Max-Planck-Institute
of Colloids and Interfaces

Encapsulation and Release by multilayer Capsules

A. G. Skirtach, G. B. Sukhorukov, H. Möhwald

Max-Planck Institute
of Colloids and Interfaces
Golm / Potsdam
Germany


Deutschland/Germany
DANMARK
OSTSEE
NORDSEE
POLAND
THE NETHER-
LANDS
BEL-
GIUM
LUXEM-
BOURG
FRANCE
SWITZERLAND
AUSTRIA
ITALY
CZECH REPUBLIC
LIECHTENSTEIN
HAMBURG
BREMEN
BERLIN
HANNOVER
ROSTOCK
LEIPZIG
DRESDEN
DORTMUND
ESSEN
DUISBURG
DÜSSELDORF
KÖLN
FRANKFURT a. M.
HEIDELBERG
STUTTGART
MÜNCHEN
Legend
© Huber Kartographie • 80992 München • Deutschland

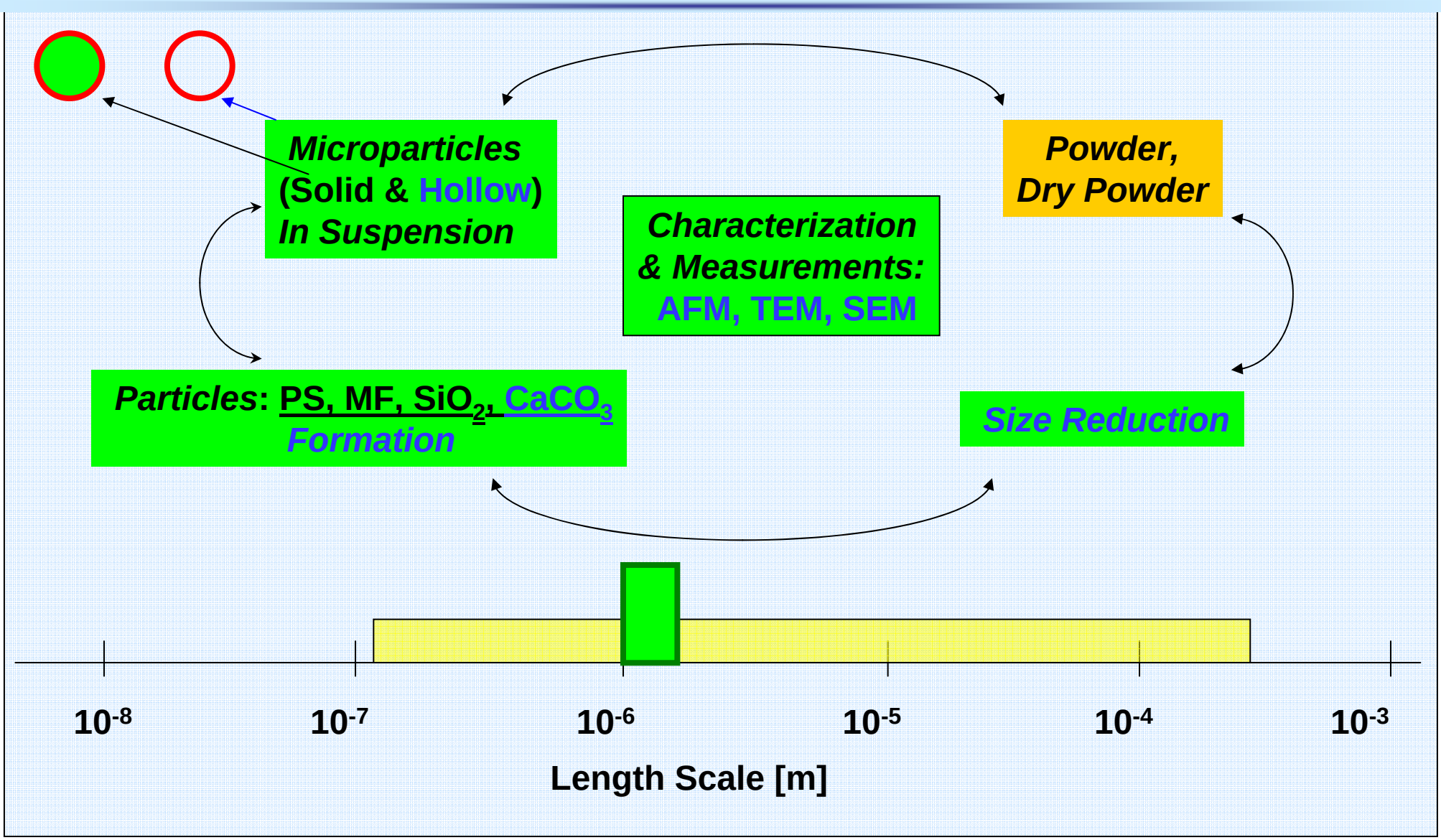

Pasewalk
Szczecin
Parchim
Müritz
Neustrelitz
Prenzlau
Ludwigslust
Pritzwalk
Wittstock
Schwedt
Perleberg
Dannenberg
Wittenberge
Löwenberg
Ucker-
mark
Kyritz
Neuruppin
Eberswalde
Oranienburg
Bernau
Havel
Odra
Oder
Kostrzyn
Nauen
Rathenow
Havel-
land
BERLIN
Brandenburg
Fürsten-
walde
Frankfurt
(Oder)
POTSDAM
Beeskow
Eisen-
hüttenstadt
Krosno
Odrańskie
Luckenwalde
Märkische
Heide
Jüterbog
Lübben
Guben
Lutherstadt
Wittenberg
Luckau
Cottbus
Forst
Herzberg
Torgau
Lauch-
hammer
Senftenberg
Bad Muskau
Eilenburg
Hoyerswerda
Riesa
Elbe
Meißen
Radebeul
BRANDENBURG
0
50 km
©RB-DESKKART www.welt-atlas.de
URHEBERRECHTLICH GESCHÜTZT • IRRTÜMER VORBEHALTEN

Table of Contents

Max-Planck-Institute of Colloids and Interfaces

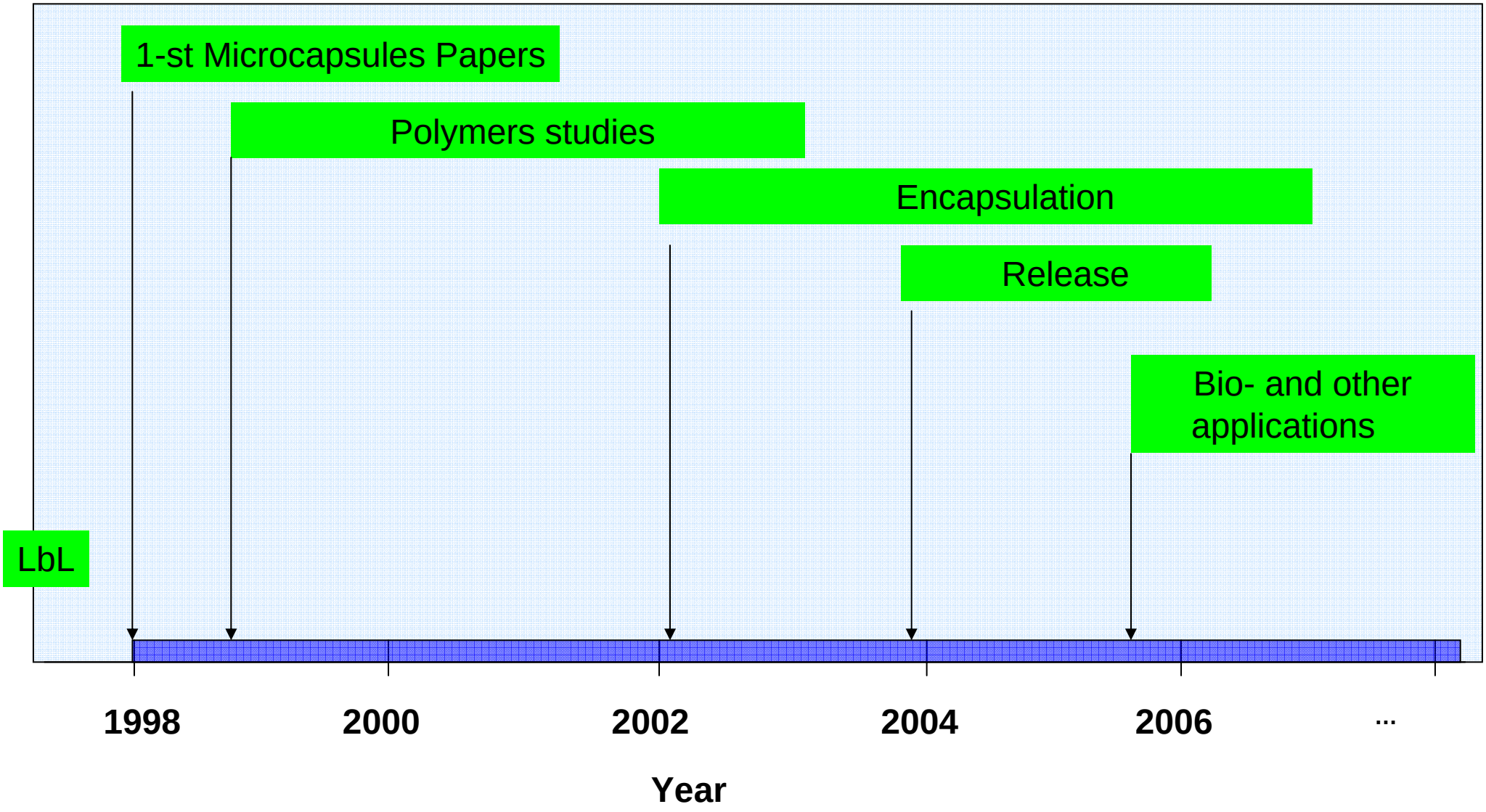
Microcapsules and **IFPRI**’*s scope*

Max-Planck-Institute
of Colloids and Interfaces



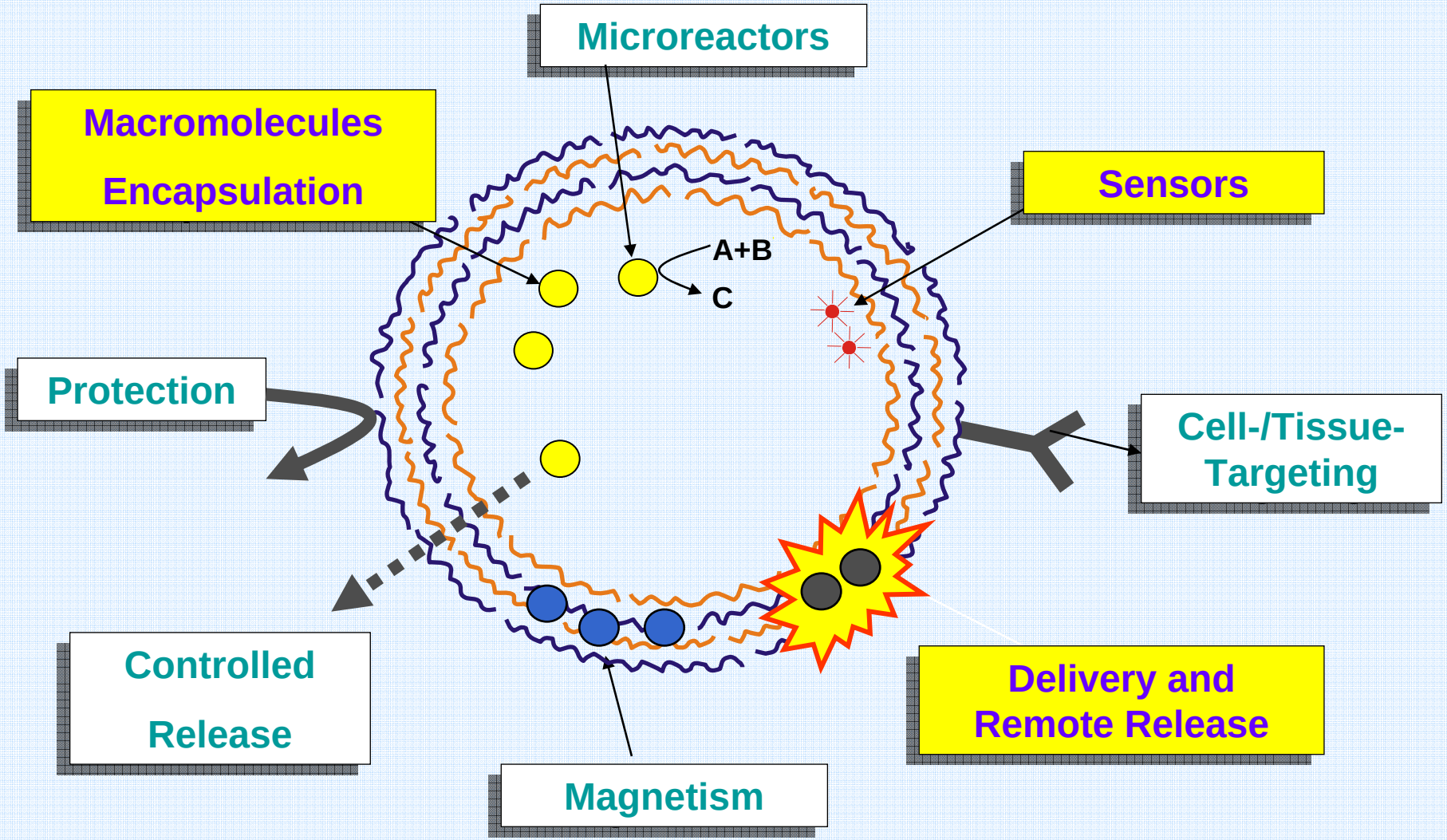
Encapsulation and Release Timeline

Max-Planck-Institute
of Colloids and Interfaces



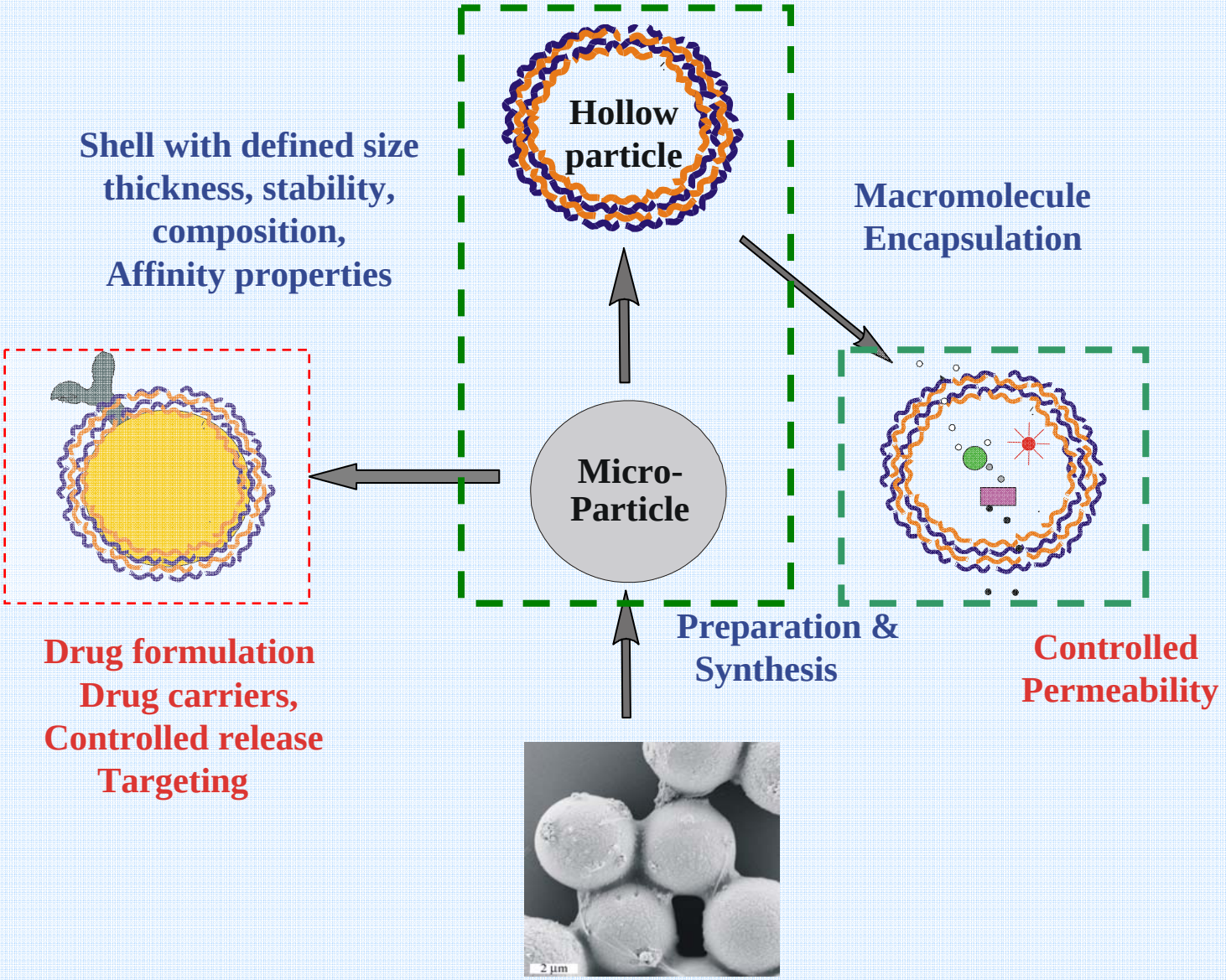
Multifunctionality of Polyelectrolyte Multilayer Capsules

Max-Planck-Institute of Colloids and Interfaces



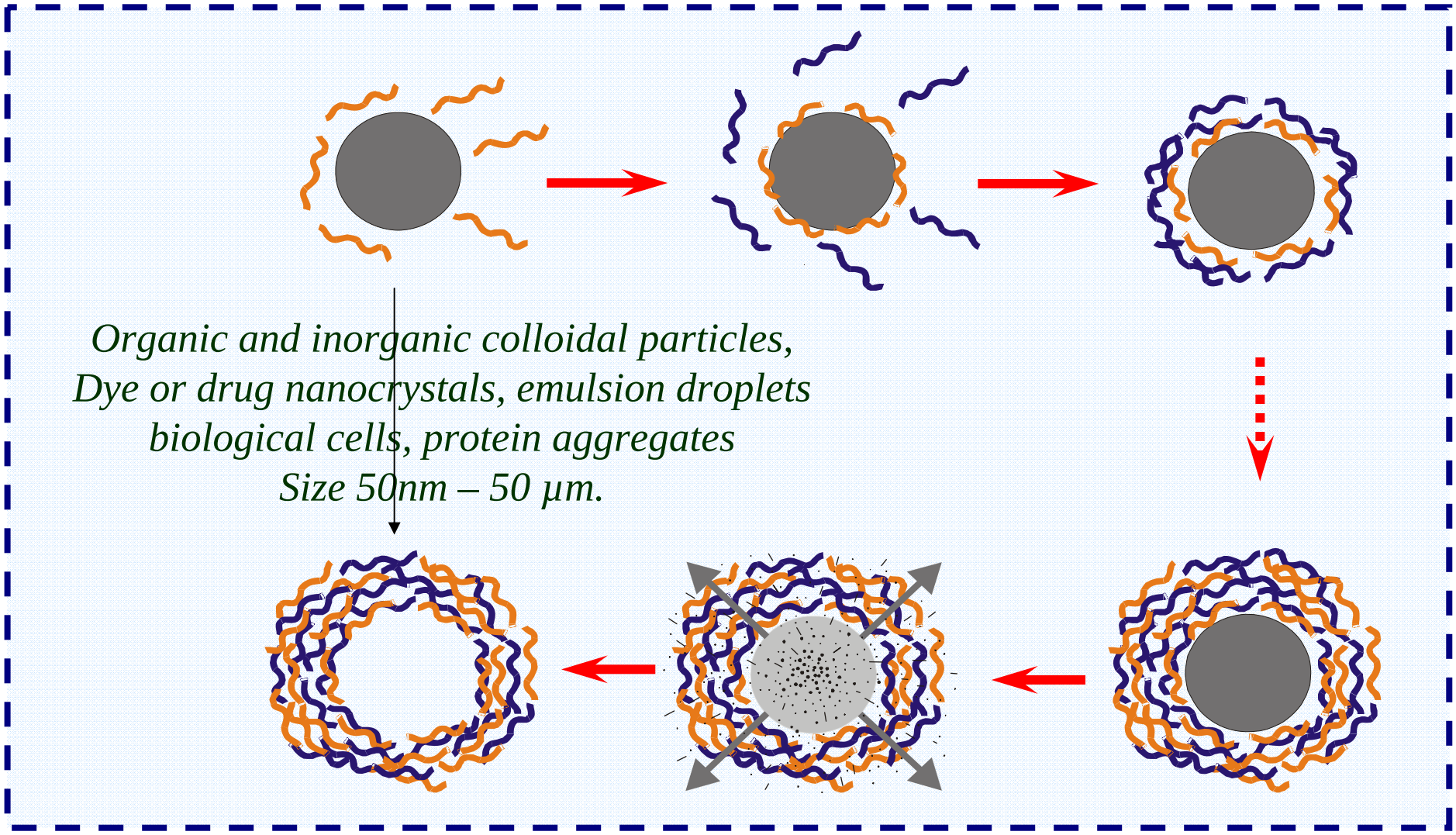
Multifunctional Nanoengineered Microcapsules

Max-Planck-Institute of Colloids and Interfaces



LbL Preparation Method of Microcapsules

Max-Planck-Institute of Colloids and Interfaces



Hollow Microcapsules: PS, MF, SiO_2, $CaCO_3$

Formation

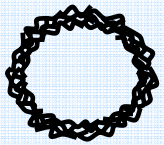
Table of Contents

Max-Planck-Institute of Colloids and Interfaces

2.a) Principle of pH induced encapsulation (PS templates)

Max-Planck-Institute of Colloids and Interfaces

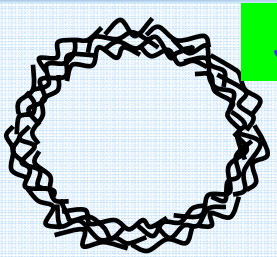
Size Reduction



10 μm

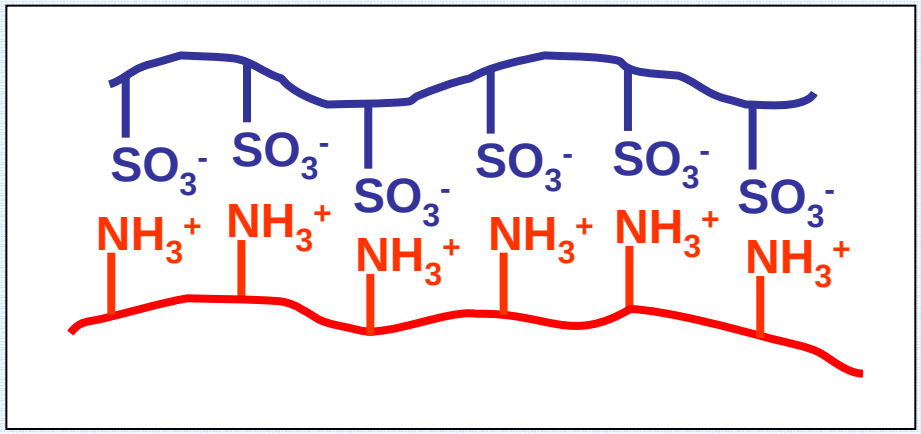
NaOH (pH > 11.2)

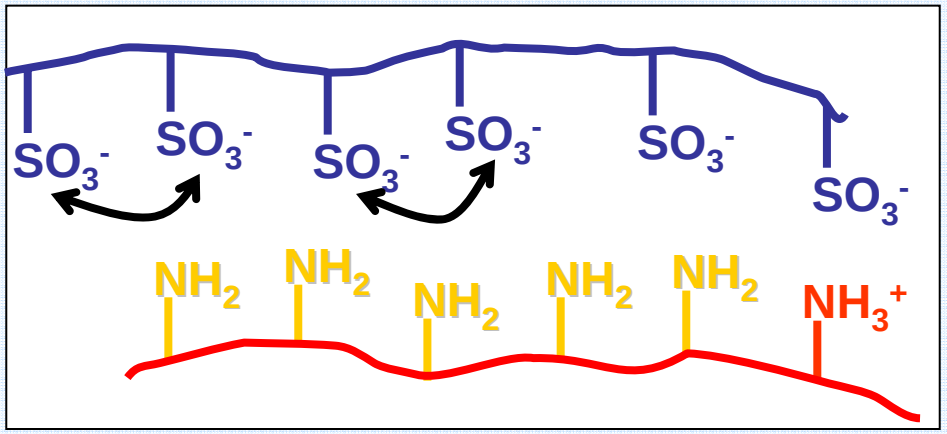
HCl



16 μm

Size Increase





PAH fully charged

Compensation of charges
$SO_3^- = NH_3^+$

PAH almost uncharged

Electrostatic repulsions
too much SO_3^-

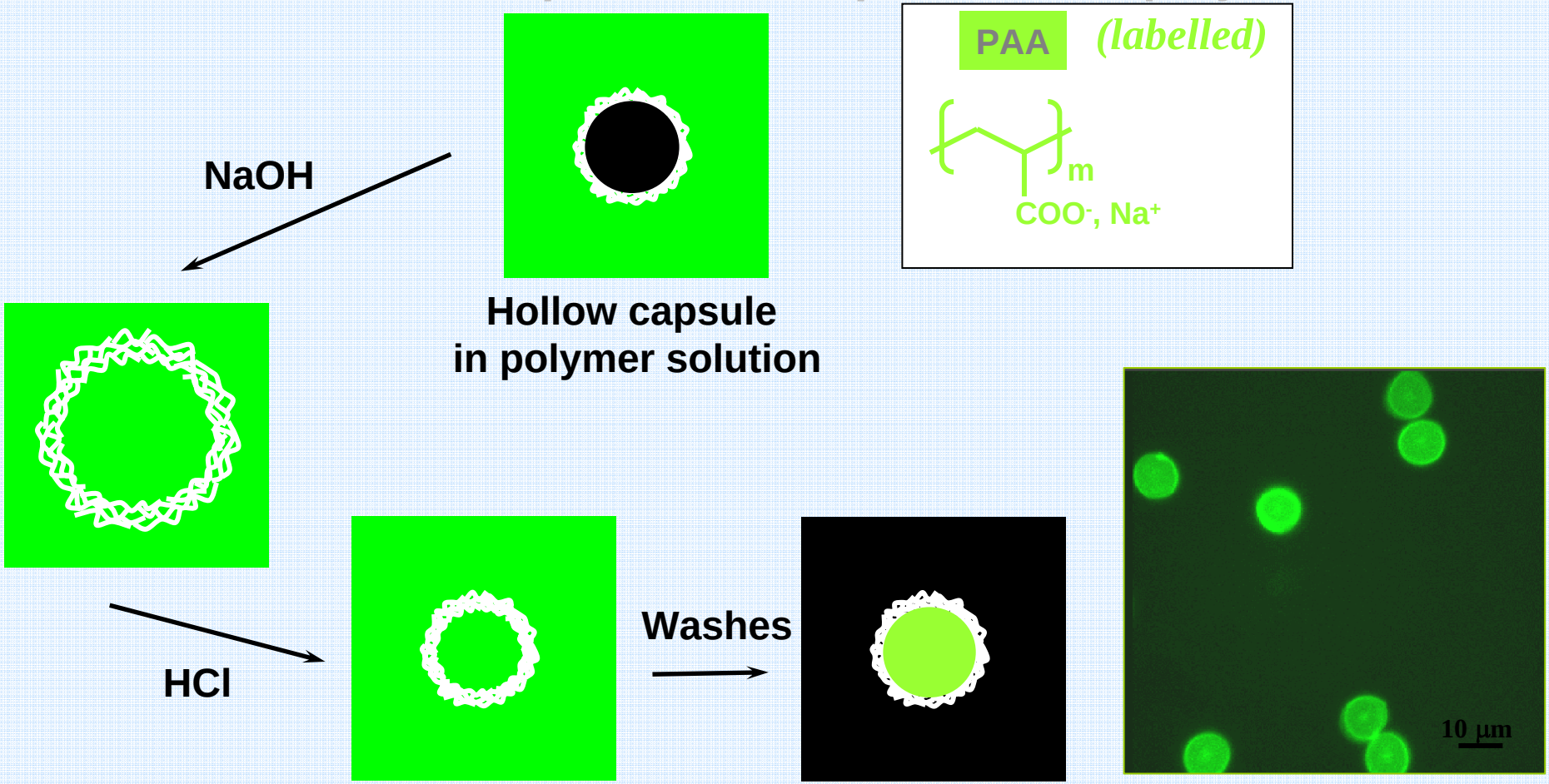
Macromol. Rap. Comm. **2005,** *26*, 961.

2.a) pH induced encapsulation

Max-Planck-Institute
of Colloids and Interfaces

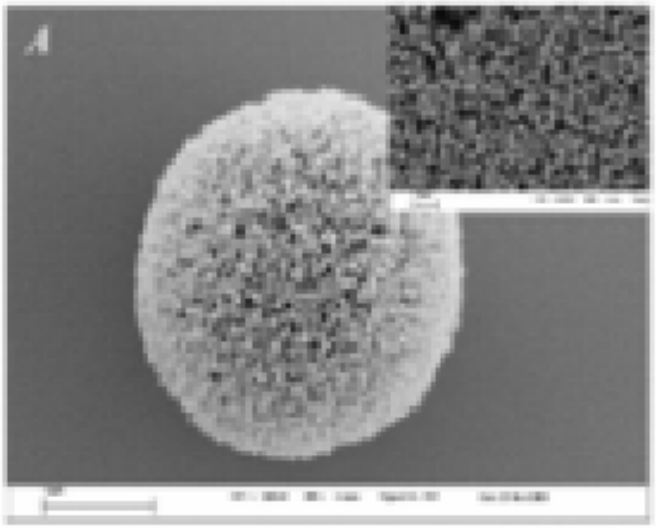
Shrunk state : not permeable to polymers
Swollen state: permeable to polymers

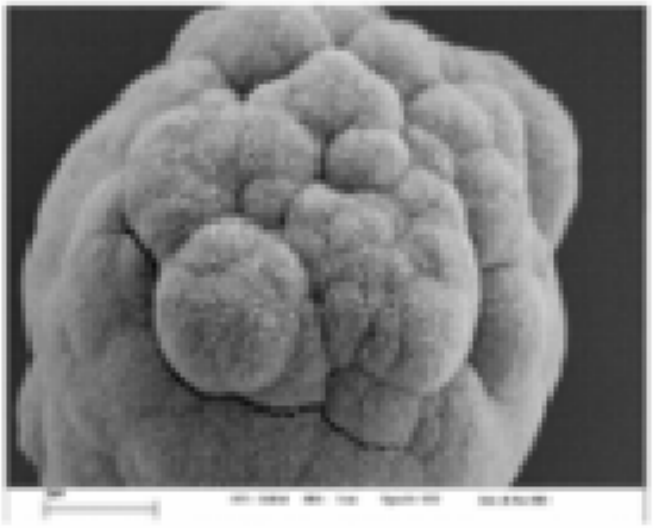
Swell then shrink the capsules in the presence of polymer



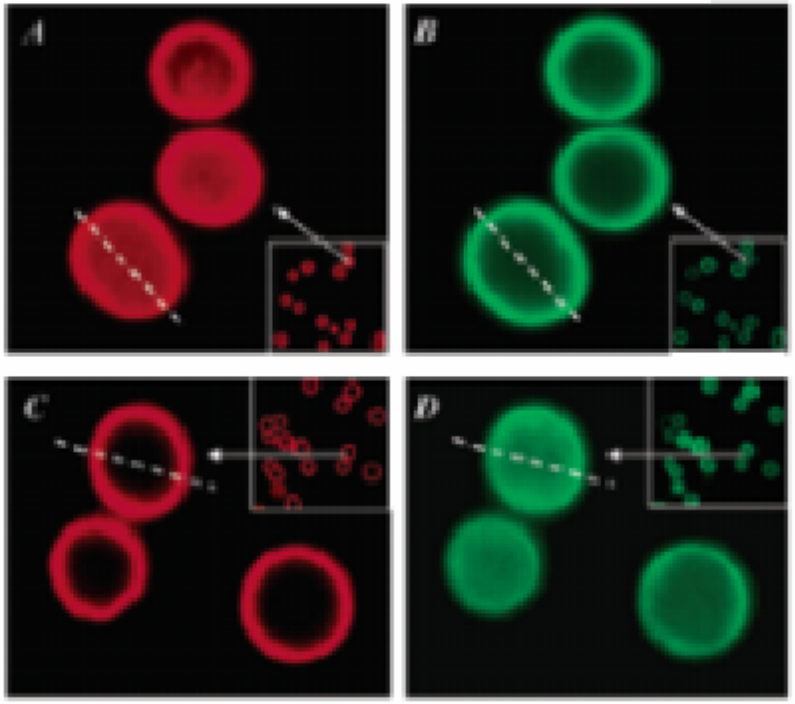
2.b) Co-precipitation method ($CaCO_3$)

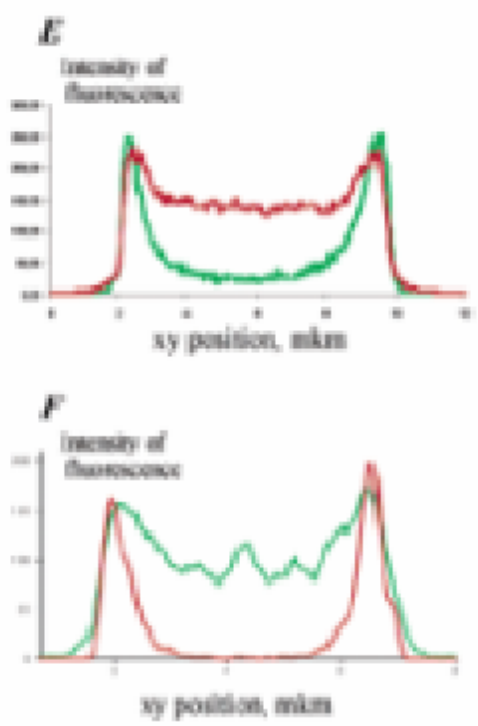
Max-Planck-Institute
of Colloids and Interfaces





$CaCl_2 + Na_2CO_3$

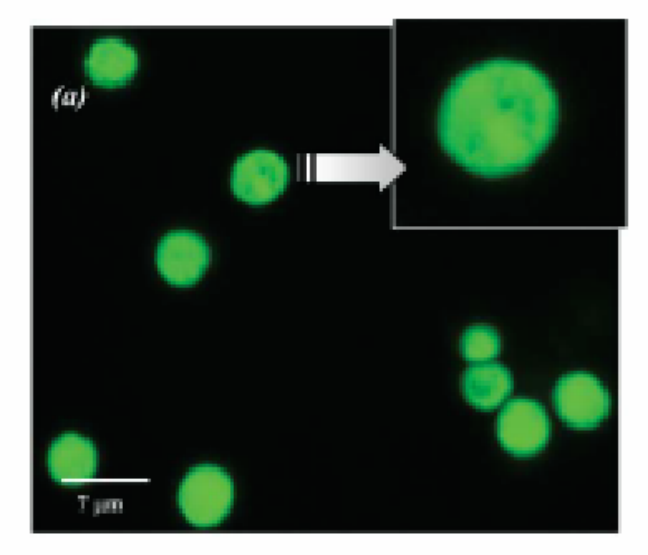




Biotech. Prog. **2005**, *21*, 918.

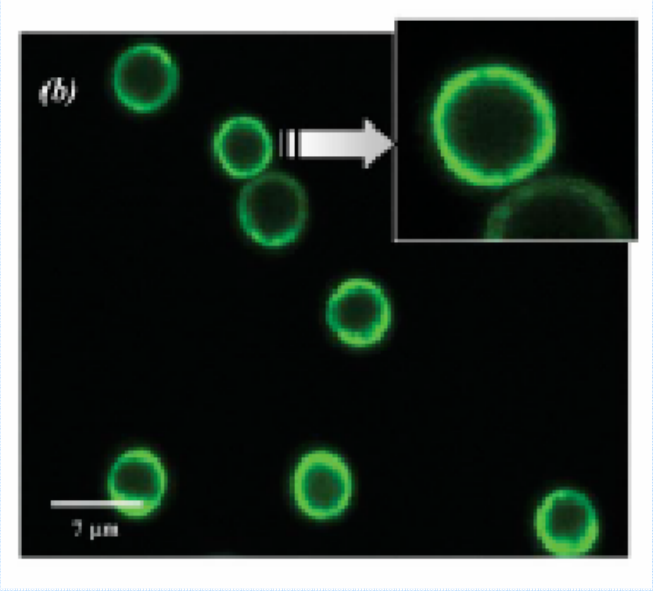
2.b) Co-precipitation method ($CaCO_3$)

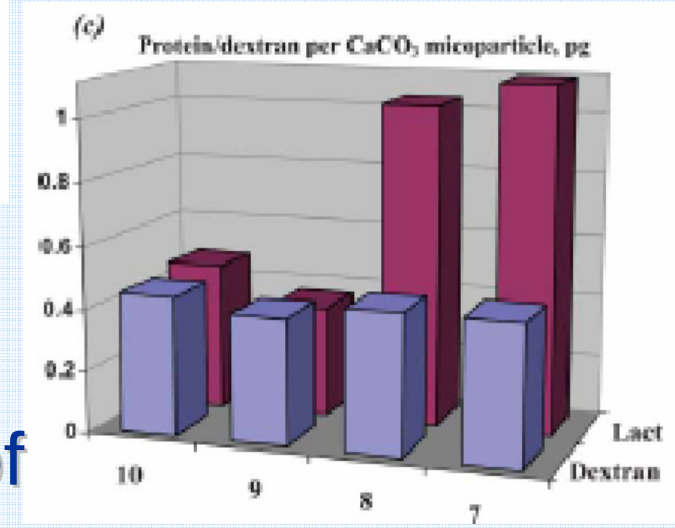
Max-Planck-Institute of Colloids and Interfaces



Dextrane/FITC 4 kD

Dextrane/FITC 2000 kD



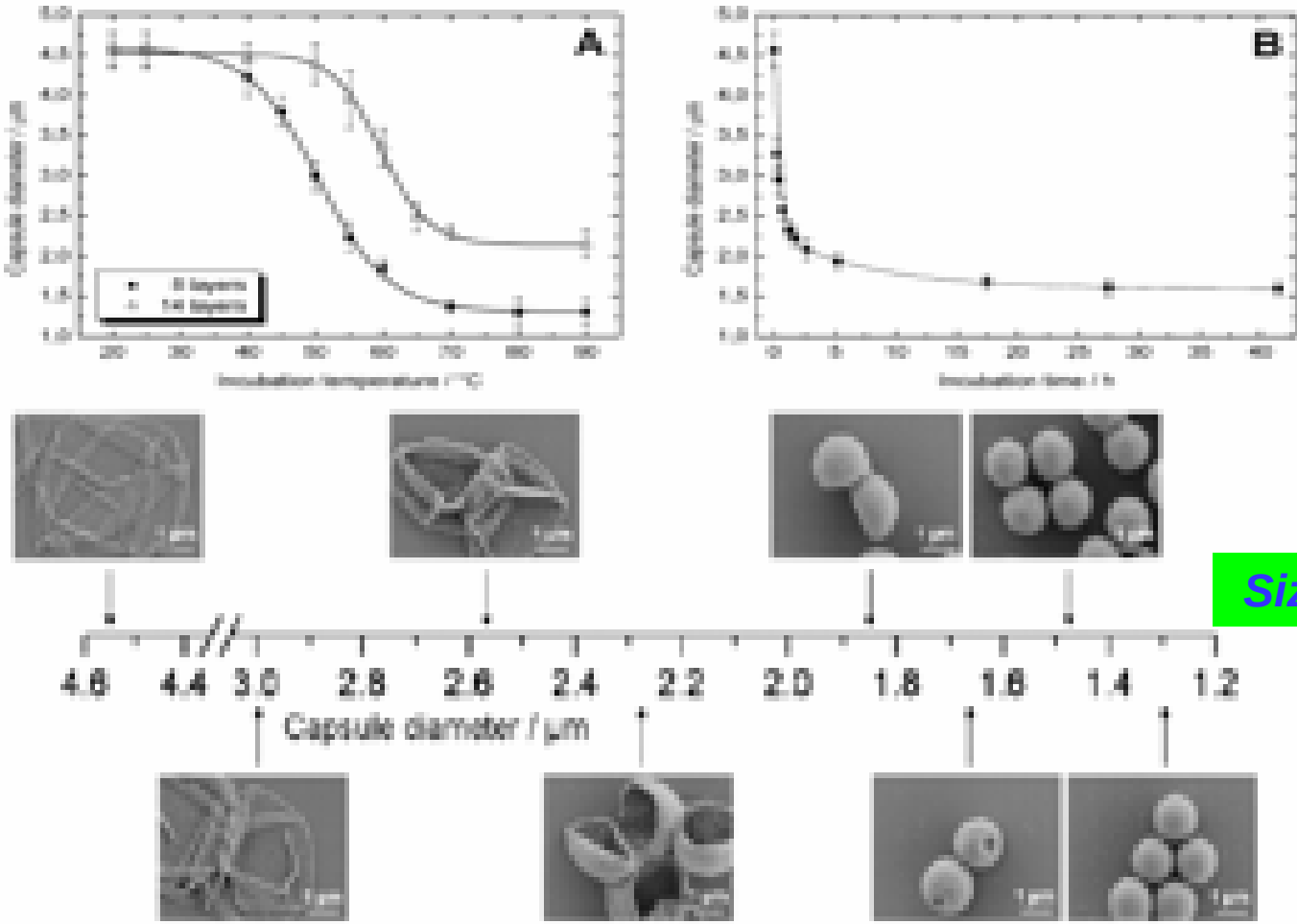


pH dependence of Adsorption of Dextrane

J. Mater. Chem. **2004**, *14*, 2073.

2.c) Temperature shrinking method (SiO_2)

Max-Planck-Institute of Colloids and Interfaces



Size Reduction

Varying the size of microcapsules by changing the temperature

J. Phys. Chem. B **2005,** *109***,** 18250.

2.c) Thermally shrunk microcapsules

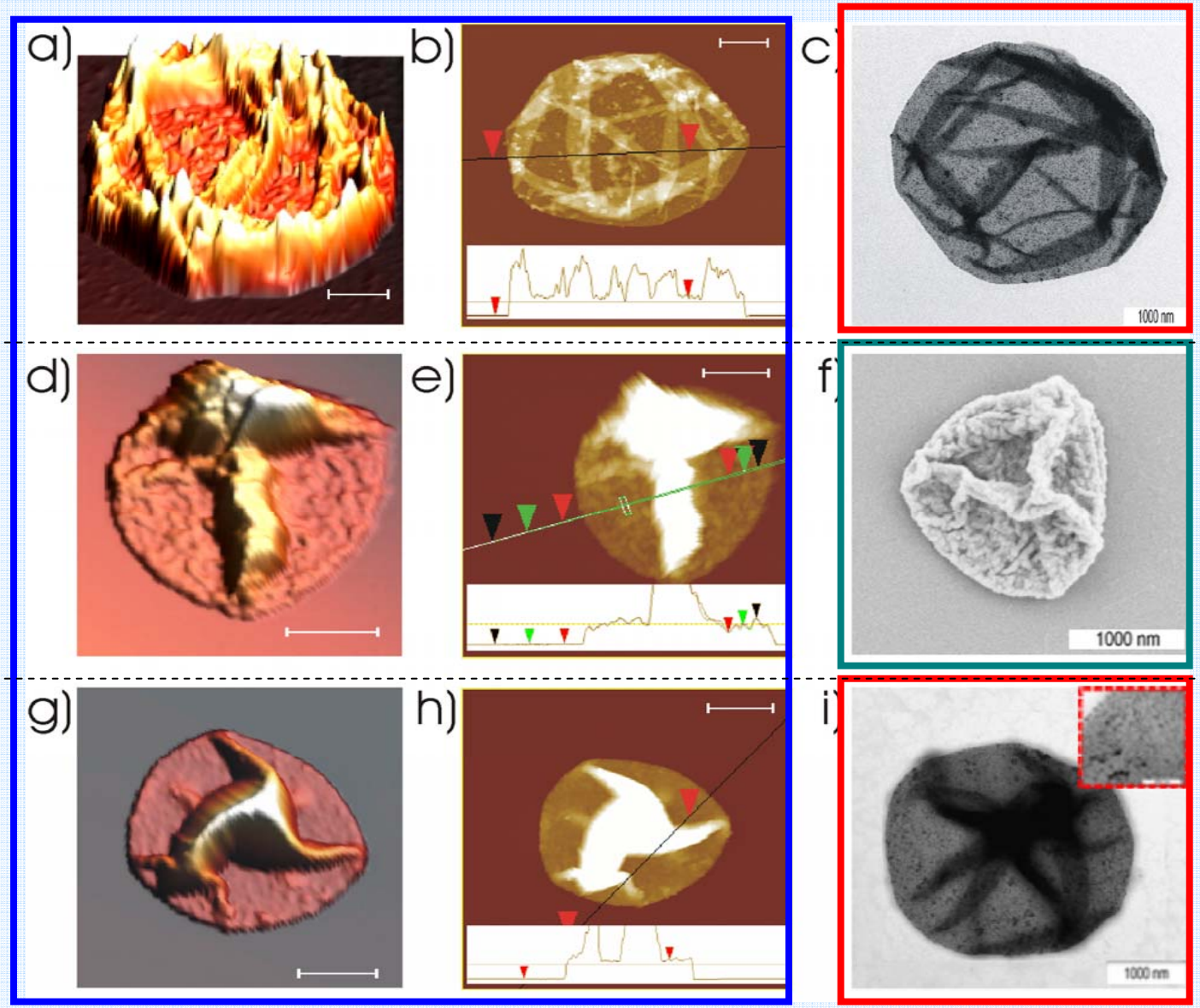
Max-Planck-Institute of Colloids and Interfaces

Characterization & Measurements:
AFM, TEM, SEM

Initial →

Thermally Shrunk →

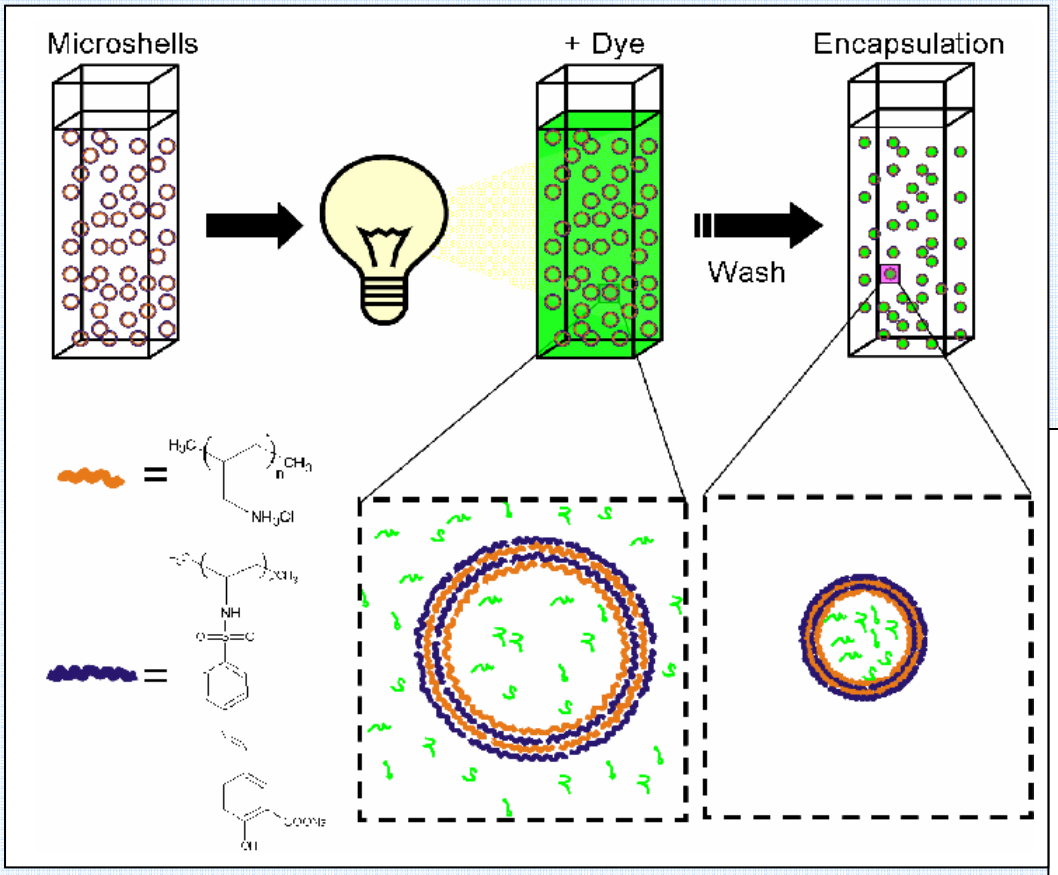
Thermally Shrunk & Encapsulated Polymers →



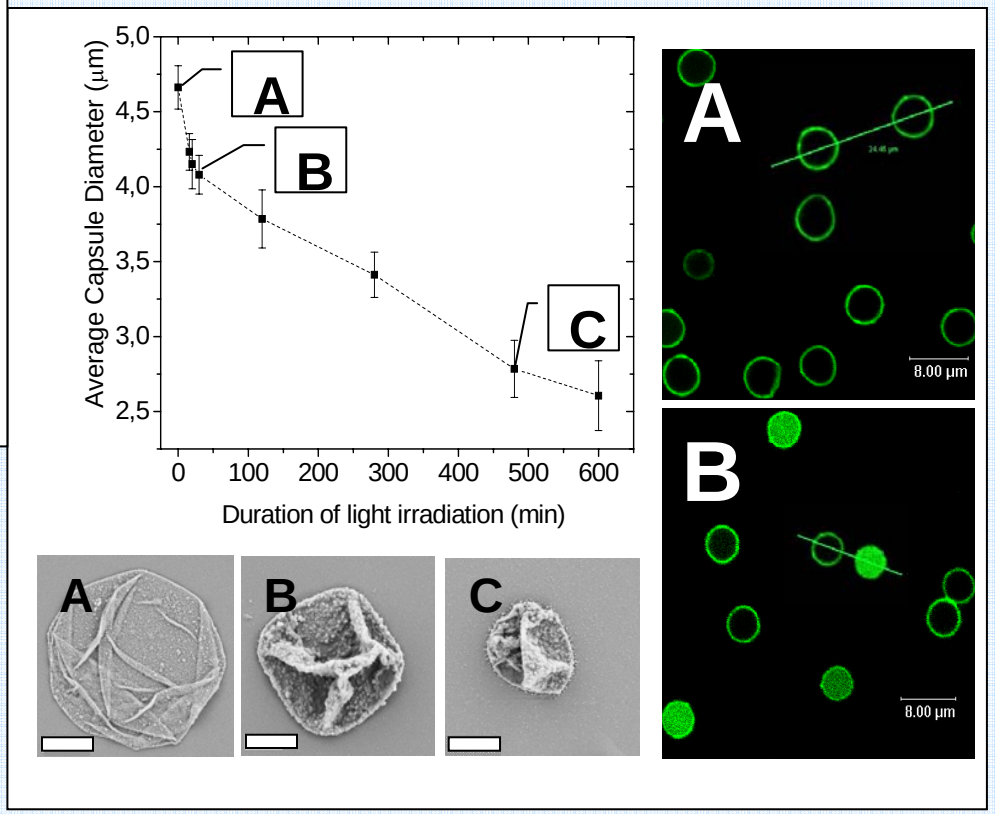
Angew. Chem. Int. Ed. **2006,** *55***,** 6412.

2.d) Optically Induced Encapsulation

Max-Planck-Institute of Colloids and Interfaces



Schematics

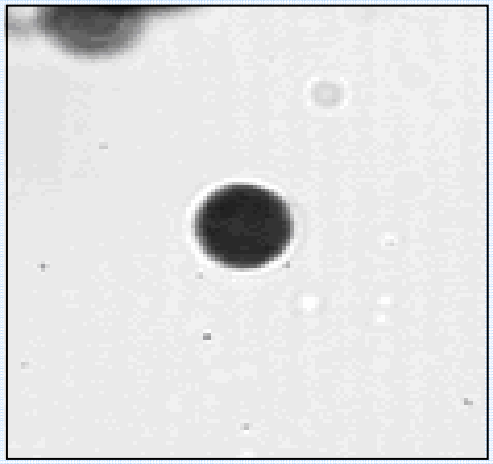


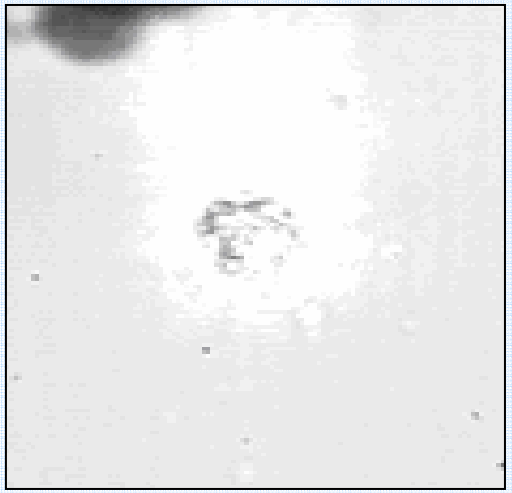
Encapsulated Polymers

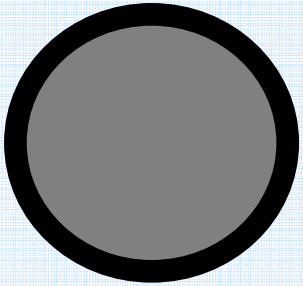
Table of Contents

3.a) Laser Light induced Remote Release

Max-Planck-Institute
of Colloids and Interfaces

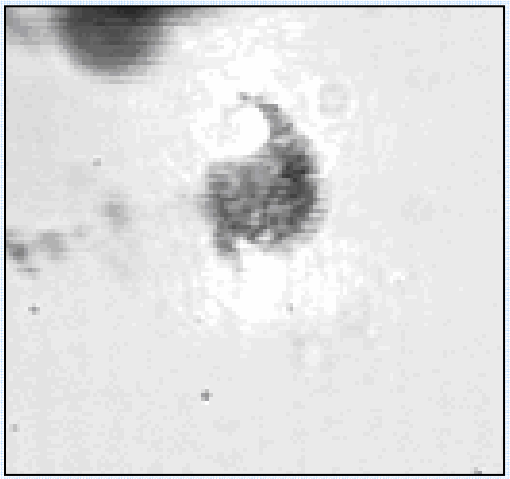


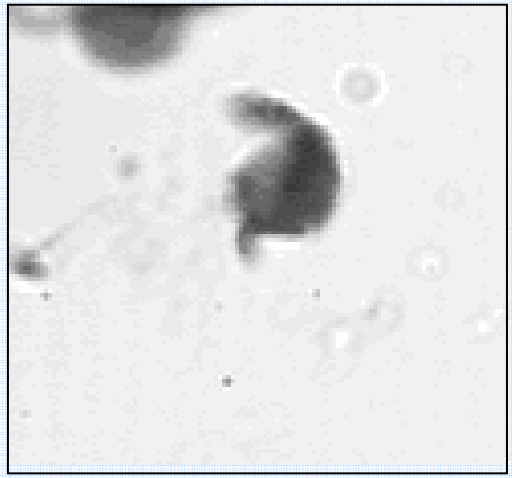




LASER

LASER

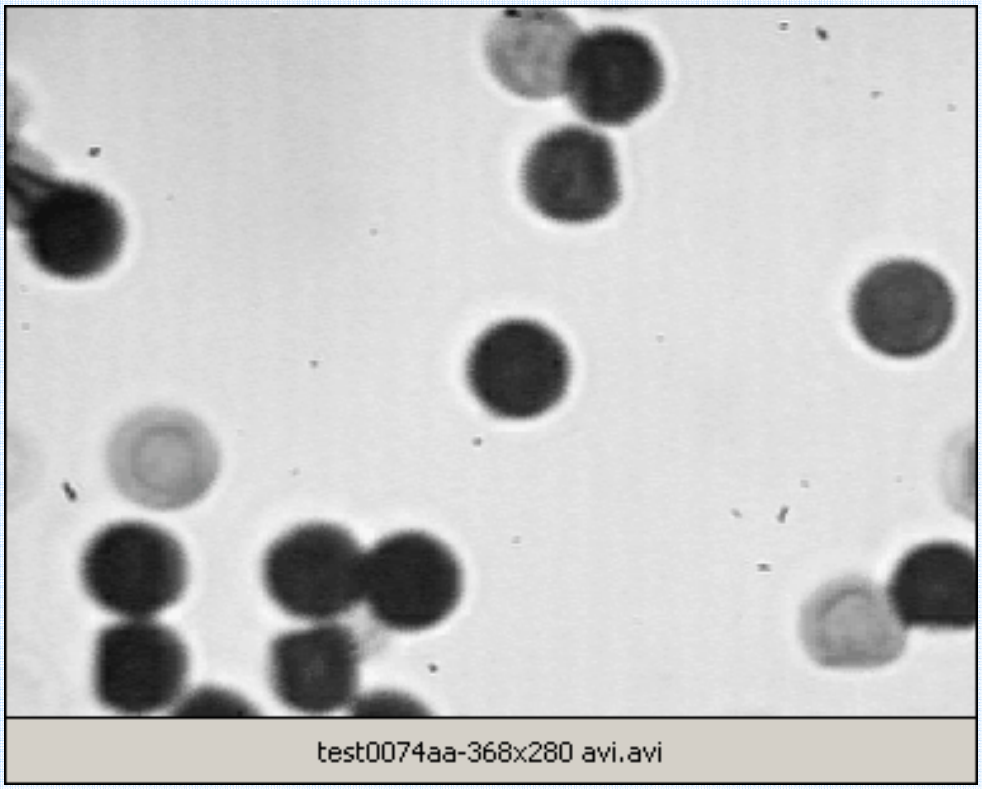




Langmuir **2004**, *20*, 6988.

3.a) Laser Light induced Remote Release

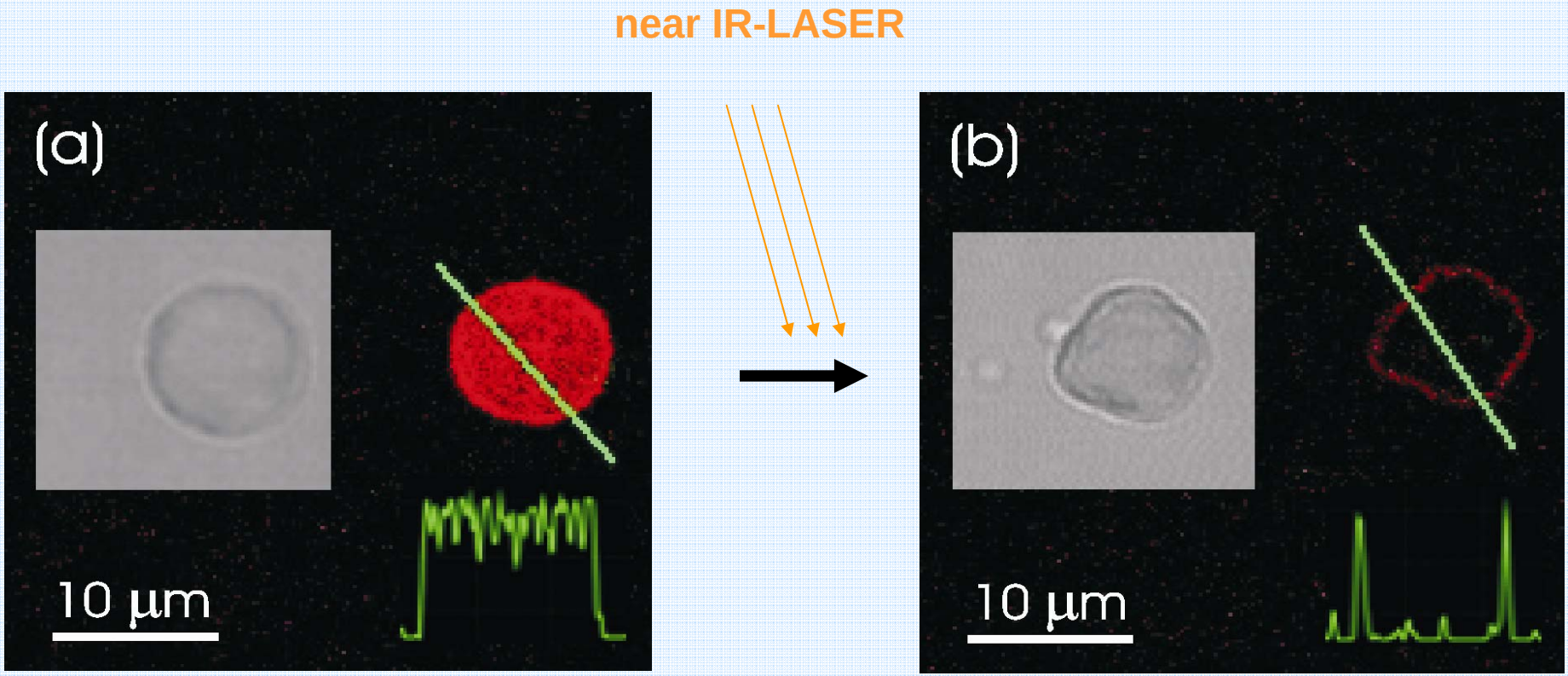
Max-Planck-Institute
of Colloids and Interfaces



Langmuir **2004**, *20*, 6988.

3.a) Laser Light induced Remote Release

Max-Planck-Institute of Colloids and Interfaces



Nano Lett. **2005,** *5*, 1371.

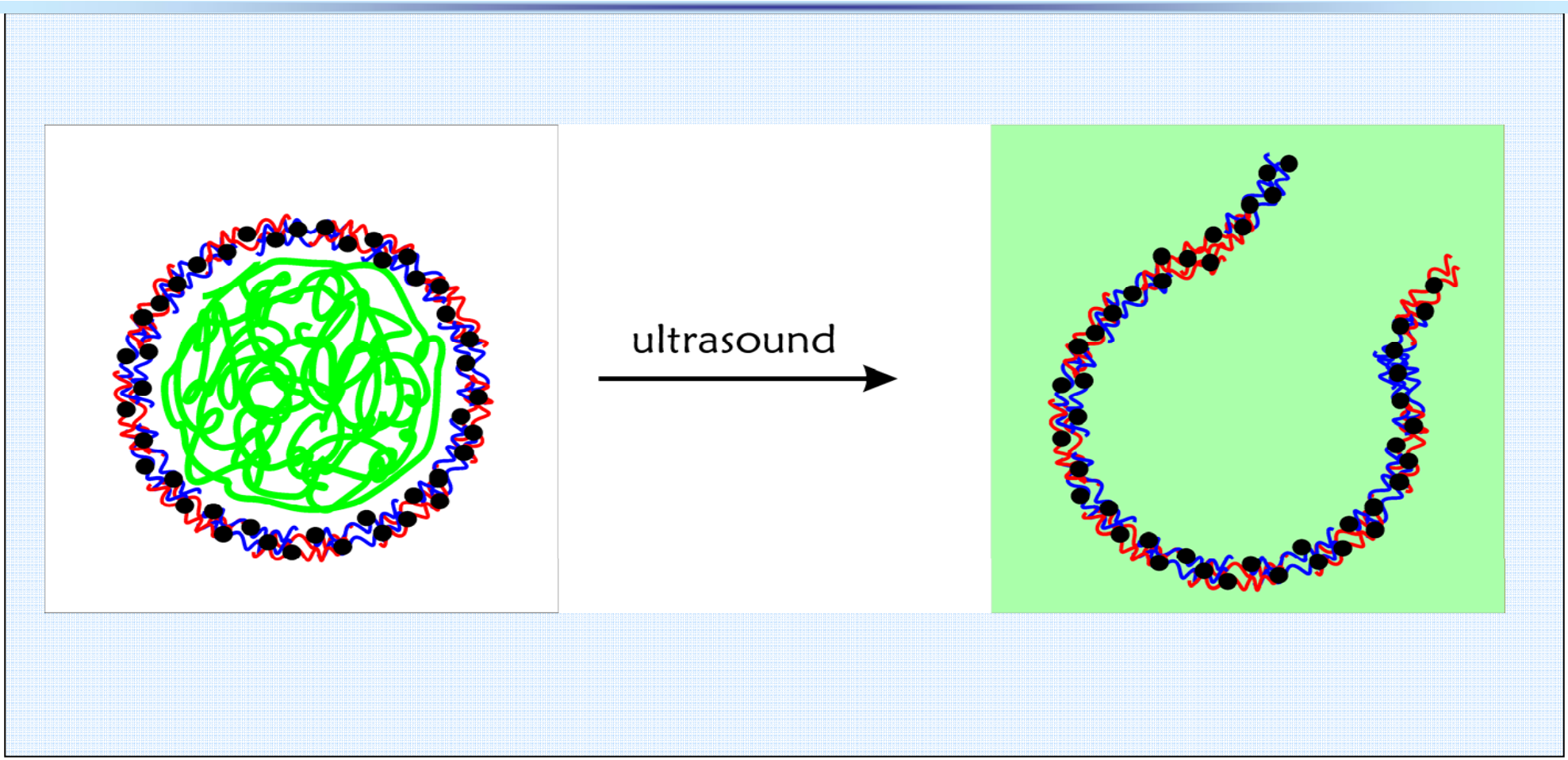
3.a) Laser Light induced Remote Release

Max-Planck-Institute
of Colloids and Interfaces

Nano Lett. **2005,** *5*, 1371.

3.b) Ultrasound induced Release

Max-Planck-Institute
of Colloids and Interfaces



Langmuir ***2006****, 22,* 7400*; J. Mater. Chem.* **2007**, *17*, 1050.

3.b) Ultrasound induced Release

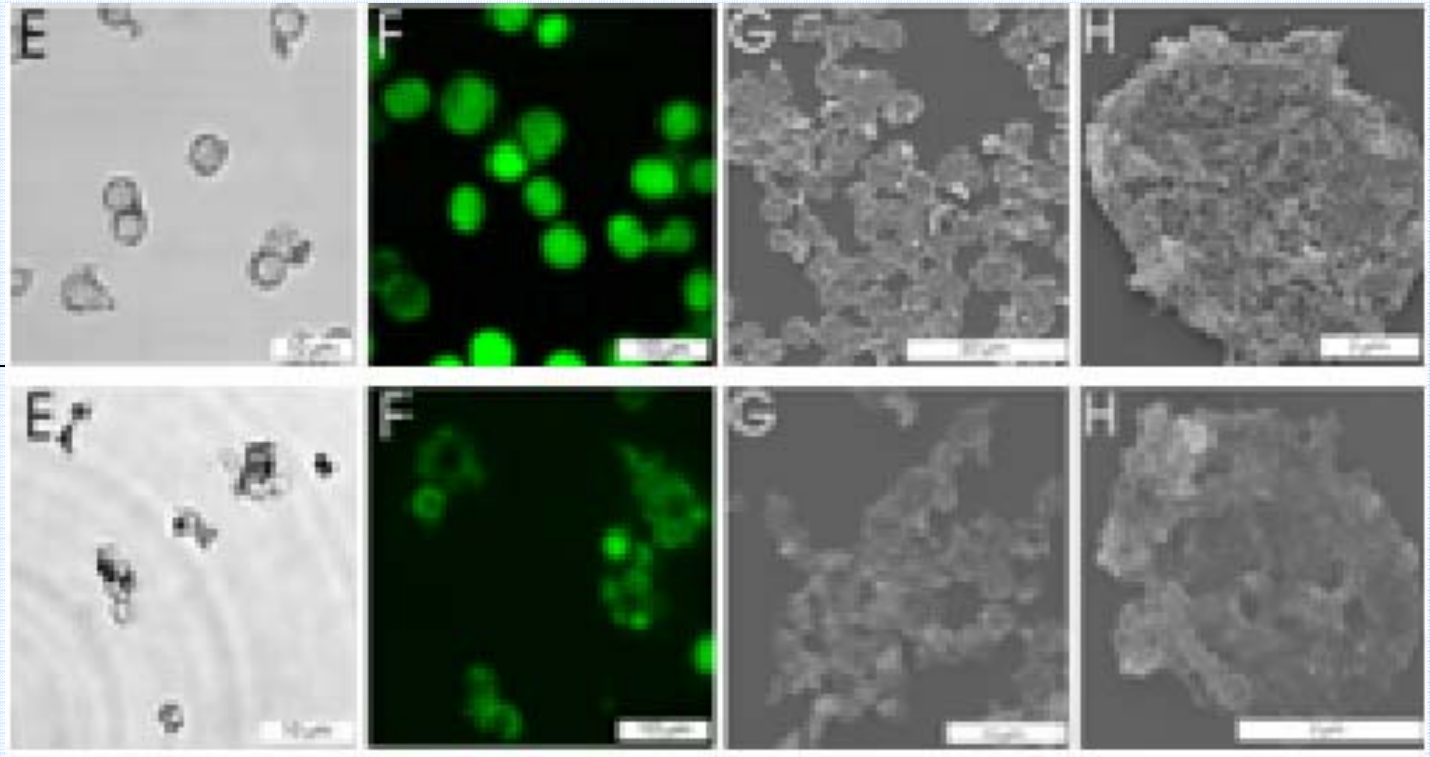
Max-Planck-Institute of Colloids and Interfaces

Without NP

With NP

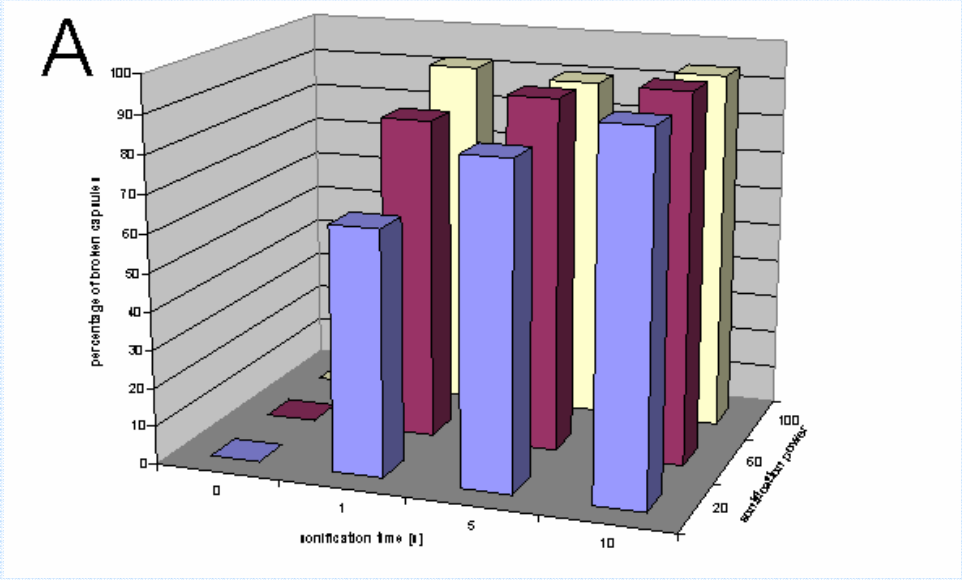
Before

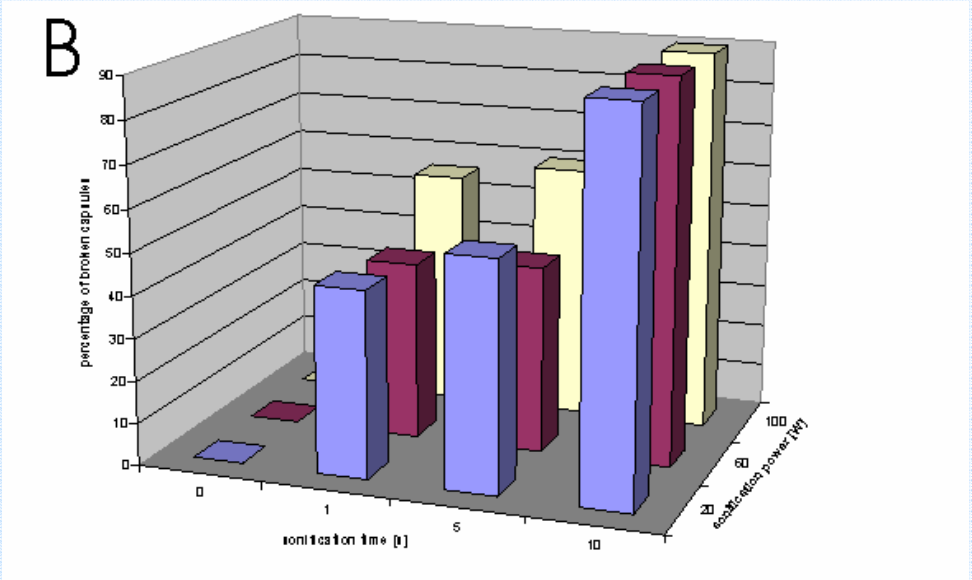
After



3.b) Destruction with time in ultrasound

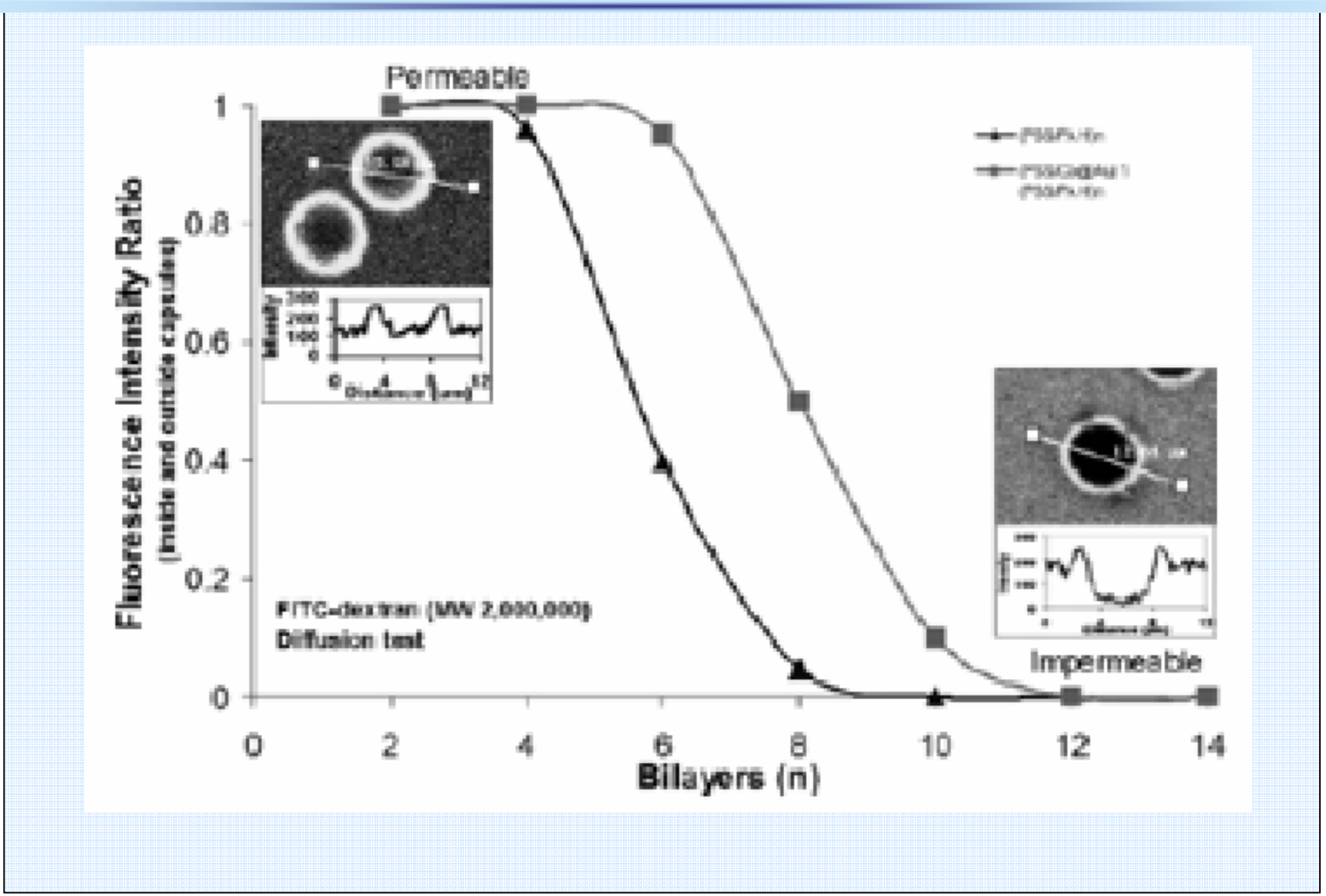
Max-Planck-Institute of Colloids and Interfaces





3.c) Magnetically induced Release

Max-Planck-Institute
of Colloids and Interfaces

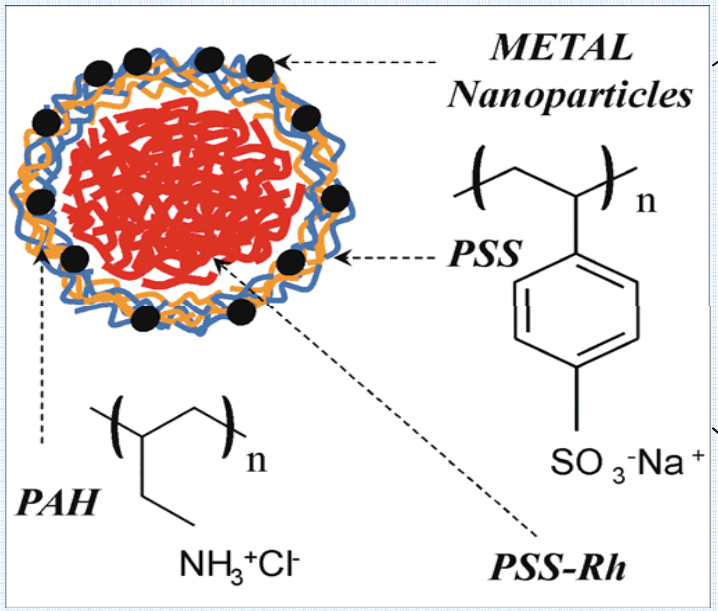


Langmuir ***2005***, *21*, 2042.

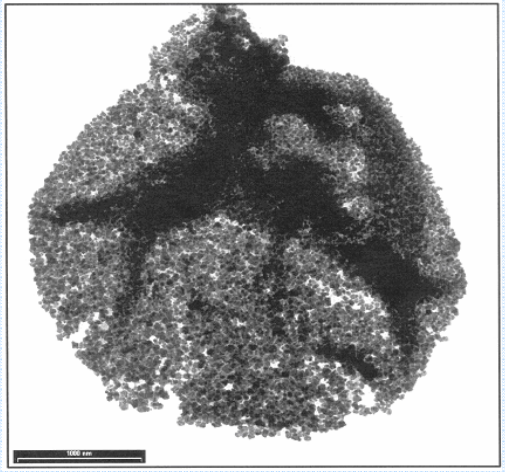
Table of Contents

Nanoparticles for Remote Release

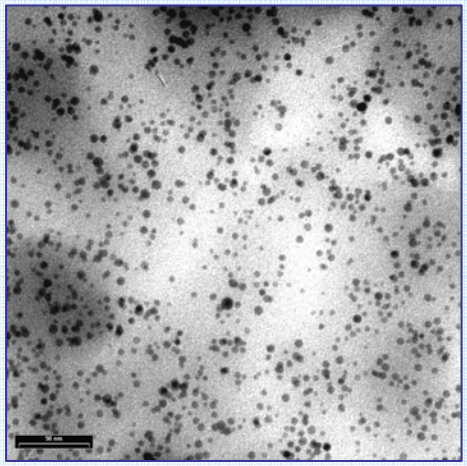
Max-Planck-Institute
of Colloids and Interfaces



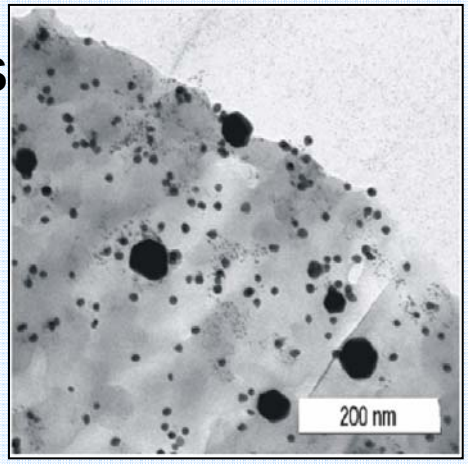
Ag



Au



Au/Au_2S



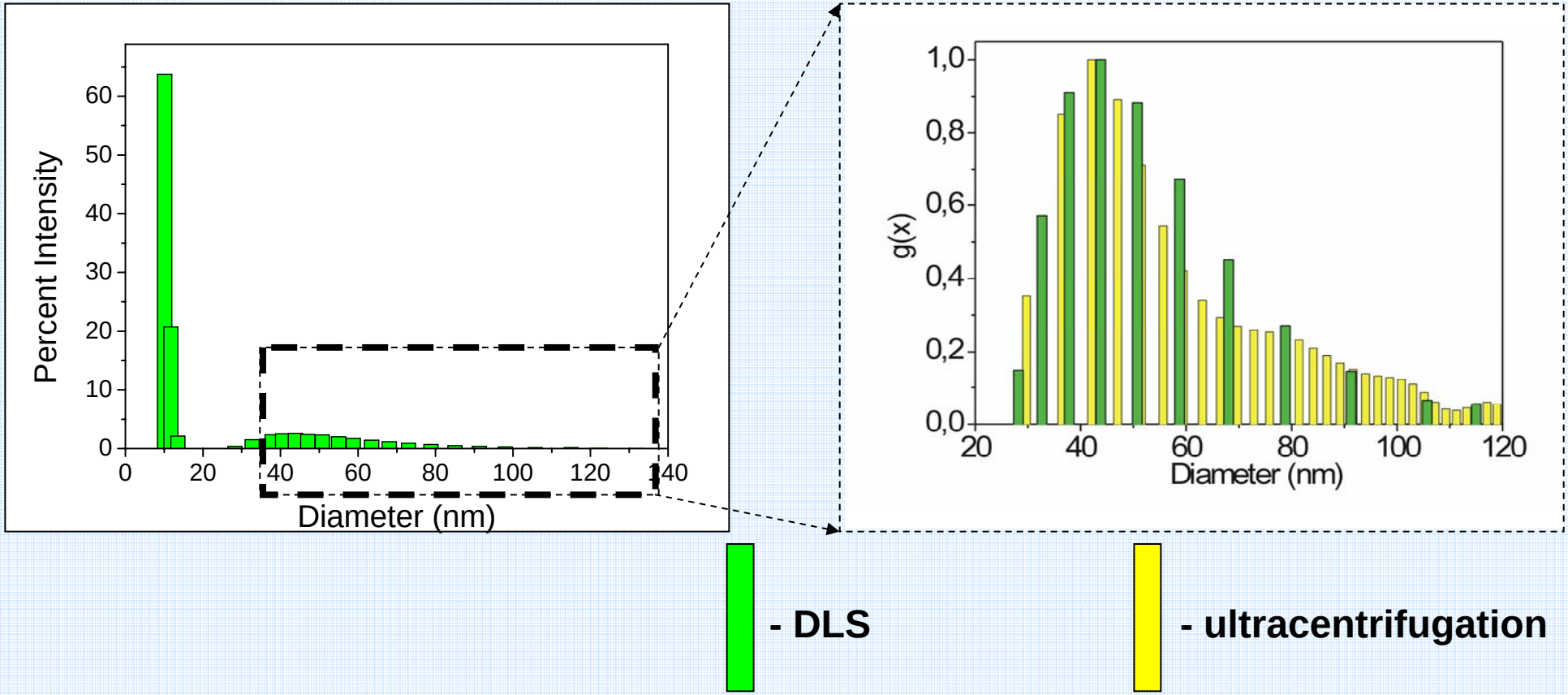
Langmuir **2004,** *20***,** 6988; *Nano Lett* **2005**, *5*, 1371.

Gold/Gold Sulfide NP's size distribution

Max-Planck-Institute of Colloids and Interfaces

Characterization & Measurements:
DLS, Ultracengr., Z-potential.

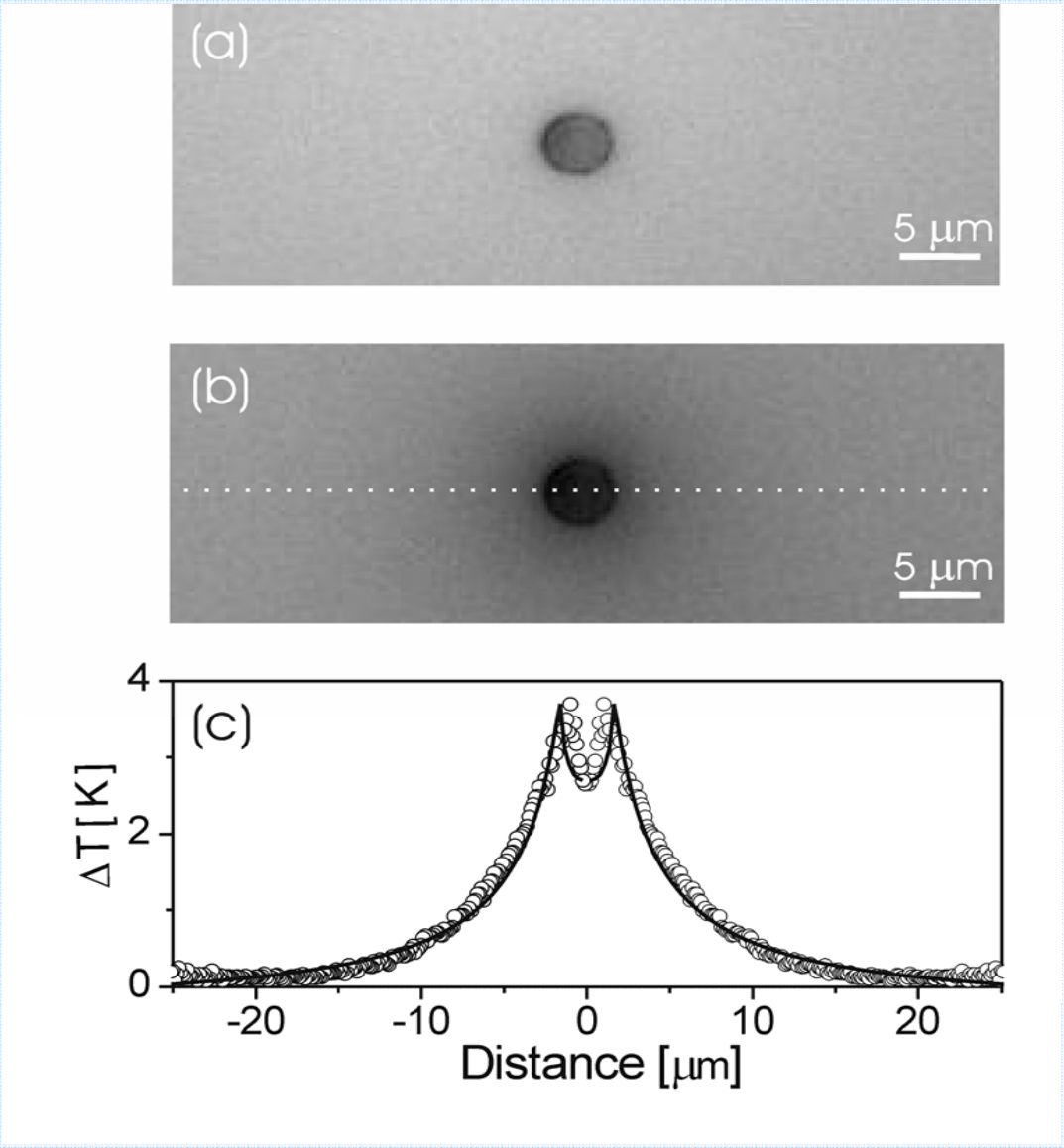
Dynamic Light Scattering (DLS) and Untracentrifugation

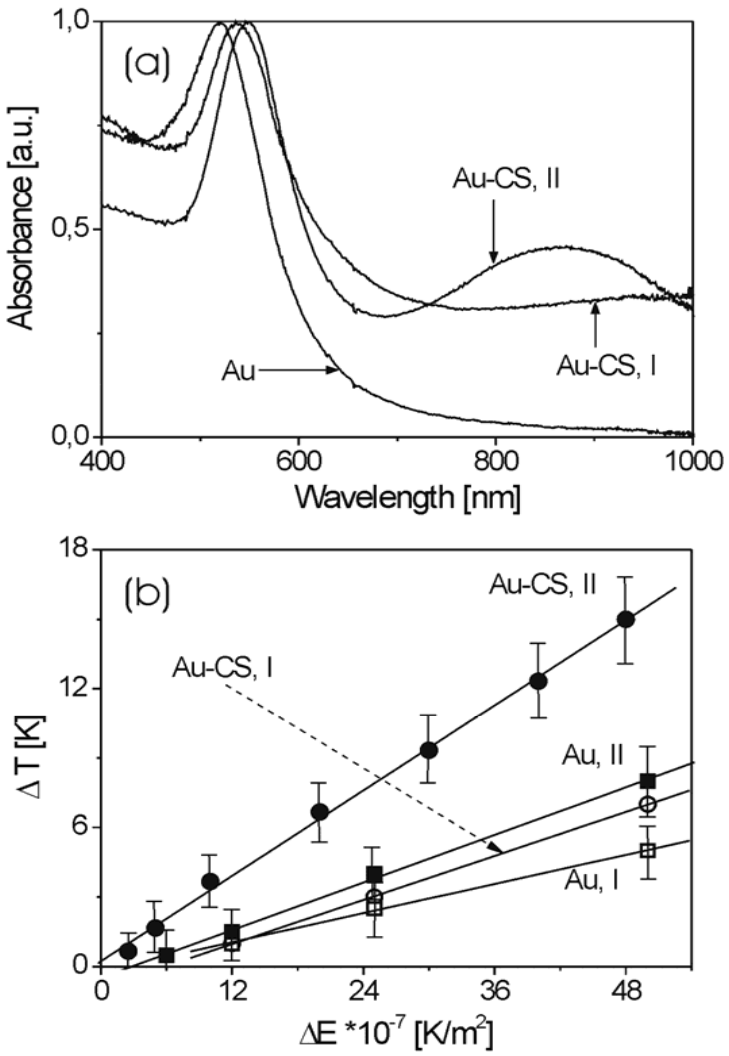


J. Phys. Chem. C **2007,** *111*, 555.

Measurement of Temperature Increase

Max-Planck-Institute of Colloids and Interfaces





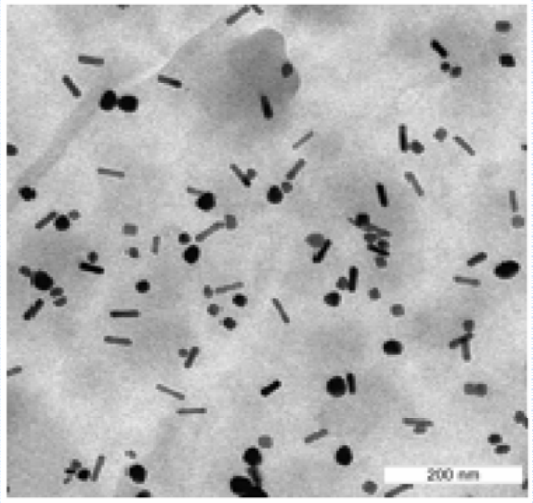
Nano Lett. **2005,** *5***,** 1371.

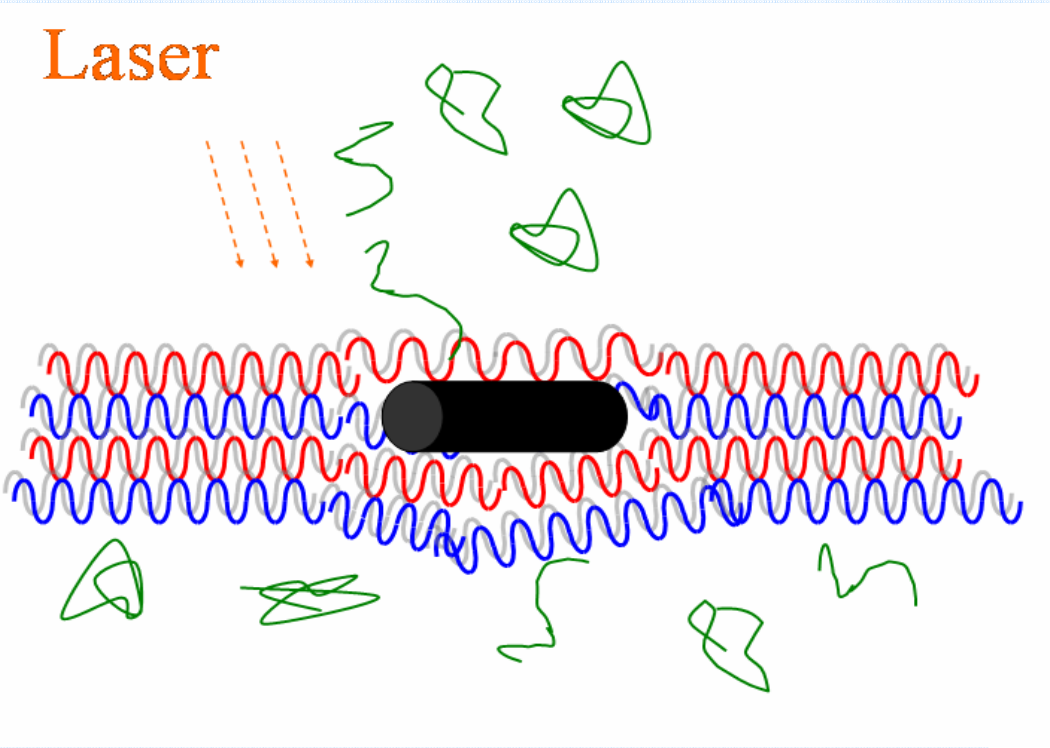
Table of Contents

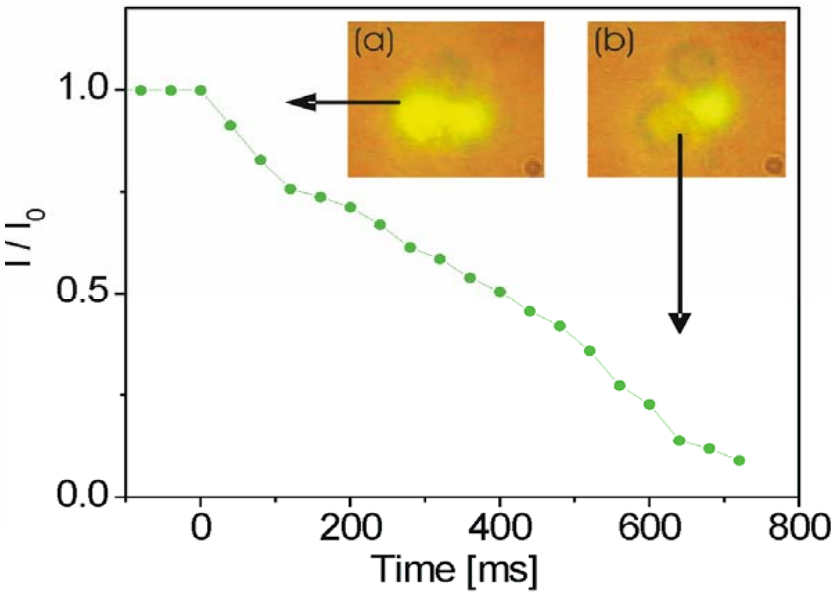
Nanorods:

Max-Planck-Institute
of Colloids and Interfaces

as New Materials for Remote Release

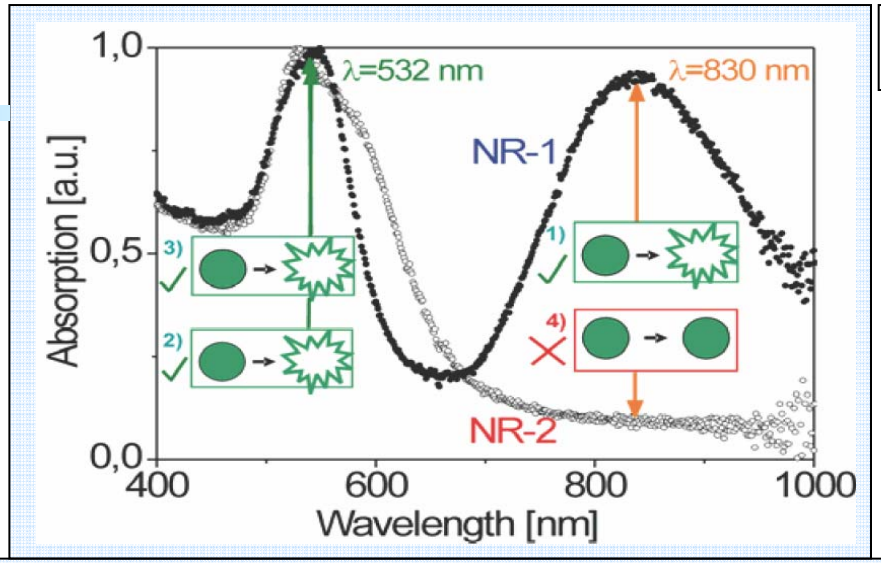






Nanorods:

Wavelength Selective Activation



Max-Planck-Institute of Colloids and Interfaces

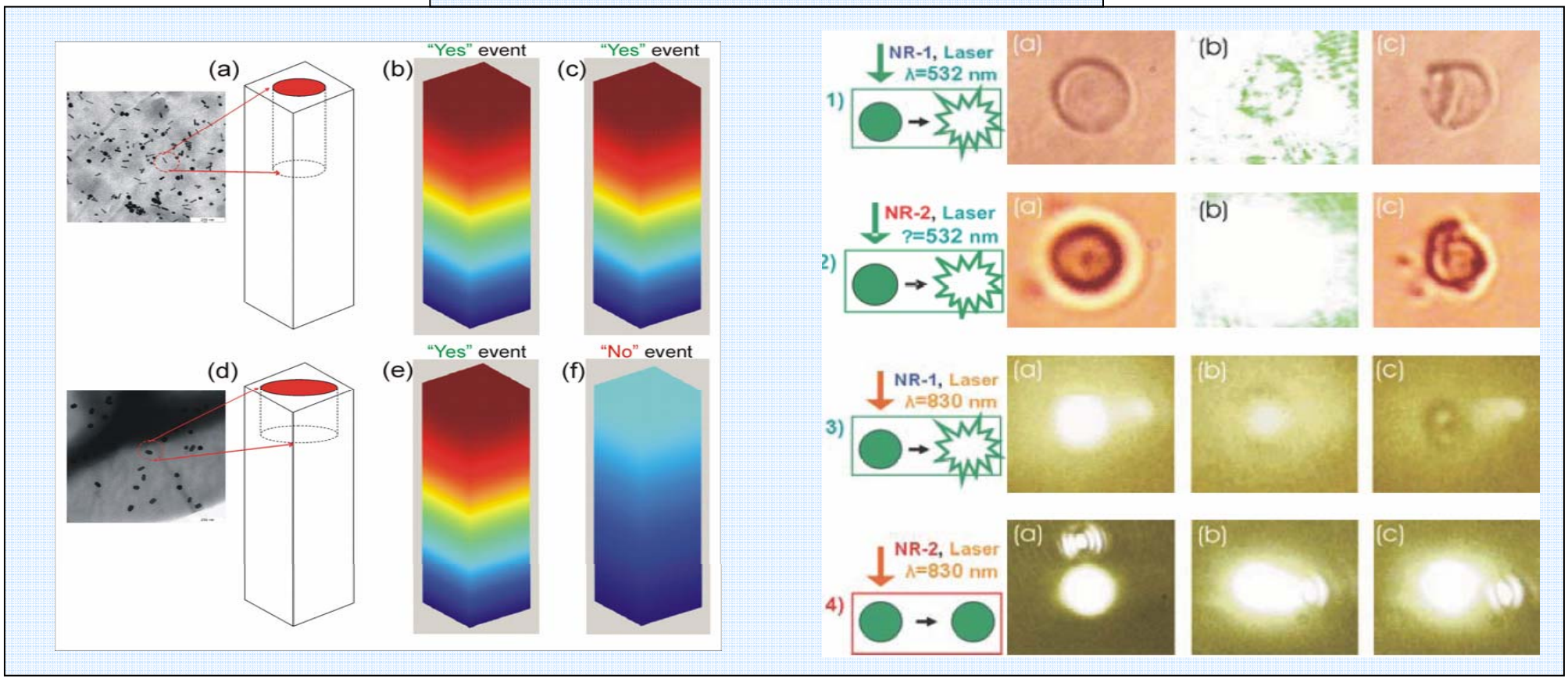


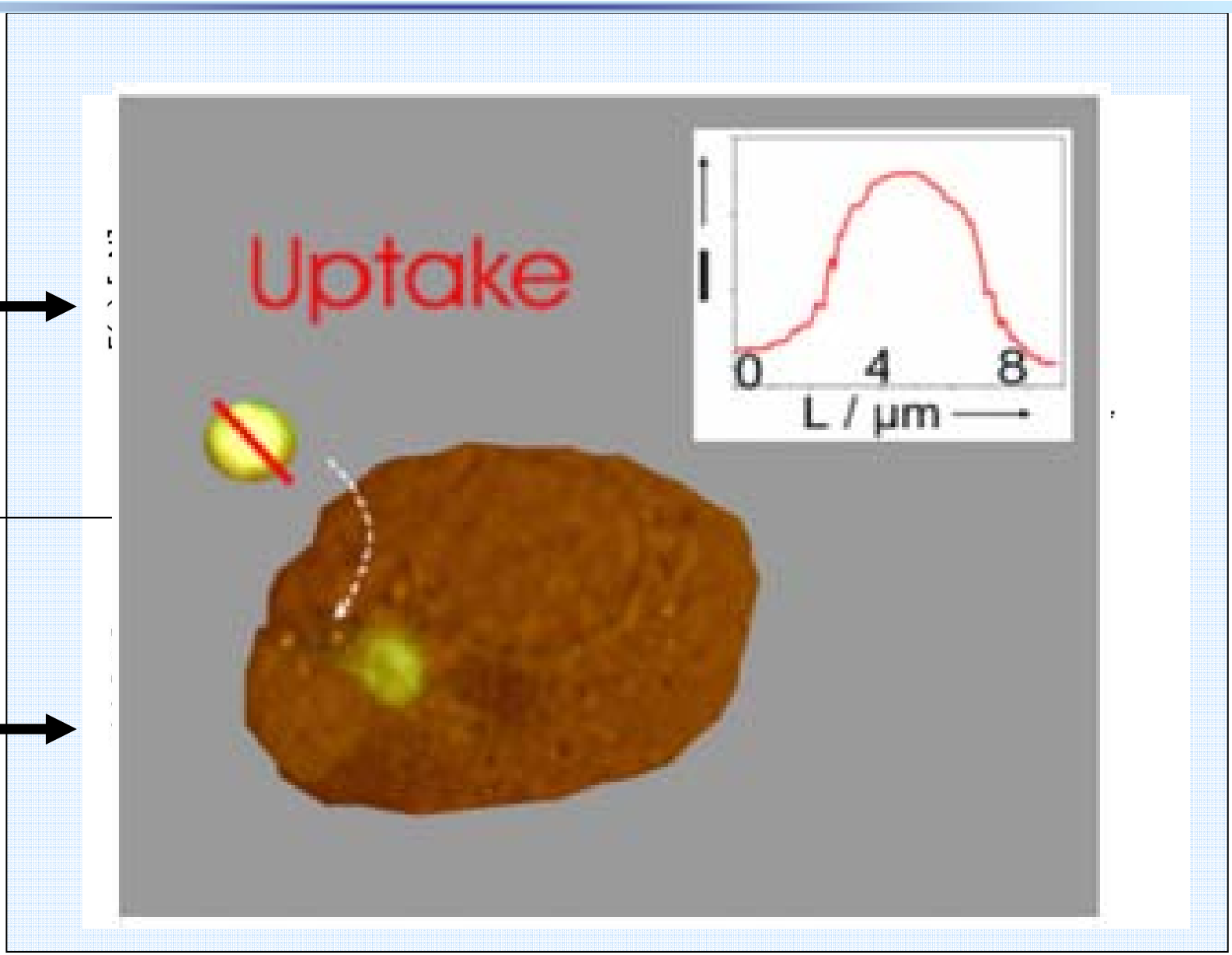
Table of Contents

Uptake of Capsules by Cells: AFM study

Max-Planck-Institute of Colloids and Interfaces

No-Interaction of Capsules at the AFM tip with Cells

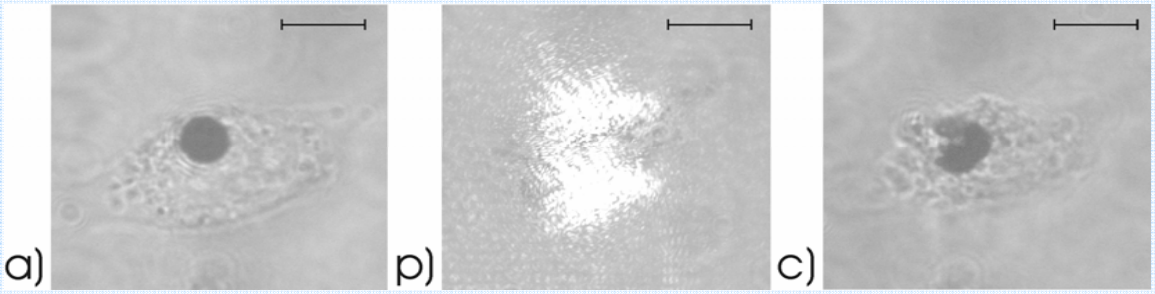
Interaction of Capsules at AFM with Cells

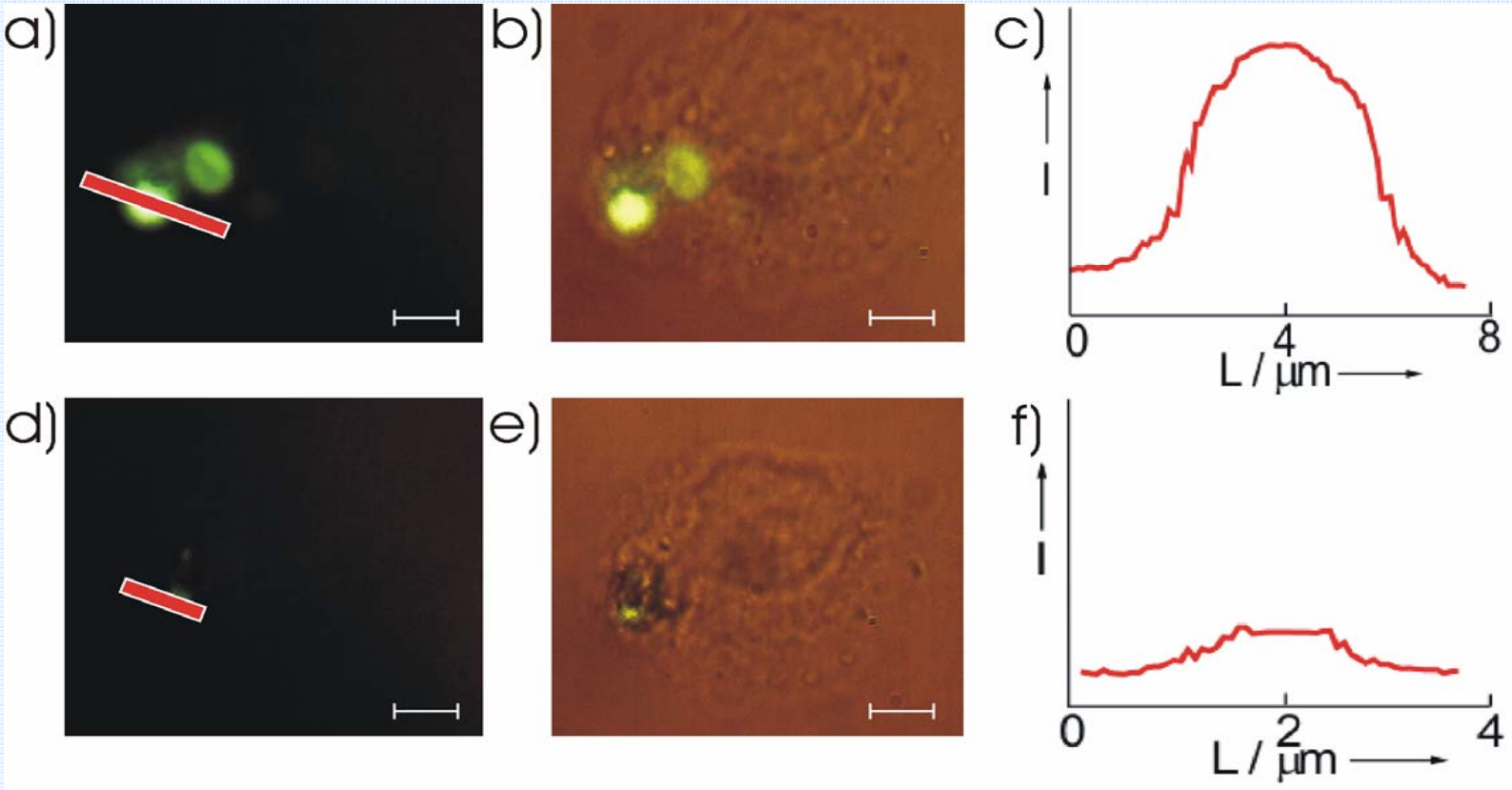


Small **2006,** *2*, 394.

Release Inside Living Cells

Max-Planck-Institute
of Colloids and Interfaces



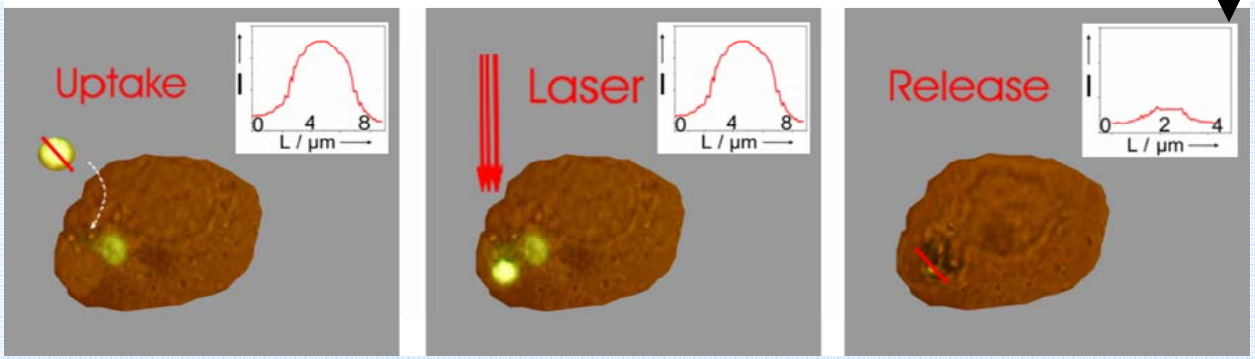


Angew. Chem. Int. Ed. **2006,** *55***,** 6412.

Pushing Not-uptaken Capsules by Laser

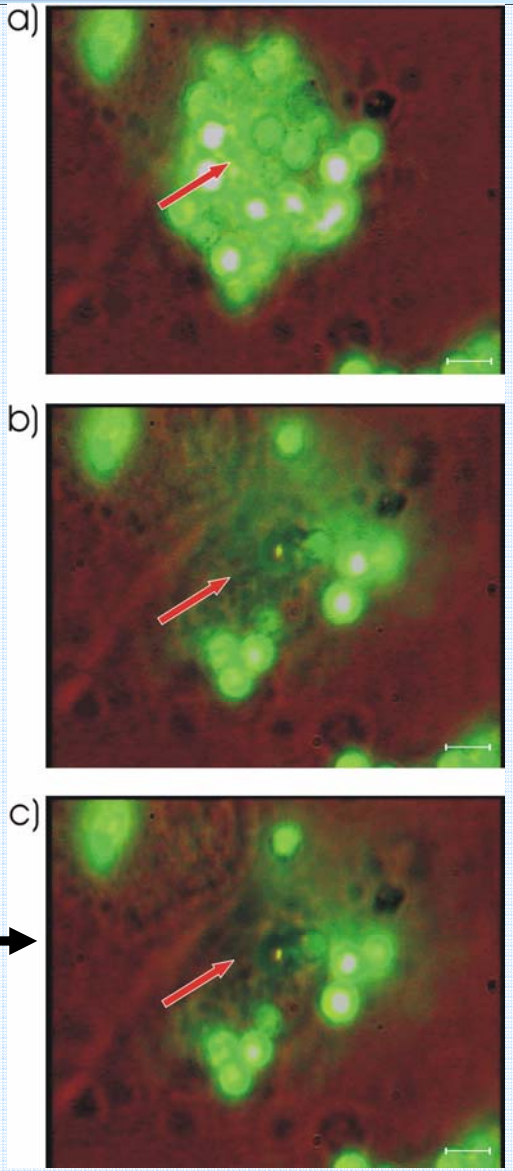
Max-Planck-Institute of Colloids and Interfaces

Intracellular Release of **Uptaken** Capsules



VERSUS

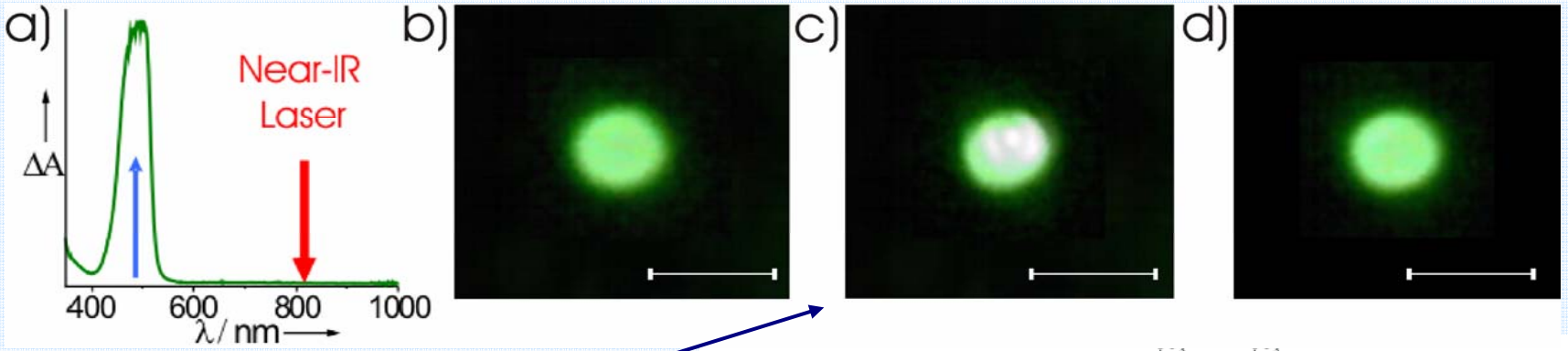
Pushing-Up **Non-uptaken** Capsules



Angew. Chem. Int. Ed. **2006,** *55***,** 6412.

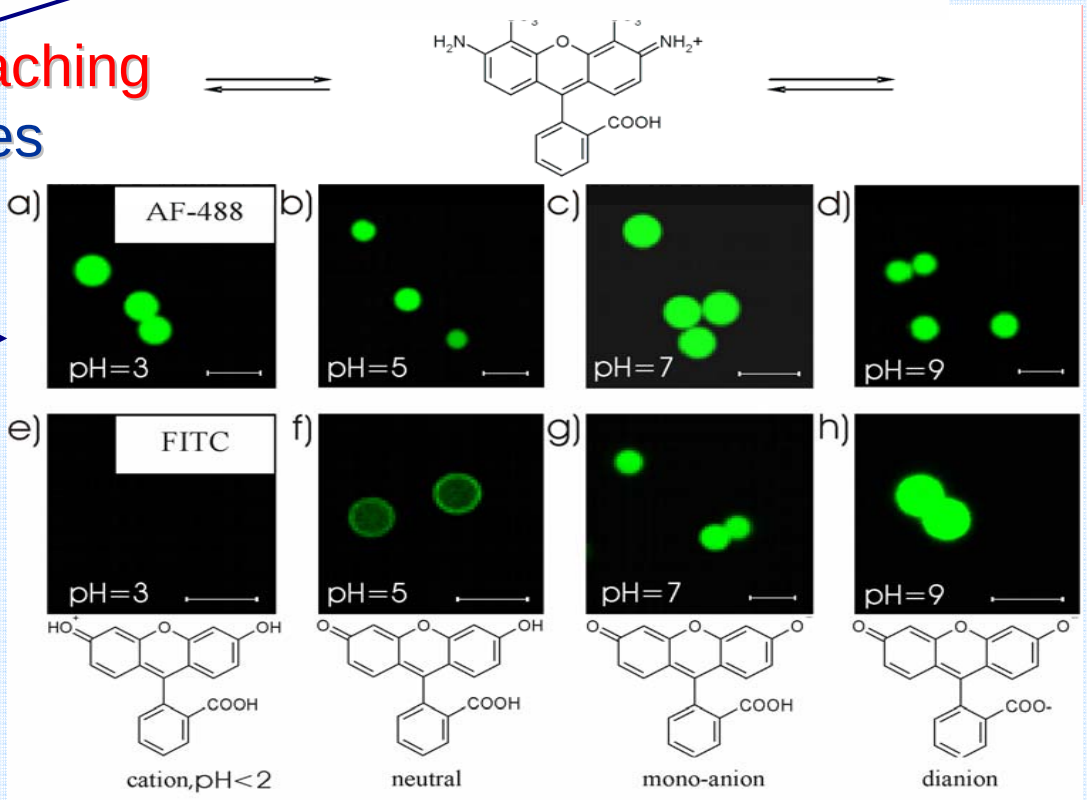
Control Experiments

Max-Planck-Institute of Colloids and Interfaces



Light Stability Control: no-Photobleaching on Capsules without Nanoparticles

pH Control



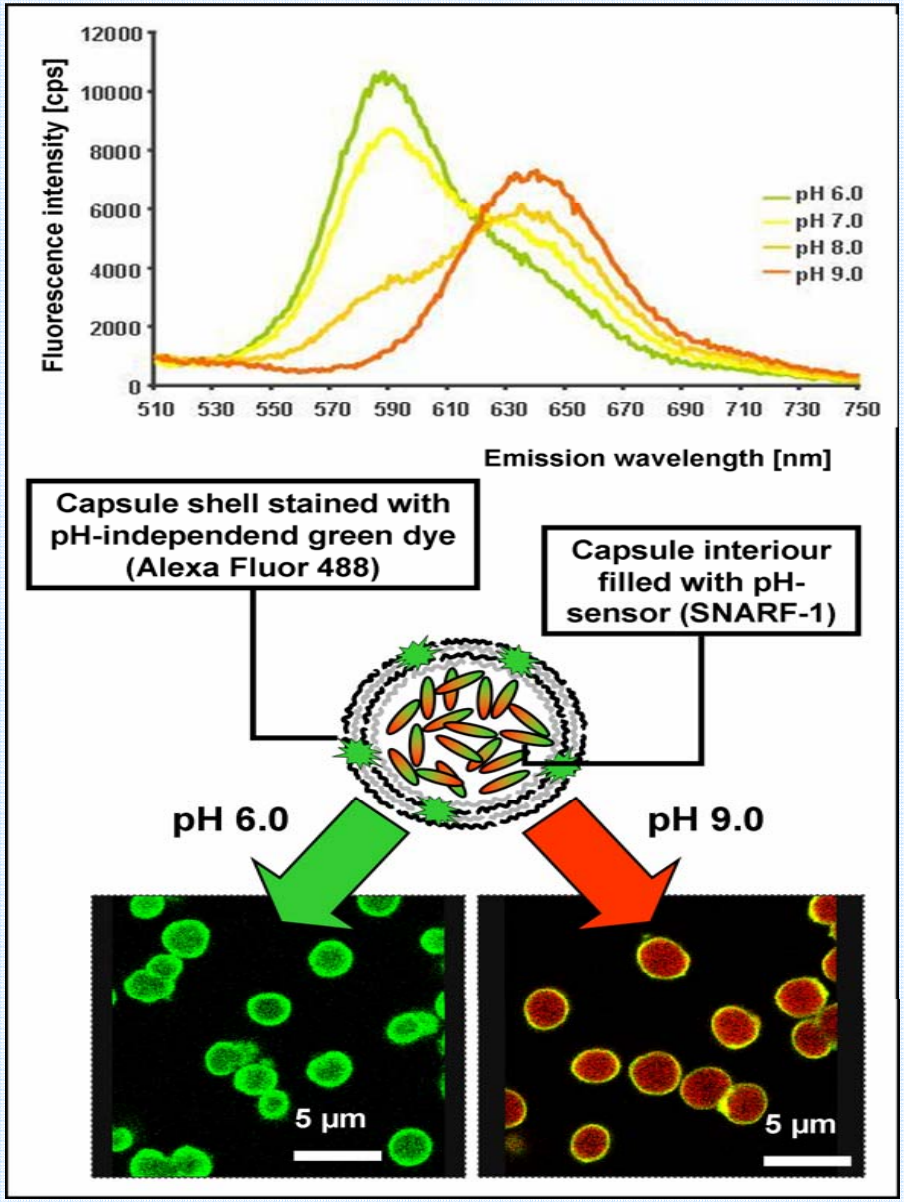
Angew. Chem. Int. Ed. **2006,** *55***,** 6412.

Sensor Applications

Max-Planck-Institute
of Colloids and Interfaces

pH sensors encapsulated in
PEM microcapsules

This work is relevant for
Intracellular sensing (O. Kreft)



CONCLUSIONS:

Max-Planck-Institute of Colloids and Interfaces

1. **Polyelectrolyte multilayer capsules based on coating of polymers on microparticles were developed as carriers of encapsulated cargo.**

2. **Encapsulation by *pH induced swelling*, *co-precipitation* and *temperature shrinking methods* has been developed.**

3. **Remote release of encapsulated materials can be performed by a number of methods. The mechanism relies on interaction of absorbing metal nanoparticles and external energy sources, for example, laser light or ultrasound.**

4. **Nanorods are identified as effective absorbing centers for biologically relevant release applications.**

5. **A variety of applications (*bio-medicine, pharmaceutical, perfume, chemical*) can exploit encapsulation and remote release from polyelectrolyte multilayer capsules. Intracellular sensors and remote release have been developed.**

Max-Planck-Institute
of Colloids and Interfaces

ACKNOWLEDGMENTS:

- **Max-Planck Institute of Colloids and Interfaces and Max-Planck Gesellschaft.**

- **EU FP-6 framework projects "*SelectNANO*" and "*Nanocaps*".**

- **VW foundation.**

Thank you for your attention.