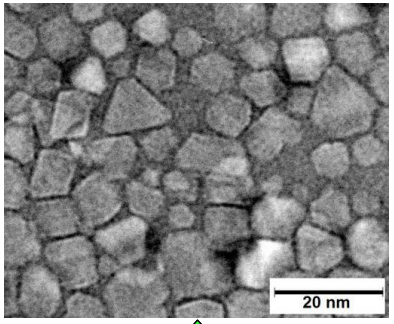
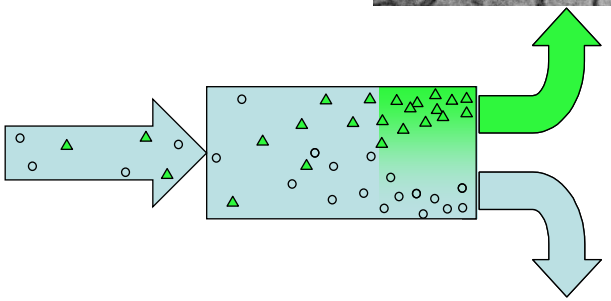
Recycling von Nanopartikeln

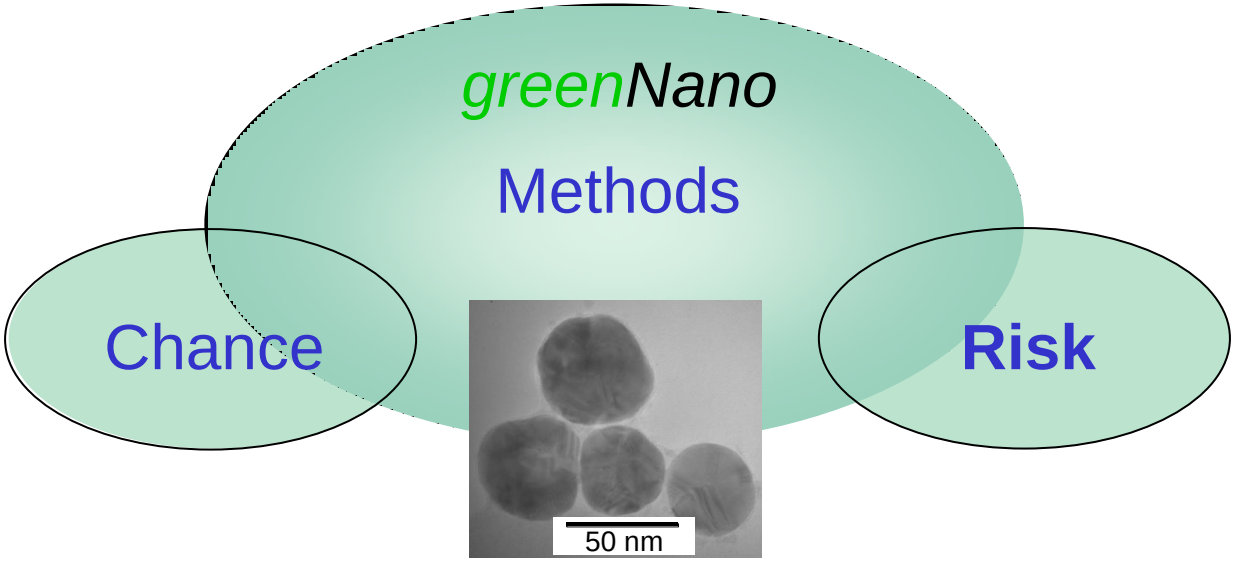
Aktuelle Entwicklungen

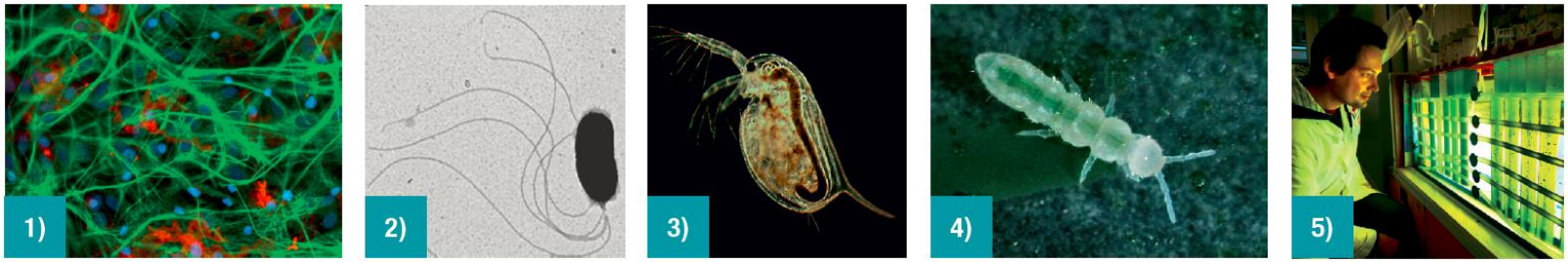




Prof. Dr.-Ing. Jorg Thöming
Zentrum für Umweltforschung und nachhaltige Technologien - UFT
Universität Bremen

UFT research focus





Testsysteme zur Analyse der biologischen Wirkung von Nanomaterialien

1) *Gehirnzellen: Astrozyten (grün) Mikroglia (rot) und Zellkerne (blau);* 2) *Vibrio fischeri (Leuchtbakterium);*
3) *Daphnia magna (Großer Wasserfloh, Nano-Eisenoxid im Verdauungstrakt sichtbar);* 4) *Folsomia candida (Springschwanz);* 5) *Algenzucht*

Nanoparticles in the environment have existed ever since…

http://photocompetition.upclive.com

http://www.photolib.noaa.gov

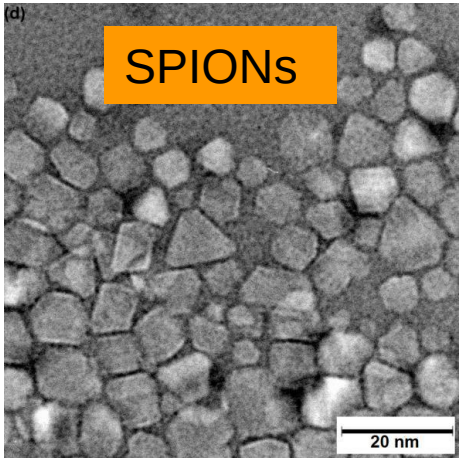
Ball lightning: *Nature* 403, 519-521 (2000)

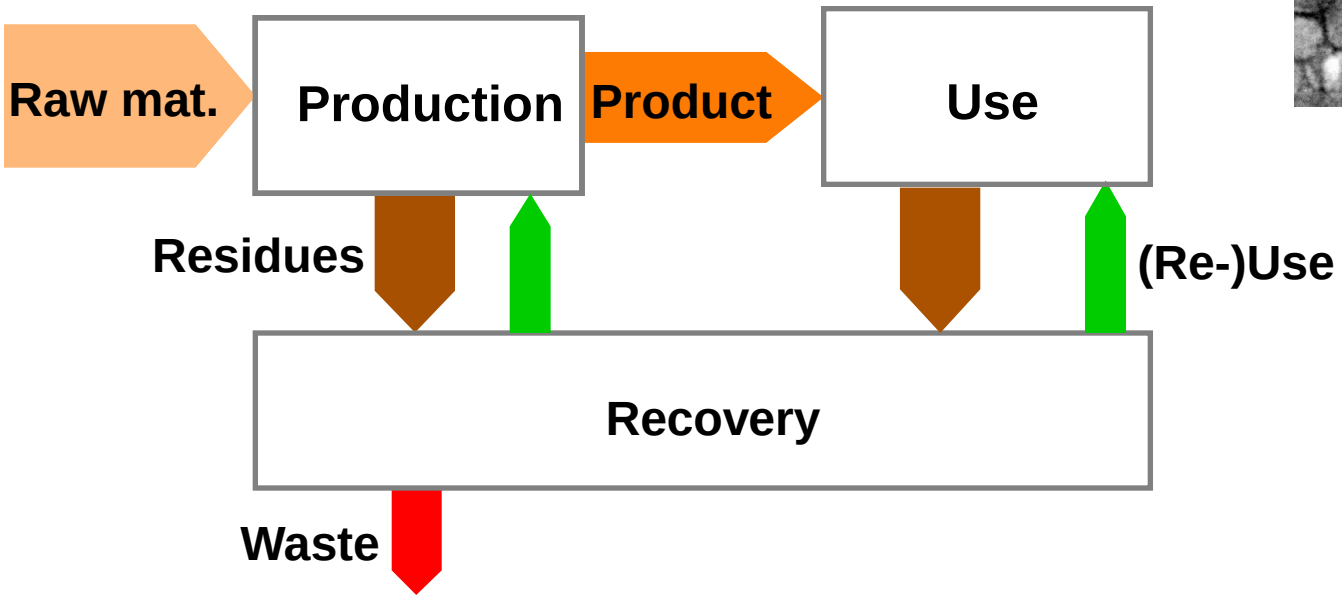
However, engineered nanoparticles have not

Recycling

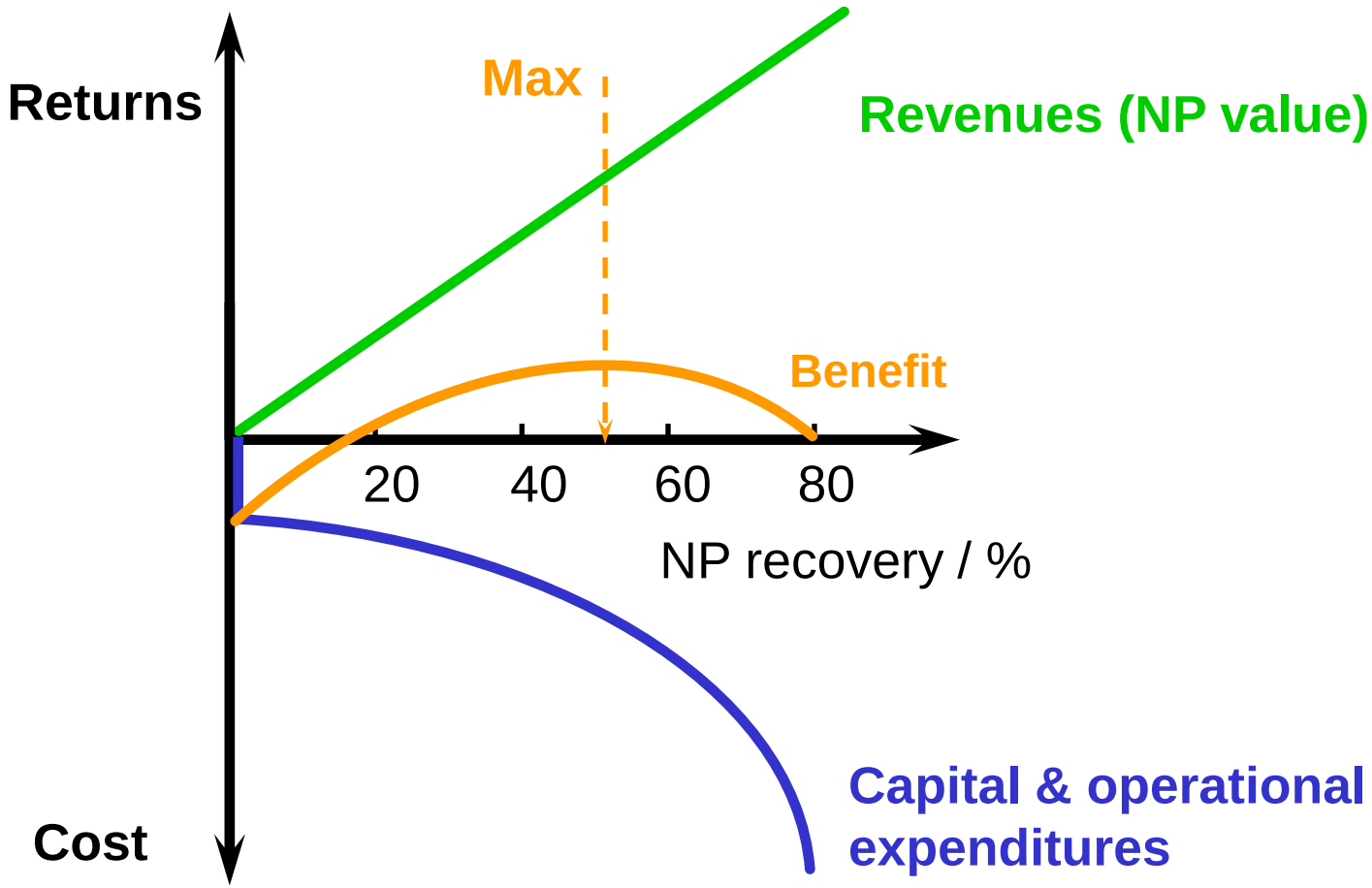
Product example:

Superparamagnetic iron oxide

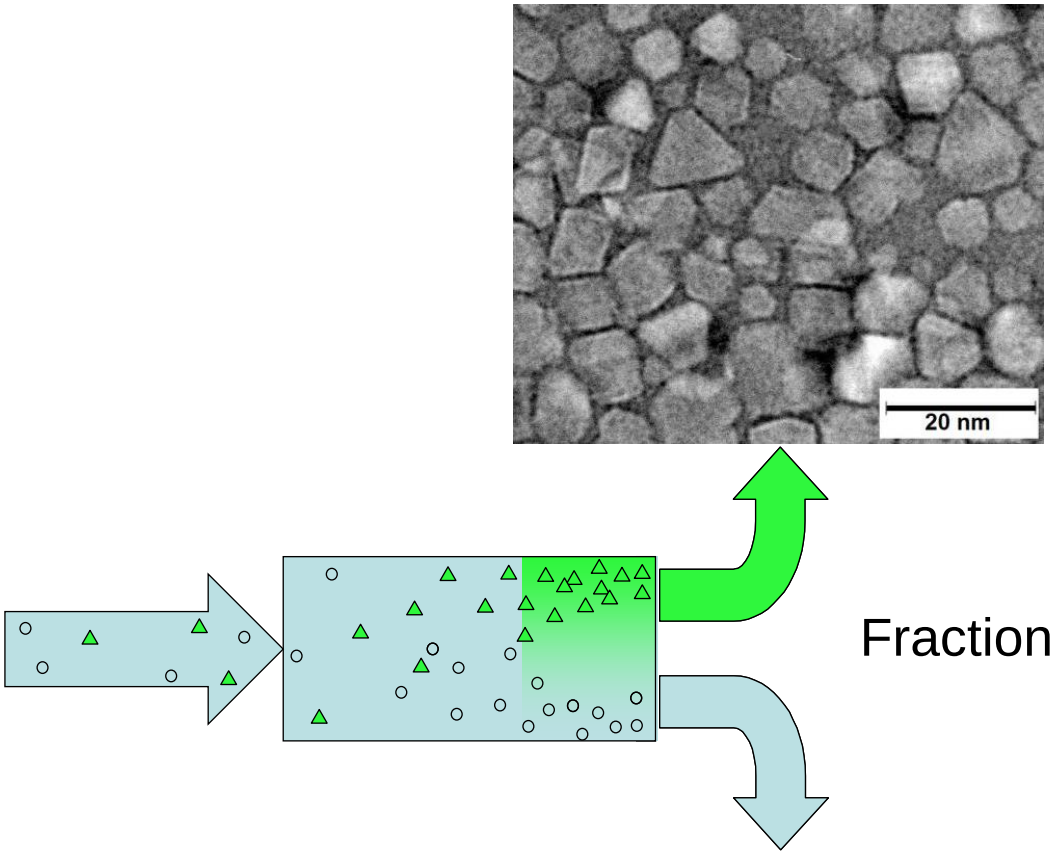




Recovery of NP – A Question of Return on Invest



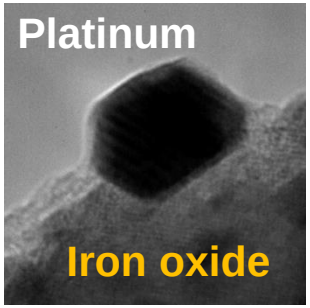
Recovery: Enrichment & Fractionation



Fractionation

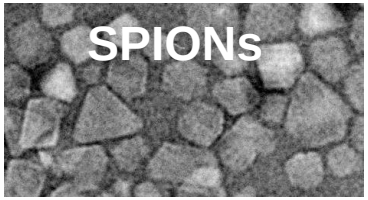
Recovery of nanoparticles – processes available?

- NPs in solid matrix



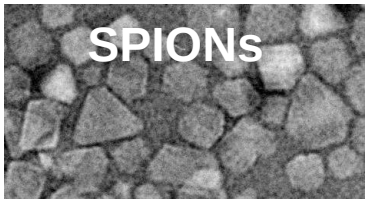
Milling + fractionation

- (Superpara)Magnetic NPs



Selective enrichment

Magnetic separation of SPIONs: selective enrichment



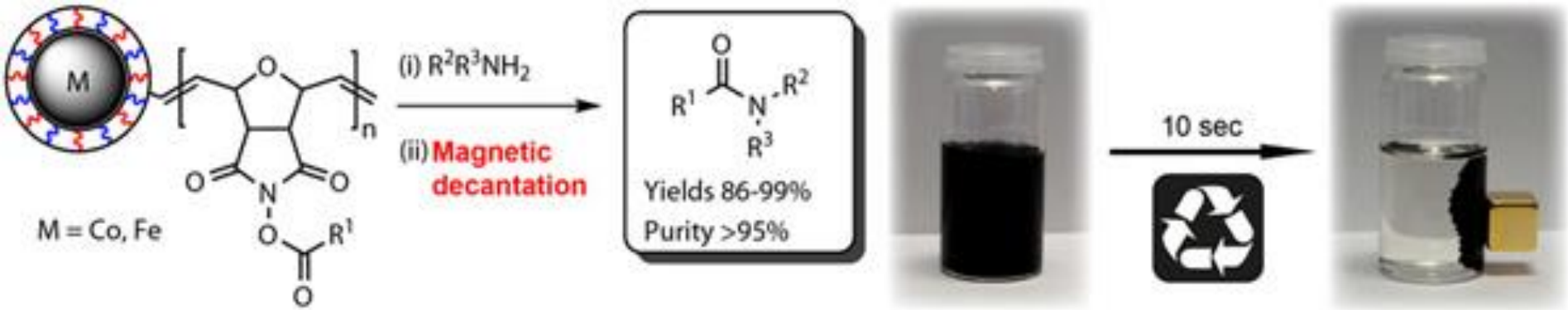
Liquid →

→

Scale-up for recycling possible

Enrichment

Magnetic separation of SPIONs

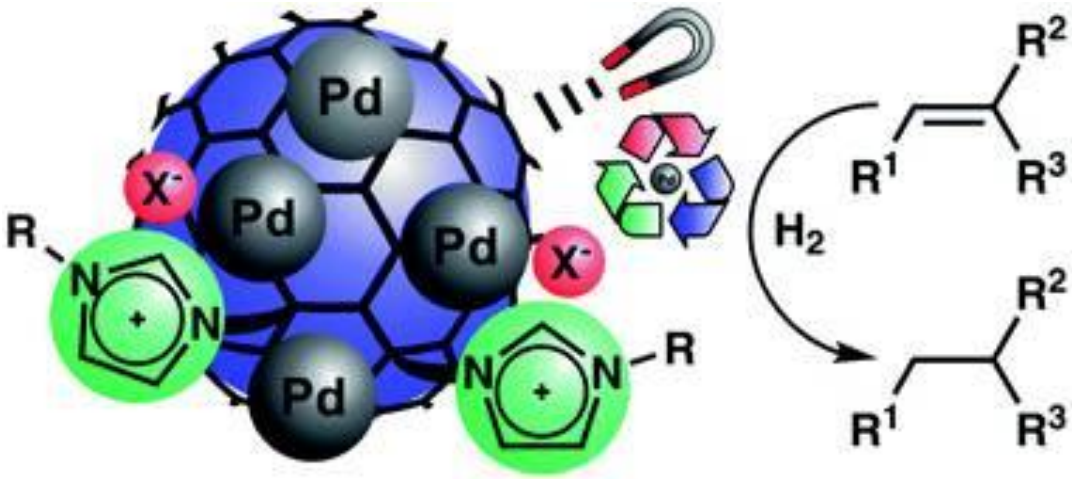


Kainz Q. M., Linhardt R., Maity P. K., Hanson P. R., Reiser O., 2013 **Ring-Opening Metathesis Polymerization-based Recyclable Magnetic Acylation Reagents**, *ChemSusChem*, 6:721

Scale-up for recycling possible

Enrichment

Magnetic separation of SPIONs

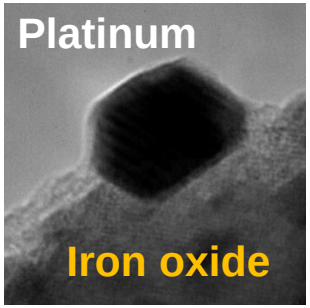


Linhardt R., Kainz Q., Grass R., Stark W., Reiser O., **Palladium nanoparticles supported on ionic liquid modified, magnetic nanobeads - recyclable, high-capacity catalysts for alkene hydrogenation**, *RSC Advances* , 4:8541-8549

Scale-up for recycling possible

Recovery of nanoparticles – processes available?

- NPs in solid matrix



Milling + fractionation

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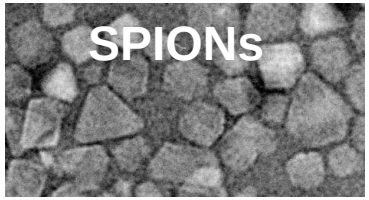
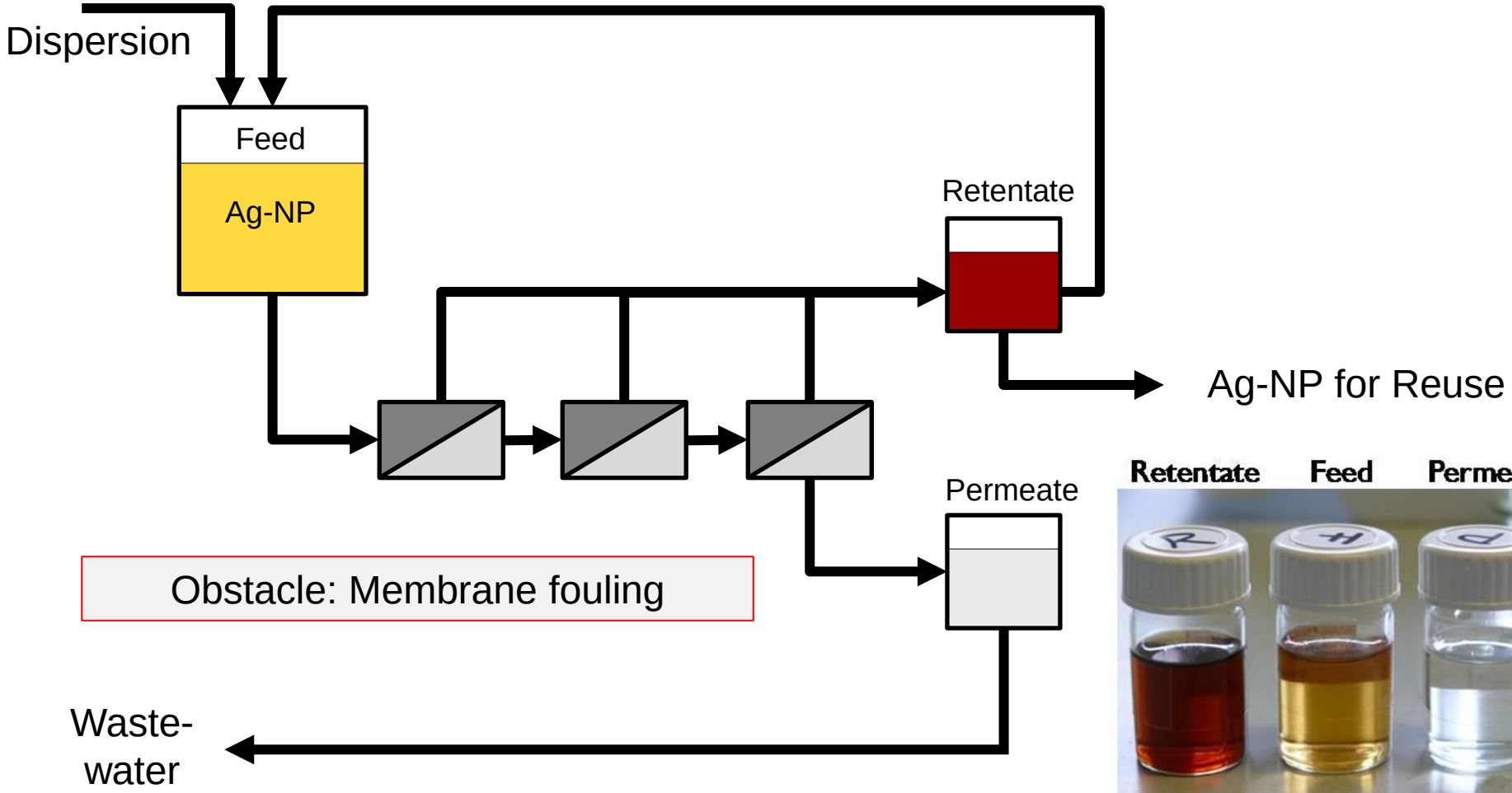


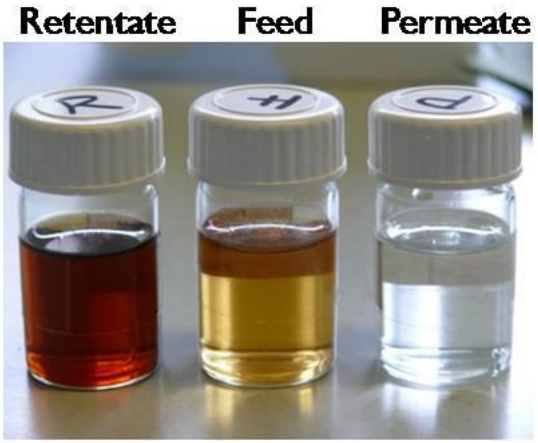
Selective enrichment

- NPs dispersed in liquid

Enrichment + fractionation

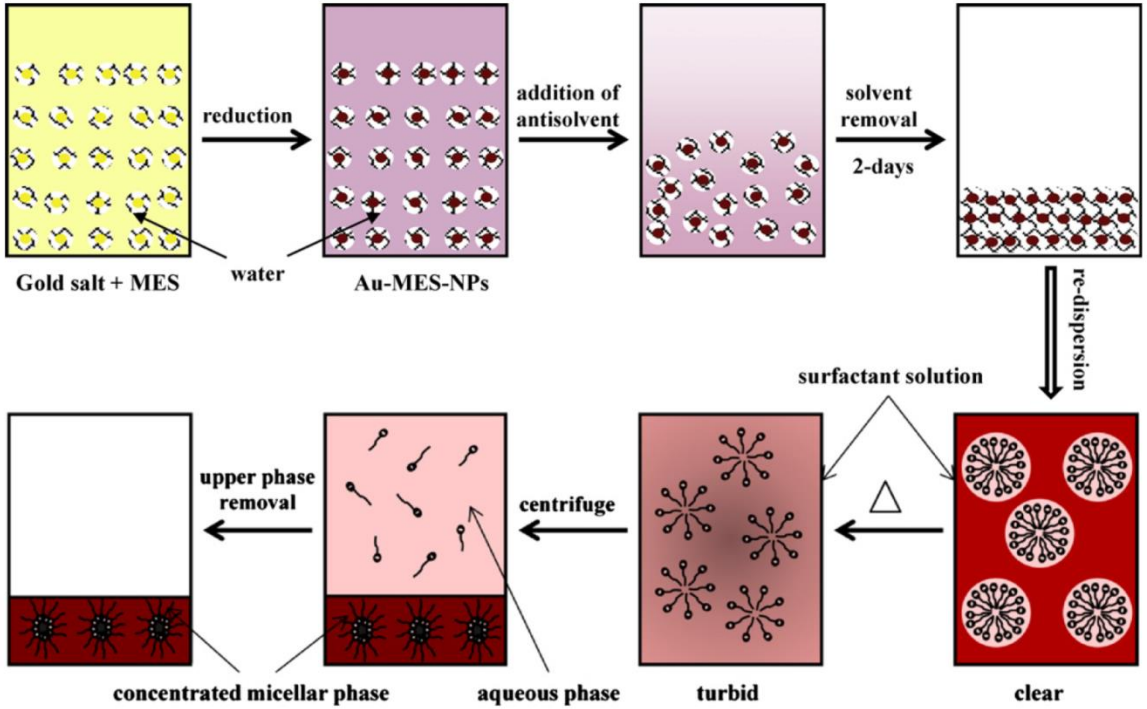
Enrichment of nanoparticles dispersed in a liquid





Enrichment of nanoparticles dispersed in a liquid

Solvent extraction



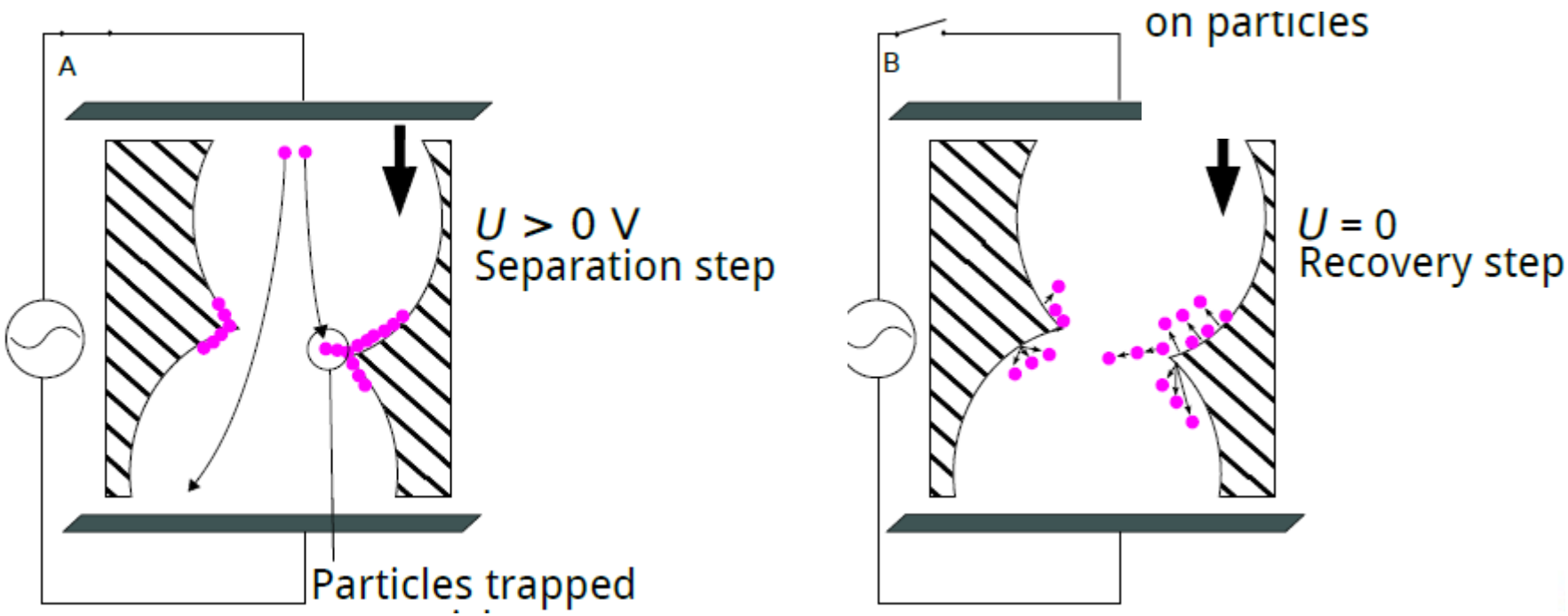
Multi stage process: (too) expensive

Here: cloud point extraction with non-ionic surfactant mixtures

R.C. Flagan, Annu. Rev. Chem. Biomol. Eng., 5, pp. 255-279, 2014

Nanoparticles dispersed in a liquid
Enrichment using dielectrics

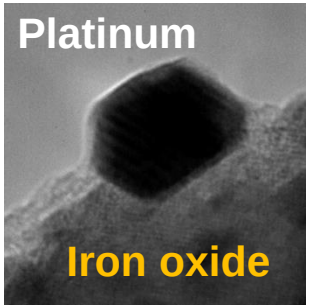
Switchable filter (UFT)



Pesch et al. (2014) Sep. Pur. Tech., 132, 728–735

Recovery of nanoparticles – processes available?

- NPs in solid matrix



Milling + fractionation

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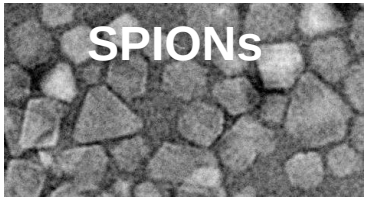


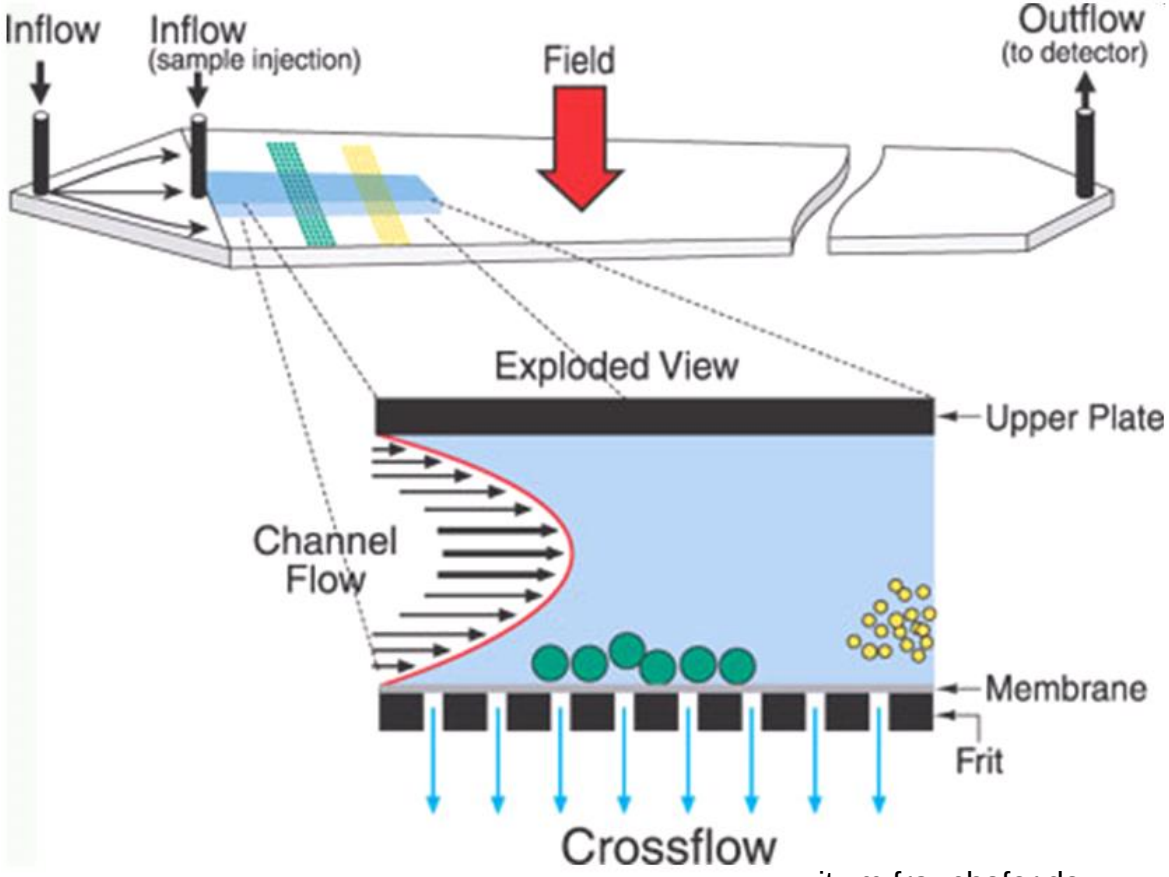
Selective enrichment

- NPs dispersed in liquid

Enrichment + fractionation

Nanoparticles dispersed in a liquid
Fractionation

Particle analysis: Asymmetrical Flow Field-Flow Fractionation, AFFFF

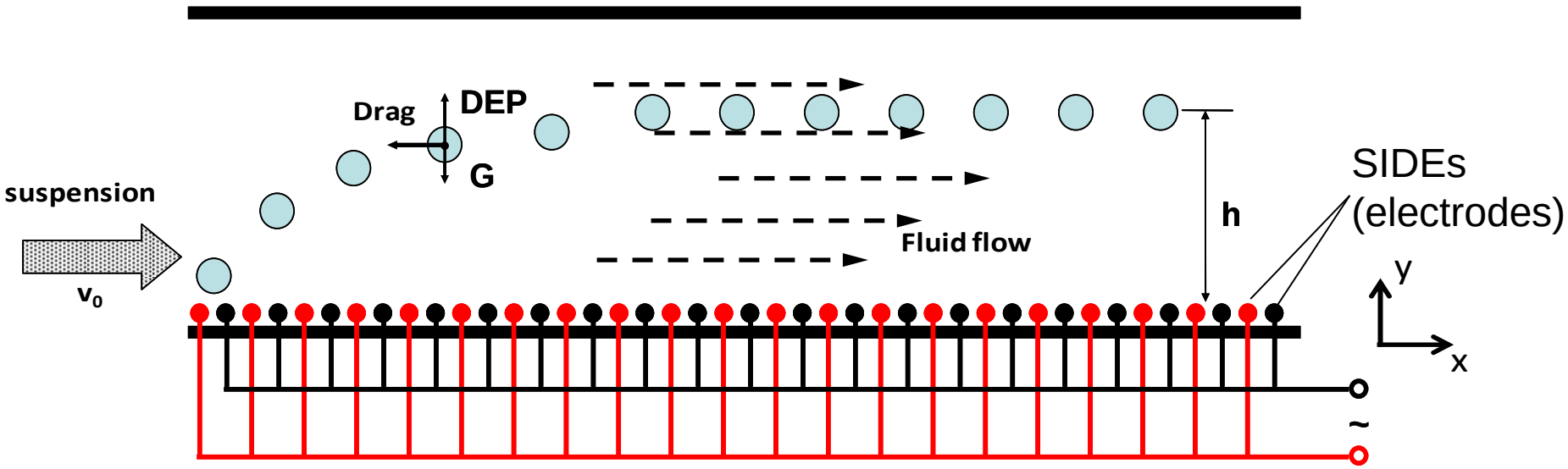


itwm.fraunhofer.de

Scale-up for recycling questionable

Nanoparticles dispersed in a liquid
Fractionation using dielectricity

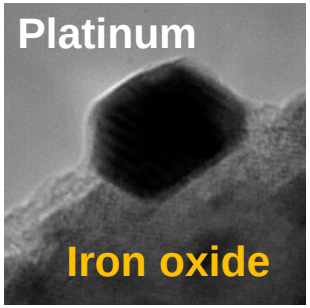
SIDE-separator (UFT)



Scale-up for recycling to be developed

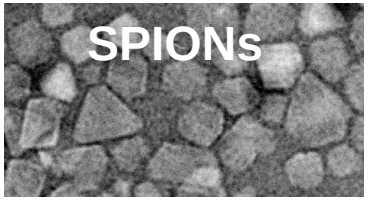
Recovery of nanoparticles – processes available?

- NPs in solid matrix



Milling + fractionation

- (Superpara)Magnetic NPs



Selective enrichment

- NPs dispersed in liquid

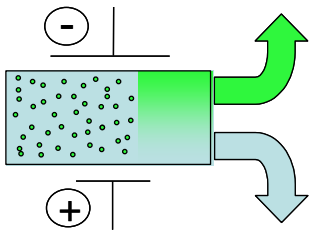
Enrichment + fractionation

- NPs dispersed in gas (aerosol)

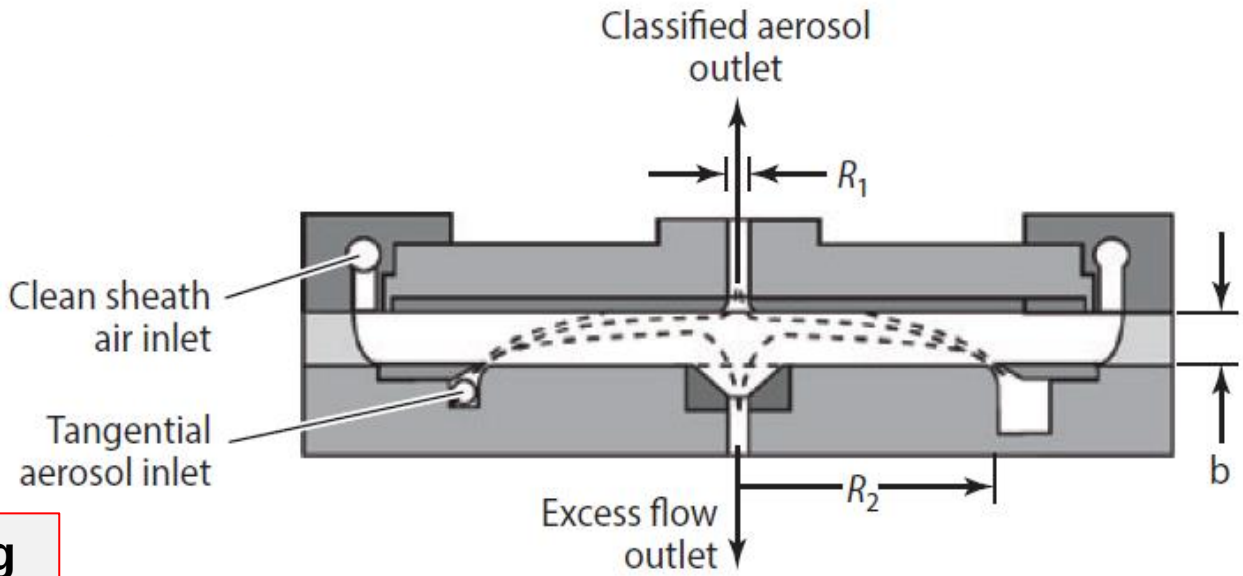
Enrichment + fractionation

Enrichment of NP from aerosols

Differential Mobility Analyzer



- Radial flow DMA (RDMA)
- Measurment range 1nm – 1 µm
- Opposite ring electrodes



Scale-up for recycling questionable

S. Zhang, Y. Akutsu, L.M. Russell, R.C. Flagan, J.H. Seinfeld, Aerosol Science and Technology, 23:3, pp.357-372, 1995

Enrichment of NP from aerosols

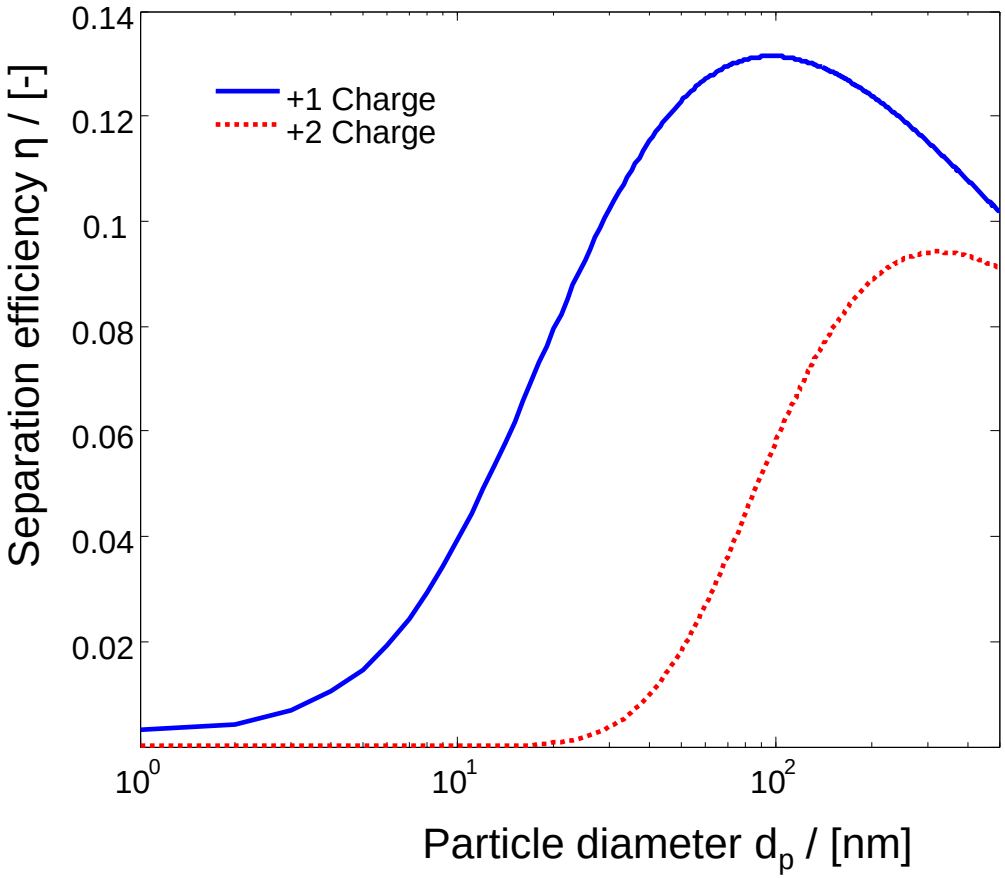
Limitations of DMA efficiency

Ideal* separation efficiency

$$\eta = \frac{2\, n_P}{3\, n_t}$$

n_p number of particles carrying p charges calculated according to Kousaka et al.*

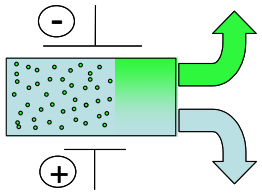
n_t total number of particles



*) *Y. Kousaka, K. Okuyama, M. Adachi, Aerosol Sci Tech,* Vol. 4, No. 2, pp. 209-255, 1985

Folgerungen

- Element-Recycling Bsp.: Sortierung, Pyro-/Hydrometallurgie
- Recycling (superpara)magnetischer NPs
- Recycling dispergierter NP
- Wirtschaftliches Recycling erfordert neue Technologie



Vielen Dank für ihre Aufmerksamkeit

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SURFLAY

Dr. habil. Lars Dähne

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Bundesministerium für Wirtschaft und Technologie

aufgrund eines Beschlusses des Deutschen Bundestages

DFG

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