

Microreaction Techniques: Challenge Between Continuous Nanoparticle Synthesis and Fluid- Based Nanoengineering

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Lichtenwalde, October 2009



Outline

Introduction

Continuous-flow preparation of metal nanoparticles

- * **Au-Nanoparticles**
- * **Ag-Nanoparticles**
- * **binary nanoparticles Au/Ag**
- * **ZnO nanoparticles**

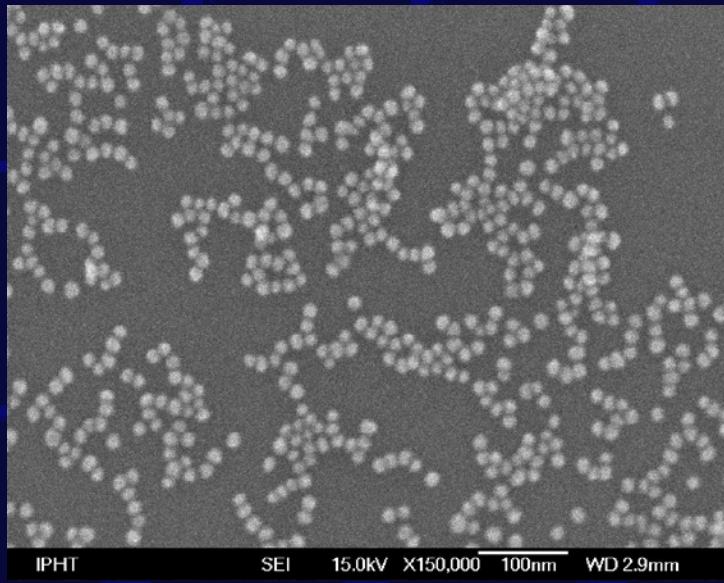
Challenges for micro segmented flow technique for nanoparticle synthesis and information processing

Conclusions



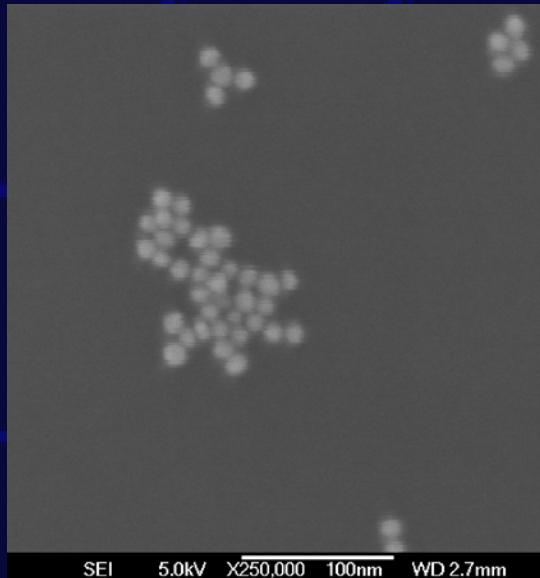
Continuous-flow preparation of Au-Nanoparticles



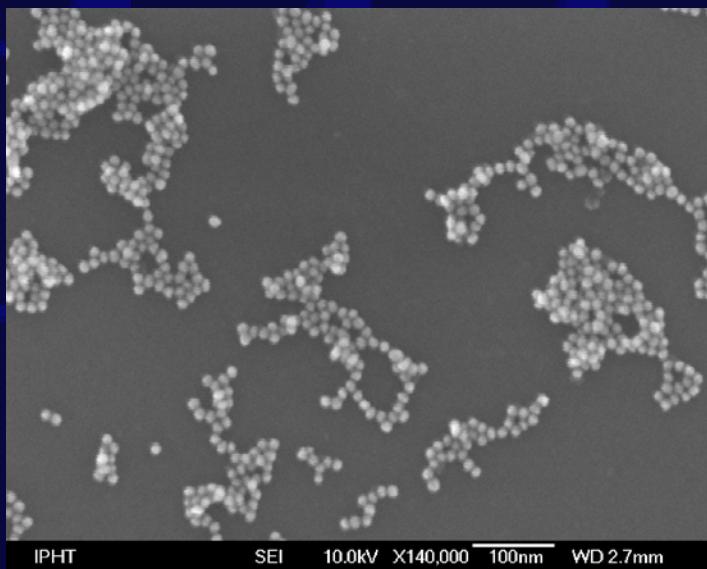


IPHT

SEI 15.0kV X150,000 100nm WD 2.9mm

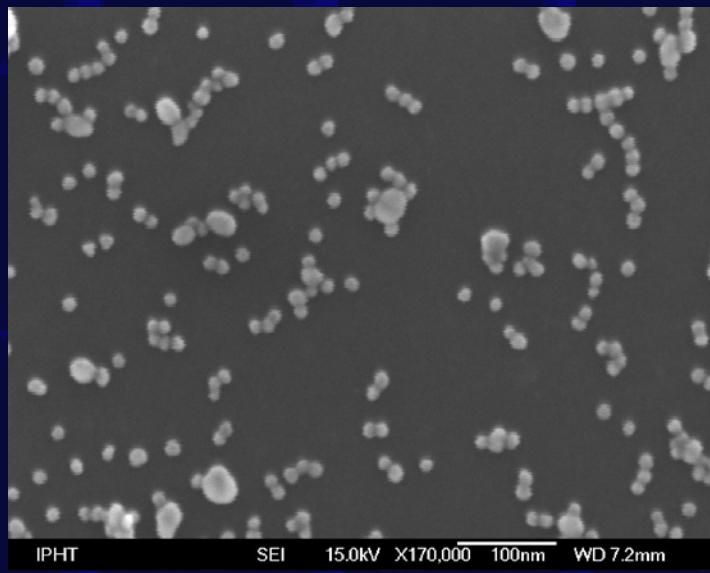


SEI 5.0kV X250,000 100nm WD 2.7mm



IPHT

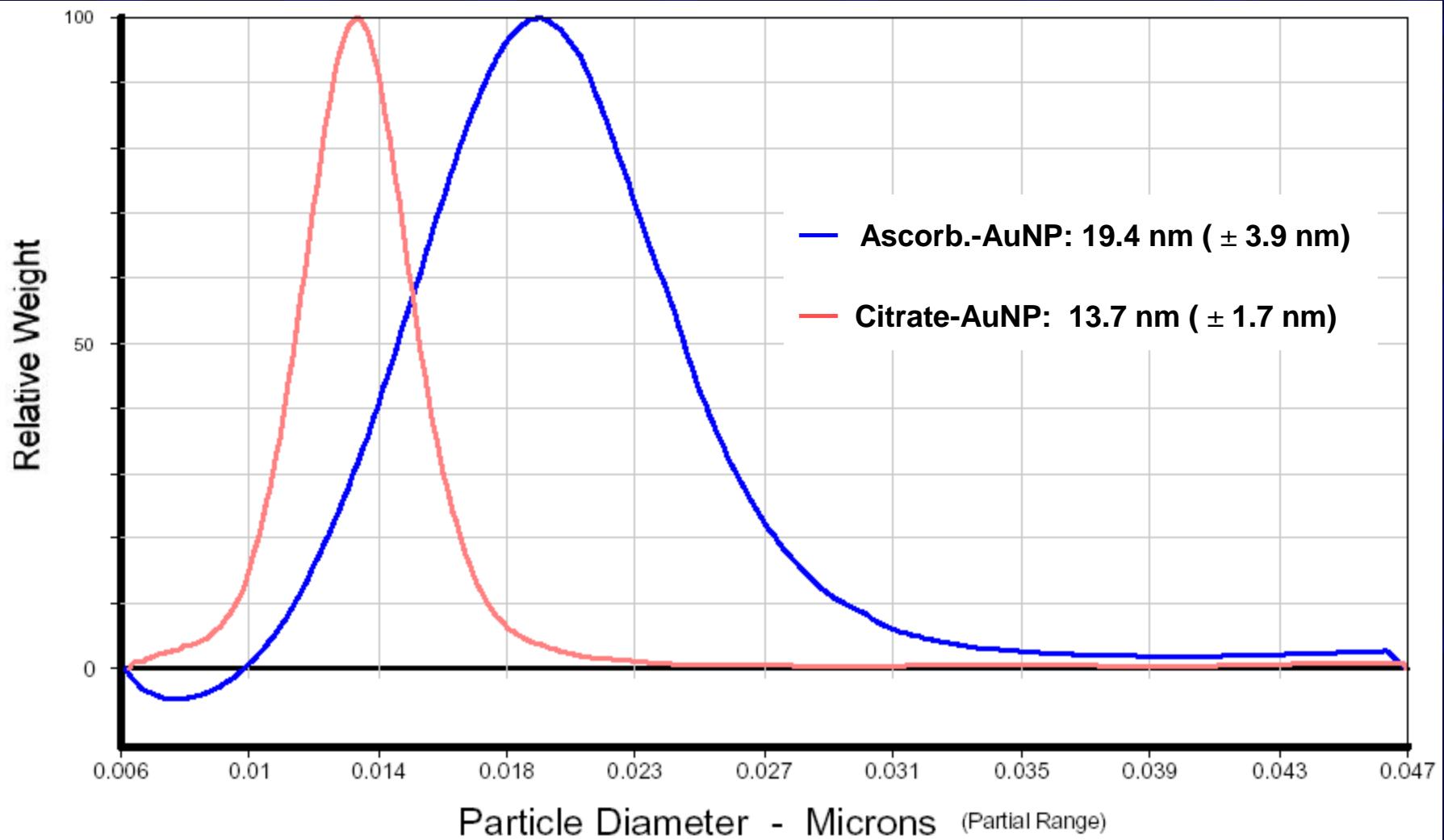
SEI 10.0kV X140,000 100nm WD 2.7mm

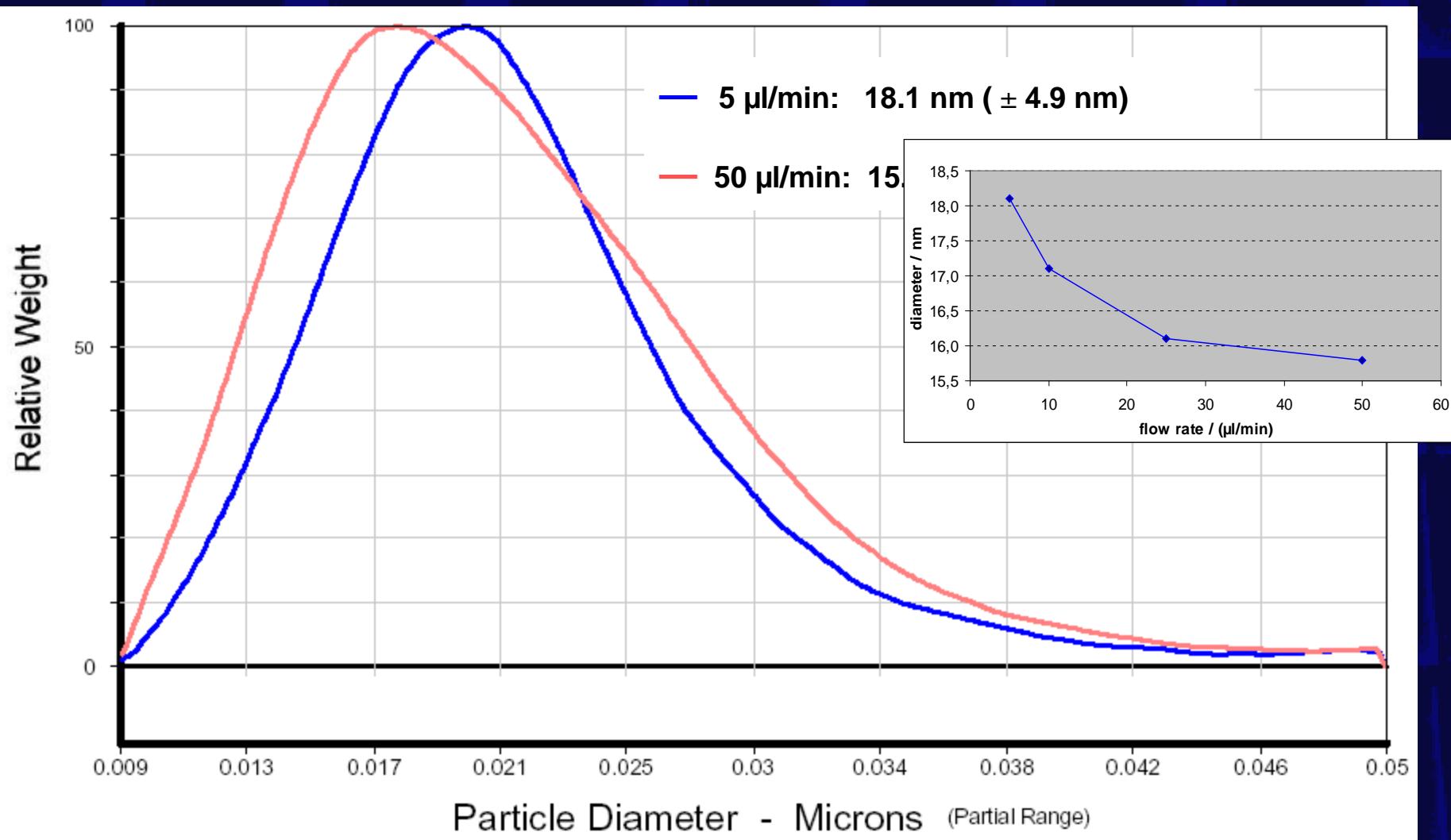


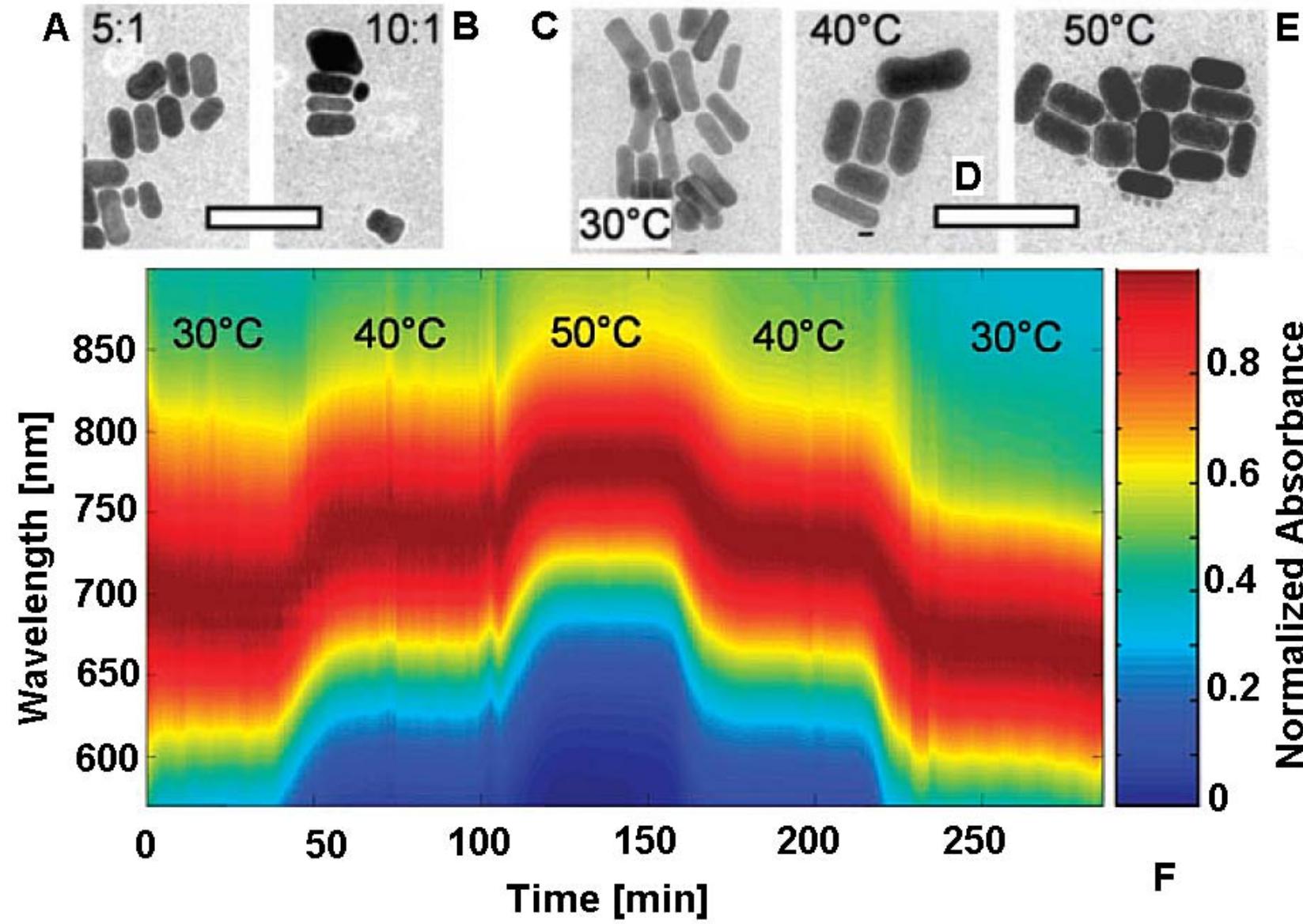
IPHT

SEI 15.0kV X170,000 100nm WD 7.2mm

Examples of Au Nanoparticles (SEM images)





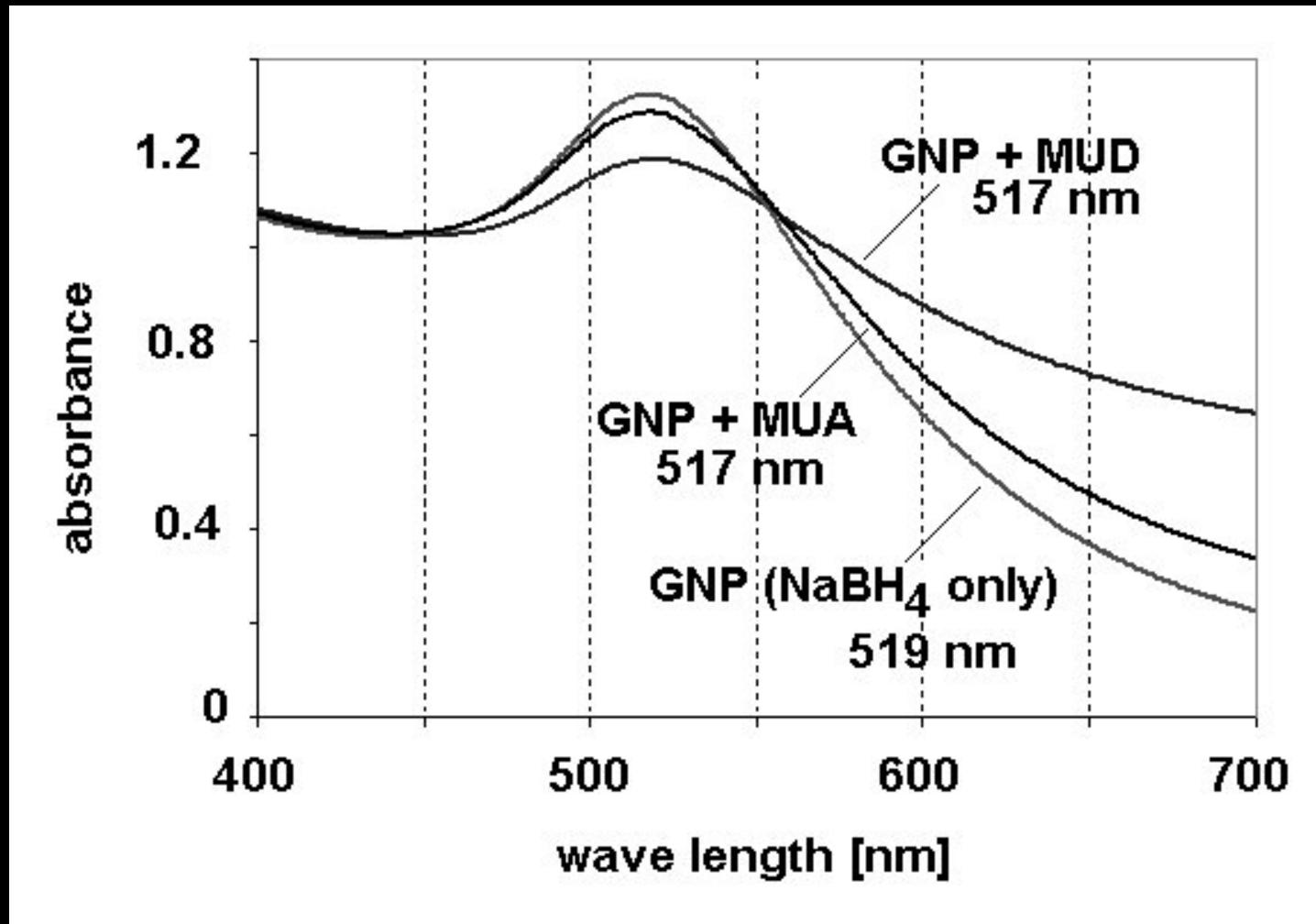


Microfluidic synthesis of Au nanorods; J. Boleininger et al. 2006, PCCP 8, 32



GNP spectra, generation by sodium borohydride

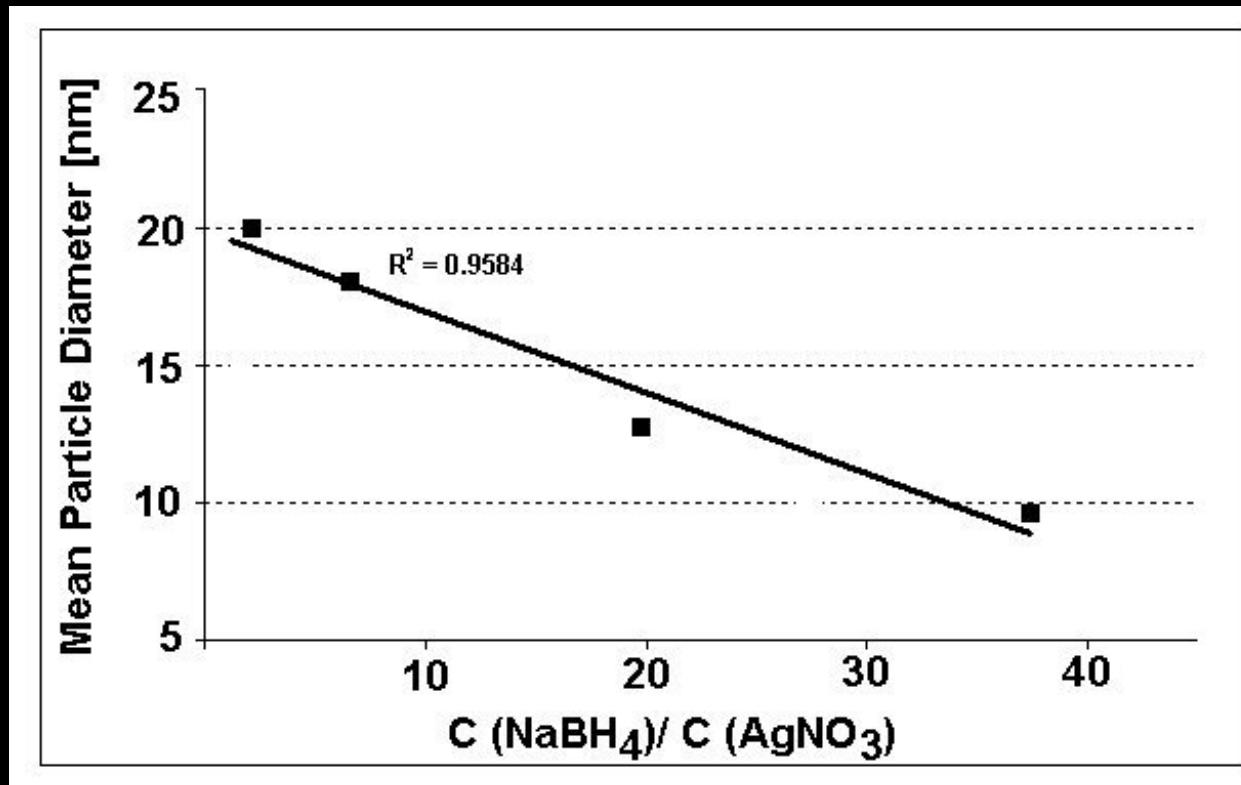
(different effectors: mercaptoundecanoic acid, mercaptoundecanol



Ag-Nanoparticles



Influence of reduction of educt ratio on particle size in SNP formation under flow-through conditions



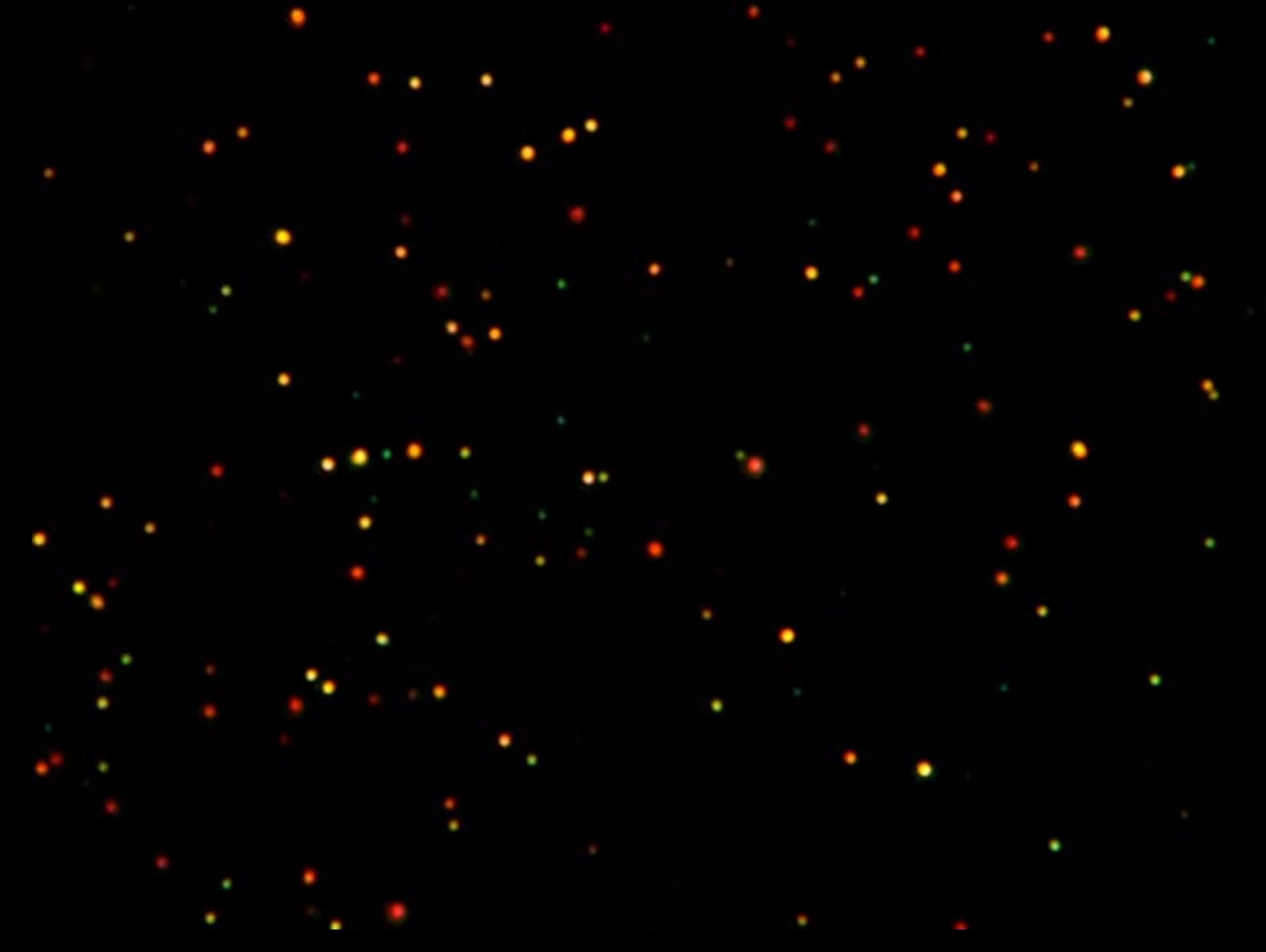
Binary nanoparticles Au/Ag



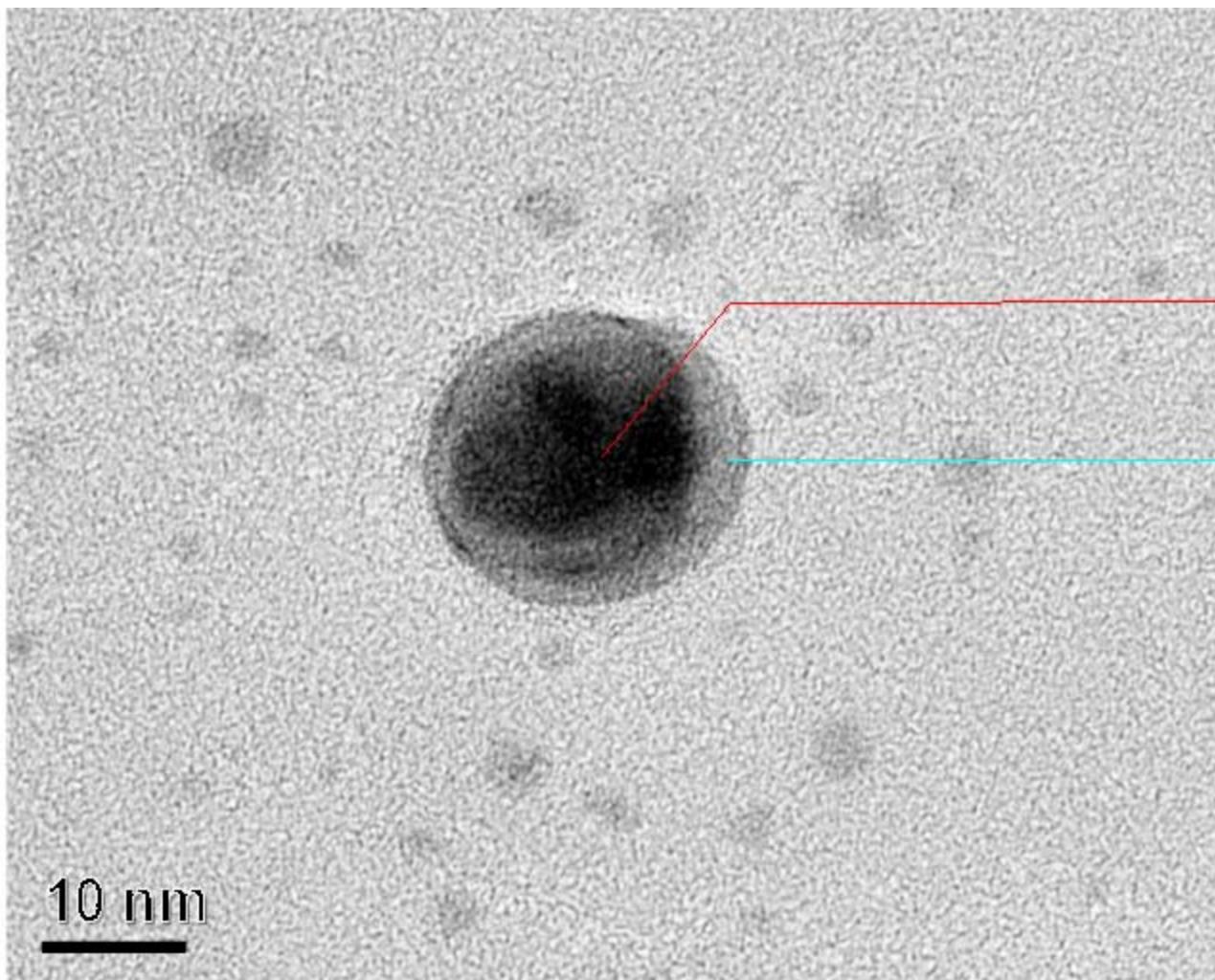
Au/Ag nanoparticles (different composition
and different conditions of formation)

A: N23 B: R2 C: Q14 D: Q4 E: R1
F: Q5 G: P7 H: R3





TEM image

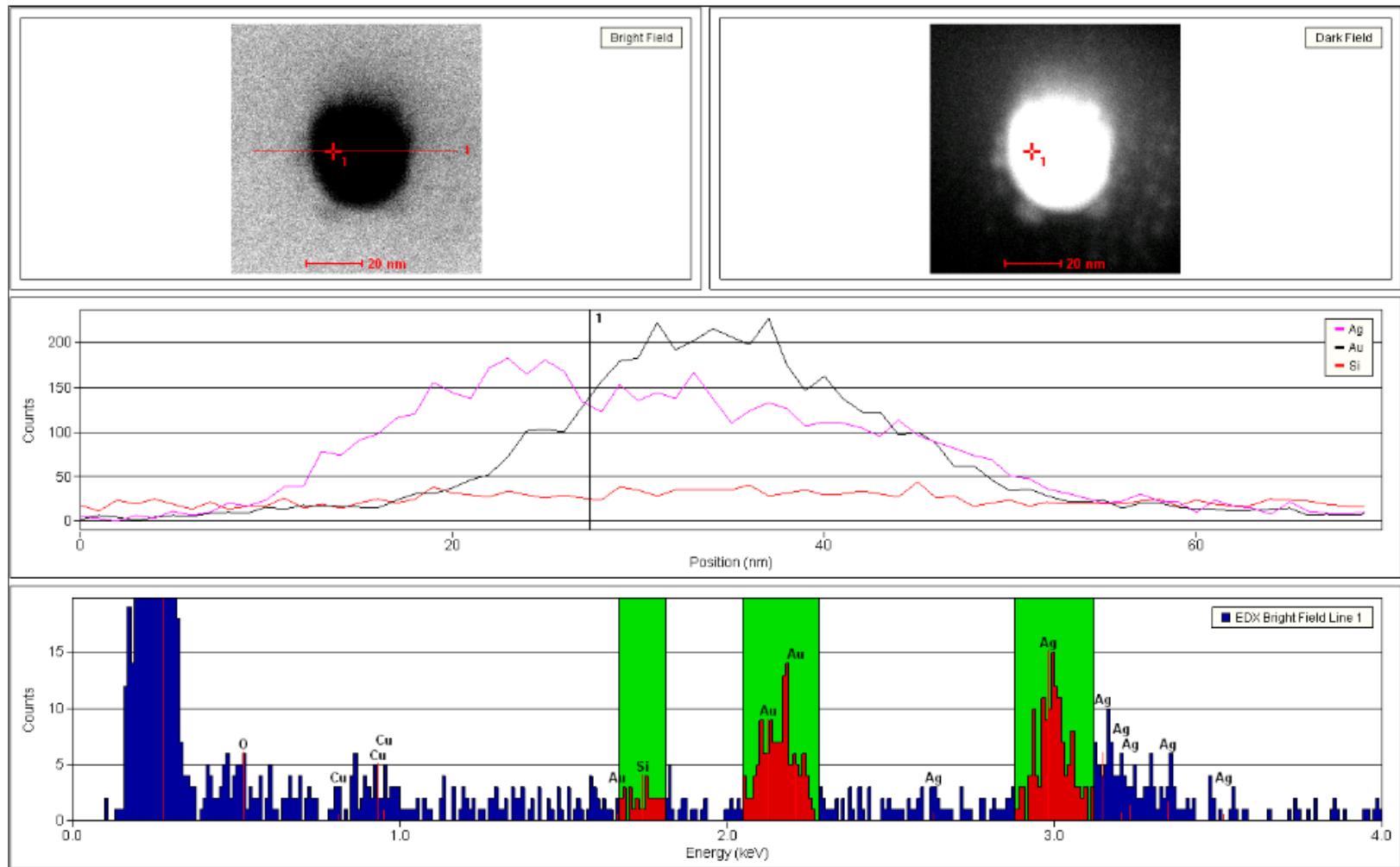


10 nm

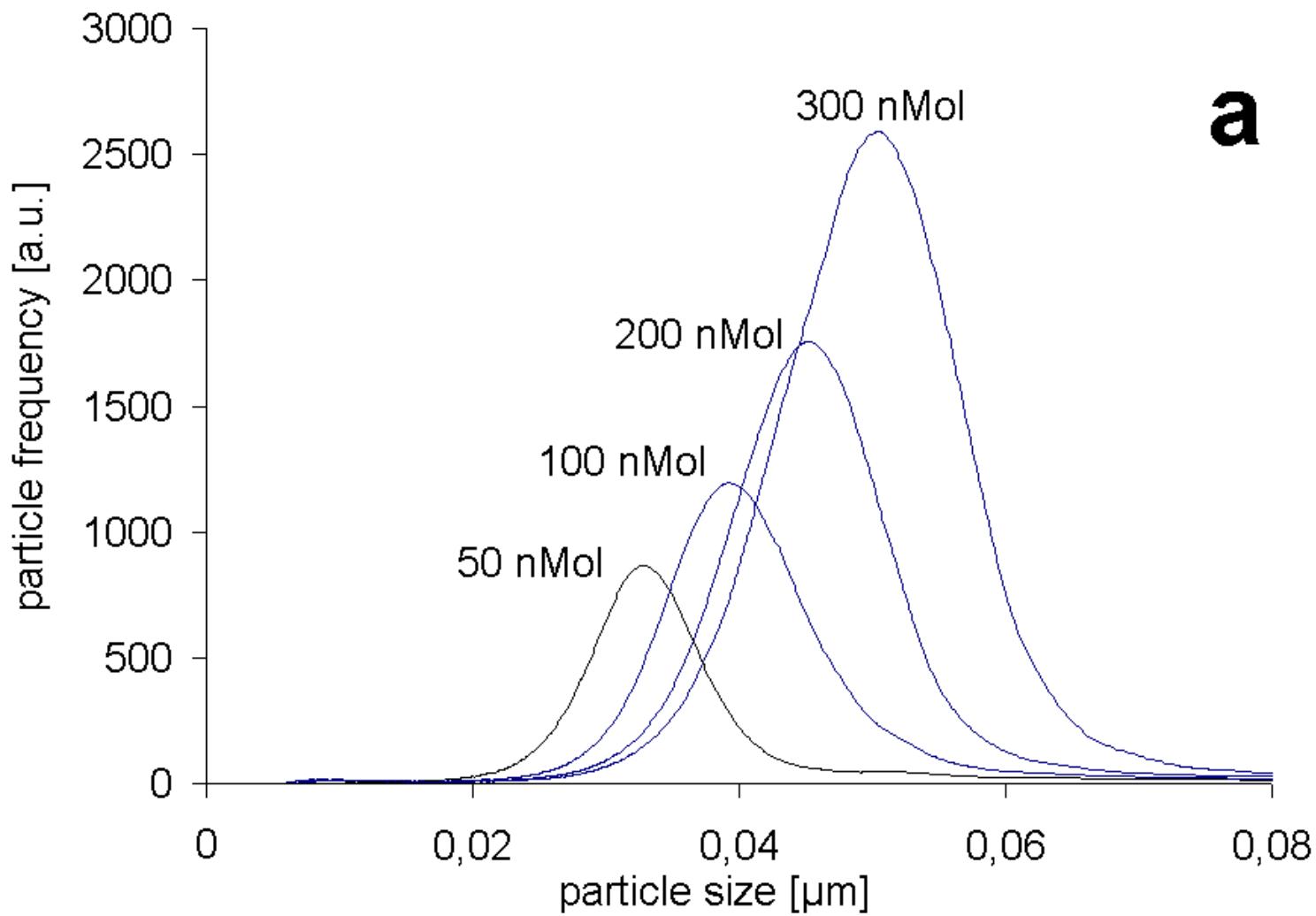
scale bar: 10 nm

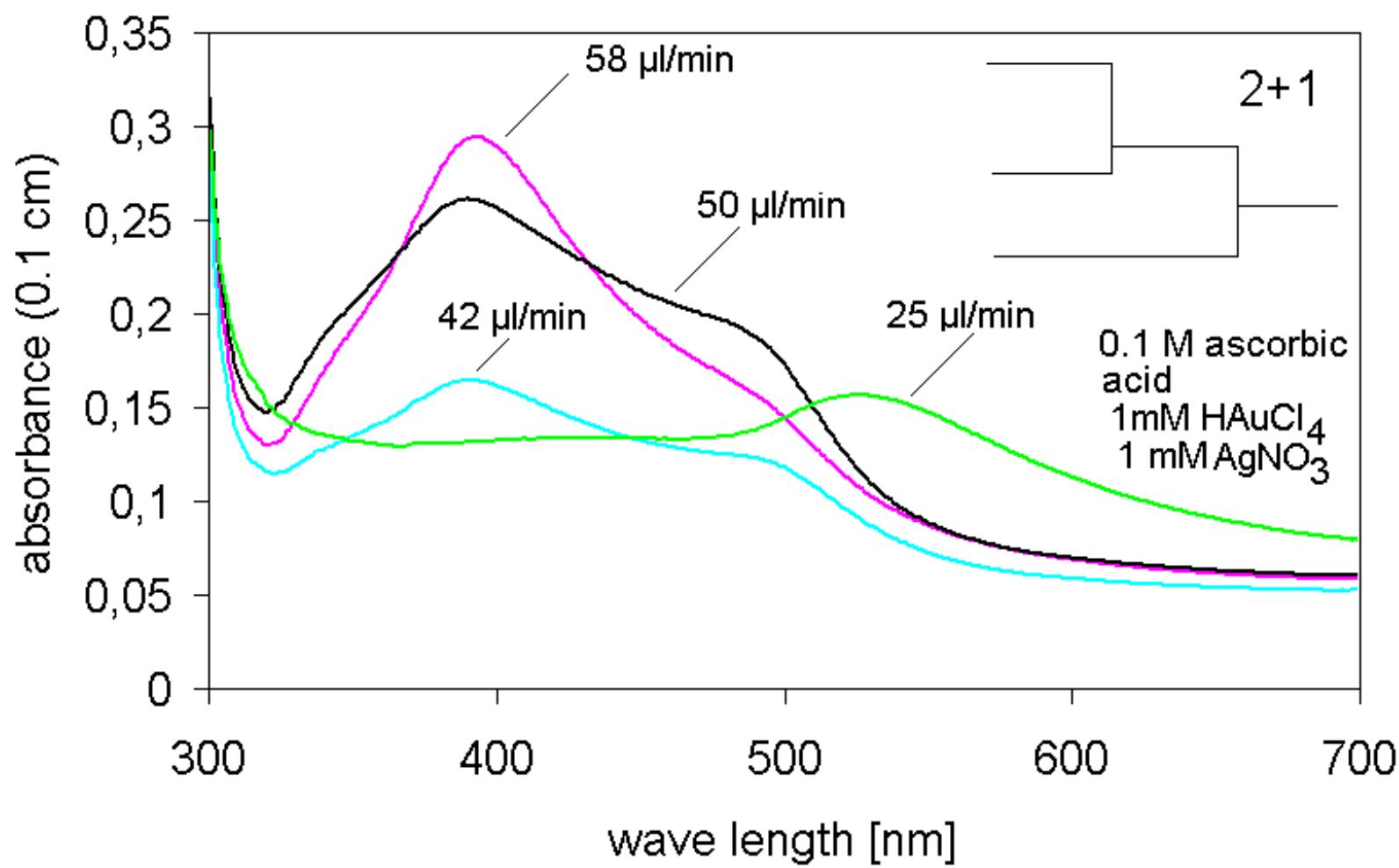


Spatially resolved EDX analysis indicating the core/shell character of obtained particles

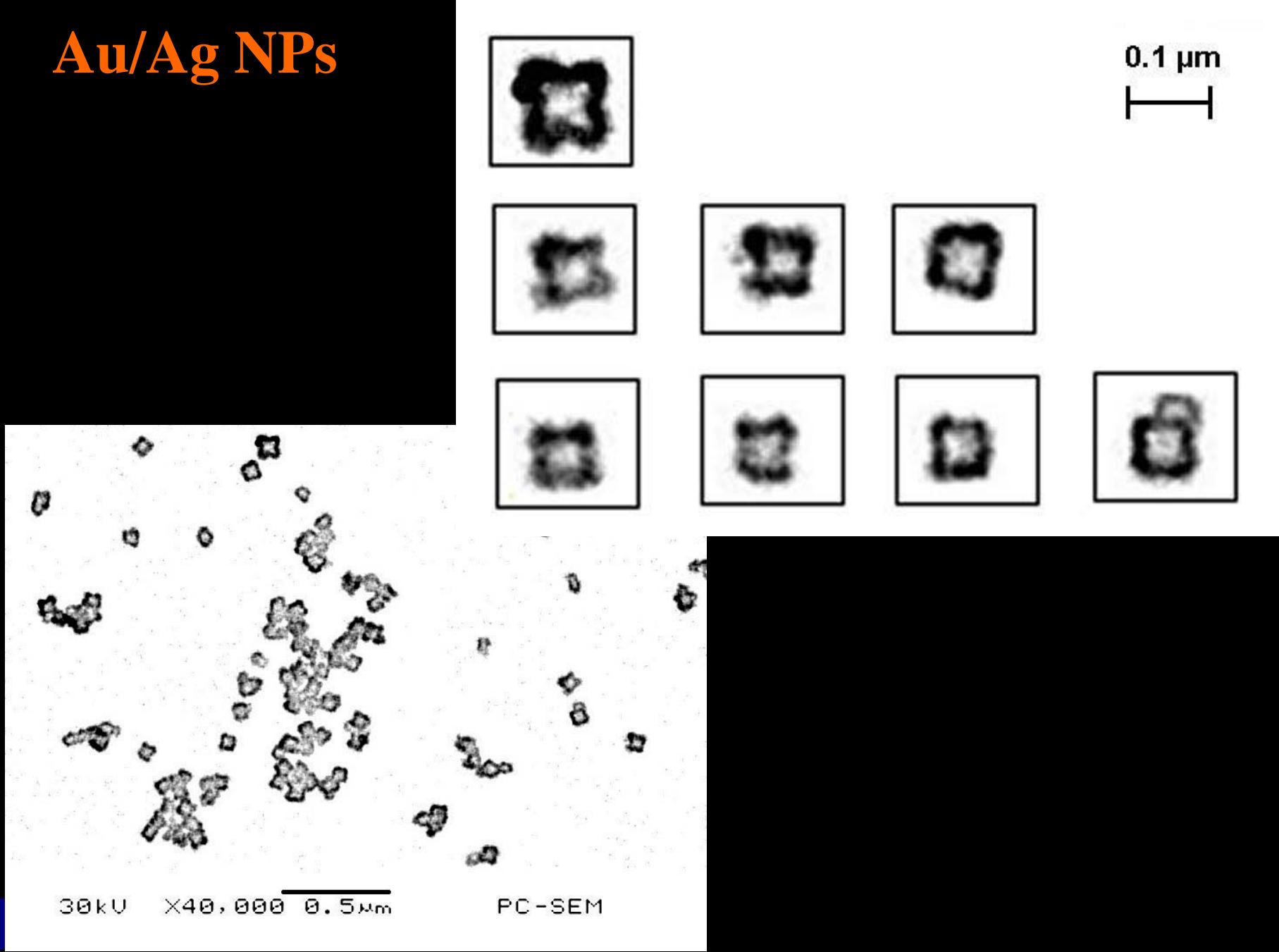


Centrifugal sedimentation spectroscopy
(mass-related signal): Increasing Ag shell diameter





Au/Ag NPs



Promising droplets:

Recent applications



0,5 mm tube /
Perfluorinated carrier
liquid
(S. Schneider 2004)

micro segmented flow



application in

nanoparticle synthesis

V. Hessel et al.
A. DeMello et al.

analytics
R.M. Ismagilov et al.

organic synthesis
P.M. Guenther

polymerization
G.A. Gross et al.

embryonic development studies
A. Broesing et al.

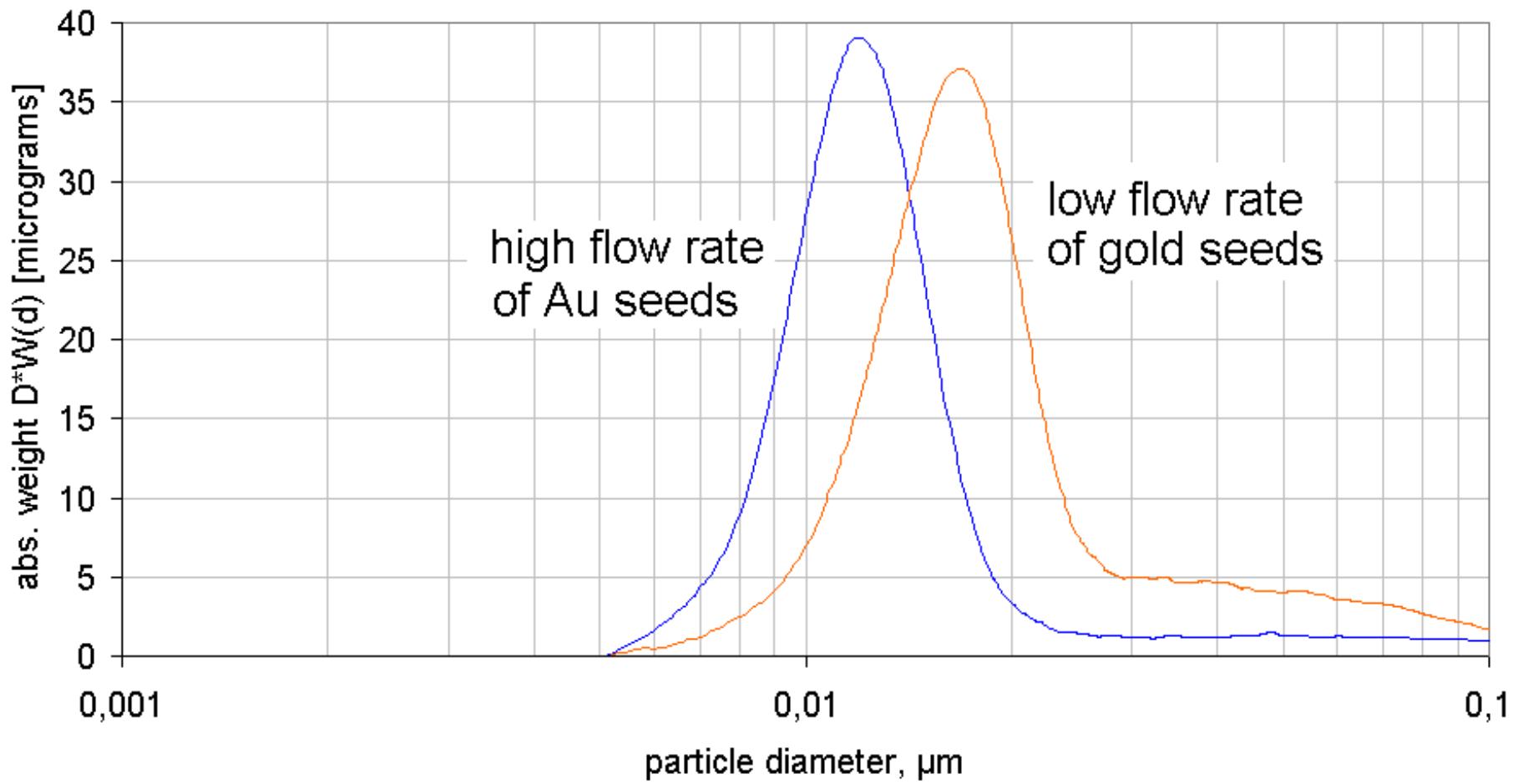
cell technology and screening
K. Martin, J. Metze et al.

toxicology
A. Funfak et al.

biochemistry
R.M. Ismagilov et al.

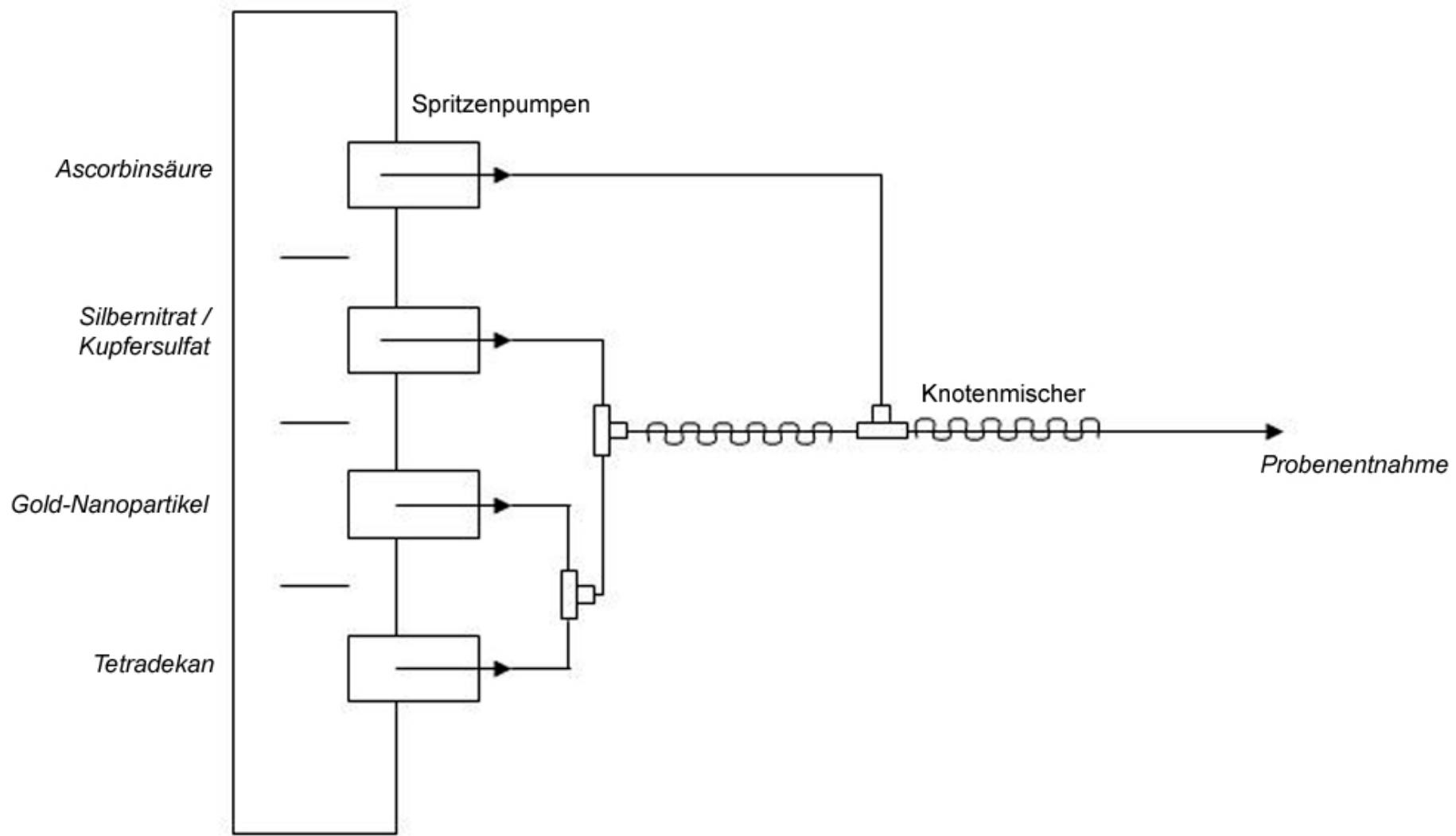


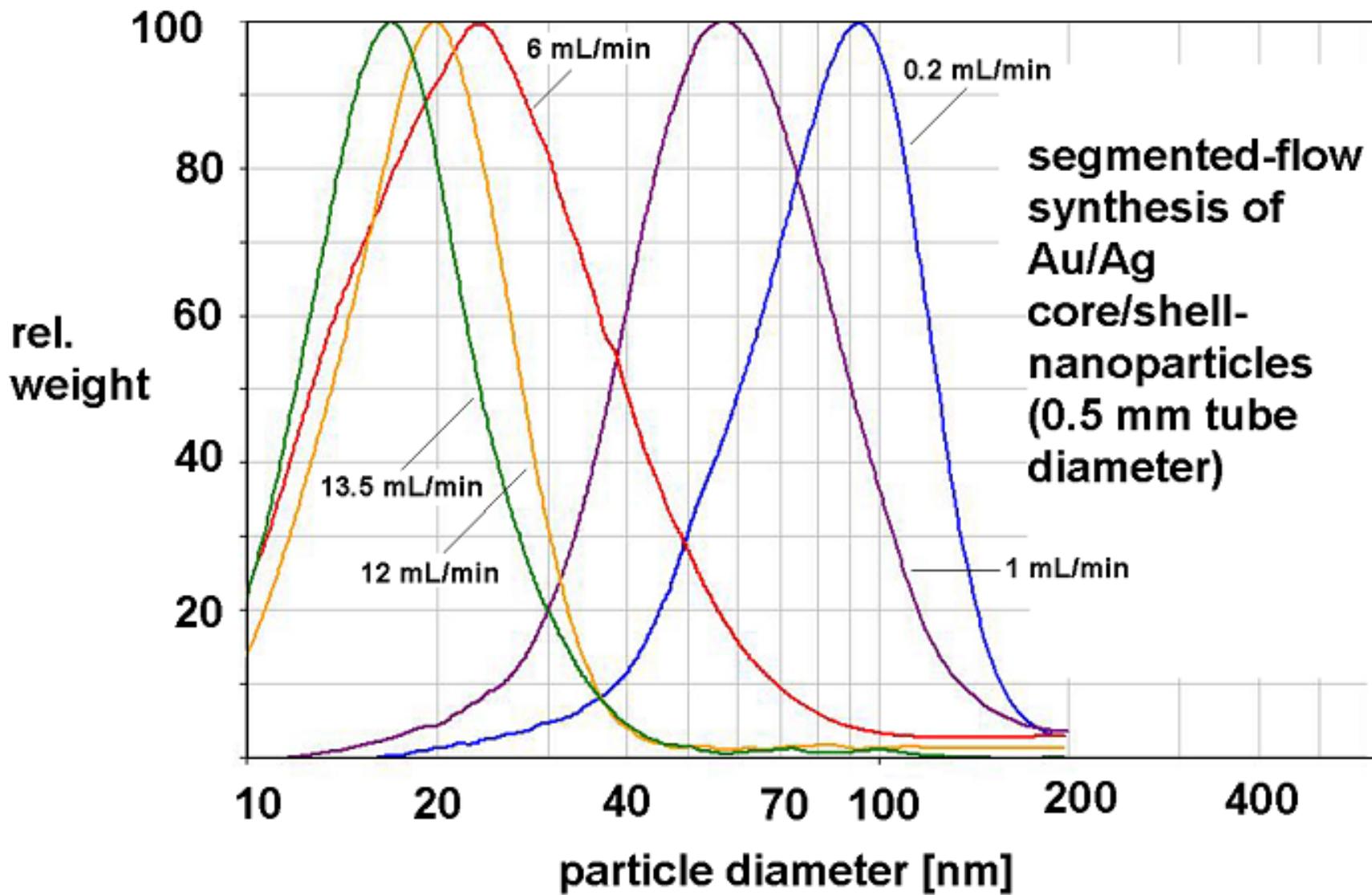




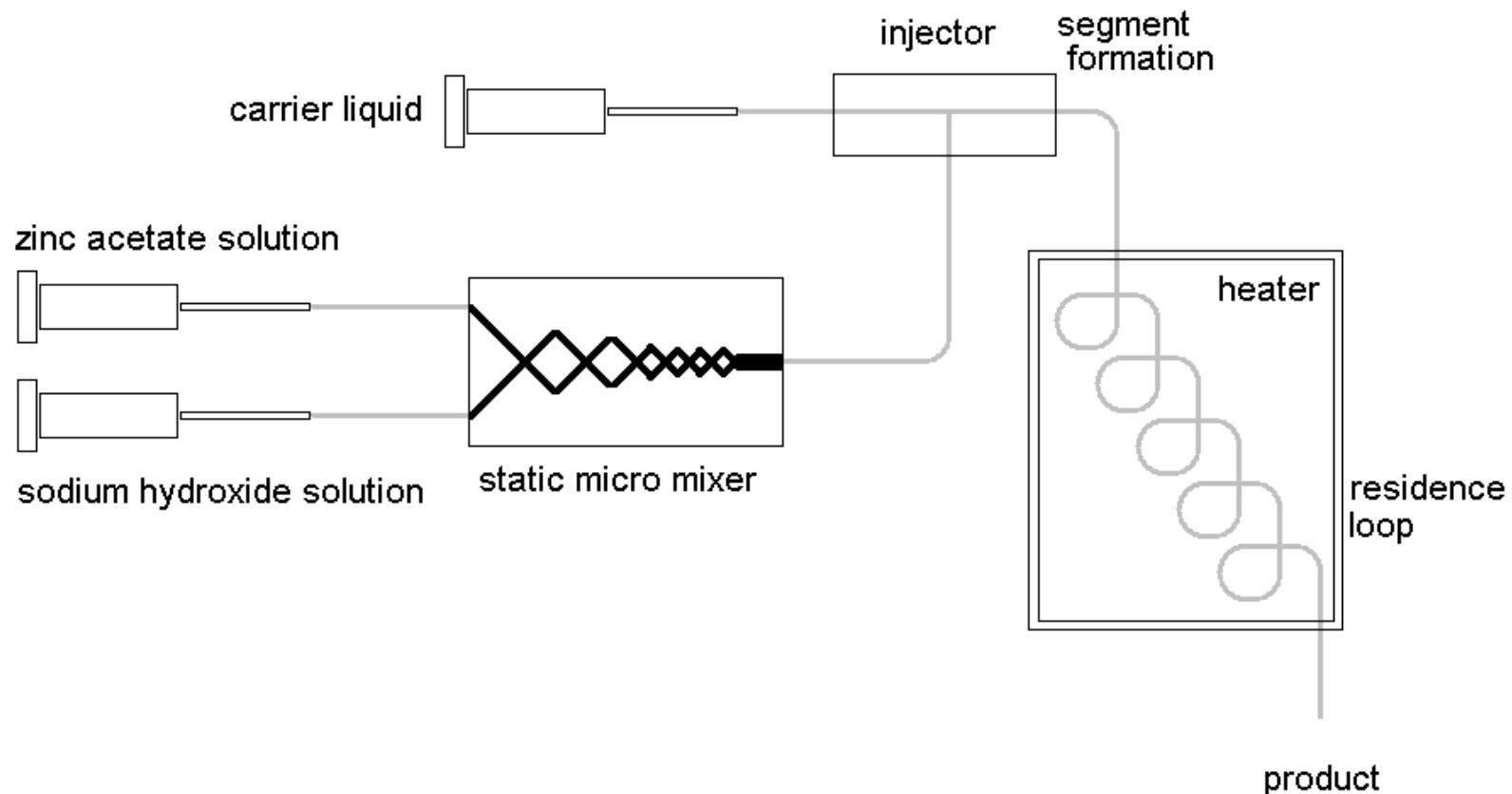
A. Knauer 2007

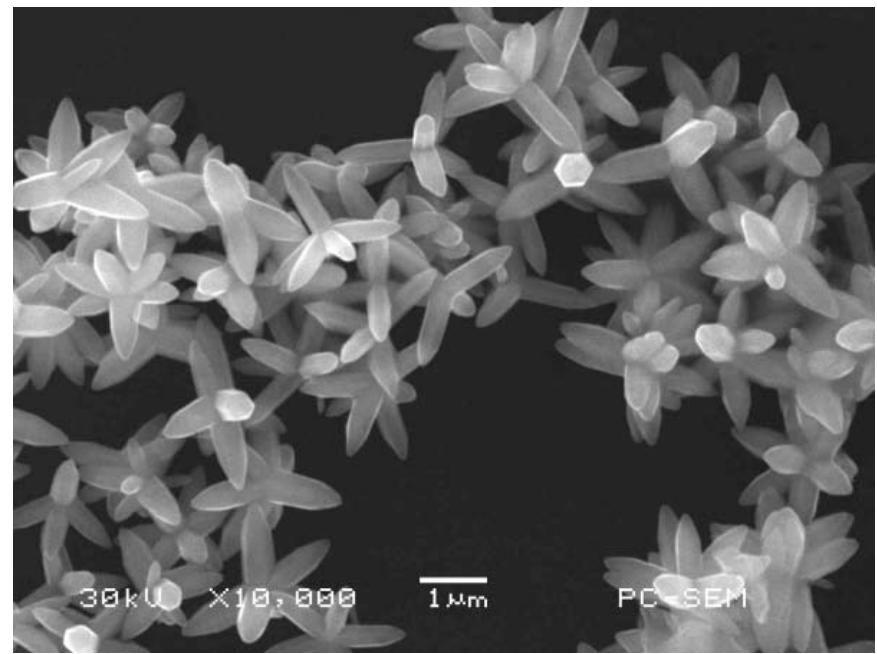
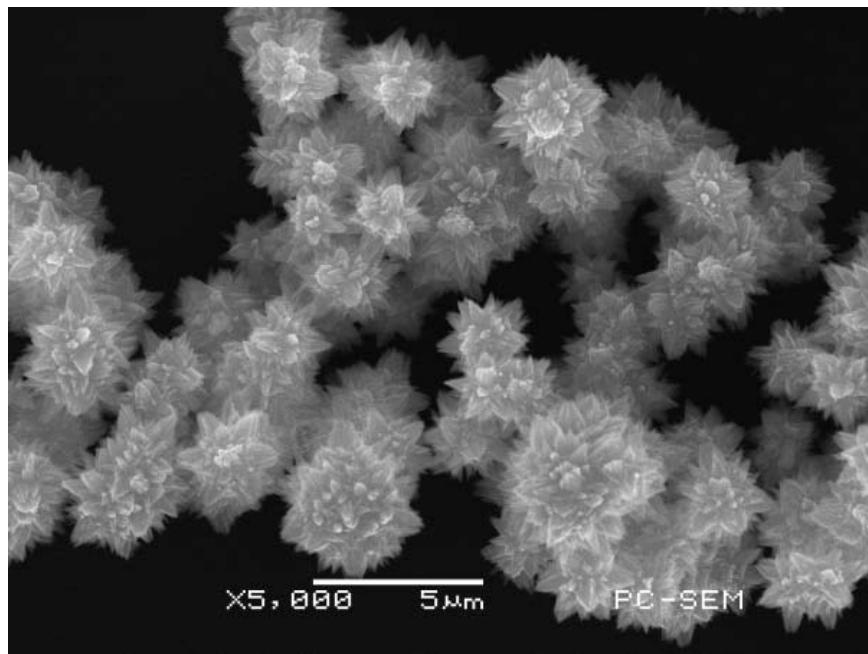
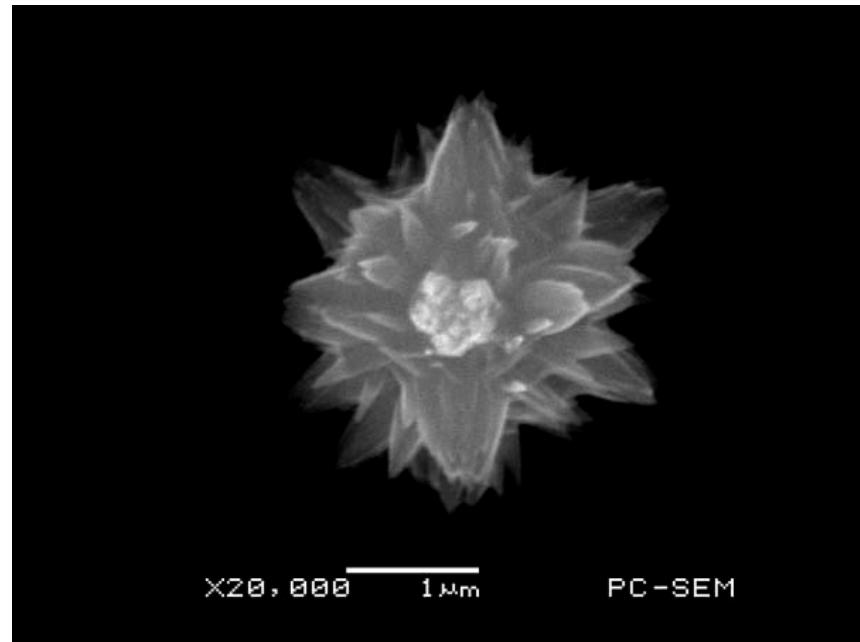
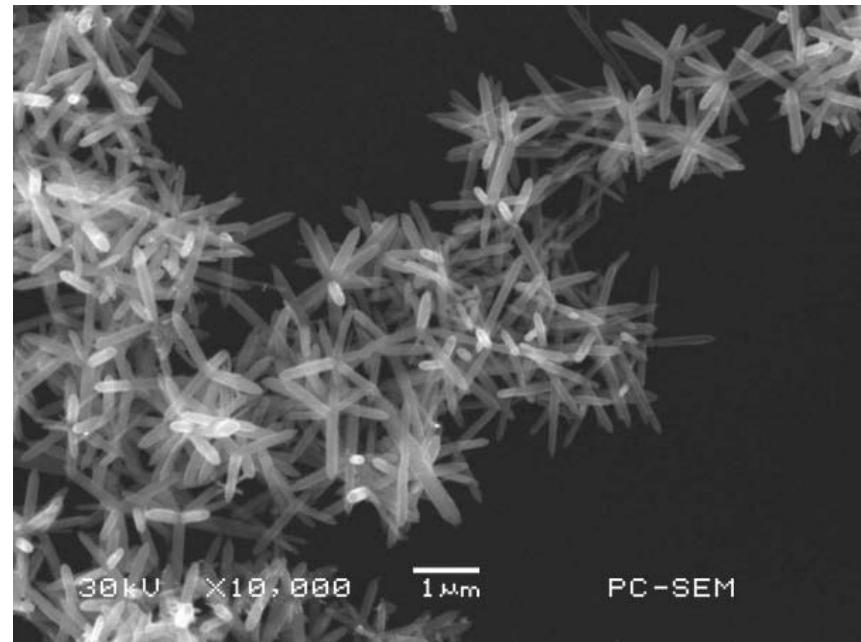


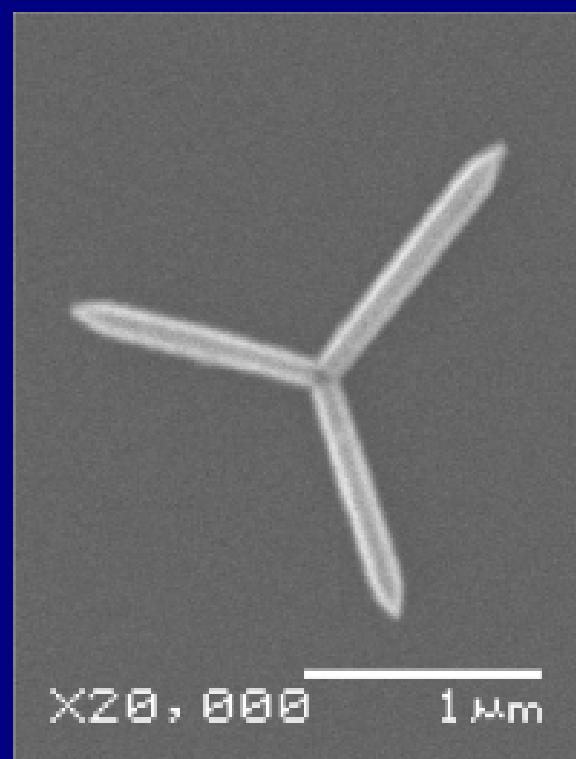
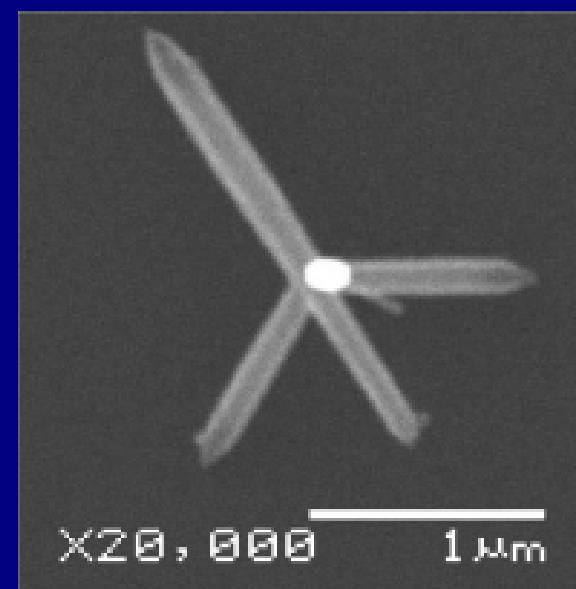
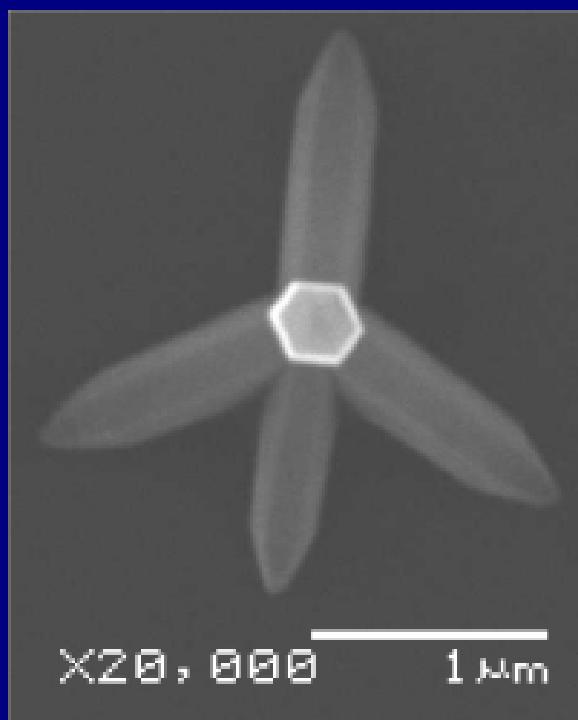
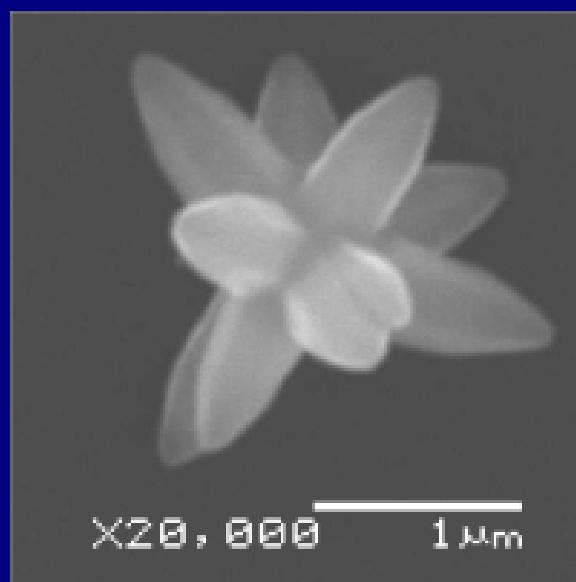
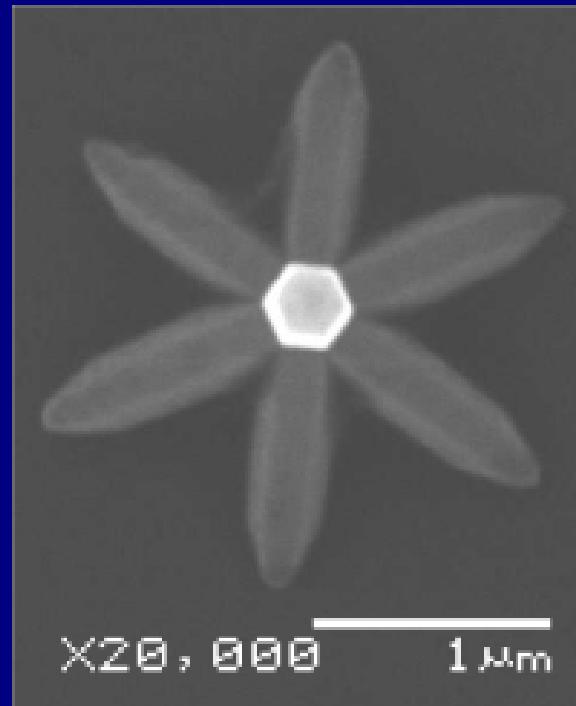
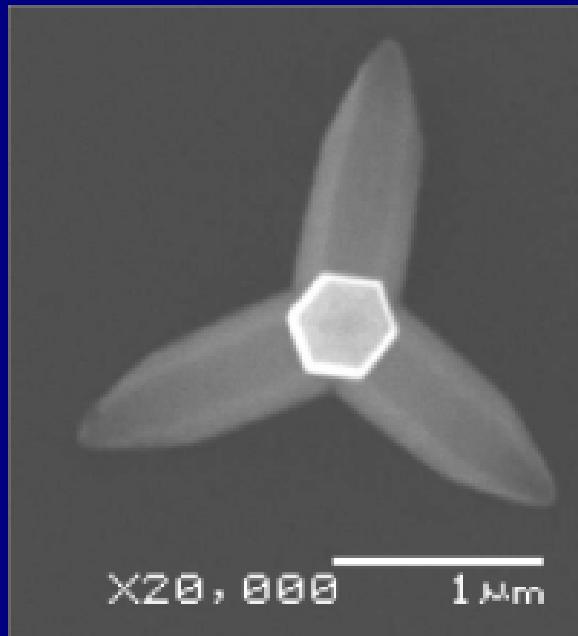


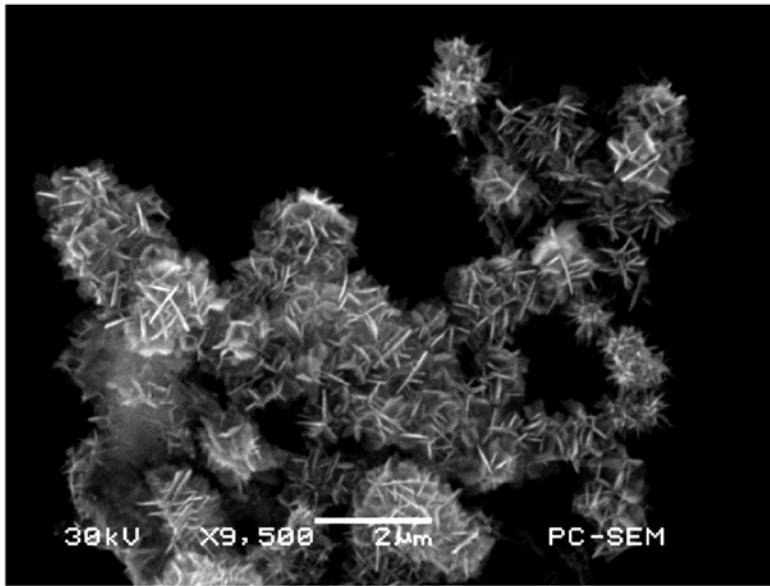


Micro continuous-flow synthesis of ZnO micro and nanoparticles

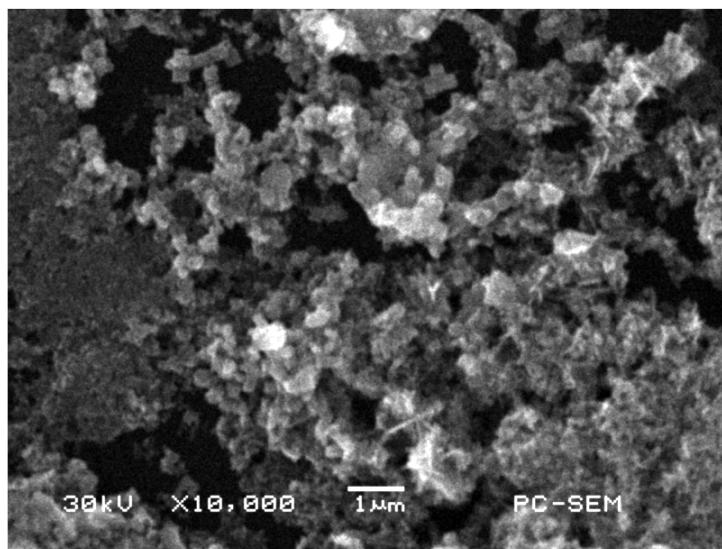




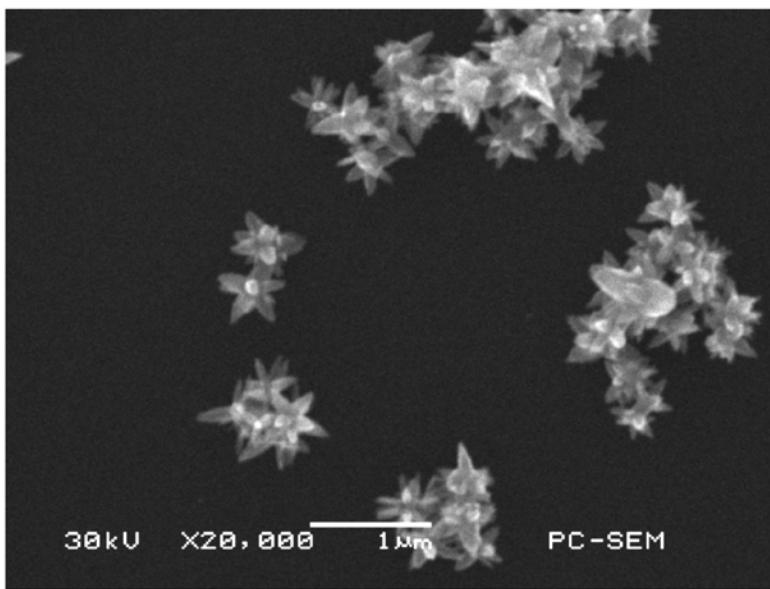




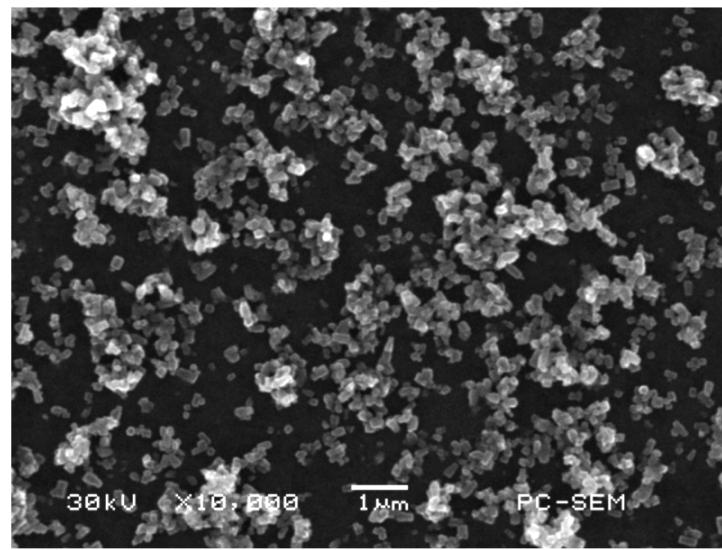
a



a



b

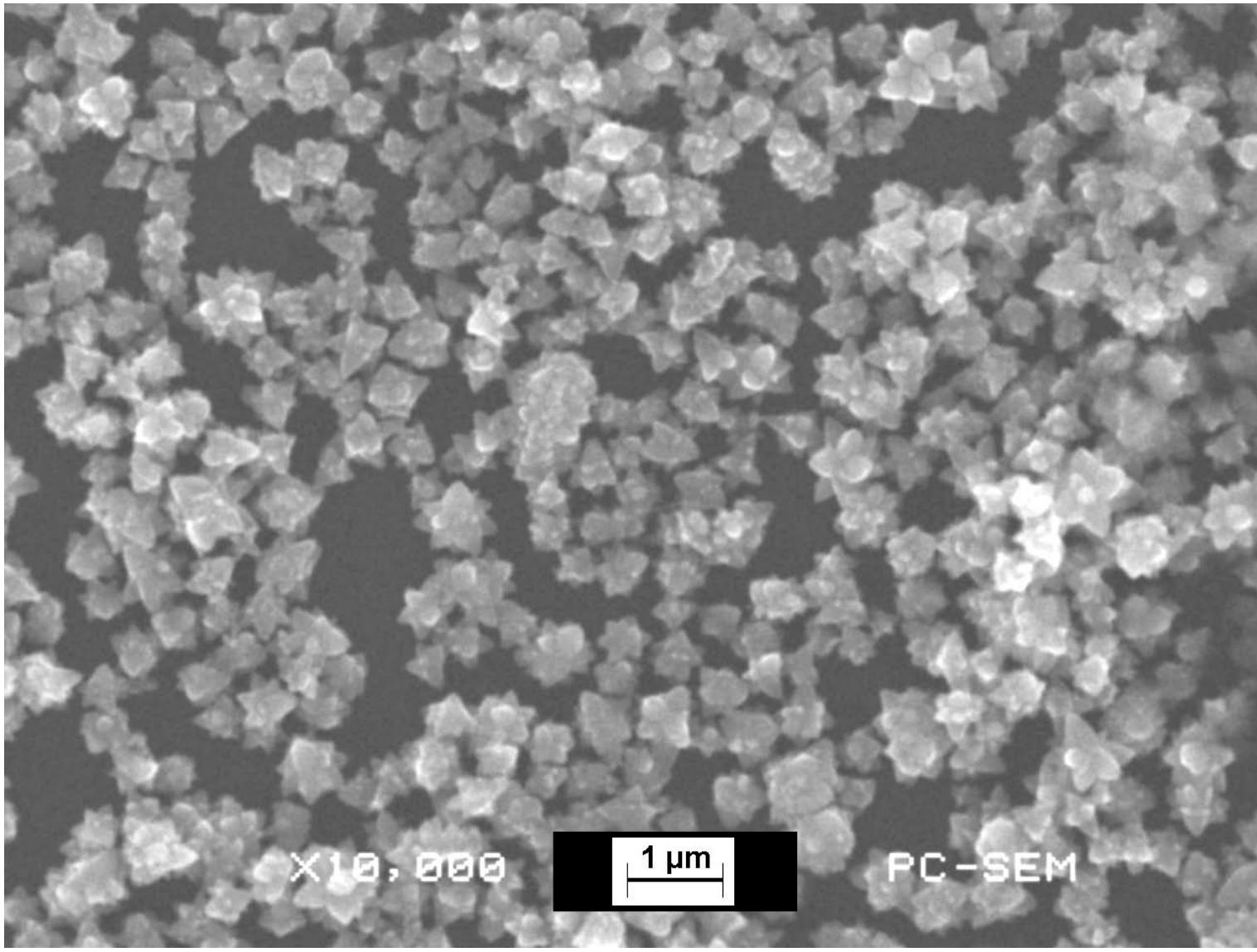


b

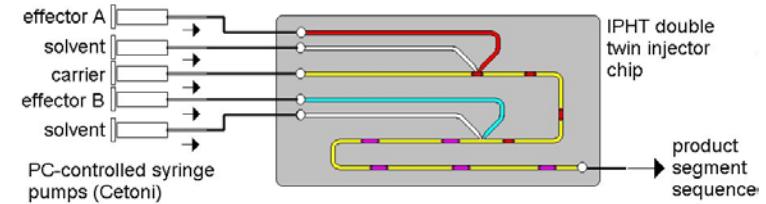
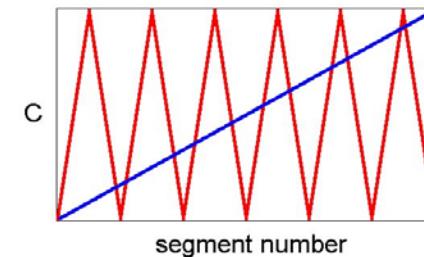


2 μm

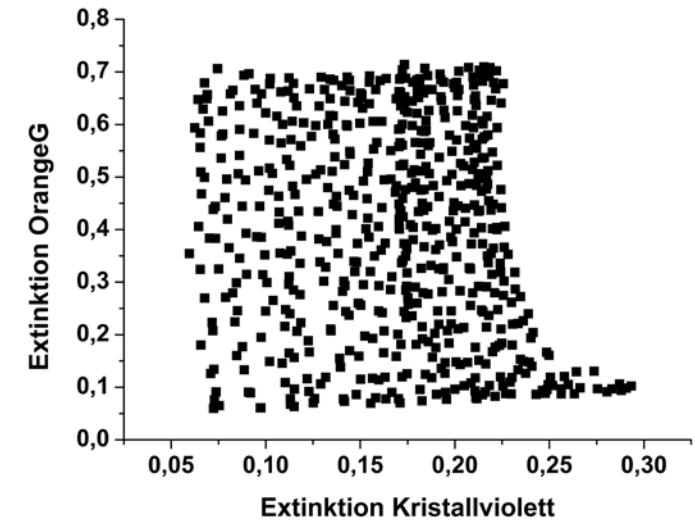
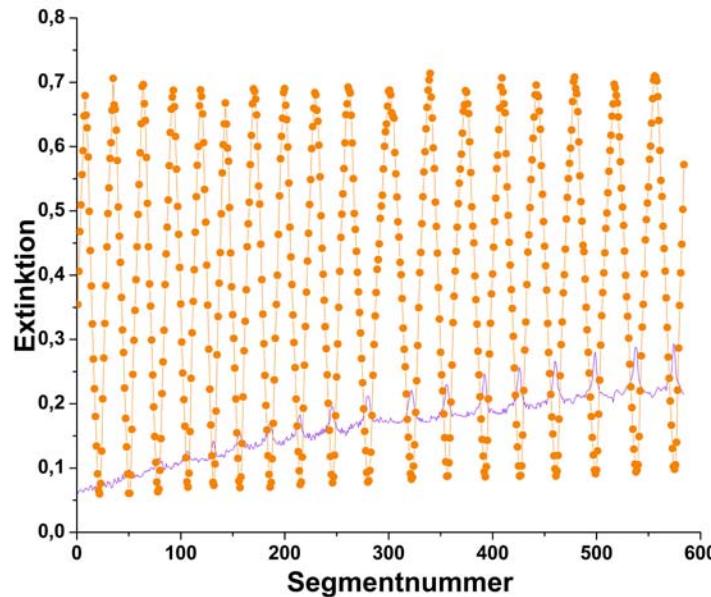
ZnO (NaOH-synthesis)



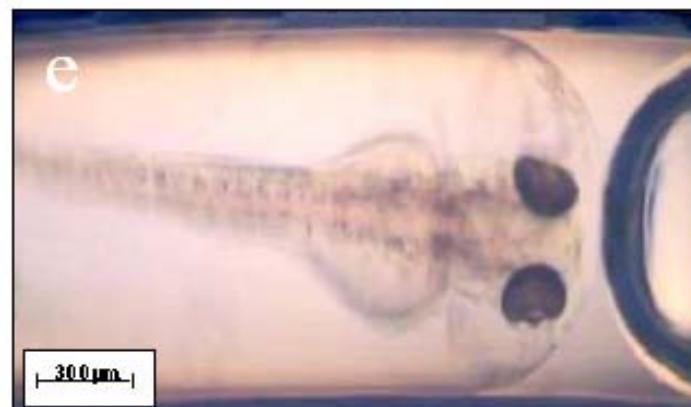
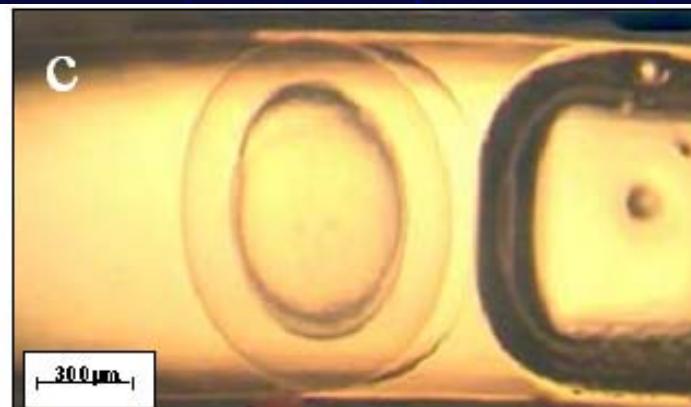
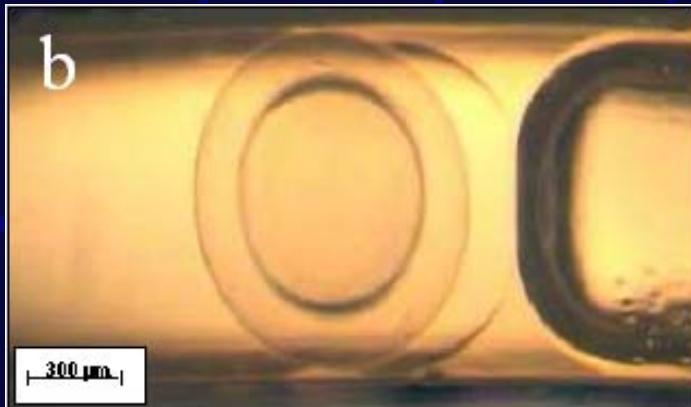
Adressing twodimensional concentration spaces

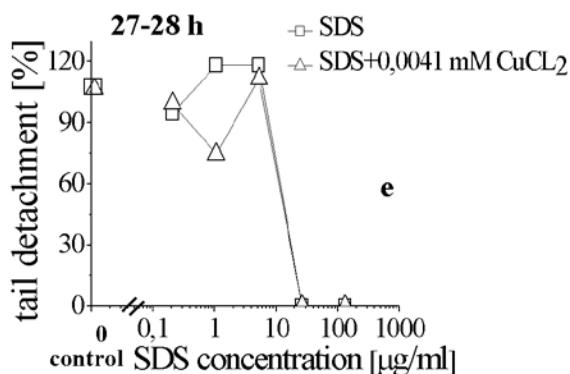
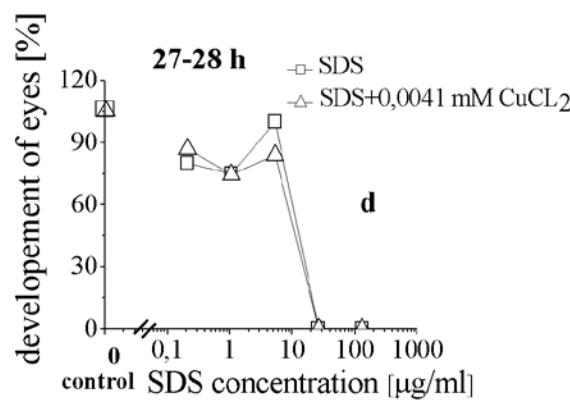
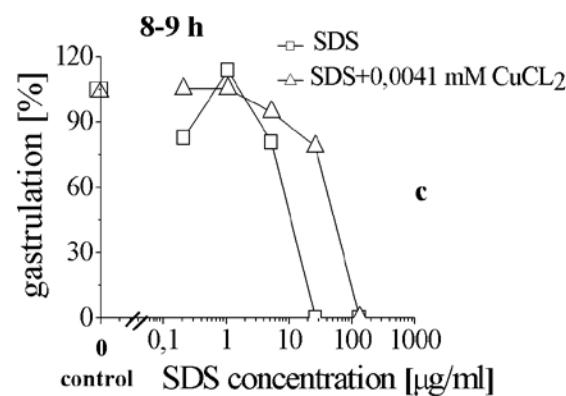
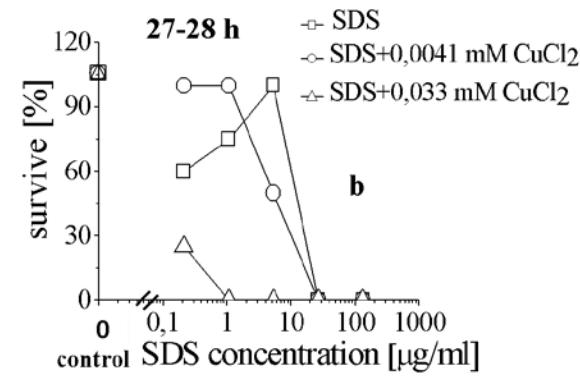
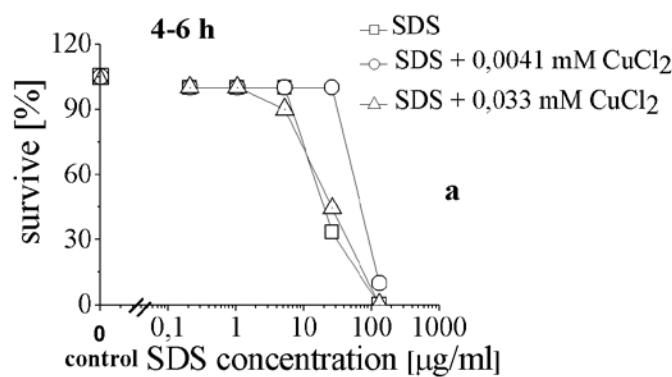


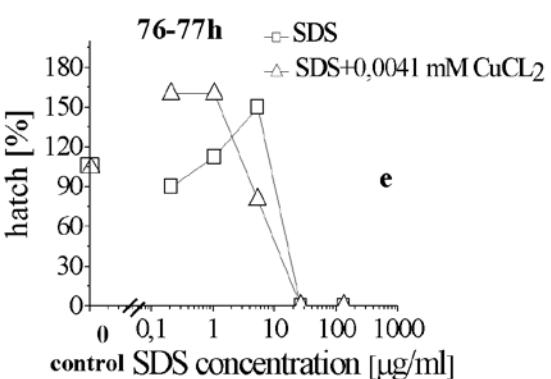
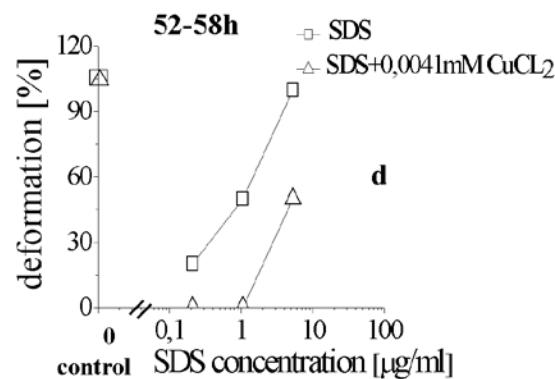
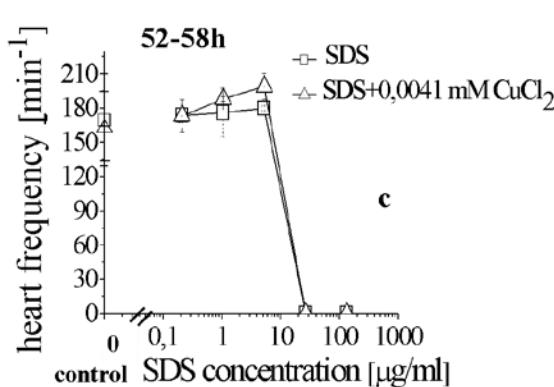
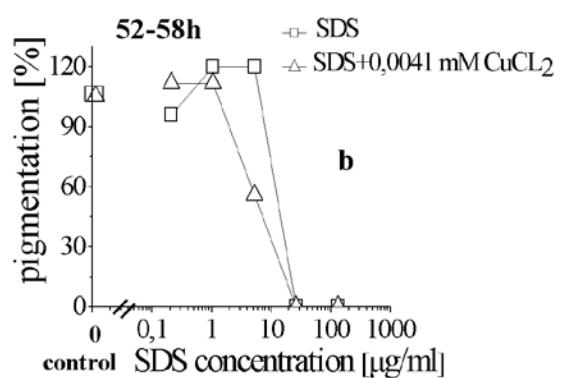
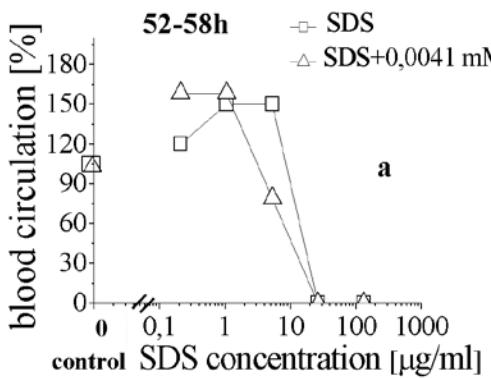
$20 \mu\text{l}/\text{min KV/H}_2\text{O} + 20 \mu\text{l}/\text{min OG/H}_2\text{O}(10 \% \text{ Glycerin}) + 20 \mu\text{l}/\text{min TD}$



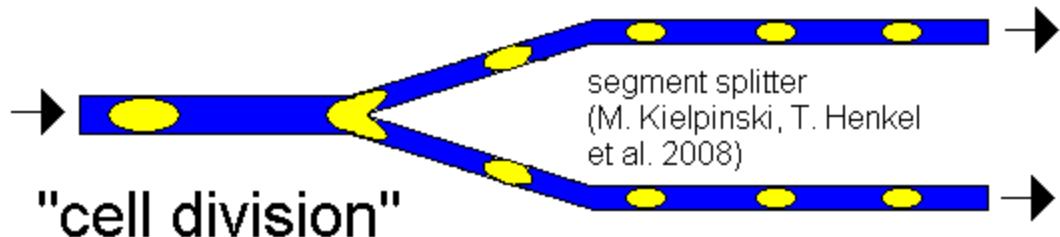
Danio rerio embryonic development in micro fluid segments



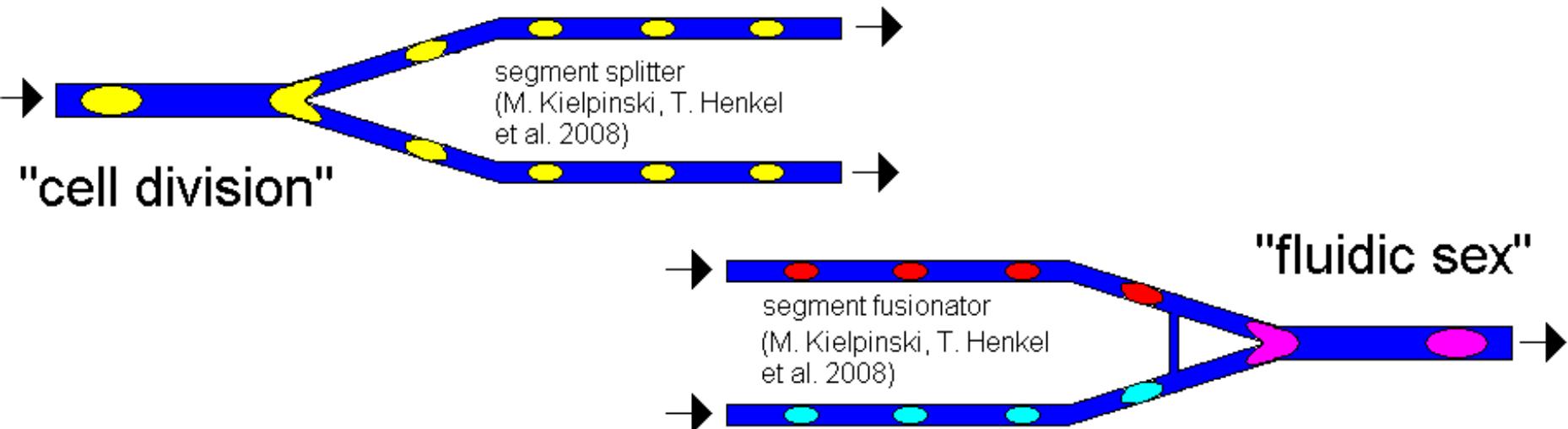




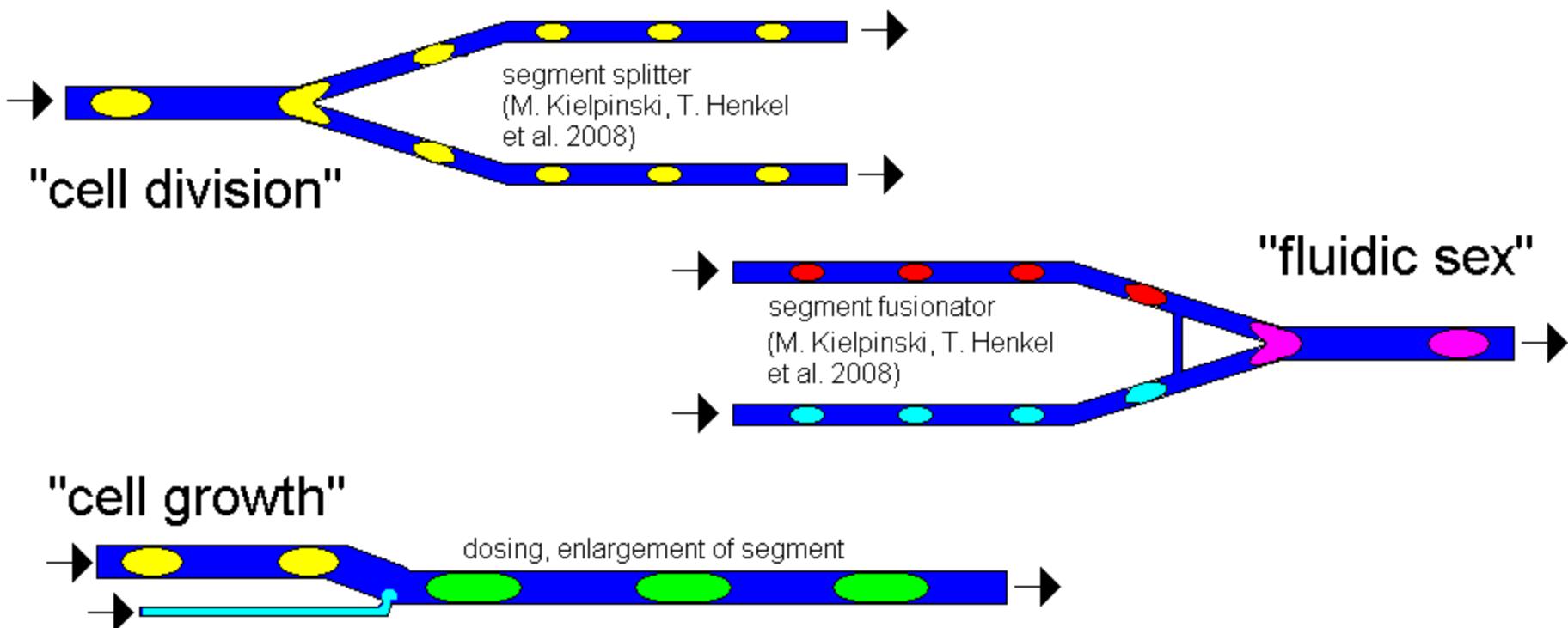
Bio-Mimetic Segment Operations



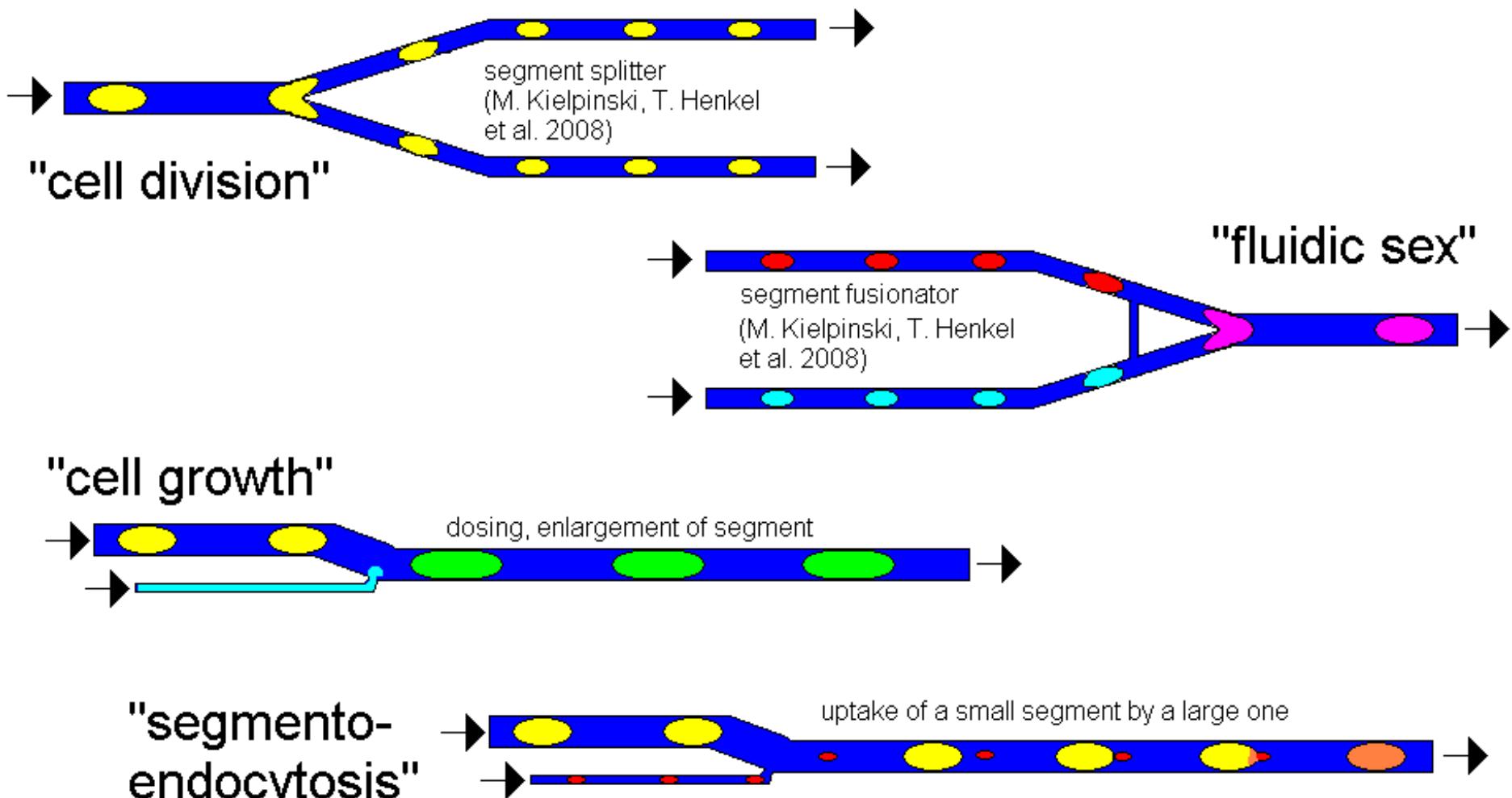
Bio-Mimetic Segment Operations



Bio-Mimetic Segment Operations



Bio-Mimetic Segment Operations



Segment on demand =

**= Information transfer into
segment sequences =**

**= „talking with sequences“
(input direction)**

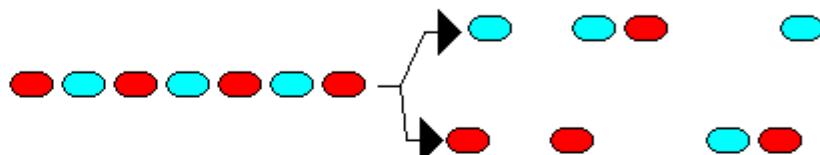


single segment procedures
(automated individual processing)

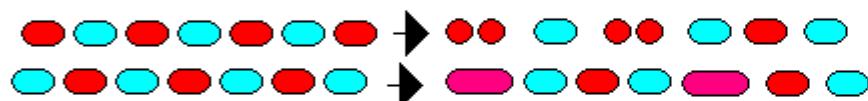
GENERATION ON DEMAND



SWITCHING ON DEMAND



SPLITTING AND
FUSION ON DEMAND



ENLARGING AND
SHRINKING ON DEMAND



PHYSICAL CONVERSION ON DEMAND



BIOPROCESSES ON DEMAND



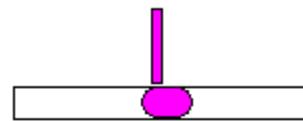
CHEMICAL ACTIVATION ON DEMAND



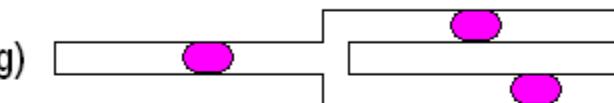
ARCHIVATION ON DEMAND

"personalized segment fates": segment-specific process chains

from individual "birth" (droplet generation)



over individual "life pathes" (switching)



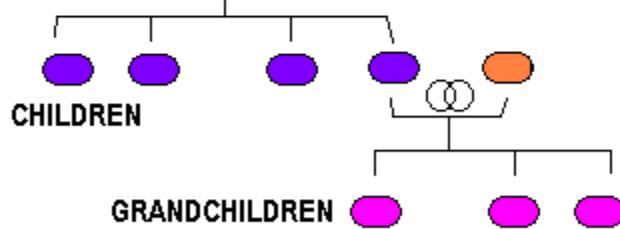
over metamorphosis (chemical, physical, biological conversion)



GRANDPARENTS over "founding droplet families"
(droplet fusion, splitting, content transfer)



PARENTS

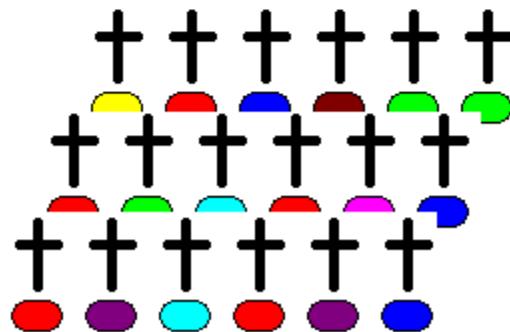


CHILDREN

GRANDCHILDREN

to segment "burial"

(storage, archivation, final conversion, fusion, collection or waste)



Challenges for nanoparticle techniques in micro reaction technology

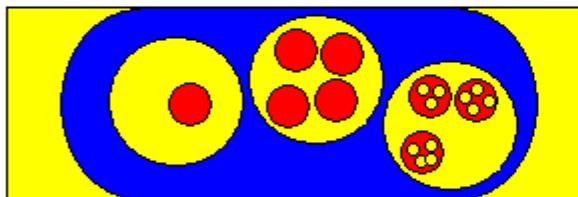




oriented molecules

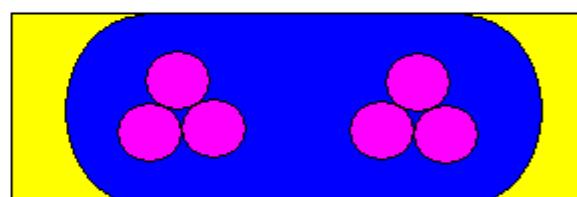


particle films at interface



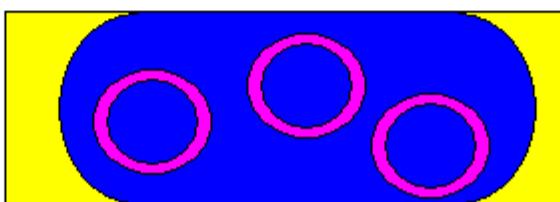
nested phases

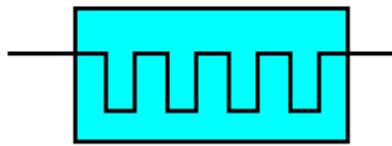
structured fluids
by
micro segmentation



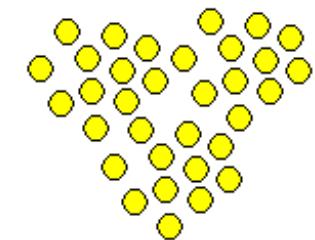
particle assemblies

vesicles





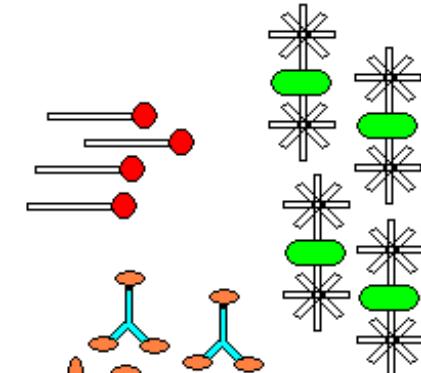
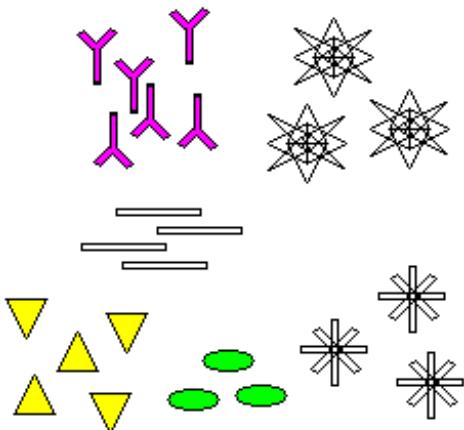
MICRO REACTION TECHNOLOGY



monodisperse
nanoparticles

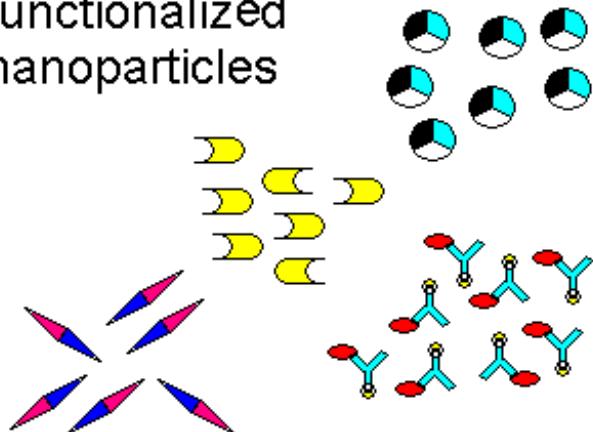


non-spherical
nanoparticles

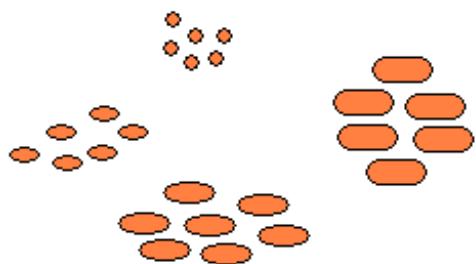


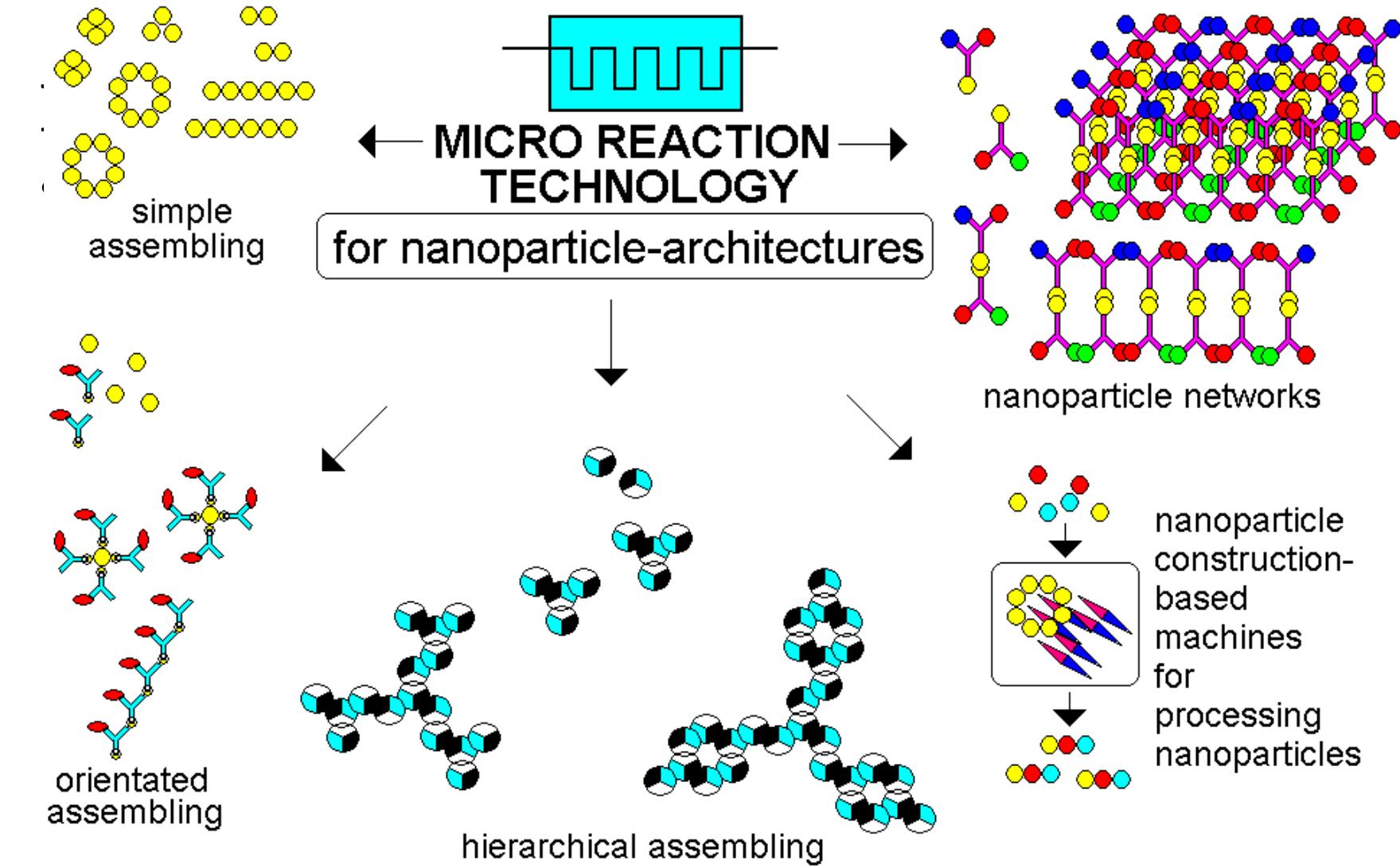
composed
nanoparticles

asymmetrically
functionalized
nanoparticles



tuning nanoparticle
size



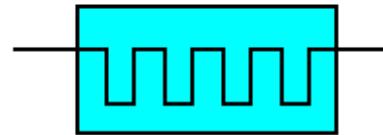


Talking with segments:

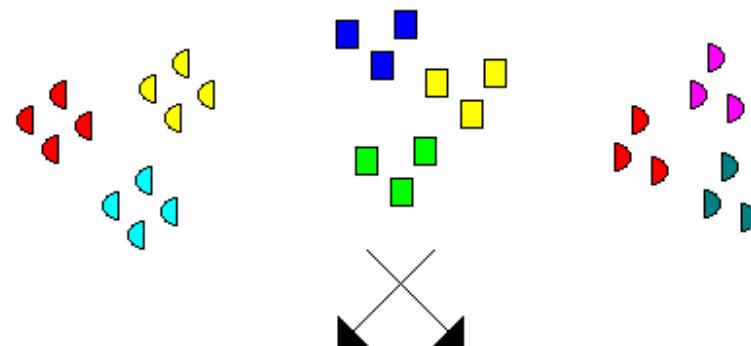
Labelling and information transfer

(on the segment-internal level)

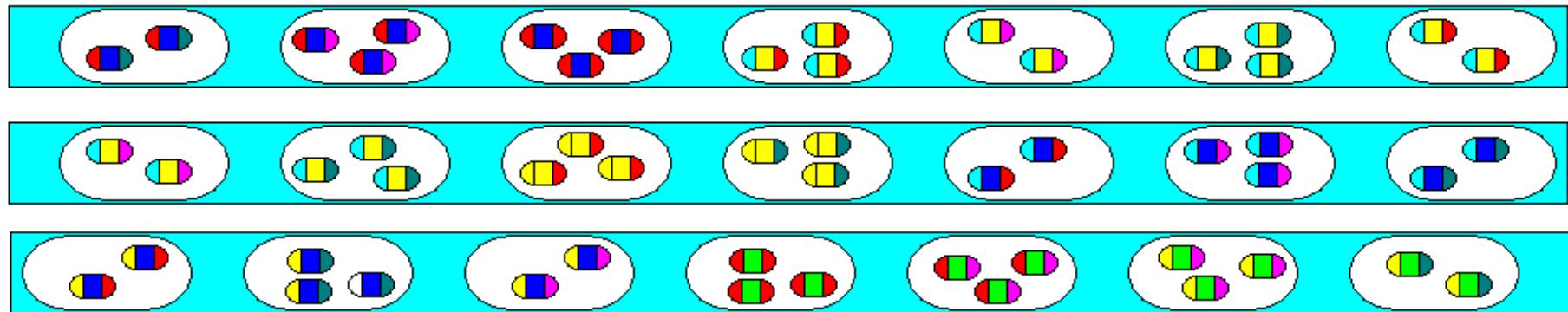




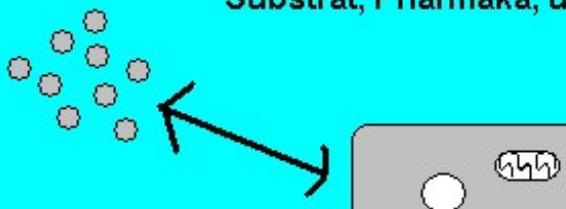
MICRO REACTION TECHNOLOGY



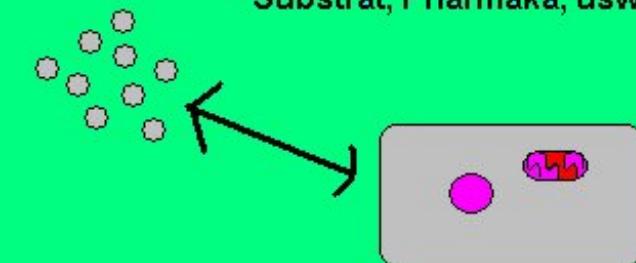
combinatorial synthesis
and handling of
nanoparticle diversity



Variablen: pH, Ionen,
Substrat, Pharmaka, usw.



Variablen: pH, Ionen,
Substrat, Pharmaka, usw.

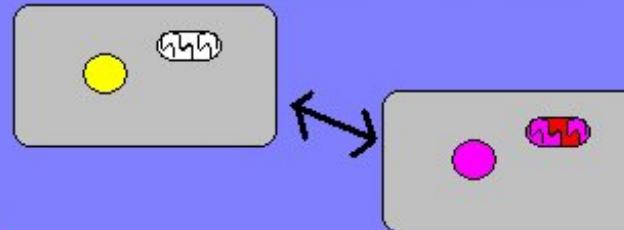


milieuabhängige Zell-Mikroorganismen-Interaktionen

Variablen: pH, Ionen,
Substrat, Pharmaka, usw.



Variablen: pH, Ionen,
Substrat, Pharmaka, usw.



Zell-Zell-Interaktionen und

Interaktionen zwischen kleinen Mehrzellern und Mikroorganismen

Reporter bead strategies

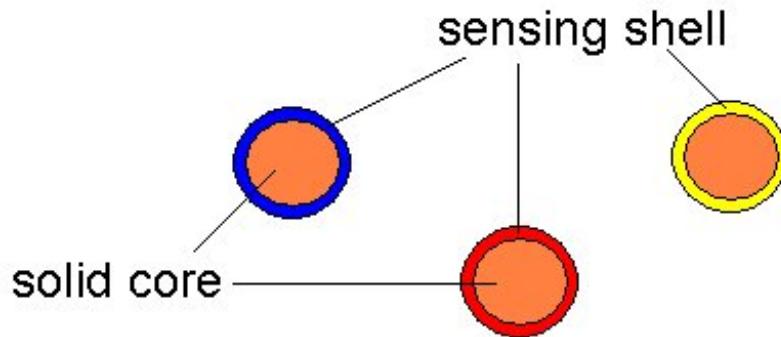
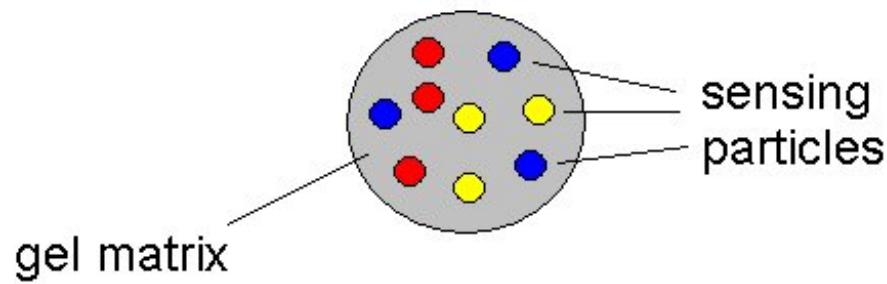
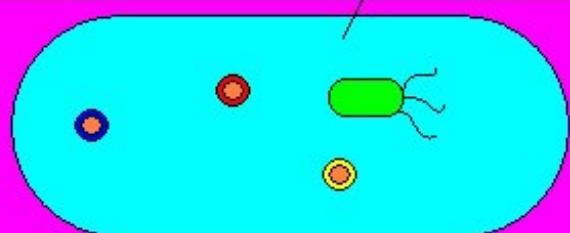
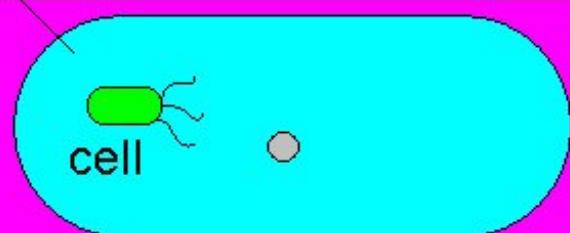
multifunctional sensor

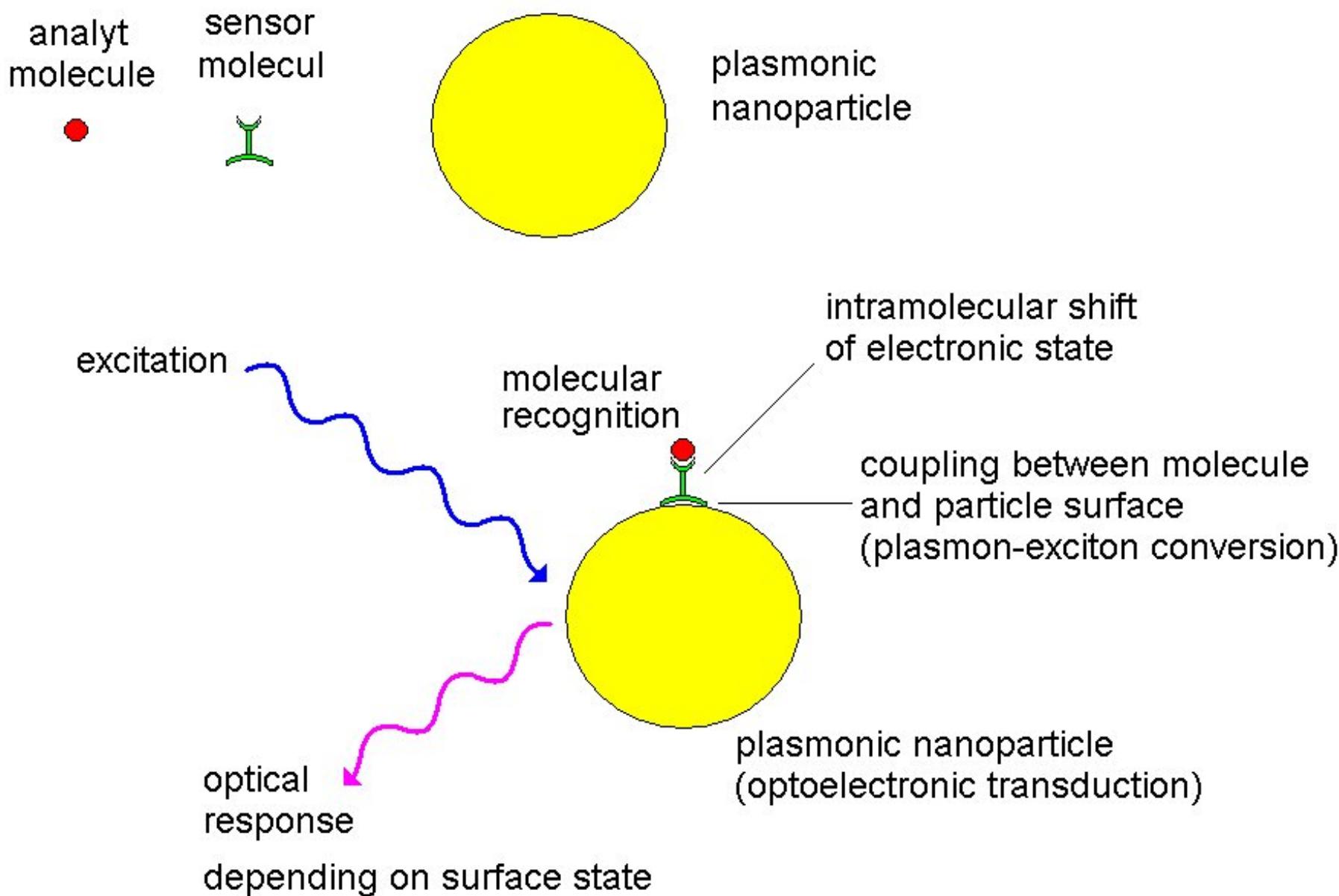
multibead sensing

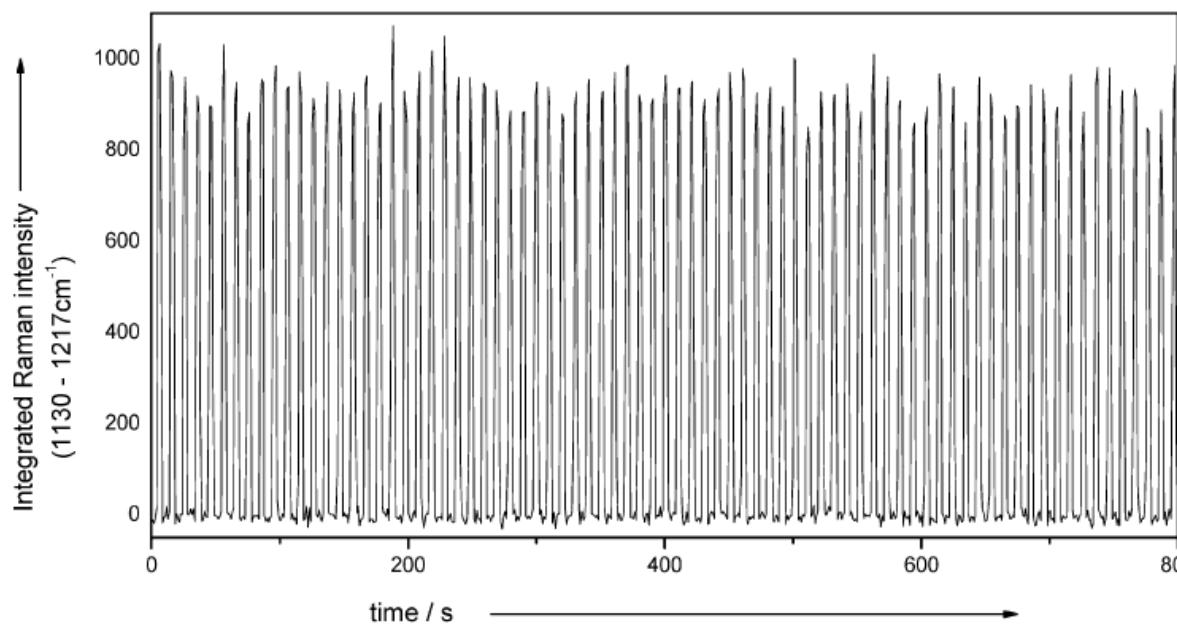
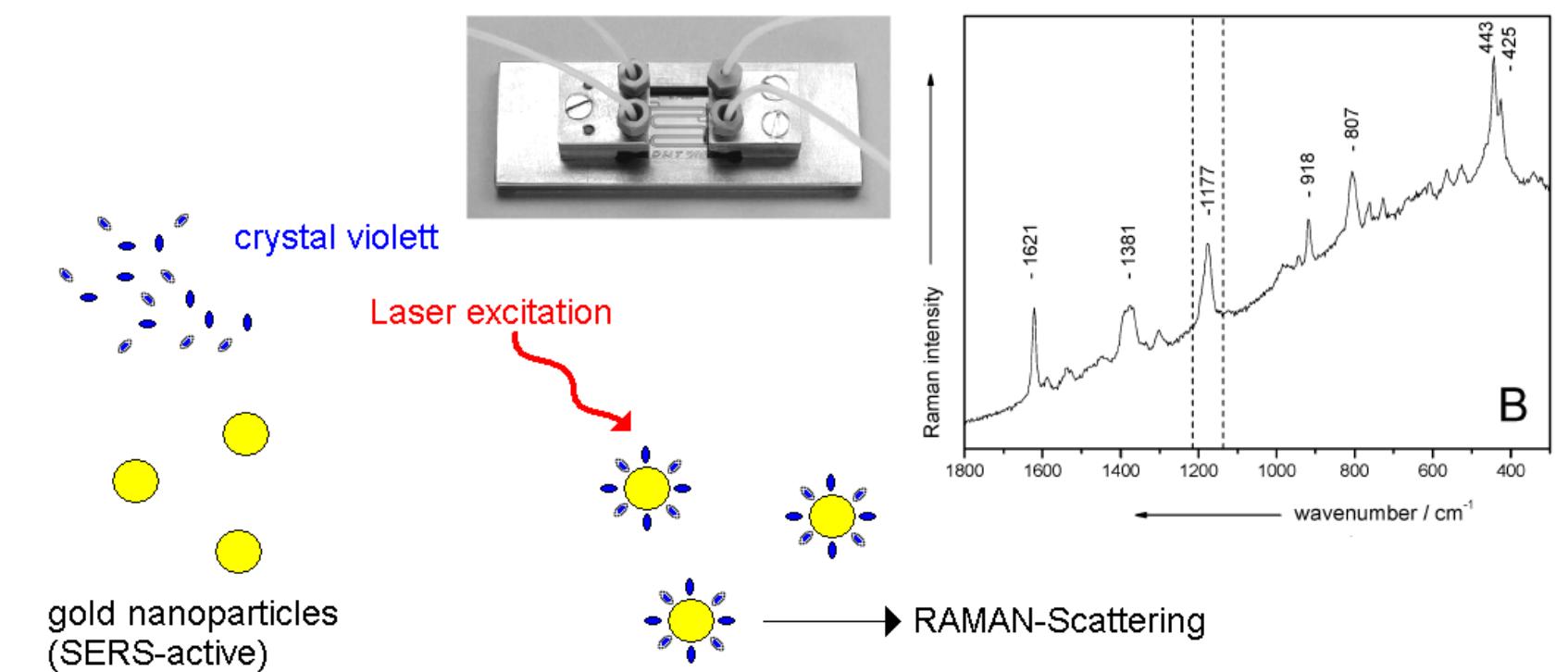
cultivation
liquid

carrier liquid

fluid segment

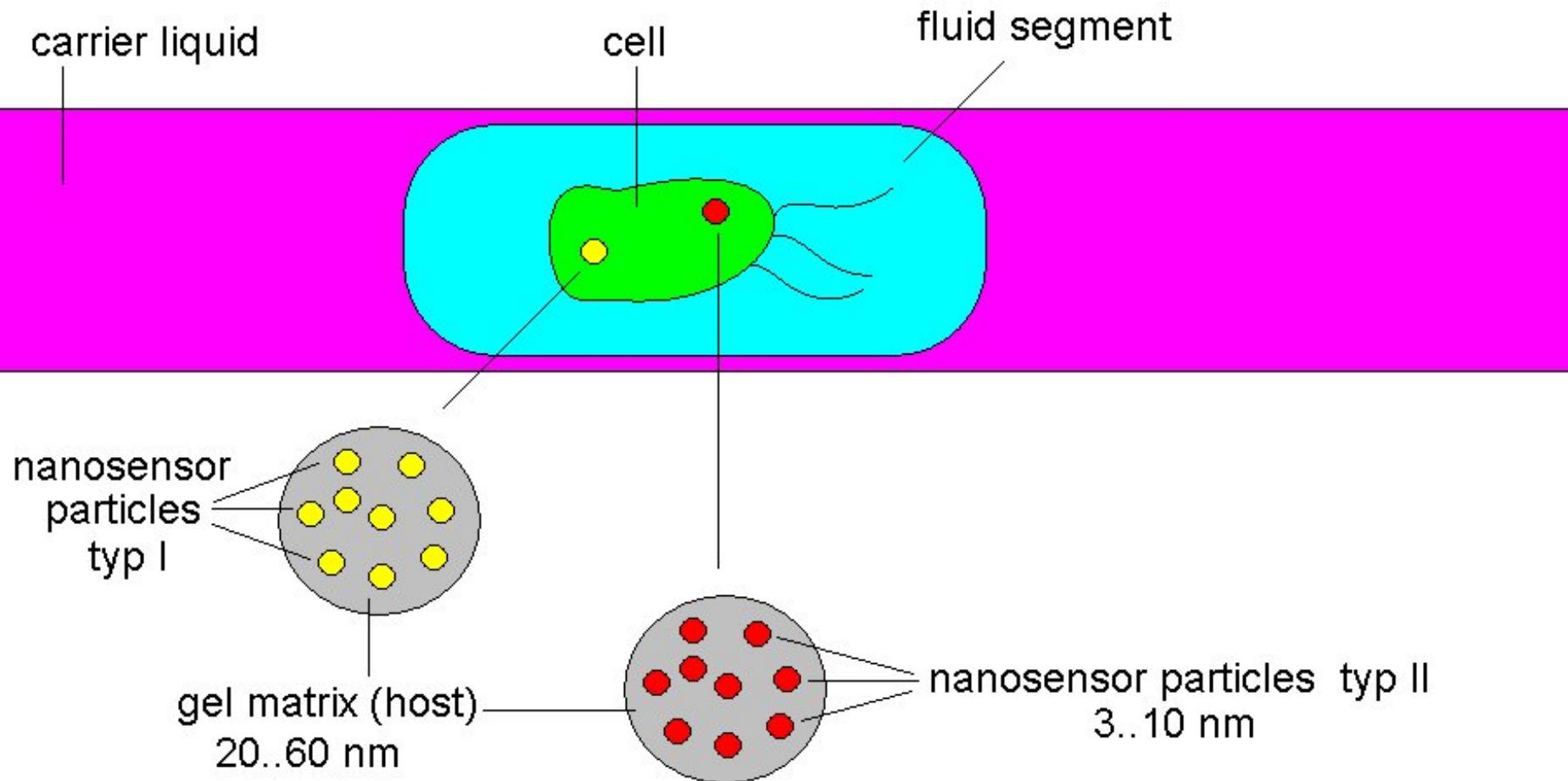




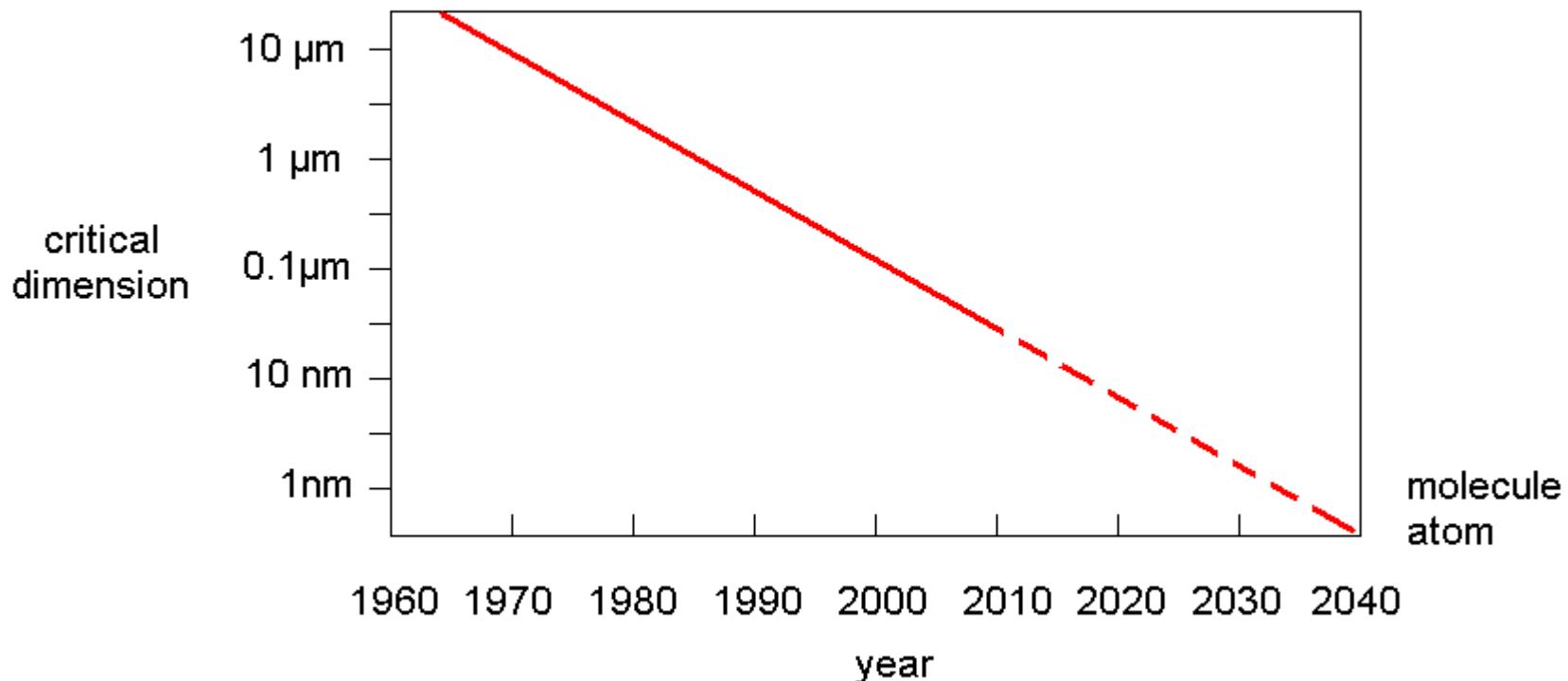


K.R. Strehle et al.,
Anal. Chem. 79, 4 (2007)
1542

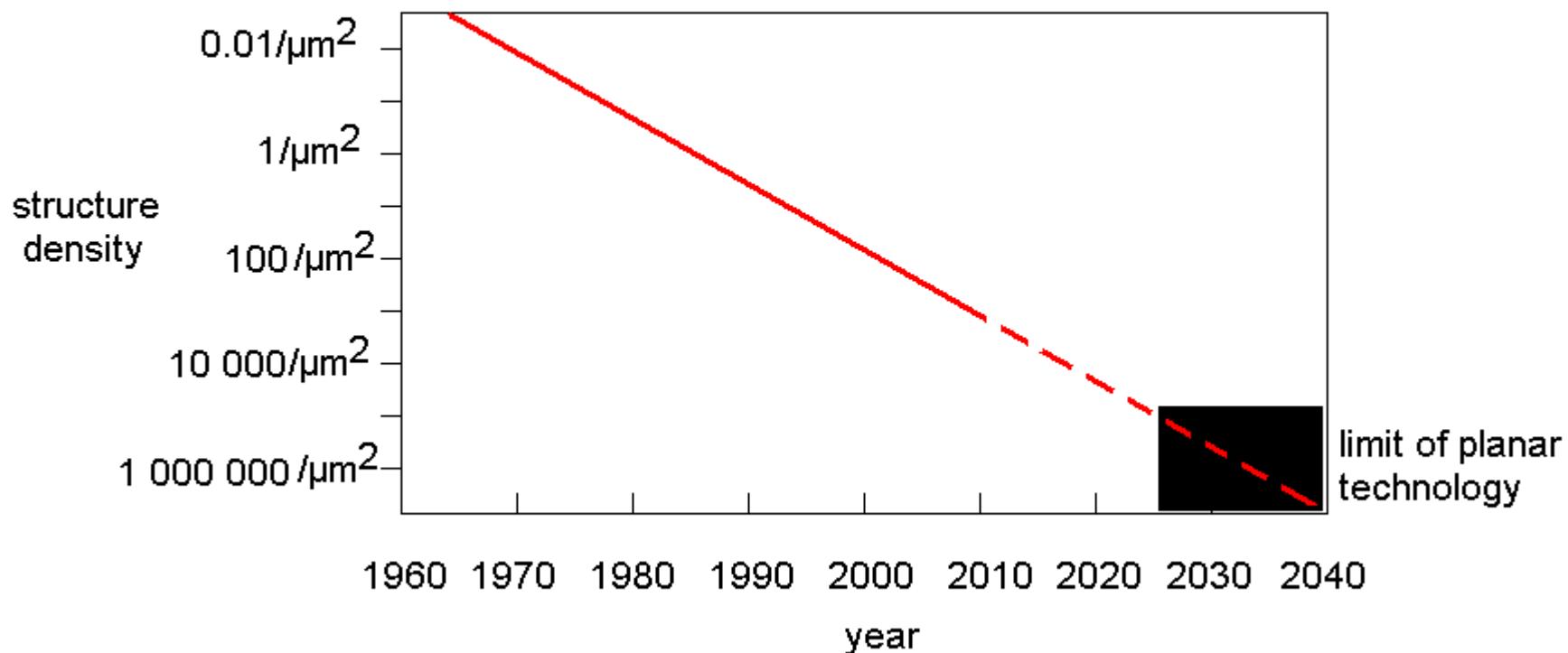
Endocytosis of nanocomposite reporter particles



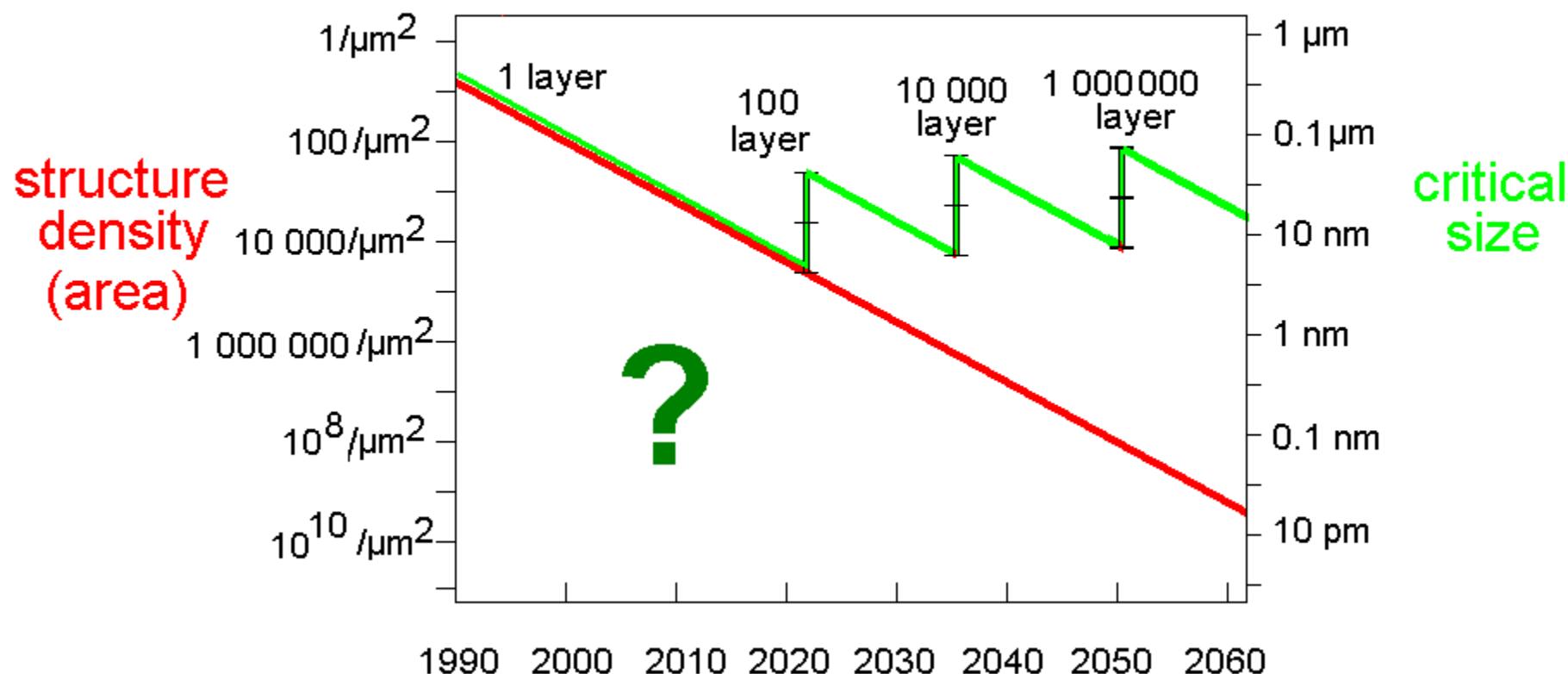
What about MOOREs LAW after 2025 ?

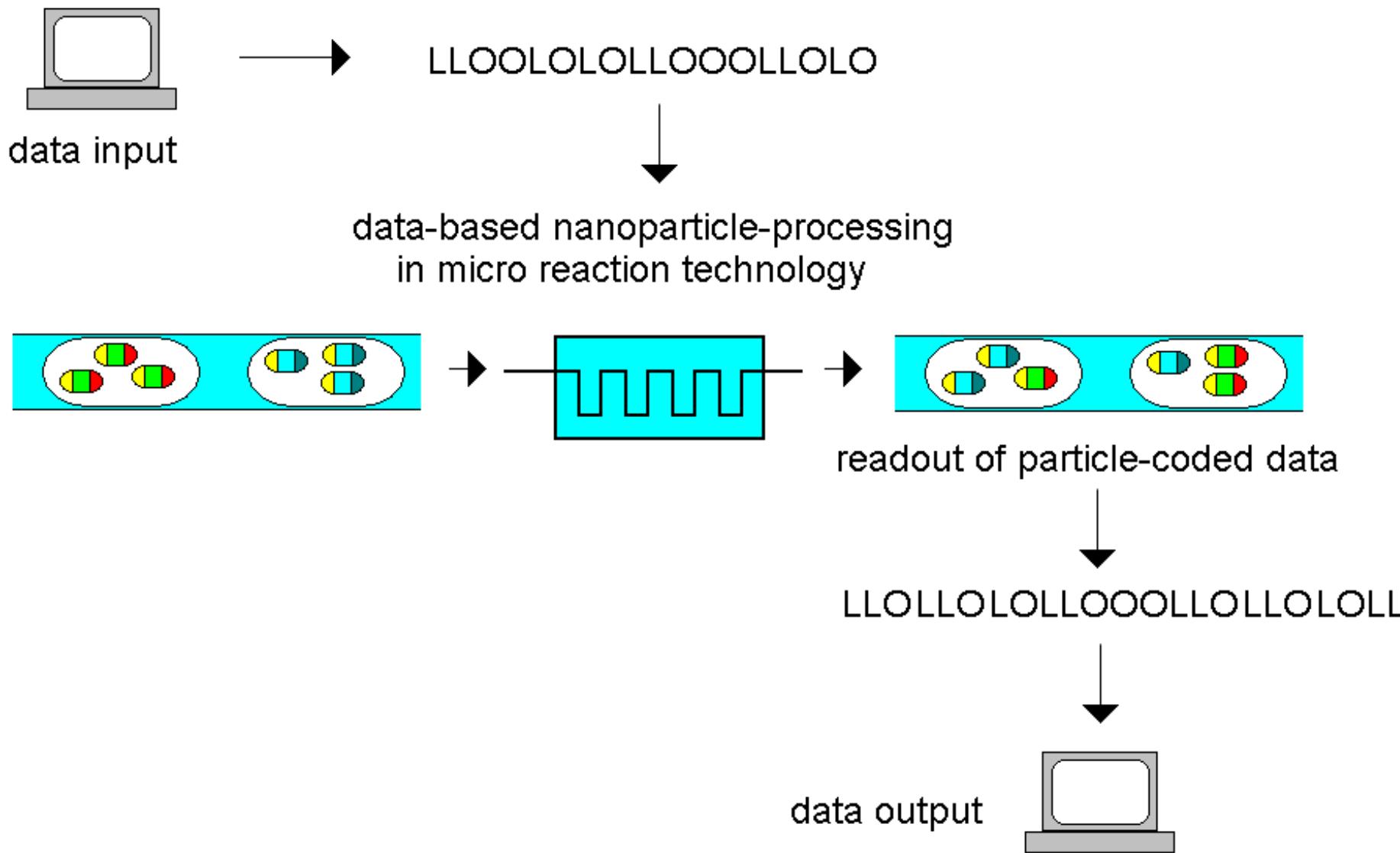


What about MOOREs LAW after 2025 ?

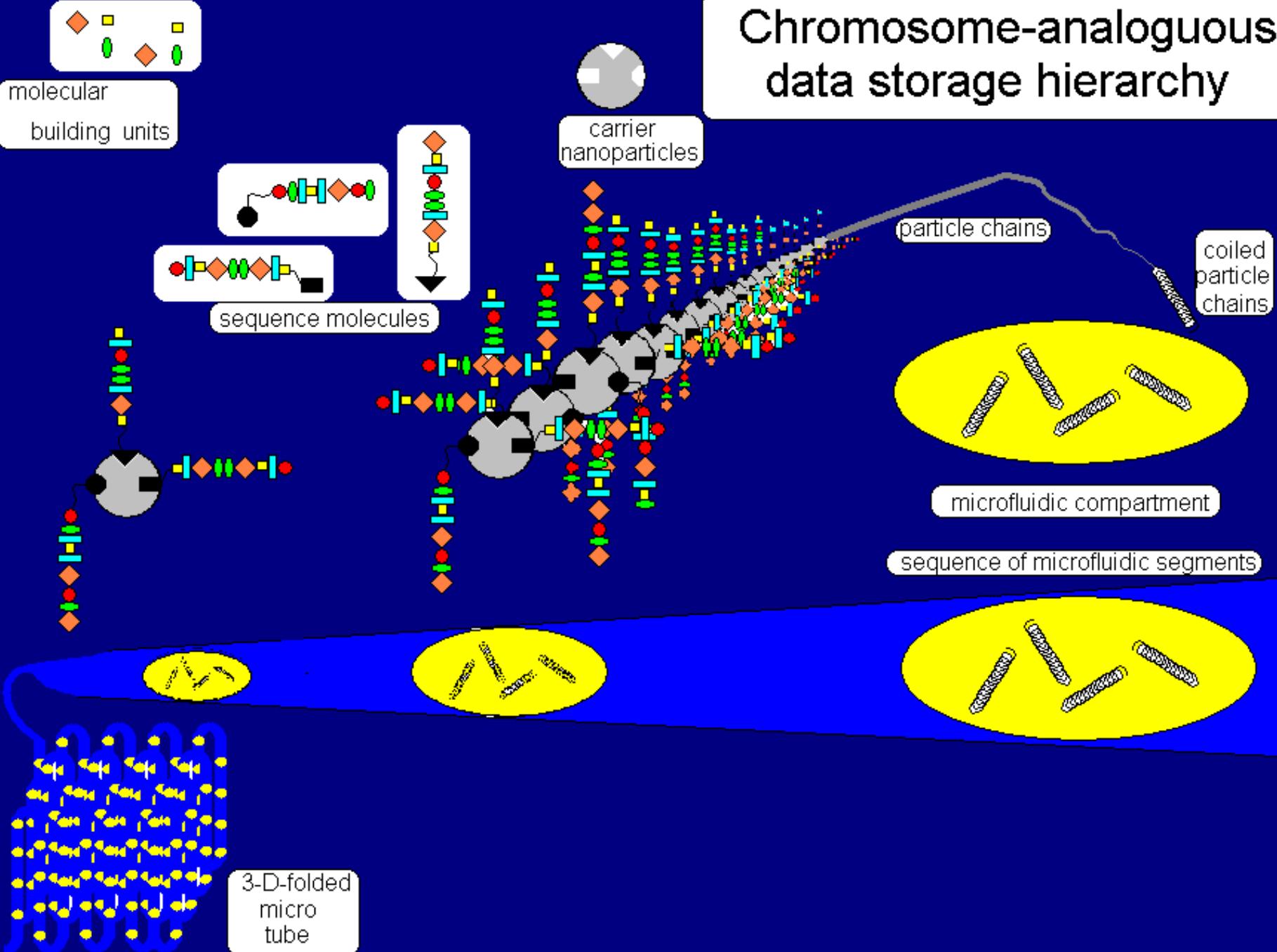


The Future of Moores Law: 3rd dimension





Chromosome-analogous data storage hierarchy



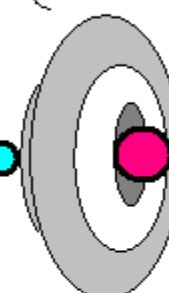
0LL0L0LL0L00L0

max. 5×10^{17} byte/cm³
(2.5% volume occupation)
= 500 000 terabyte/cm³

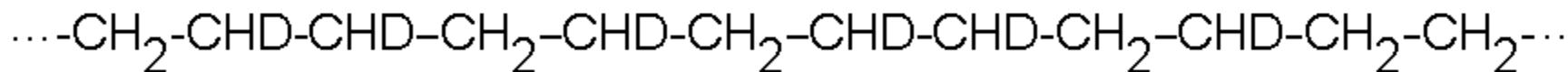
→ scanning direction



molecular data chain
(binary)



molecular
transducer



receiver

receiver

receiver

receiver

receiver



Conclusions

- microfluidics and – in particular – micro fluid segments are well suited for synthesis and screening of nanomaterials
- structured liquids support the read-out of information from molecules and cells what can be applied, for example, in drug screening and toxicological studies
- Fluid segments in the nanoliter, picoliter or smaller ranges can used for interfaces for information transfer, for example for molecular optimization in combinatorial chemistry (molecular architectures), for cell technology or for information processing
- microsegmented flows could be a promising strategy for fluid-based three-dimensional information technology



Acknowledgement

T. Henkel, D. Malsch and M. Kielpinski (IPHT Jena), J. Metze (iba Heiligenstadt), K. Martin, M. Roth (HKI Jena for cooperation

**F. Möller and S. Schneider for technical support
H. Romanus (Ilmenau) for TEM images
F. Jahn (Jena) for SEM images**

**Financial support of DBU,
of DFG (Ko1403-22/1) and of
state of Thuringia is gratefully acknowledged.**



Thank you!



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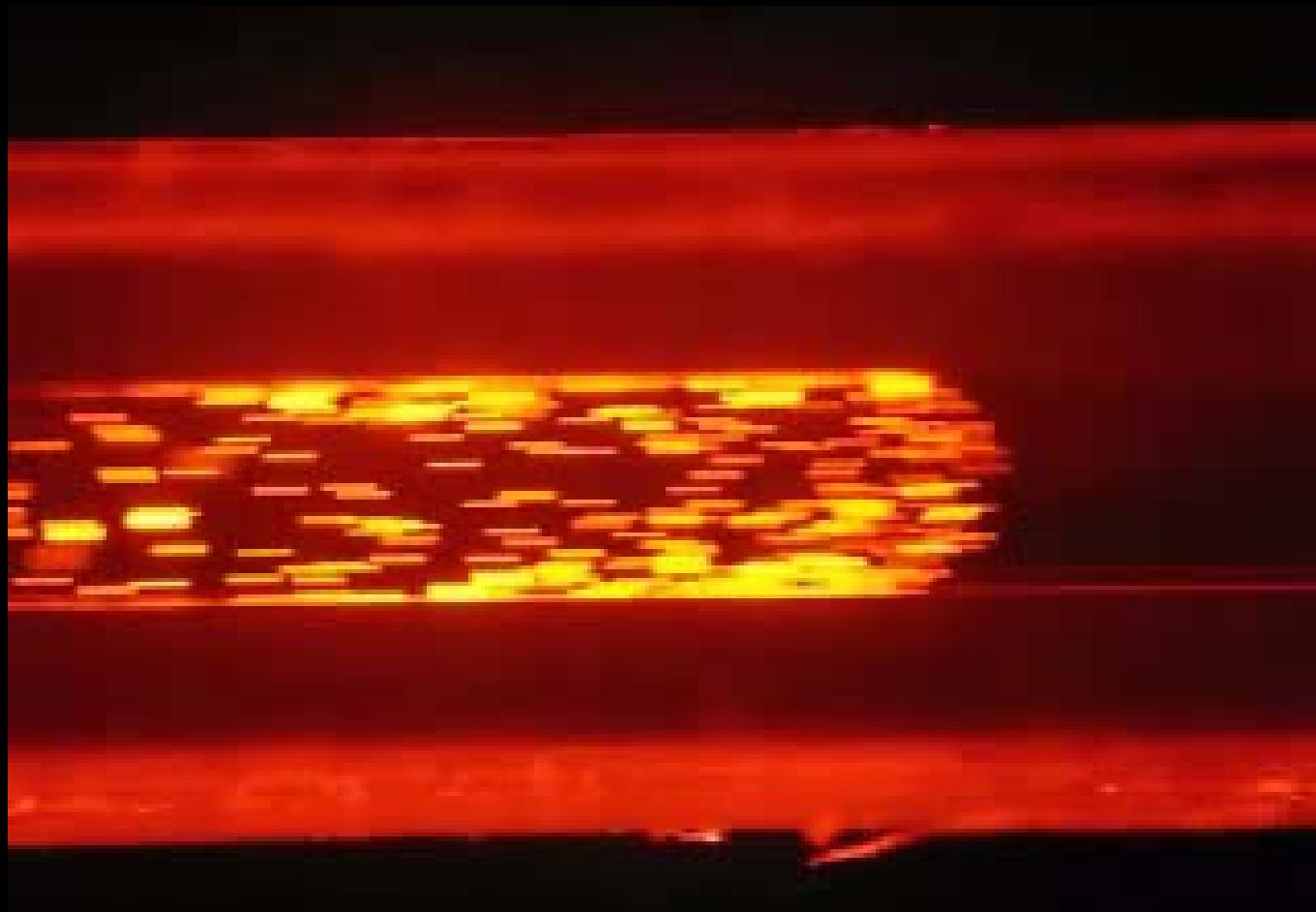


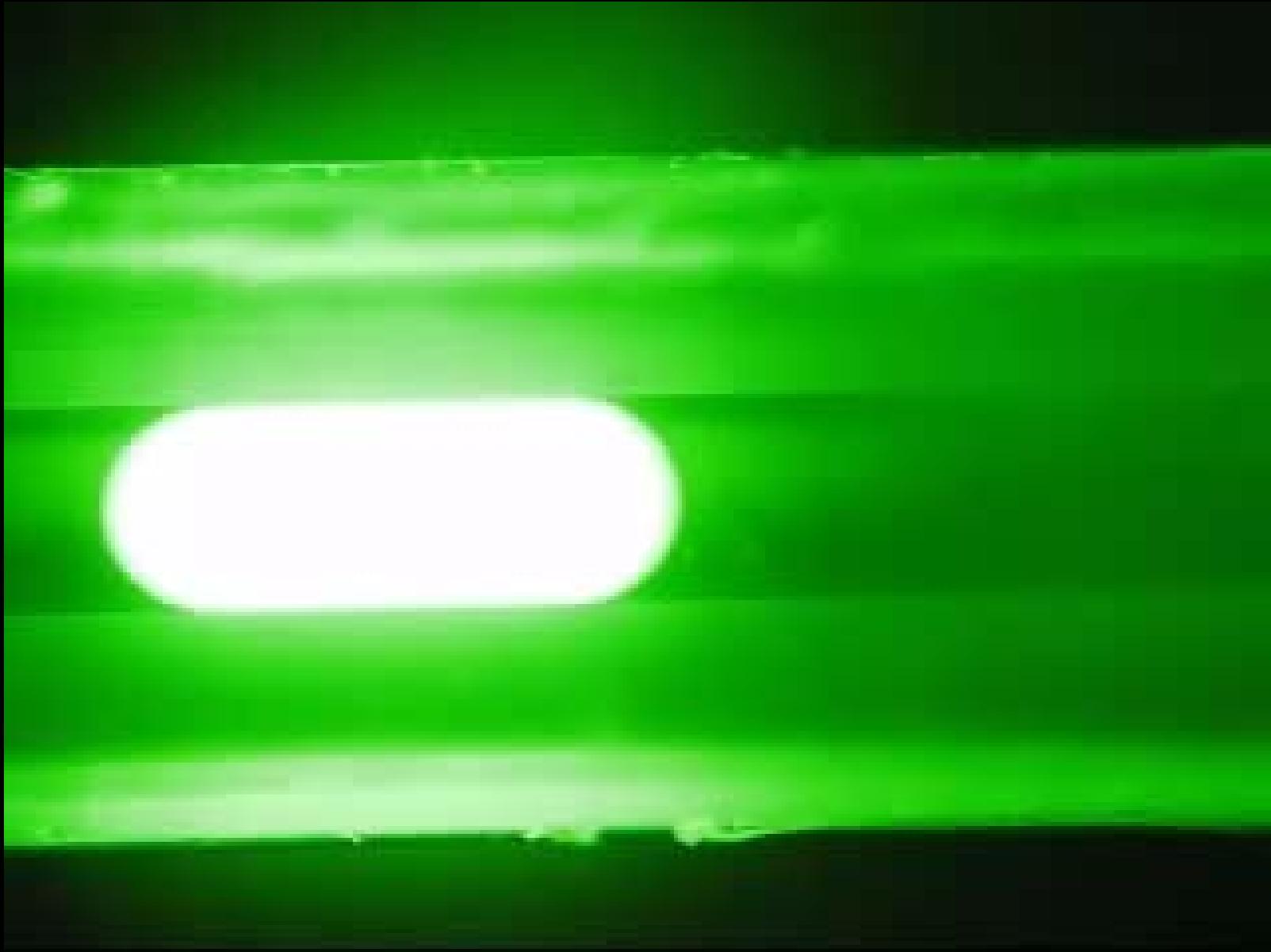
xy

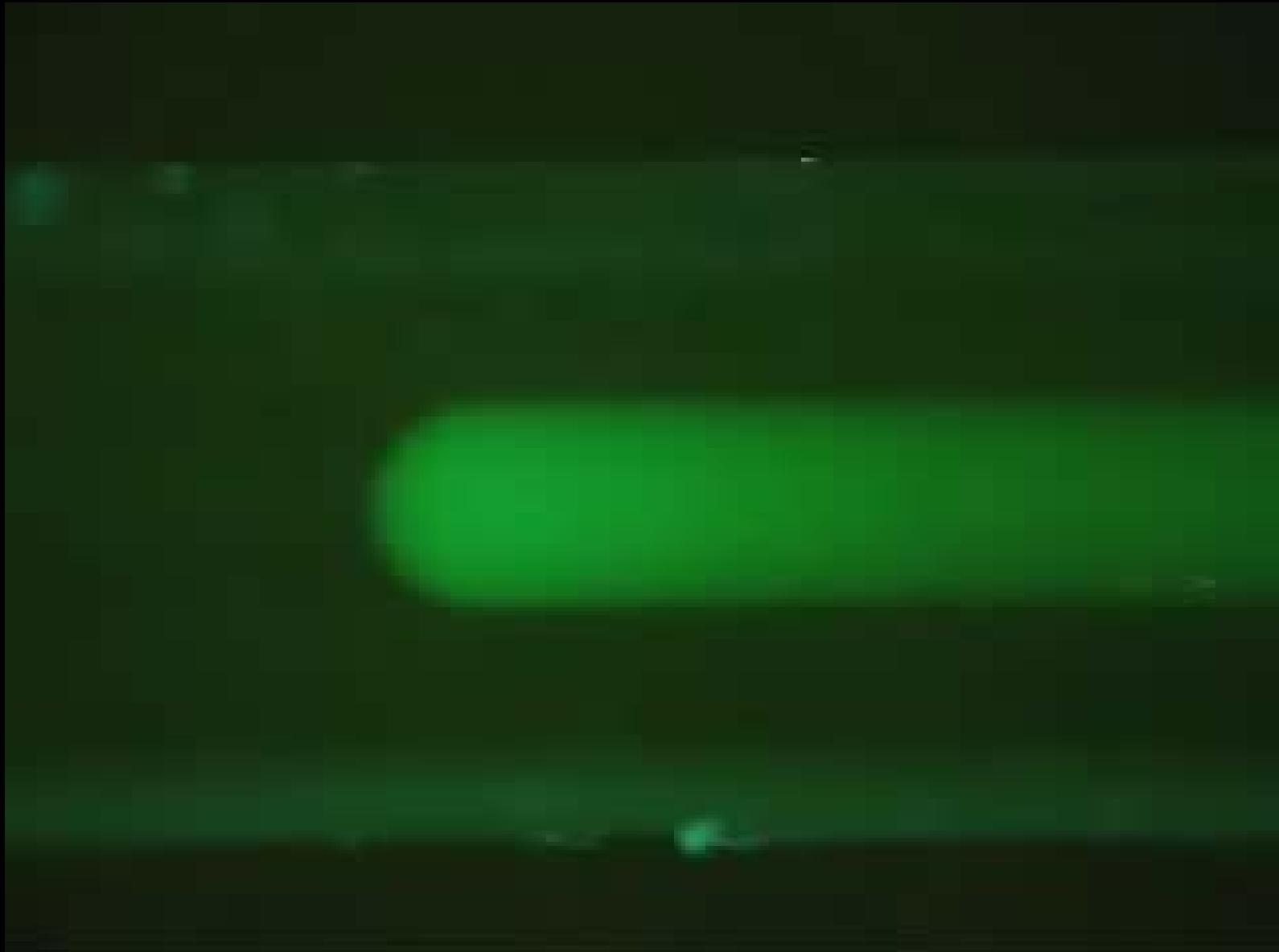


xy











Chromosome-analogueous data storage hierarchy

