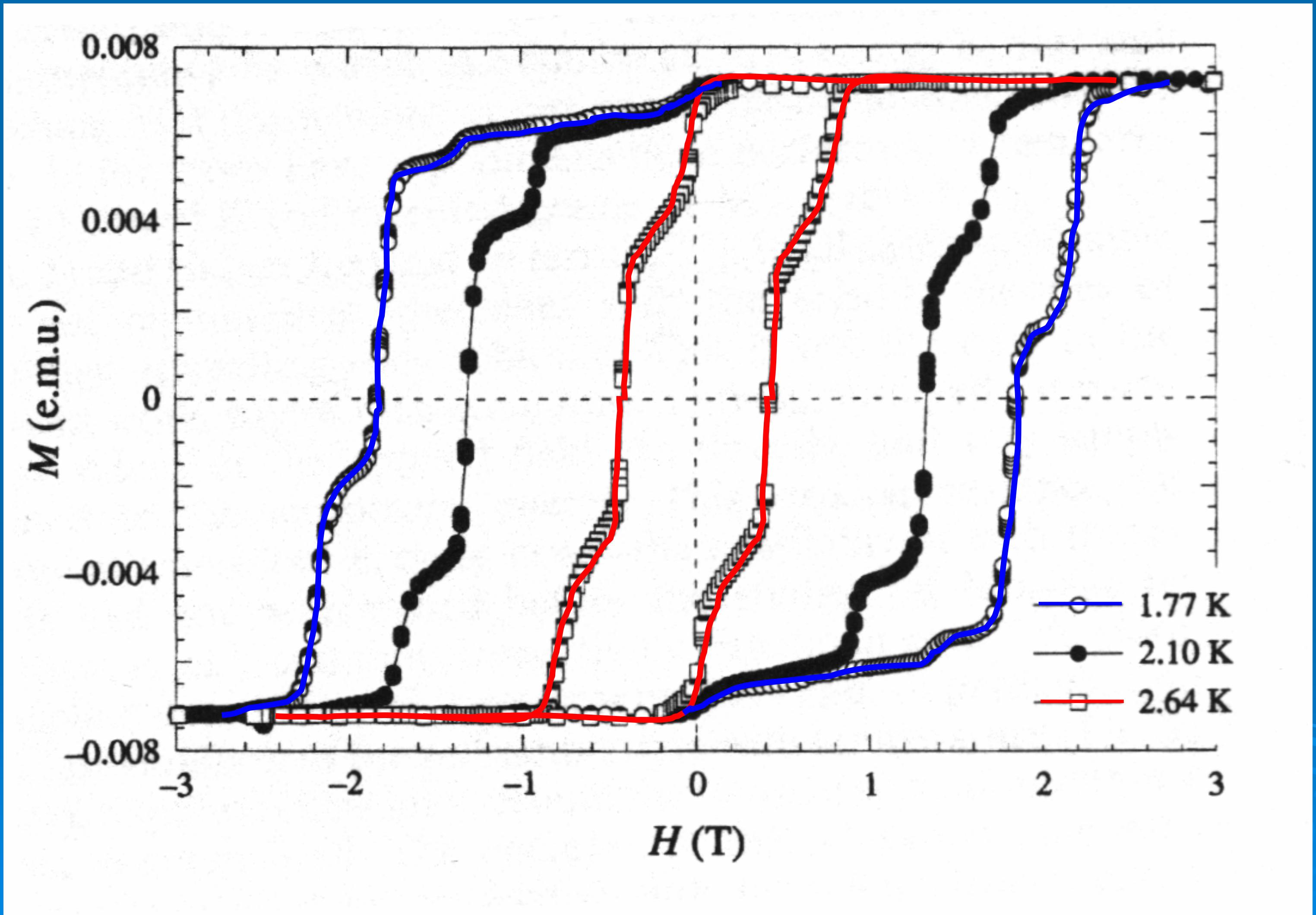
Mn^{4+} : $4s^0\ 3d^3$, oktaedrischer high-spin-Komplex

Mn^{3+} : $4s^0\ 3d^4$, verzerrt-oktaedrischer high-spin-K.

Gesamtspin: S = $8 \times 2 - 4 \times \frac{3}{2} = 10$

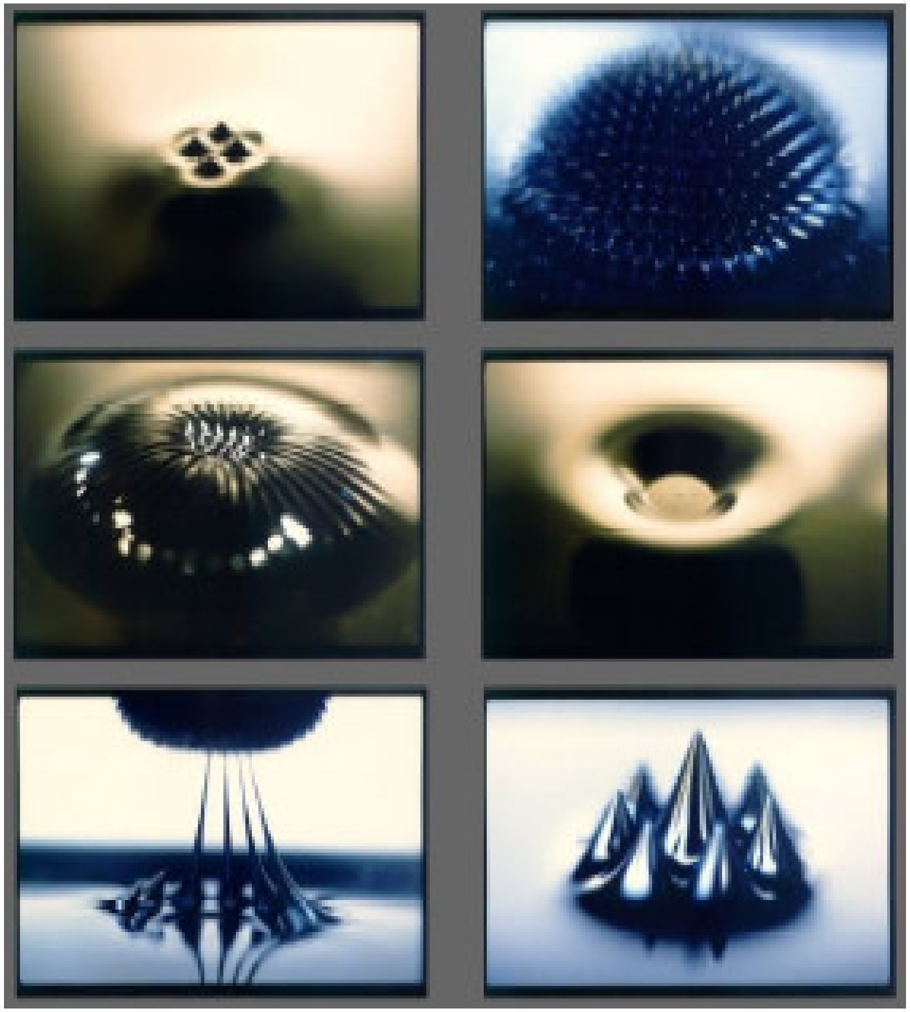
Magnetische Nanopartikel (Speicher)

Hysterese der Magnetisierung

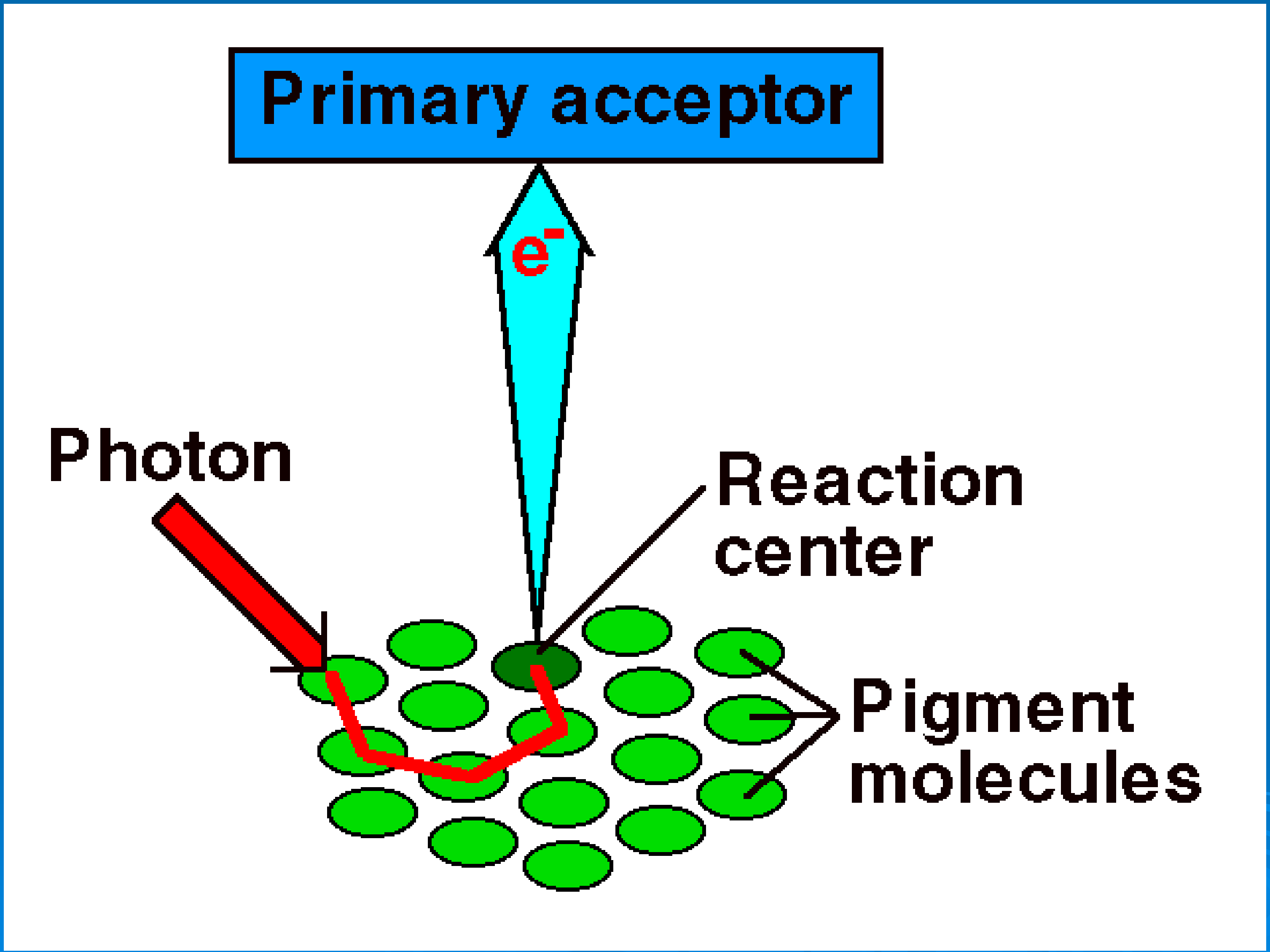


Magnetische Flüssigkeiten

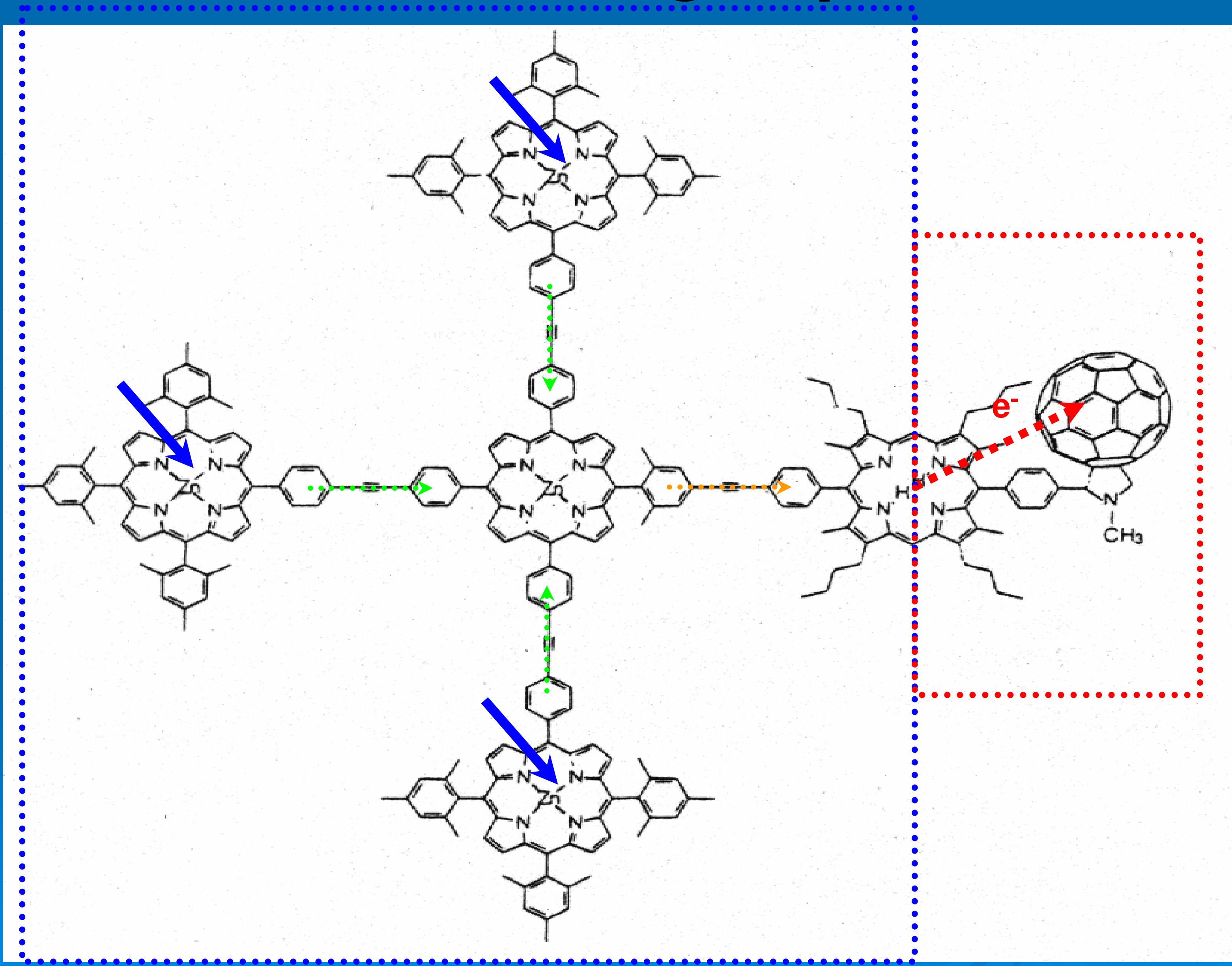
- Magnetic fluids or ferrofluids
- nano sized iron oxide particles
- superparamagnetic, meaning that these particles can be easily magnetized with an external magnetic field and redispersed immediately once the magnet is removed



Künstliche Lichtenergiespeicher



Künstliche Lichtenergiespeicher

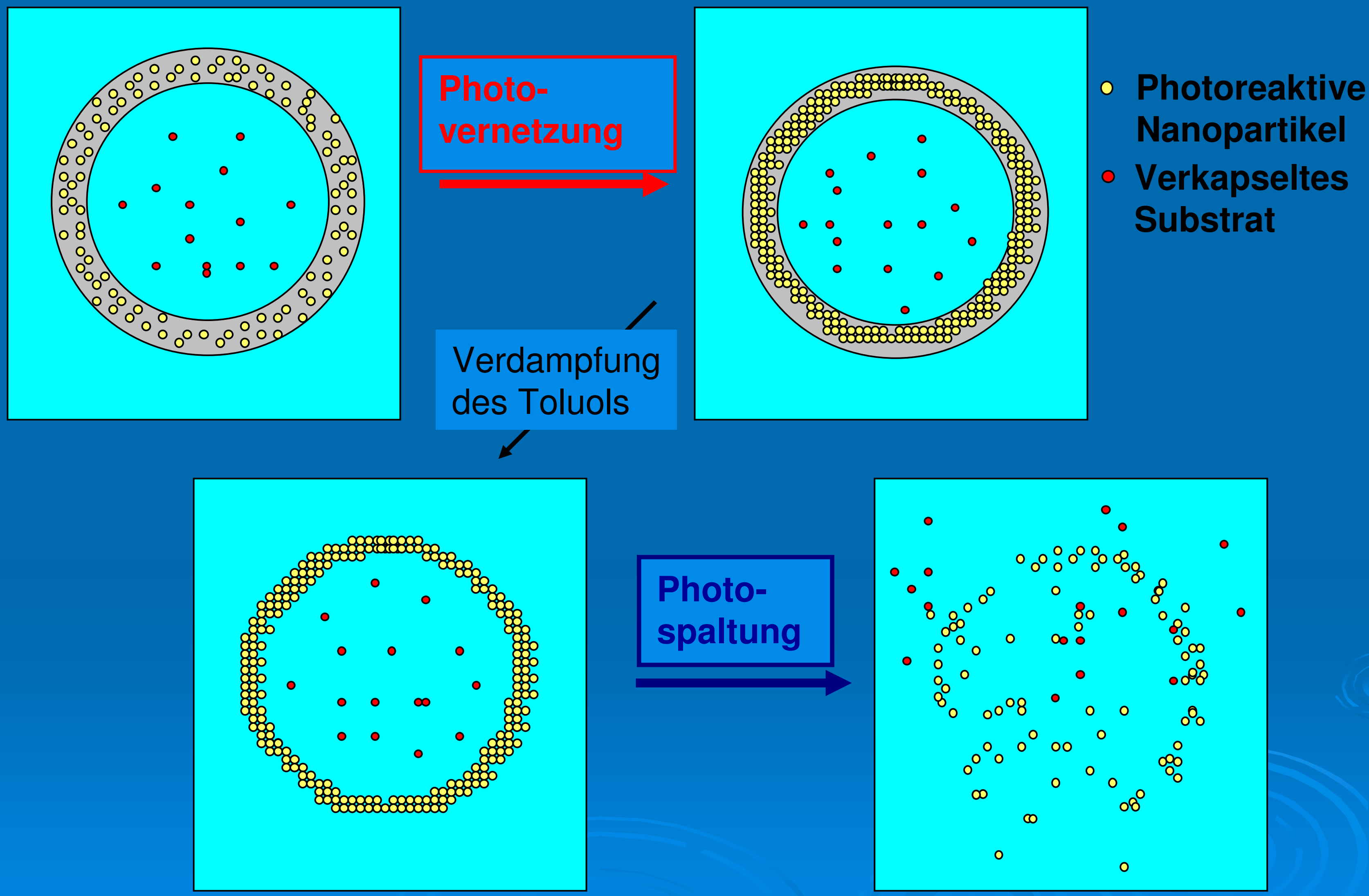


Kapseln aus photoreaktiven Nanopartikeln als Licht-empfindliche Container

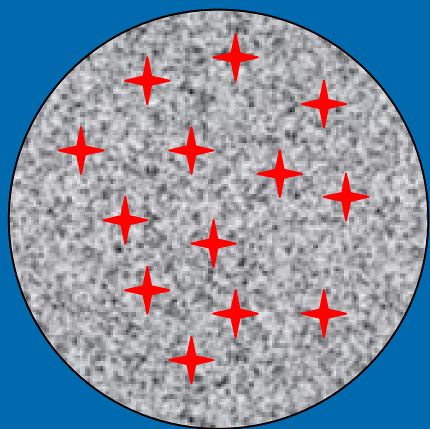
Doktorarbeit von Frau Xiaofeng Yuan, Mainz 2005

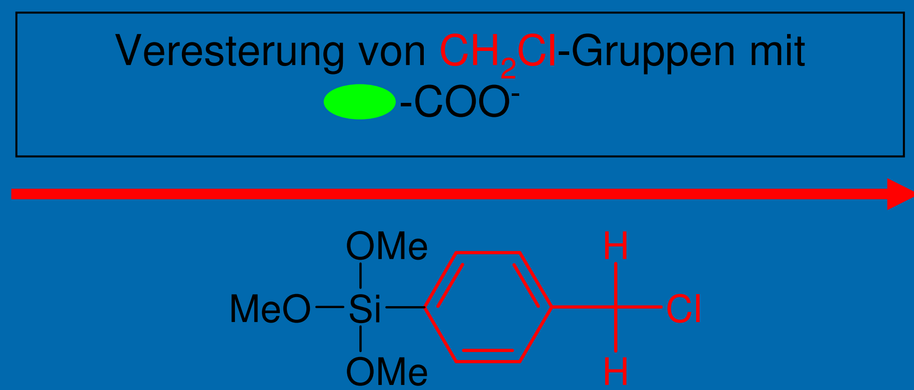
Photoresponsive Mikrokapseln - Schema

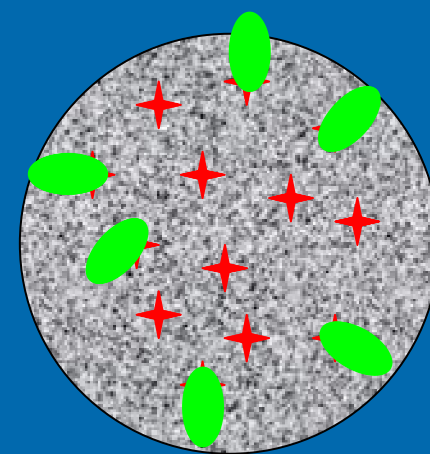
Wasser-Öl-Wasser-Emulsion



Photoresponsive Mikrokapseln -
Synthese photoreaktiver Nanopartikel

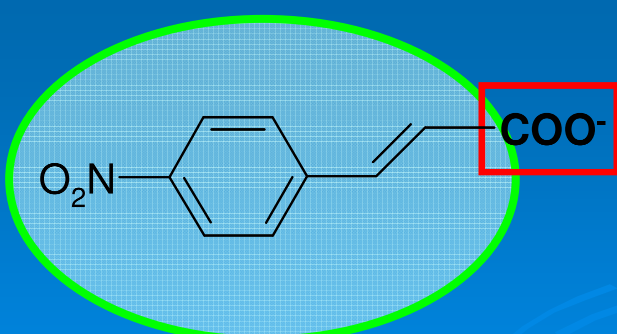




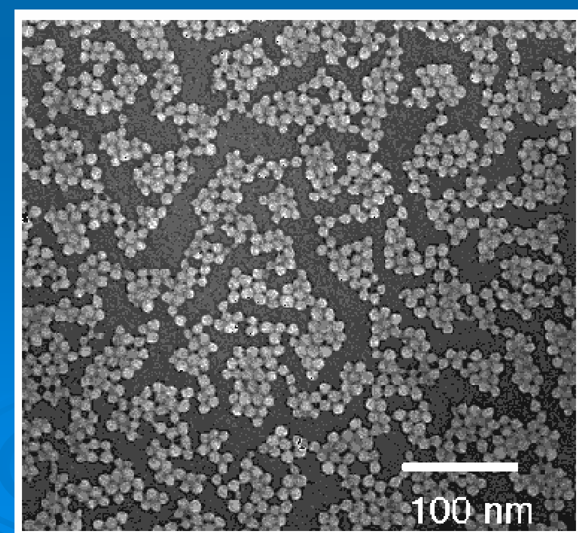


**Methyltrimethoxysilan-
Chlorbenzyltrimethoxysilan-
Nanopartikel**

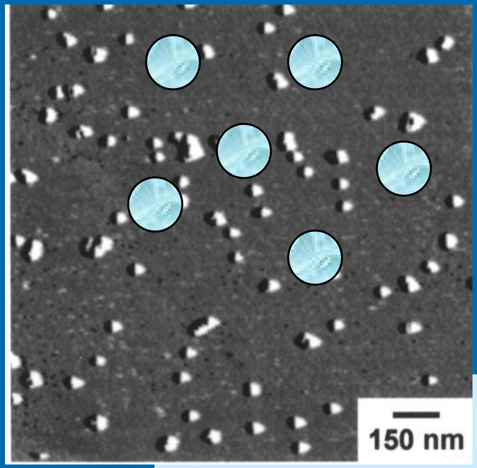
> 450 Farbst./Nanop.

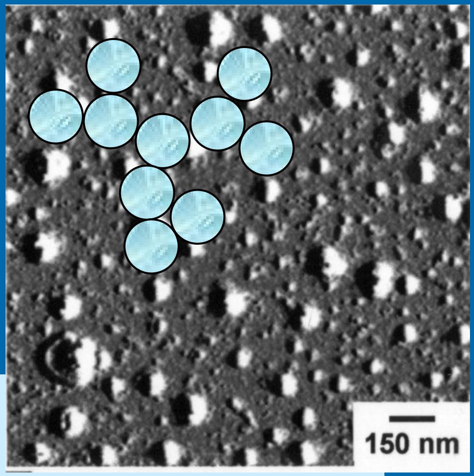


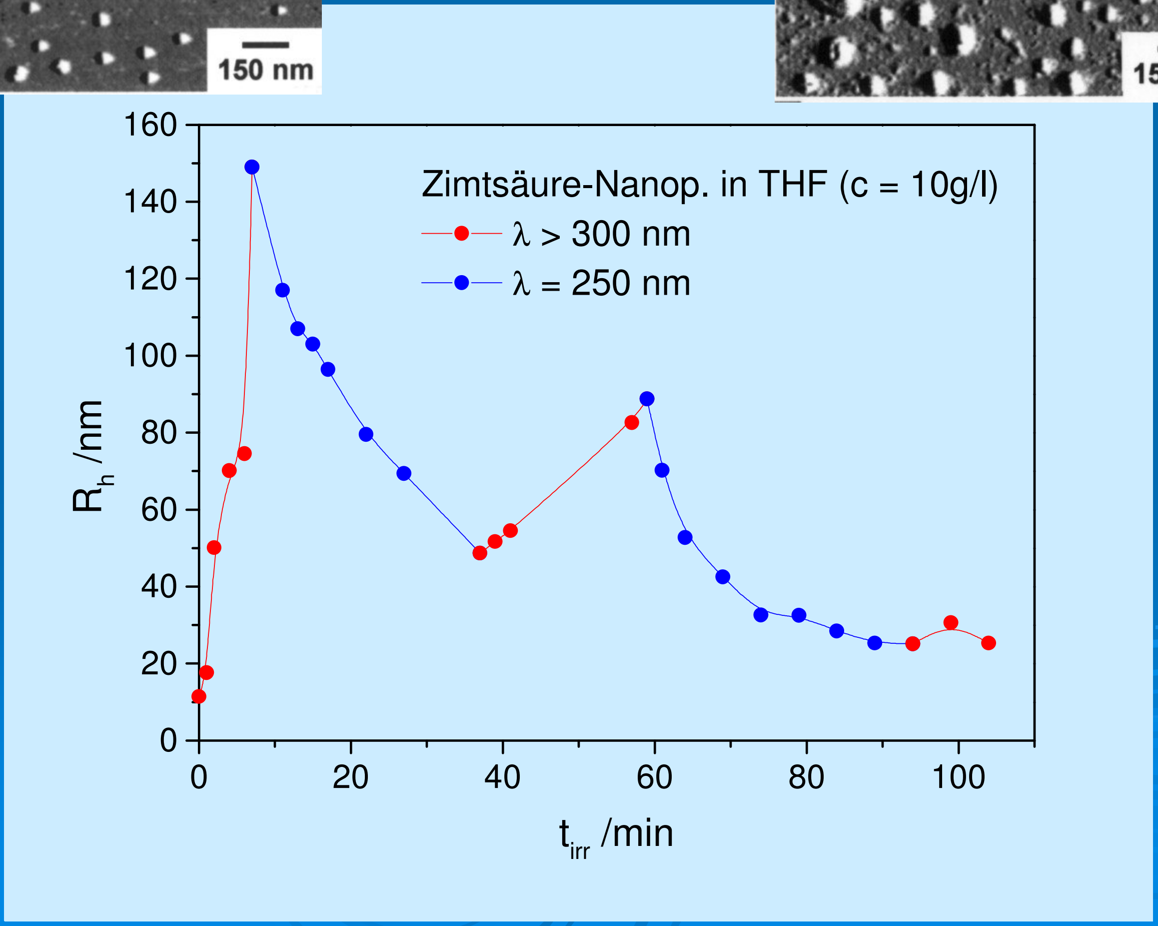
Nitrozimtsäure



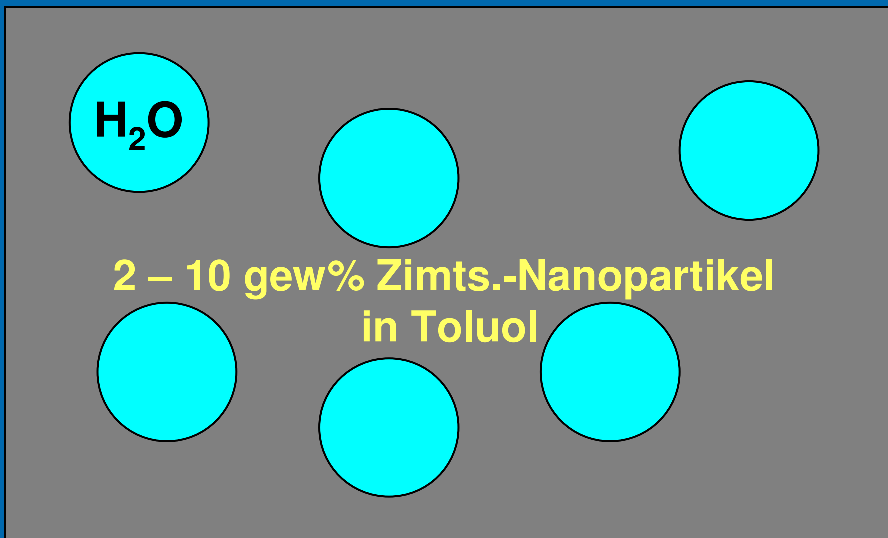
Reversible Vernetzung bei geeigneter Bestrahlung





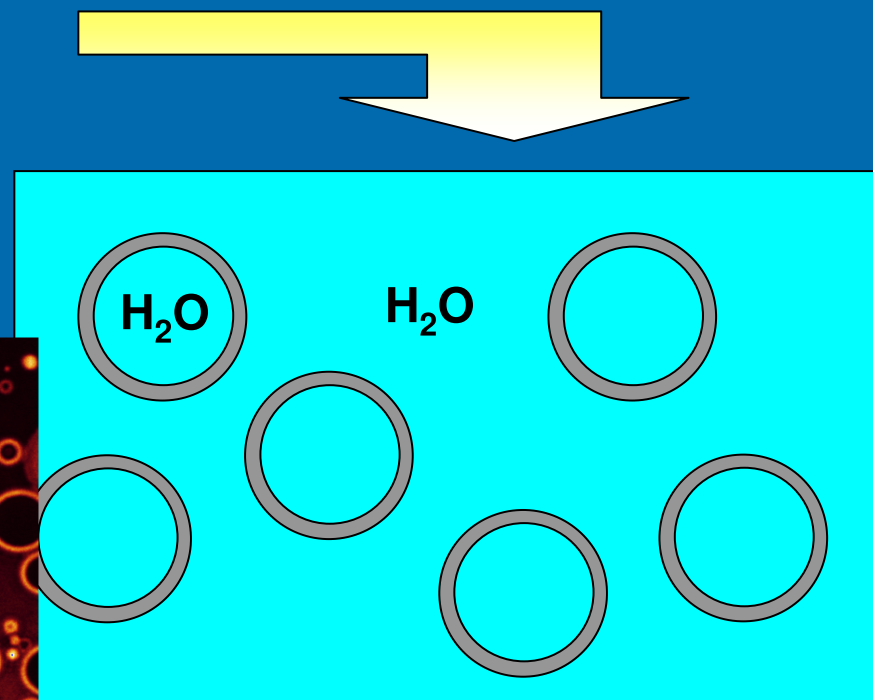


Clusterbildung in sphärischen „Toluol-Mikroschalen“ – W/O/W-Emulsionen als Templat



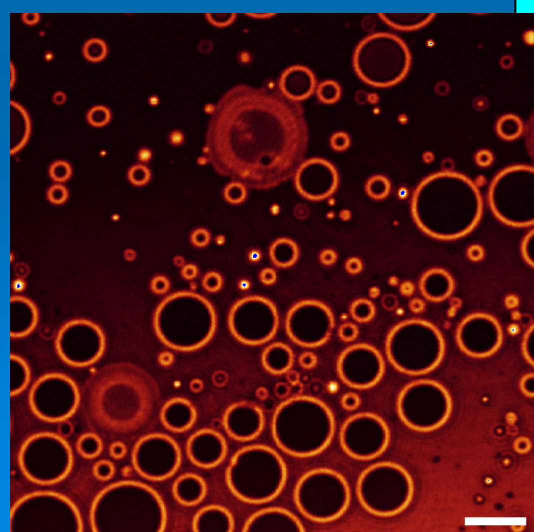
W/O - Emulsion

+ externe Wasserphase



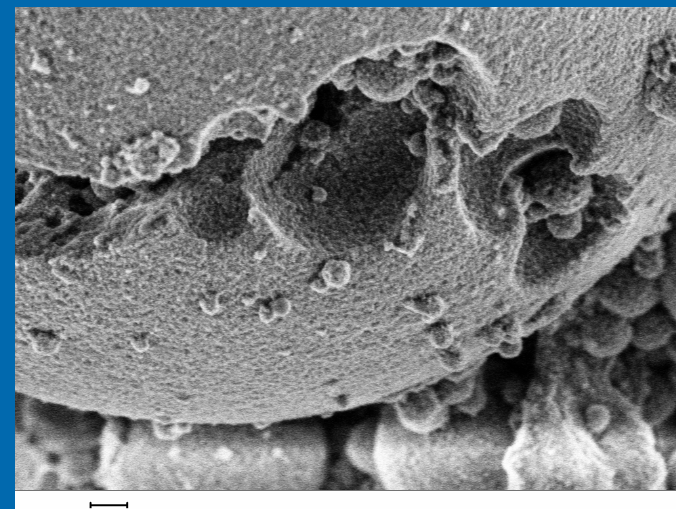
W/O/W - Emulsion

Fluoreszenzaufnahme der Toluol-Mikroschalen (kontrastiert über CdSe-Nanopartikel (- 10 µm)

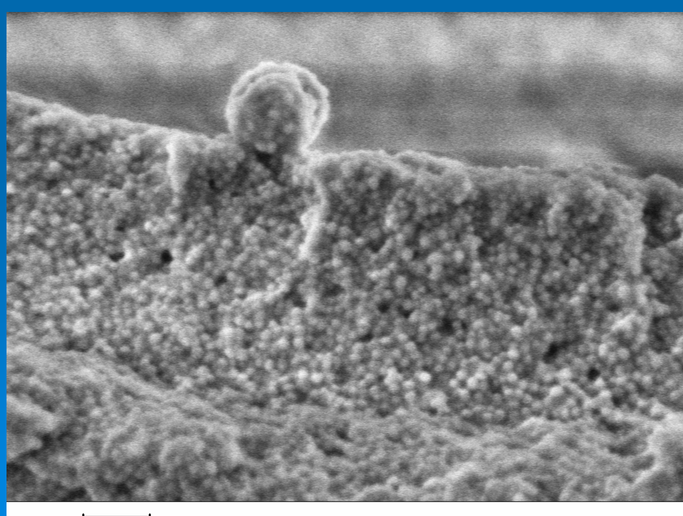


Rasterelektronenmikroskopie-Aufnahmen photolytisch gespaltener Mikrokapseln

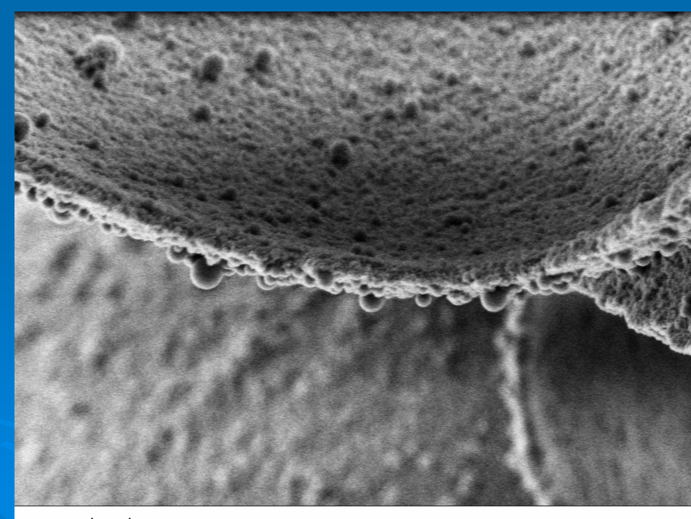
1 µm   Toluol: 10 gew% Nanop.



0.2 µm



0.1 µm



0.2 µm   Toluol: 5 gew% Nanop.

Zukunft des Projektes

- Reduktion von Kapselgröße und Polydispersität (Ziel: Nanokapseln (R ca. 200 nm))
- Variation von optischer und mechanischer Stabilität
- Wechsel zu Anwendungs-freundlicheren Farbstoffsystemen (kein UV-B-Licht !)
- Systematische Untersuchung der kontrollierten Substrat-Freisetzung