Biomolecular Tubes and Fibers

Alexander Bittner

"Chemical Nanostructuring and Self-Assembly"

Abt. Kern - Nanoscale Science

Max Planck Institute for Solid State Research, Stuttgart, DE

Group "Self-Assembly"

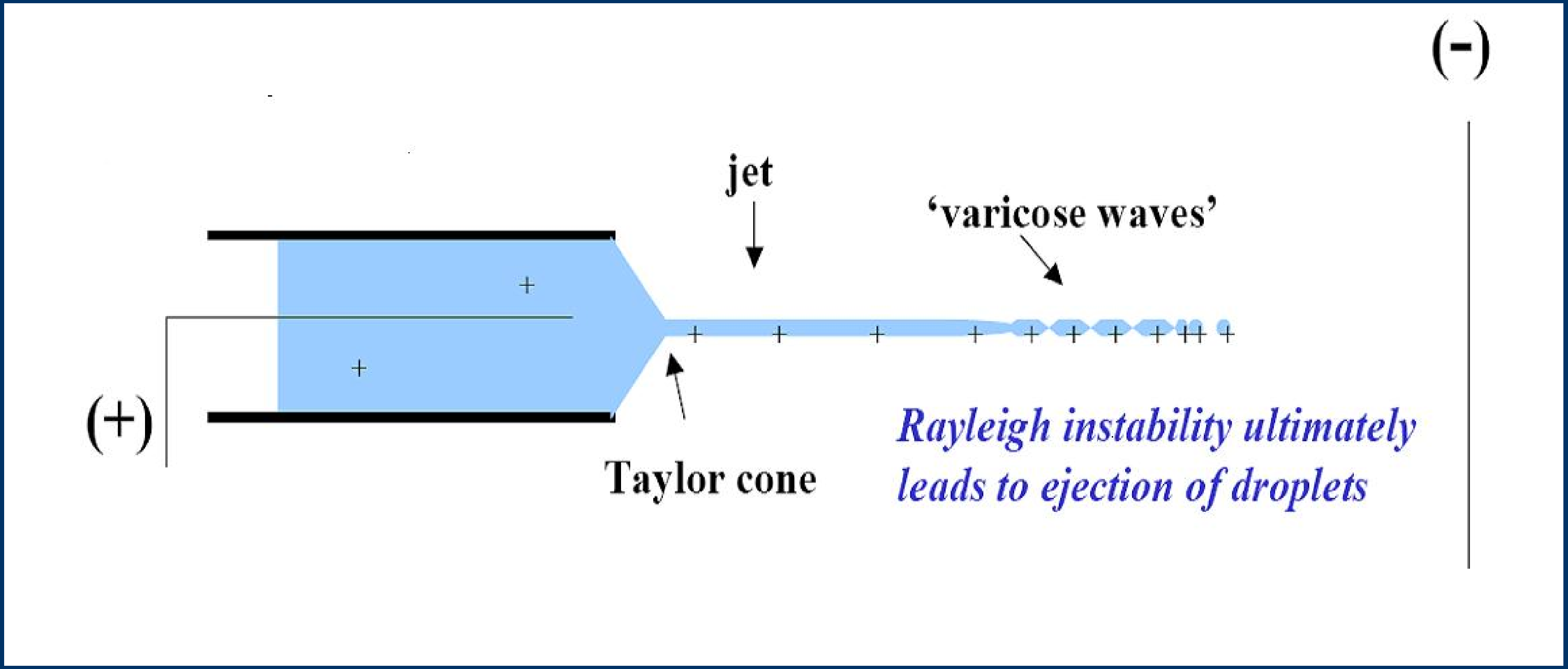
CIC Nanogune Consolider, Donostia-San Sebastian, ES

Electrospun self-assembling peptides

Nikola Malinowski
Sebastian Loscher
Gurvinder Singh
Darya Amoli
Marten Tolk
Guillaume Hupin

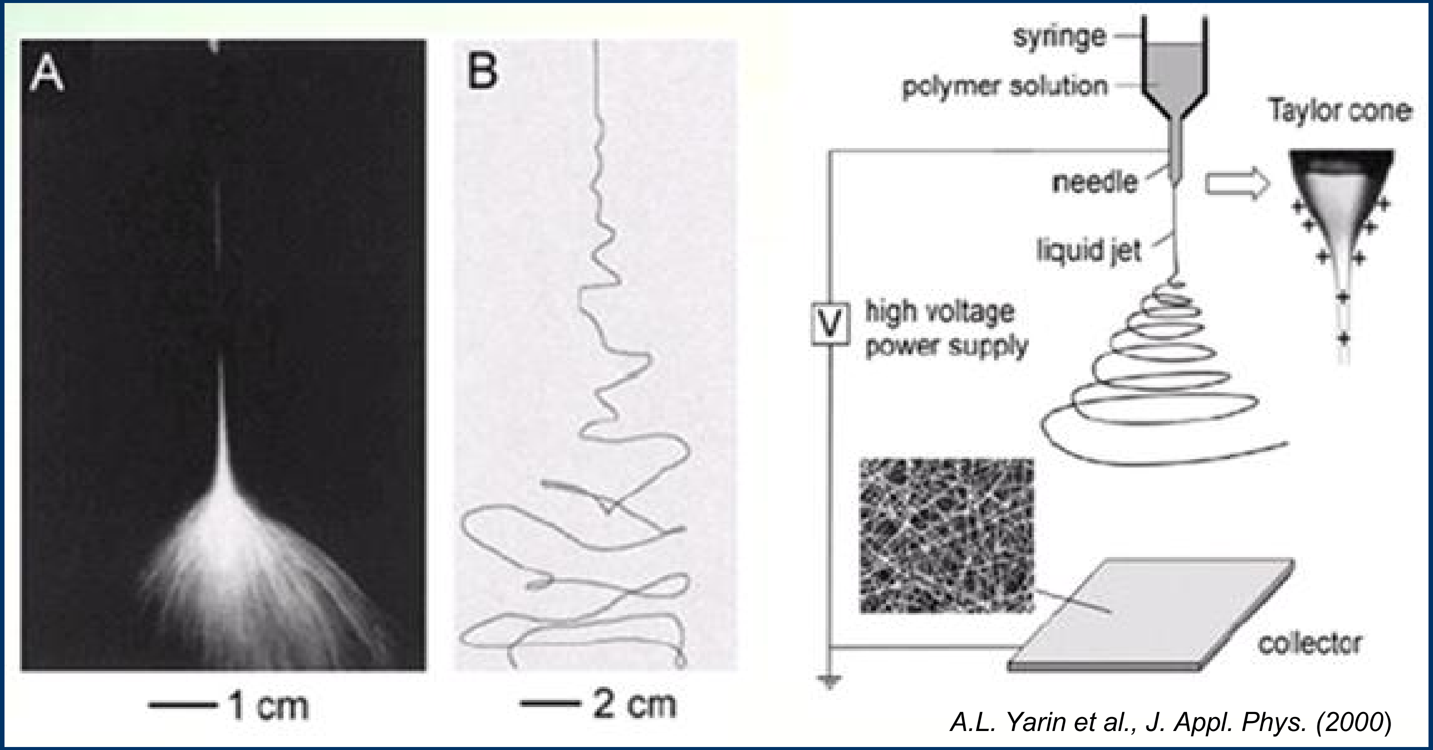
(MPI-FKF Stuttgart etc.)

Electrospraying



Surface tension σ/r ←→ E^2 field (charges on the jet)

Electrospinning (of polymers)



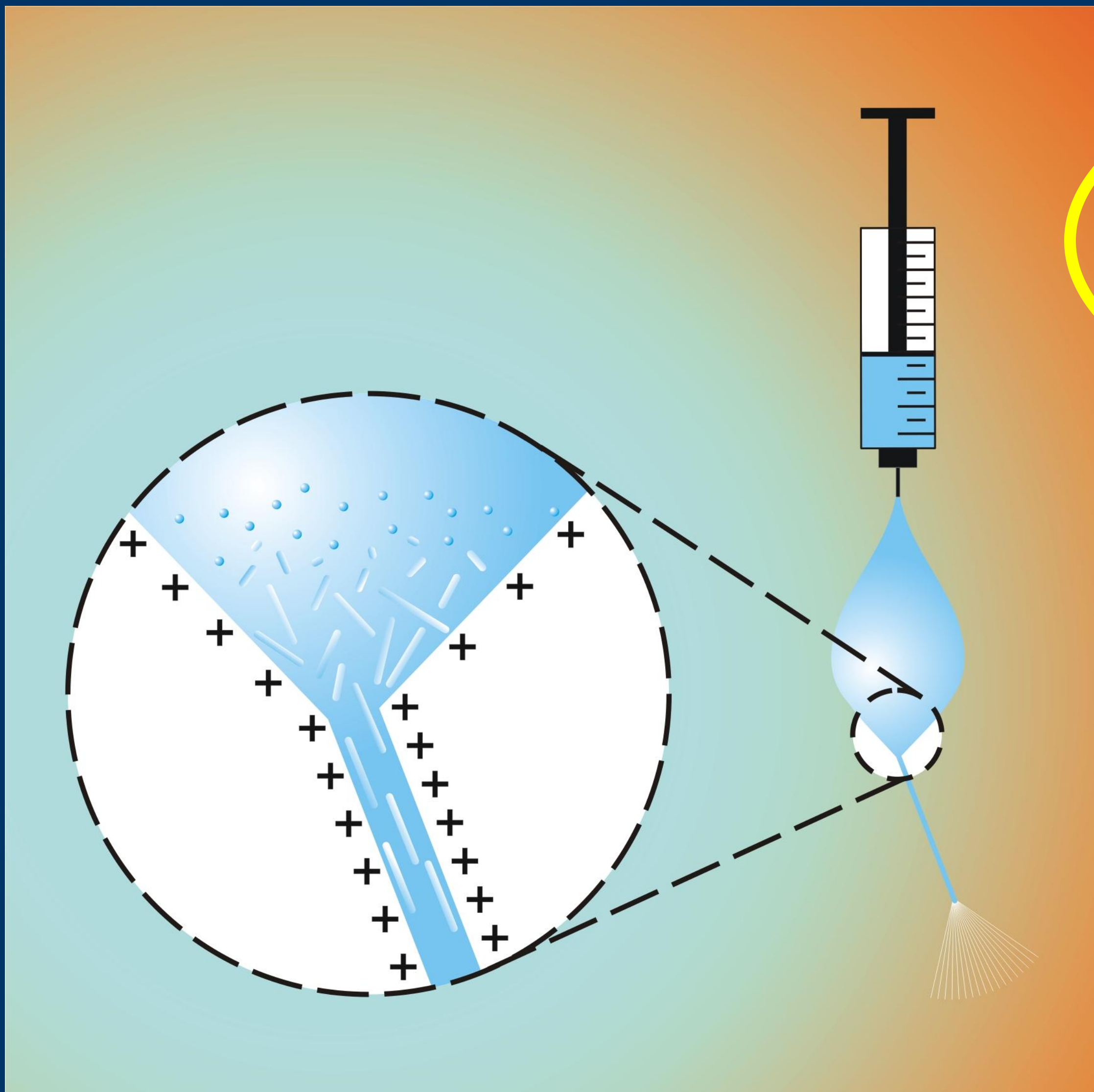
A.L. Yarin et al., J. Appl. Phys. (2000)

Highly viscous solution of polymers; constant feed; kV potential ↑

¡ Viscosity η ↓ changes with radius r ↓! But: high η ↓ vd for cone.

Evaporation of solvent: Concentration ↑ Vapour pressure ↑

Electrospinning of *monomers*

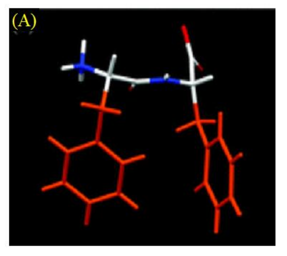


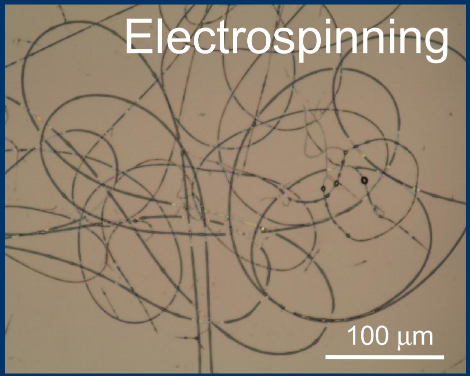
concentration

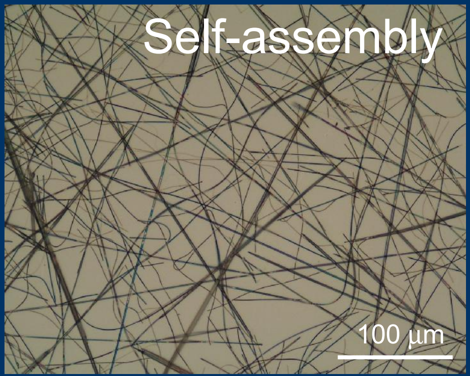
$\eta\gamma d$

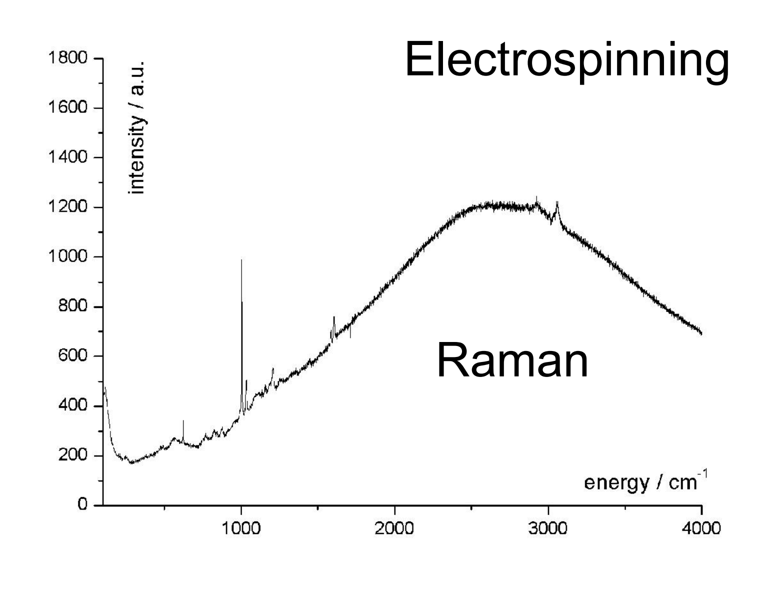
$\sigma/r \leftrightarrow E^2$

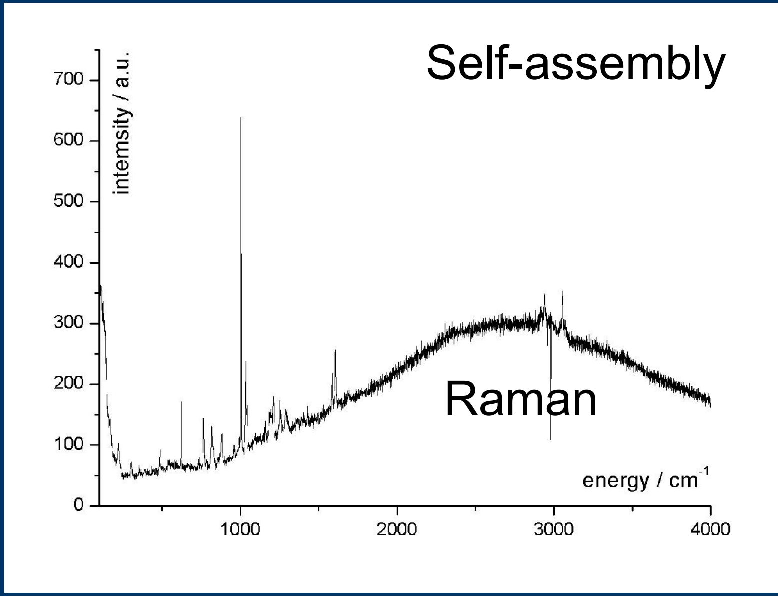
Electrospinning of self-assembling di-phenylalanine (Phe-Phe, FF)





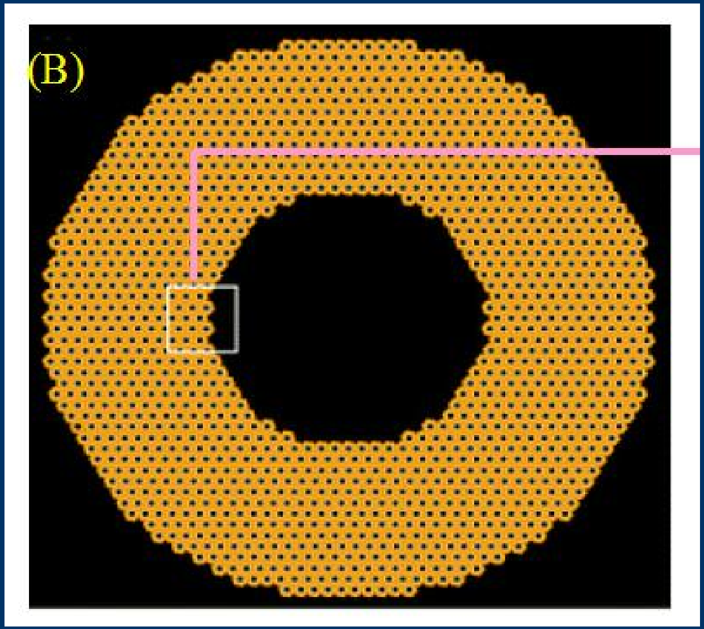


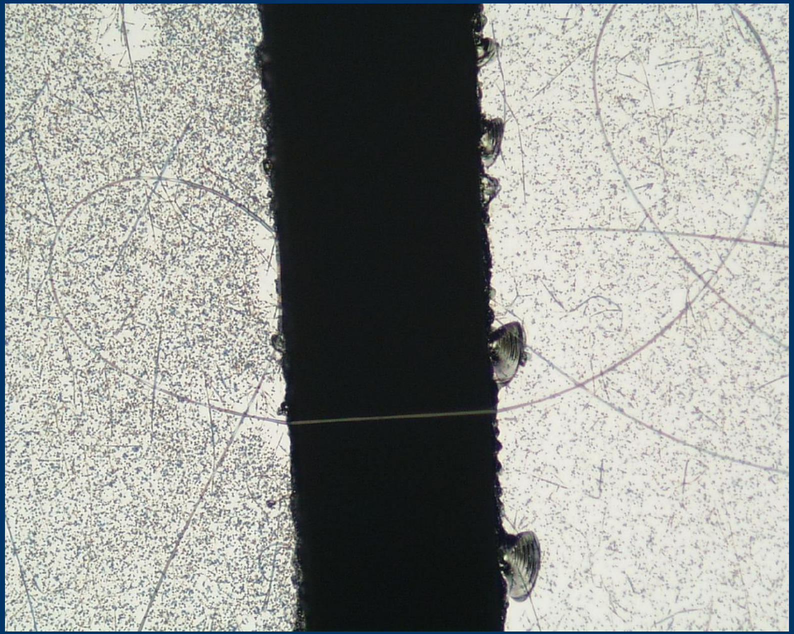




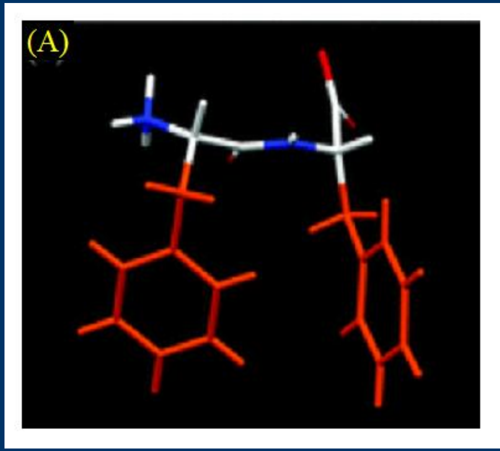
Singh et al, Adv. Mat., in print

Diphenylalanine tubes





Stretching and bridging over 0.1 mm gaps



The Tobacco mosaic virus in nanoscale science

Former Bittner group (Dept. Klaus Kern)

Gabriel Baralia, Sinan Balcı, Kei Noda, Mato Knez

Stuttgart University, Dept. of Mol. Biology & Plant Virology (Holger Jeske)

Anan Kadri, Anna Müller, Christina Wege, Emil Ruff

Max Planck Institutes Stuttgart

MPI-MF: StEM (electron microscopy group)
MPI-FKF: Von Klitzing group

Ulm University (Carl Krill III)

Zhenyu Wu, Chenchen Ma

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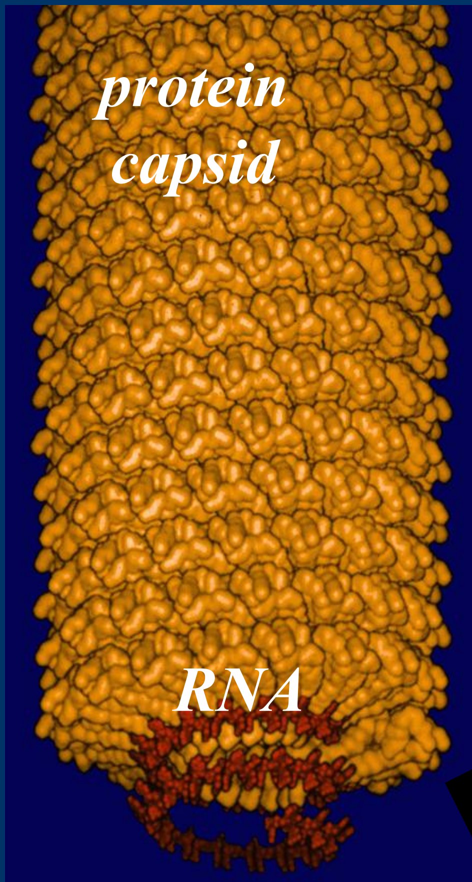
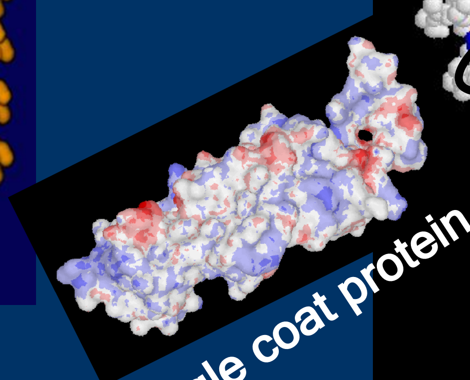
Max-Planck-Gesellschaft
Deutsche Forschungsgemeinschaft
Alexander von Humboldt-Gesellschaft
Kompetenznetz “Funktionelle Nanostrukturen“ Baden-Württemberg

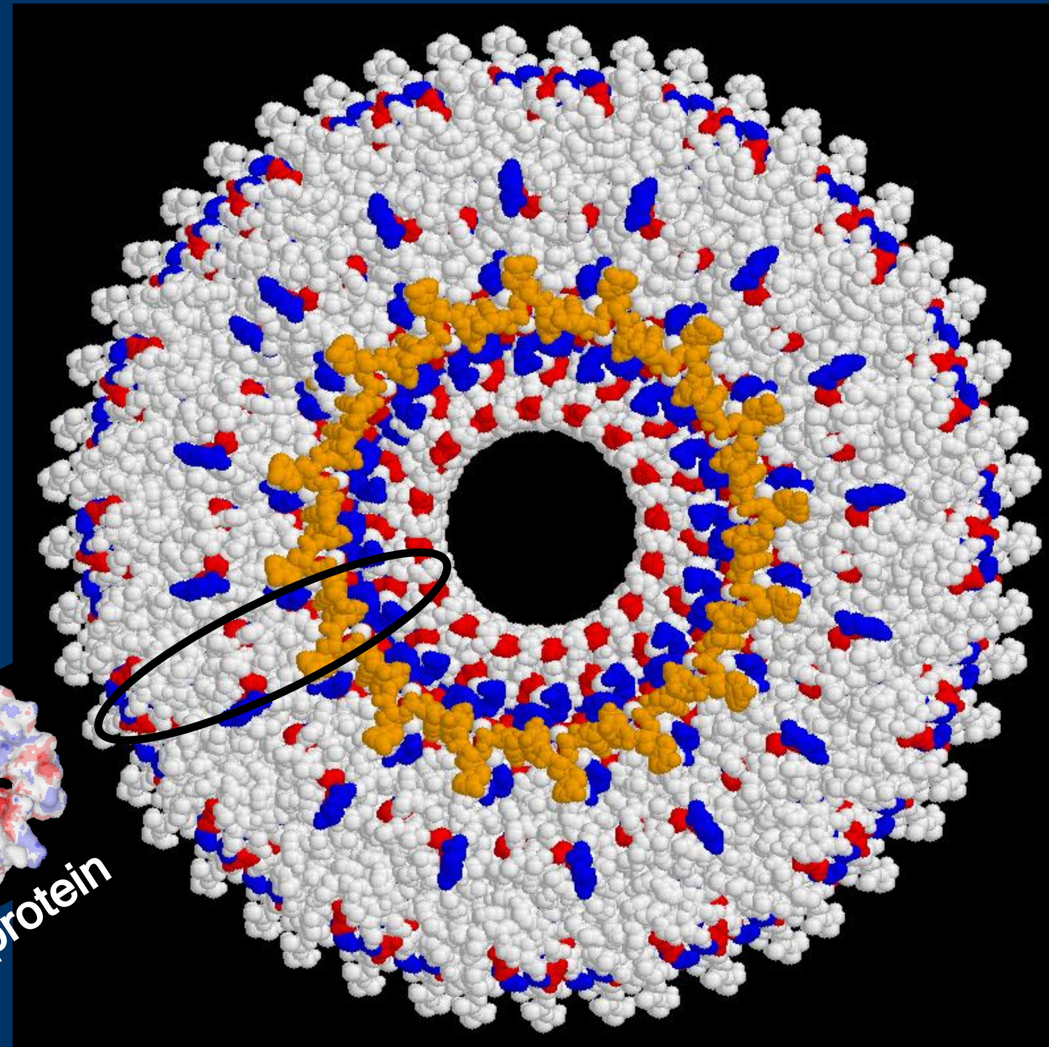
Tobacco mosaic virus (TMV)



D.L.D. Caspar, http://www.sb.fsu.edu/~caspar/

viral rod (partial)
2100 protein subunits
300 nm length

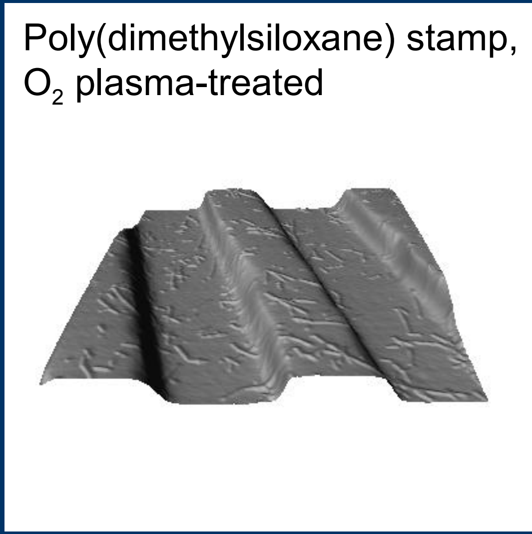




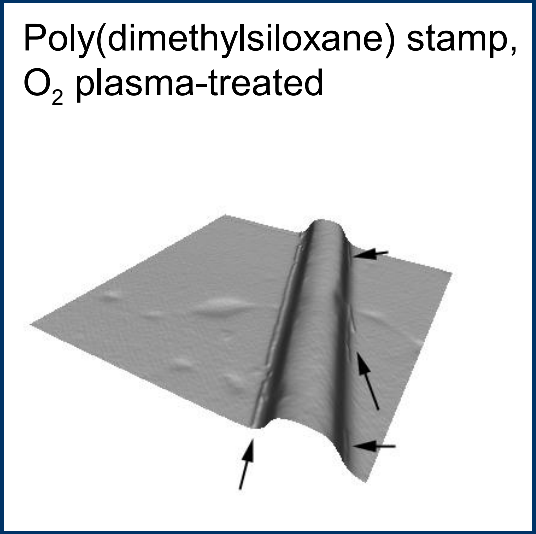
49 of 2100 subunits; 4 nm inner diameter
acidic and basic residues

Molecular models of the virus:
K. Henrick, J.M. Thornton, Trends Biochem. Sci. 23 (1998) 358; http://pqs.ebi.ac.uk/pqs-bin/macmol.pl?filename=1vtm
R. Pattanayek, G. Stubbs, J. Mol. Bio. 228 (1992) 516; K. Namba, R. Pattanayek, G. Stubbs, J. Mol. Bio. 208 (1989) 307

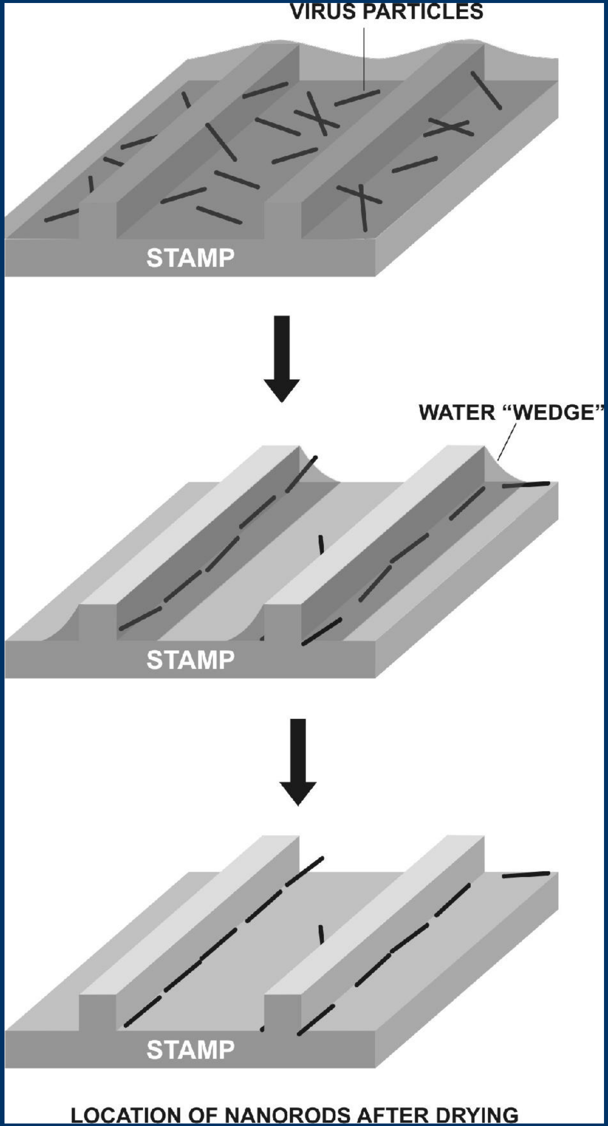
"Edge printing" of virus lines



TMV adsorbed on stamp



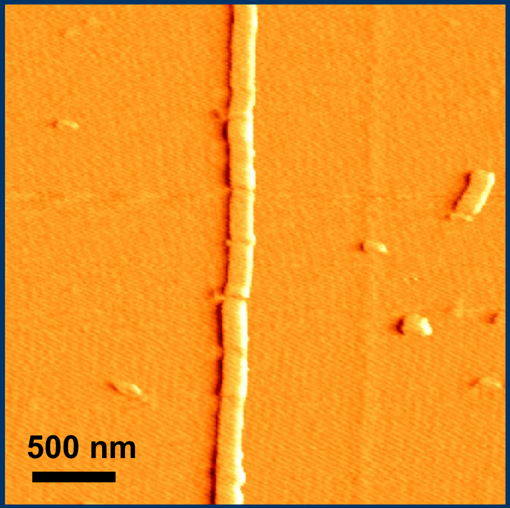
TMV adsorbed on stamp, low conc., blow dried → discontinuous dewetting



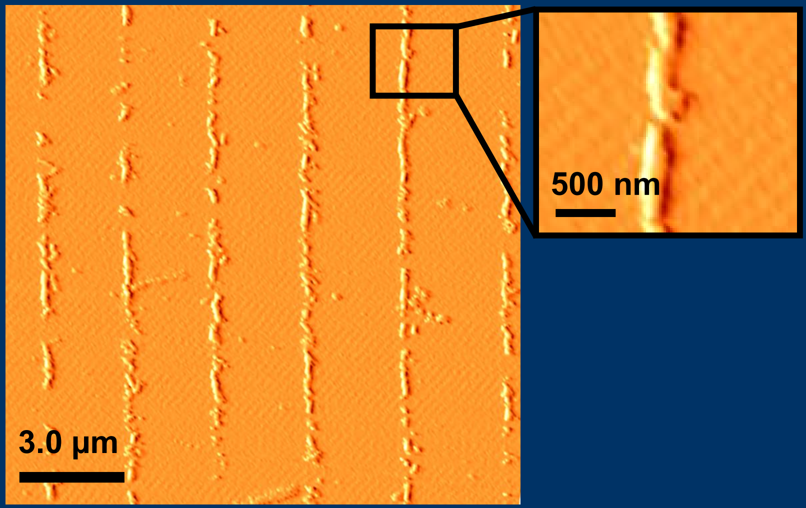
S. Balci et al., Adv. Mater. (2008)

"Edge printing" of virus lines

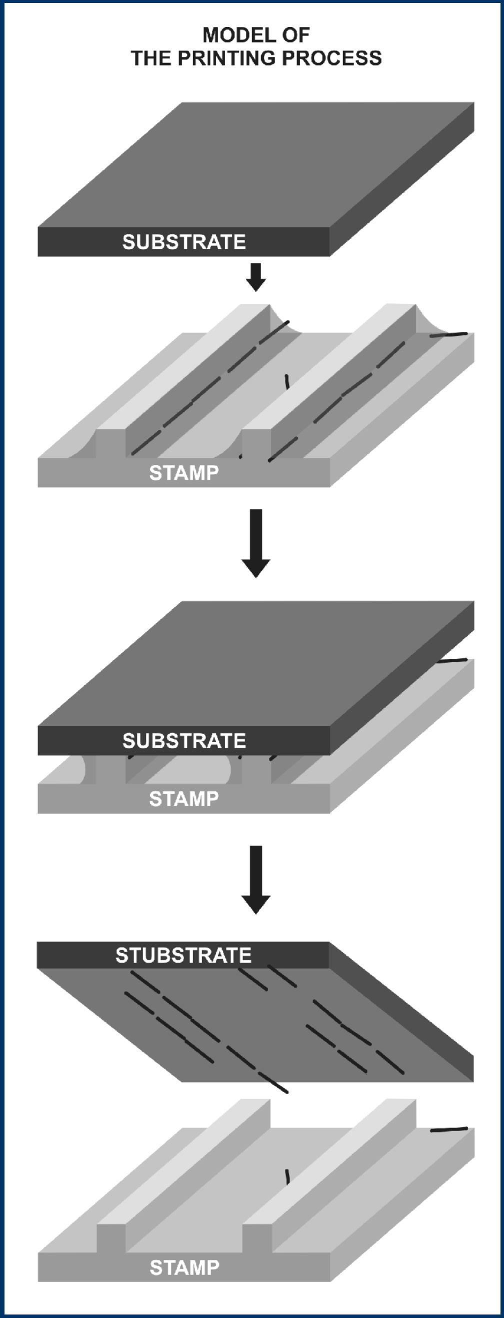
Oxidized Si



Oxidized Si

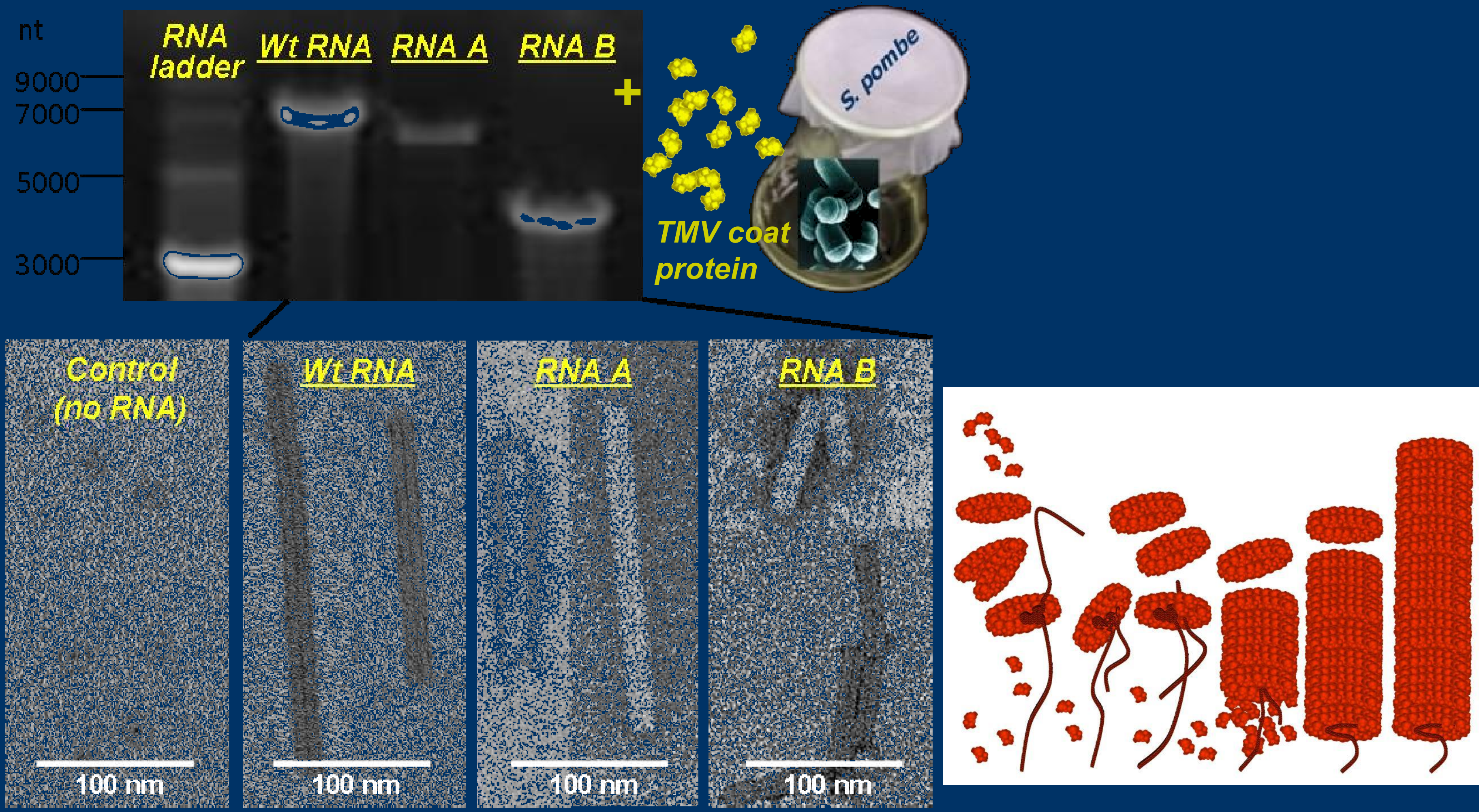


TMV lines printed on oxidized silicon wafer; width < 30 nm

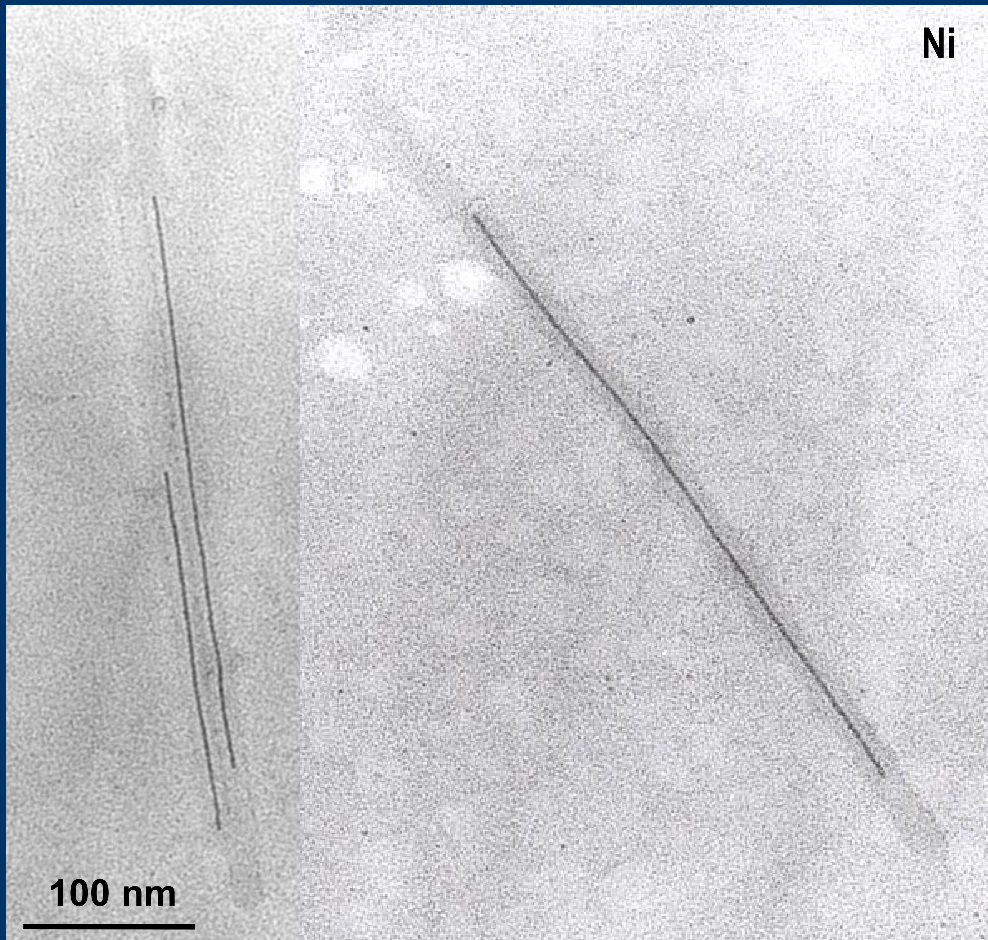


S. Balci et al., Adv. Mater. (2008)

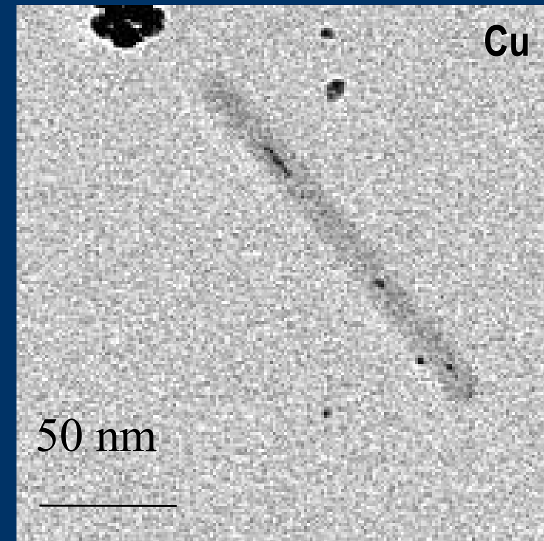
Assembly of “artificial TMV” = coat protein + RNA



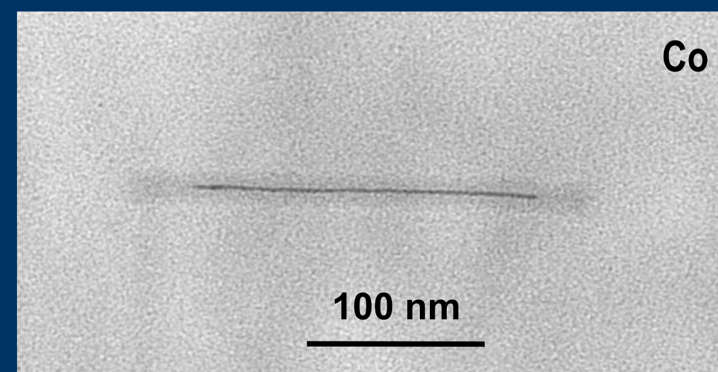
The "true" nanoscale: 3 nm wires in TMV



TEM after Pd(II) activation and Ni deposition



Pd/Cu deposition; wires and clusters



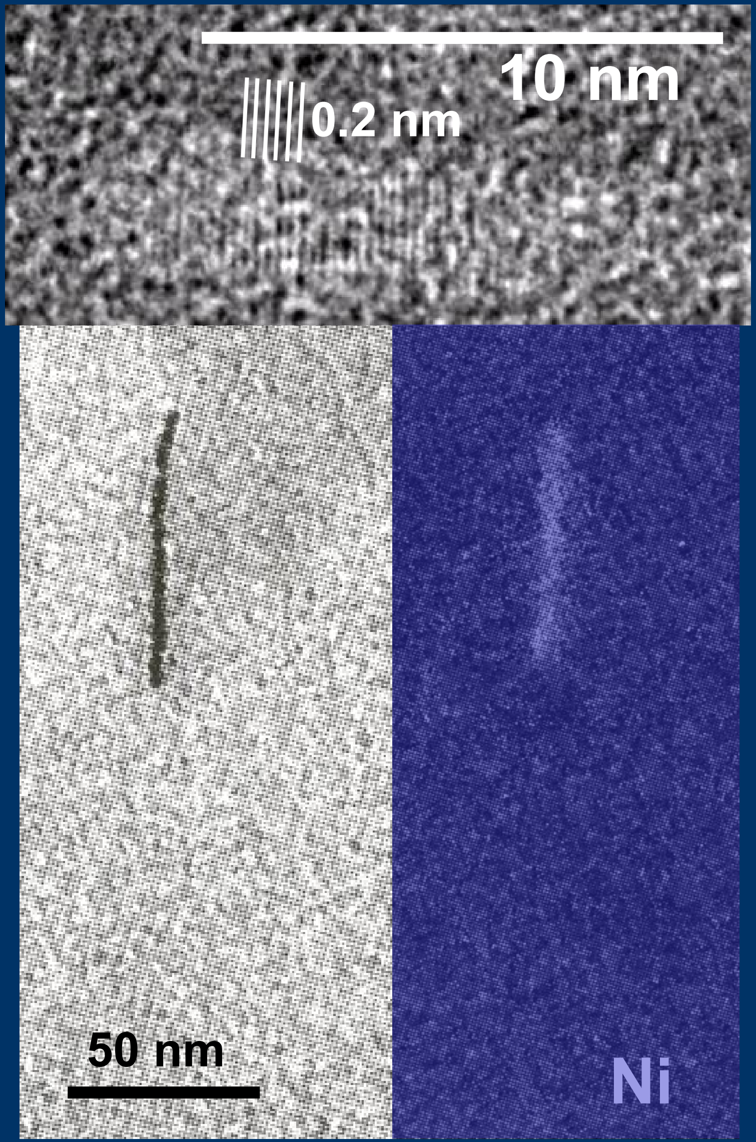
Pd/Co deposition

$$Ni^{2+} + 2\,e^- \rightarrow Ni$$

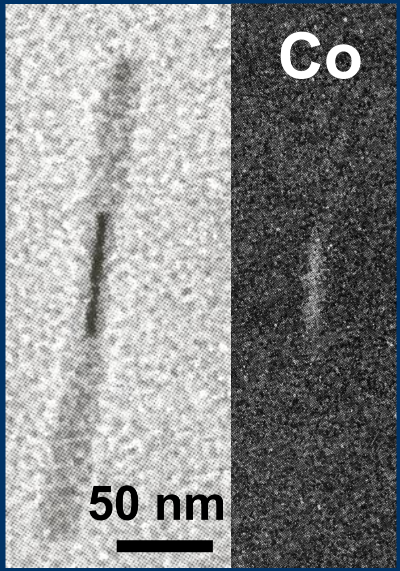
$$2\,BH_3 + 6\,OH^- \rightarrow 2\,H_3BO_3 + 3\,H_2 + 6\,e^-$$

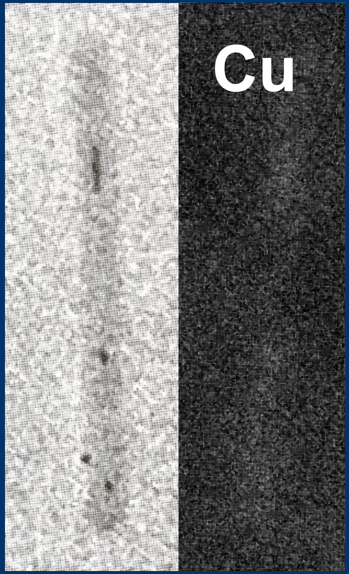
$$3\,Ni^{2+} + 2\,BH_3 + 6\,OH^- \rightarrow 3\,Ni + 2\,H_3BO_3 + 3\,H_2$$

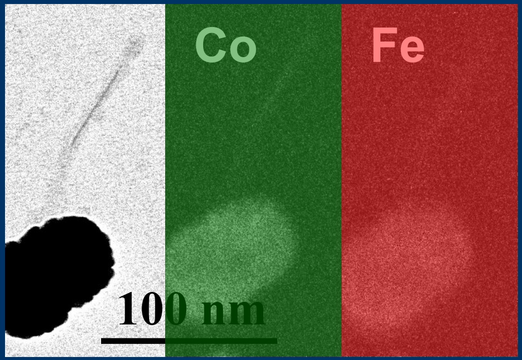
Energy filtering TEM of 3nm wires in virions



Chemical and structural analysis on the sub-5nm scale: Pure metal (little O); for Ni oriented crystallites, [111] in wire axis



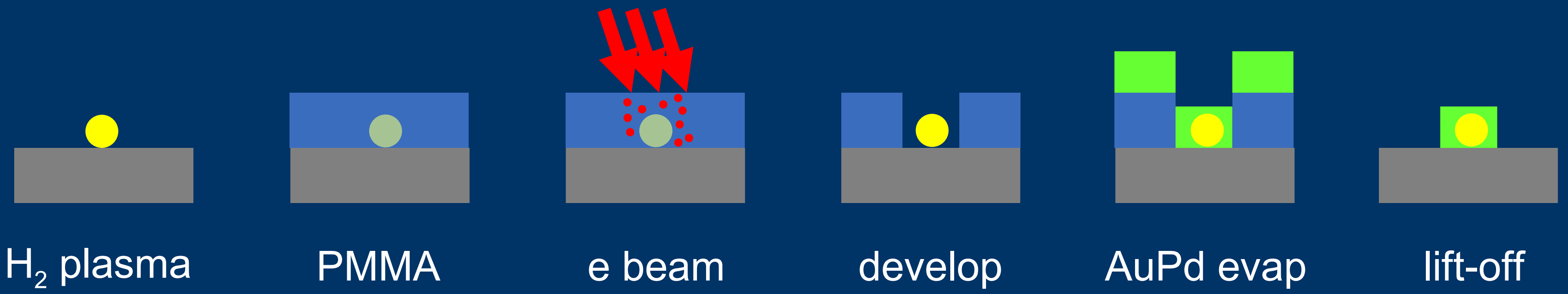


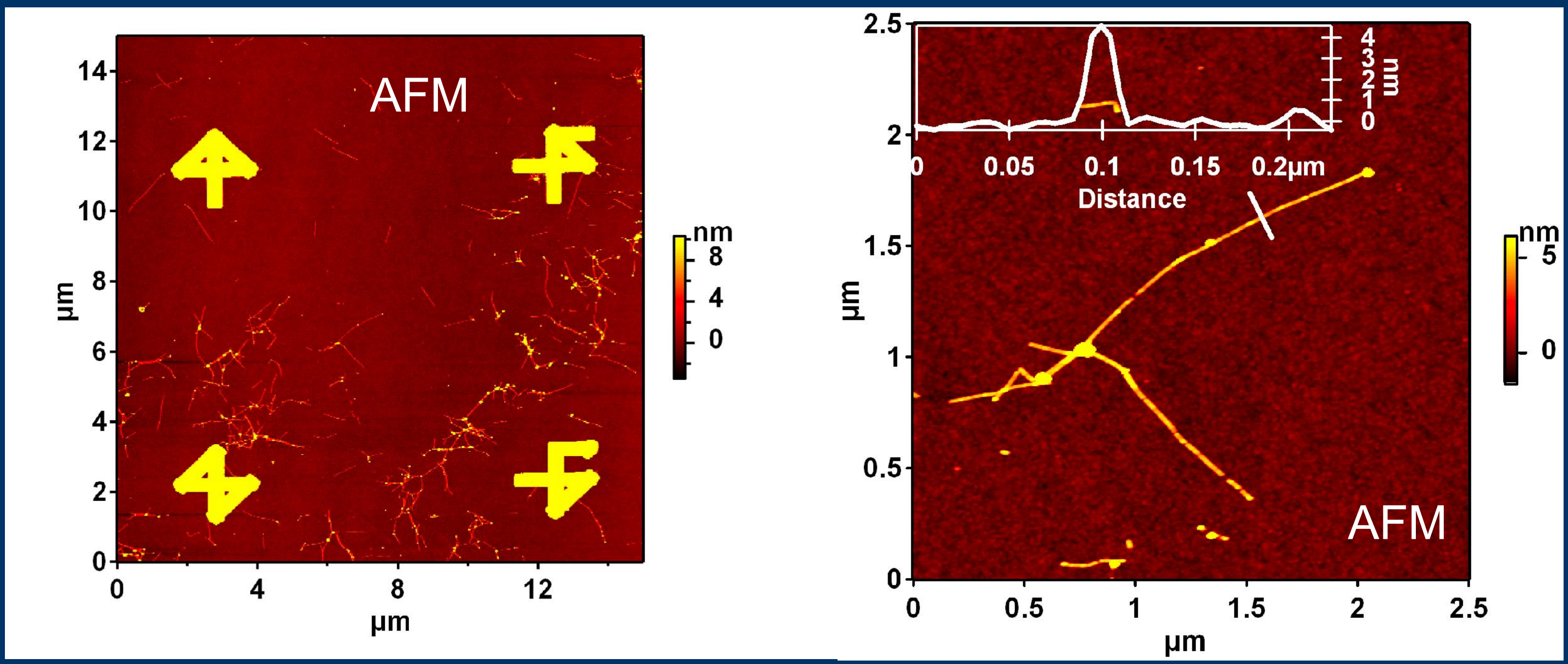


CoFe alloy wire

Balci et al., Electrochim. Acta 51 (2006) 6251; in preparation

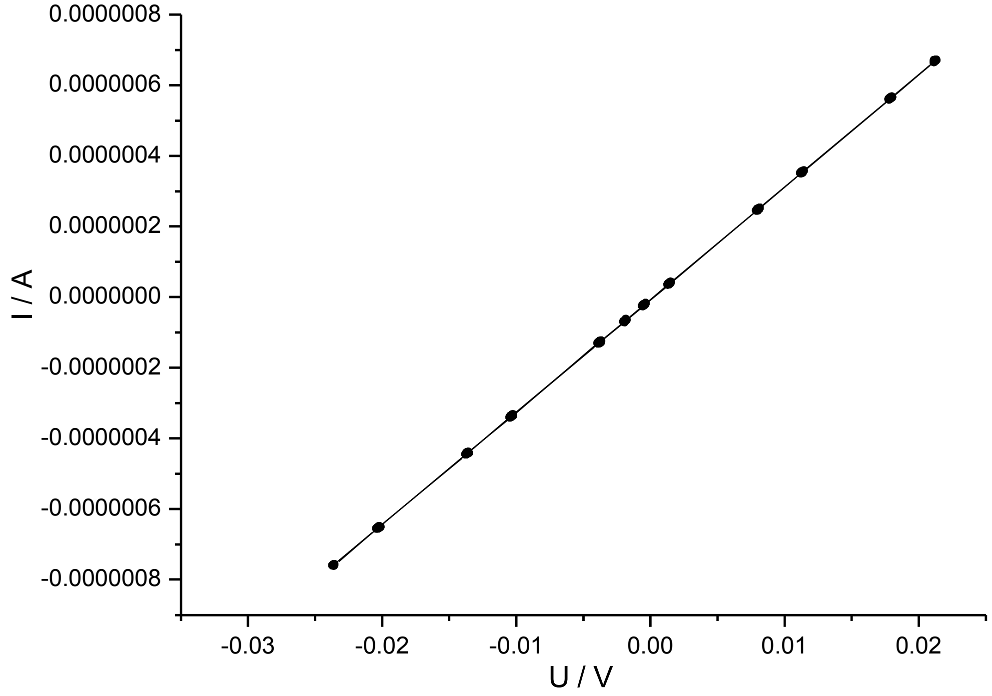
Lithography for contacting

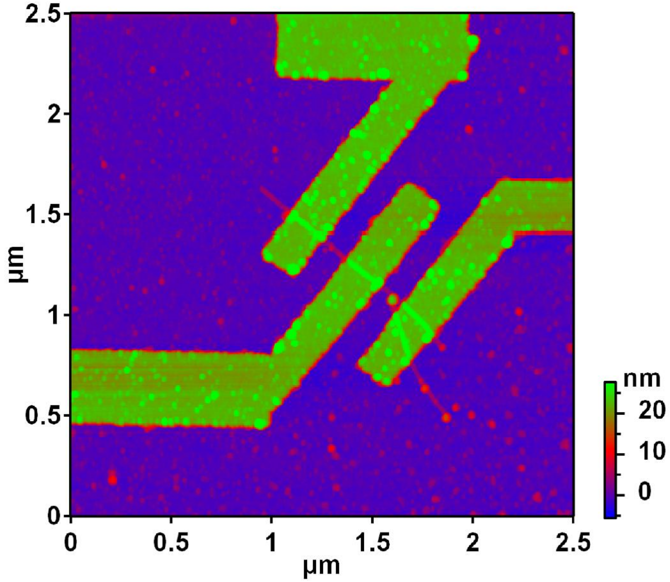




Extremely long Ni wires in E50Q-TMV on silicon / silicon oxide wafers with markers

The first contacted 3 nm nickel wires



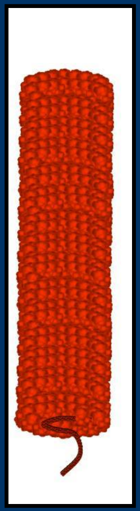


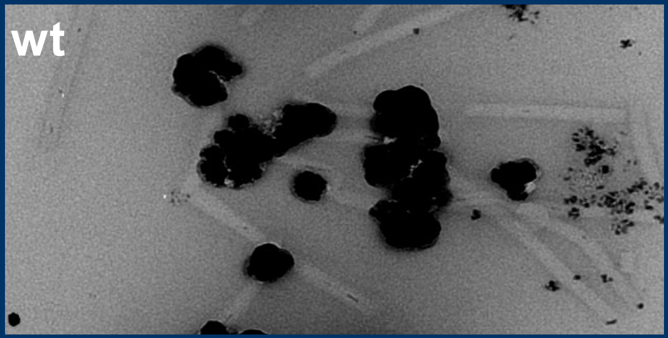
Current-voltage curve

AFM topography

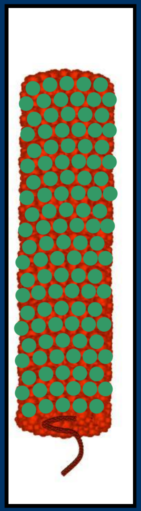
Extremely long Ni wires in virus-like TMV coat proteins
Removal of all organic material by oxygen/hydrogen plasma
Electron beam lithography, AuPd contacts
Ca. 20 kΩ

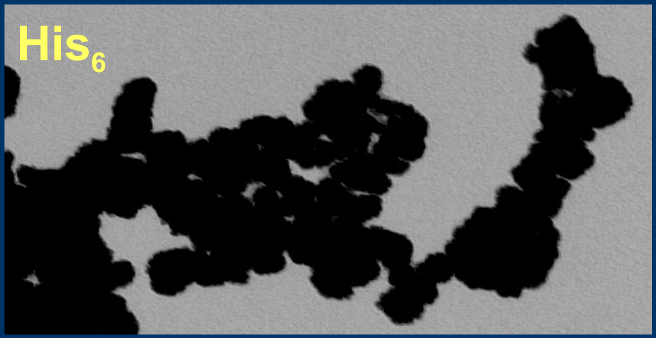
Mutations and phosphate control the deposition





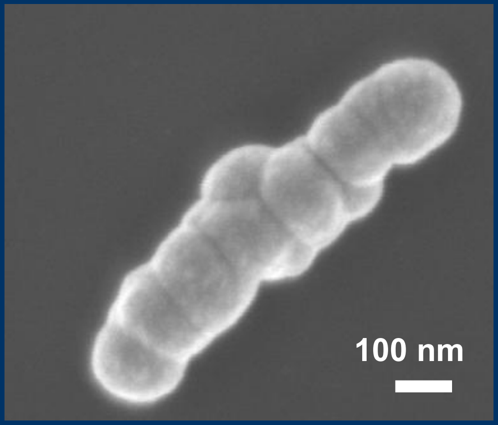
Pd(II) sensitization and
Ni(II) electroless deposition



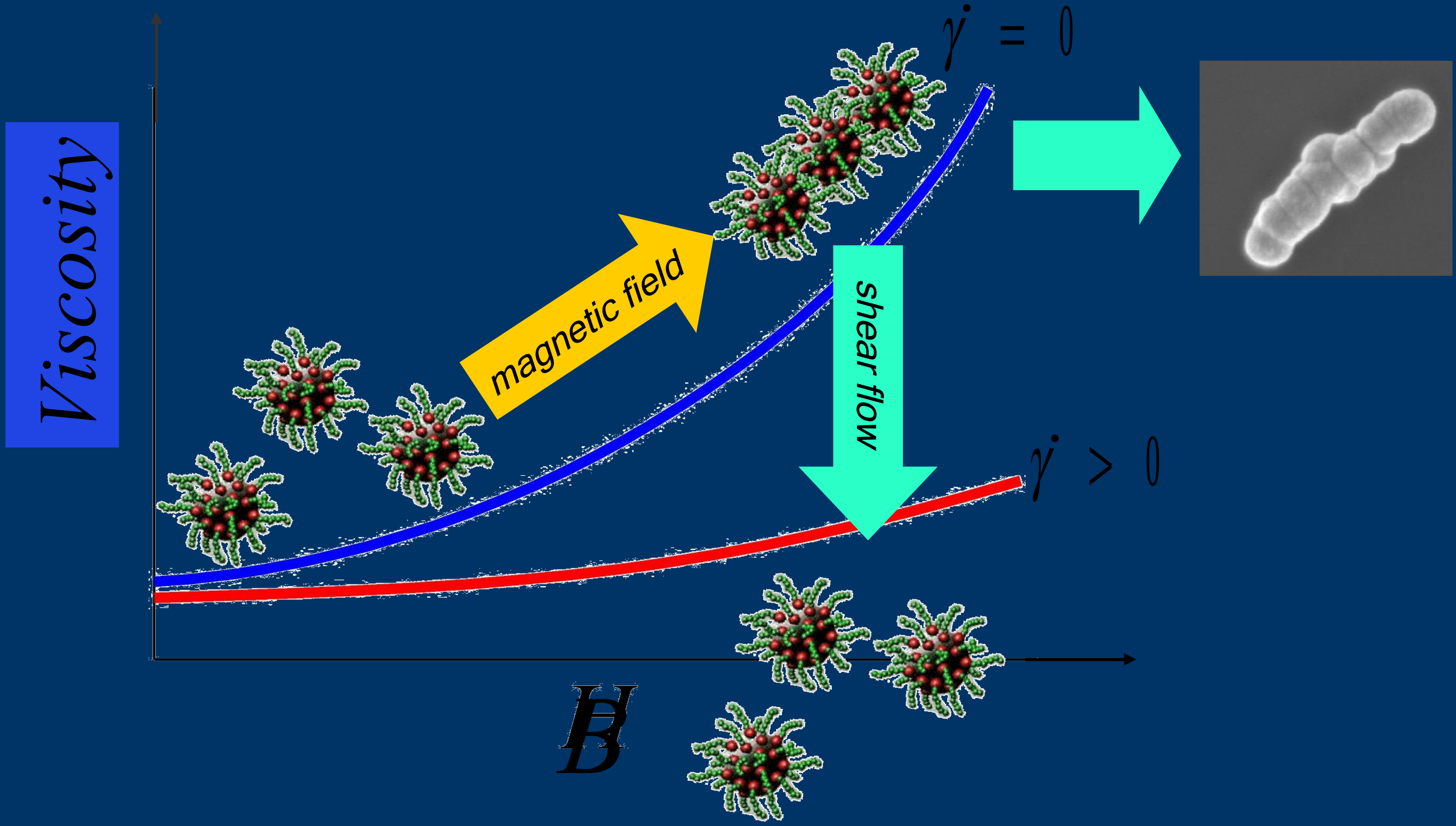


6·2100 His residues, Pd(II) and Ni(II)
coordination: deposition on the coat

Pd(II) sensitization with phosphate traces:
Ni(II) electroless deposition on coat

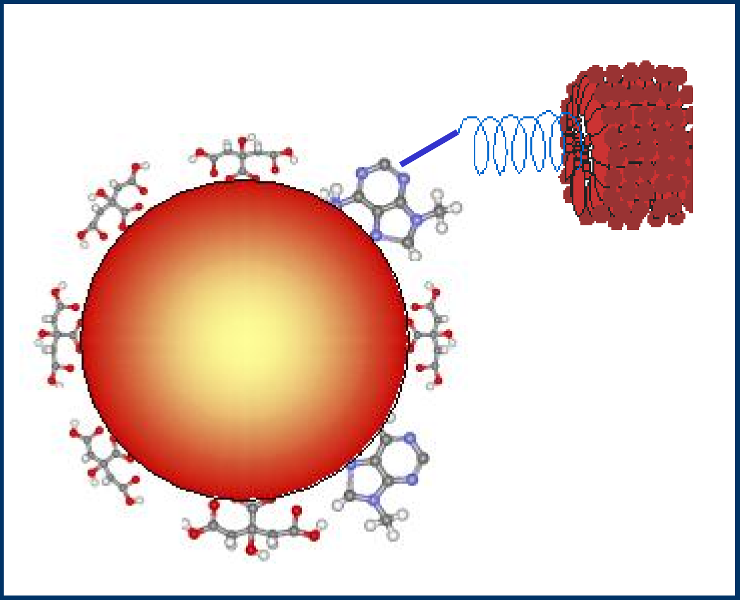


Ferrofluids: Shear thinning

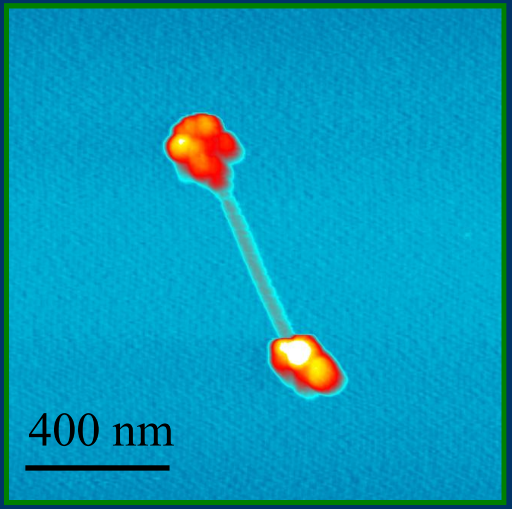


Deposition at the ends: Metal dumbbells

6 nm gold clusters



Citrate-covered gold binds to RNA (freed by the gold particle)



AFM: 50 nm gold nodules by “enhancement”, electroless deposition of gold on gold

Complete self-assembly of complex structures; switchable containers?

Balci et al., Angew. Chemie (2007)

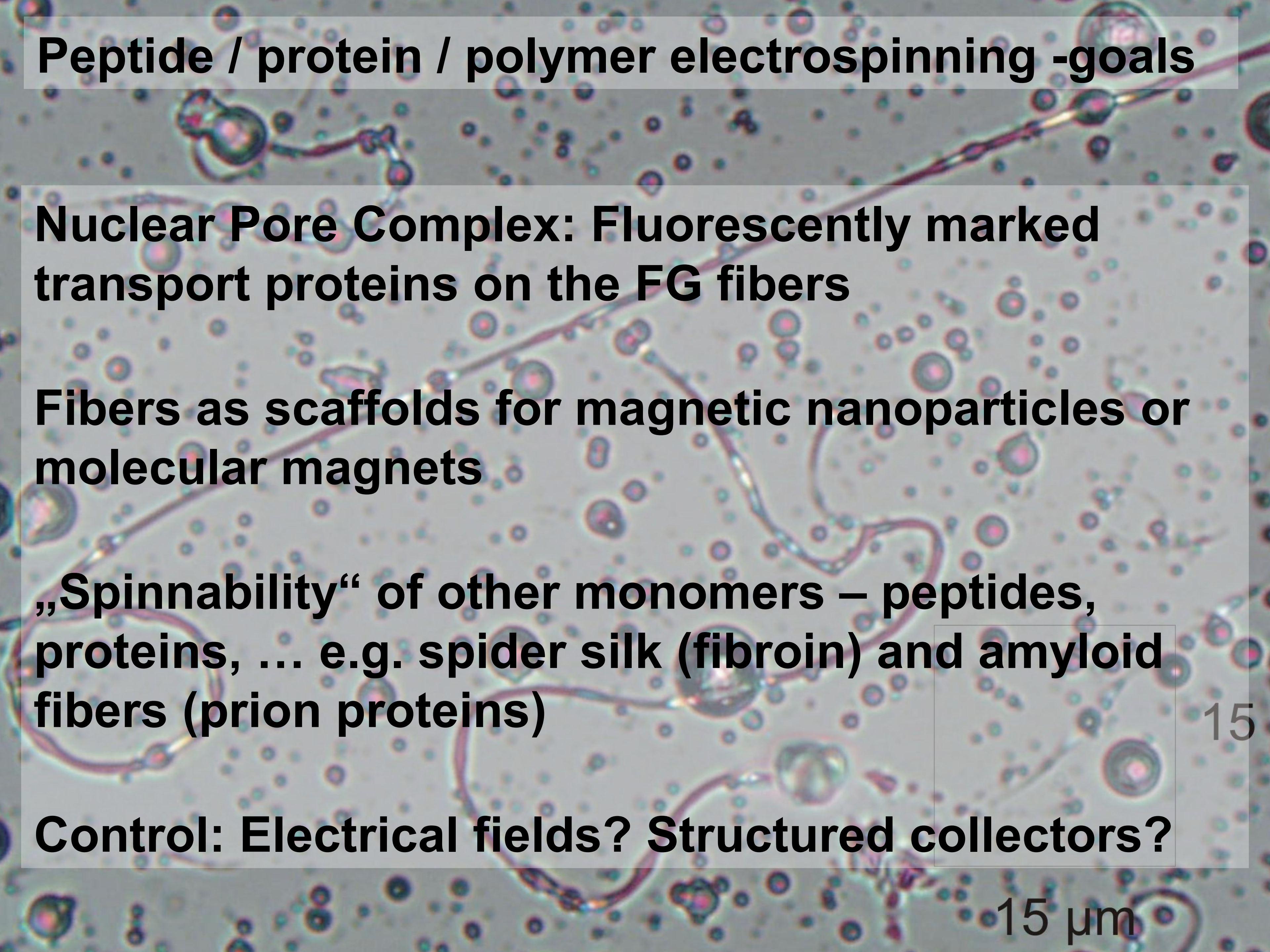
TMV - goals

Ultrathin metal wires and dumbbells - „physics“ (transport, magnetism)

Ferrofluids from metallized or mineralized viruses

Nanofluidics – a structurally and chemically defined 4 nm channel

Peptide / protein / polymer electrospinning -goals



Nuclear Pore Complex: Fluorescently marked transport proteins on the FG fibers

Fibers as scaffolds for magnetic nanoparticles or molecular magnets

„Spinnability“ of other monomers – peptides, proteins, … e.g. spider silk (fibroin) and amyloid fibers (prion proteins)

Control: Electrical fields? Structured collectors?

nanoGUNE

Director:
J.-M. Pitarke

Nanomagnetism

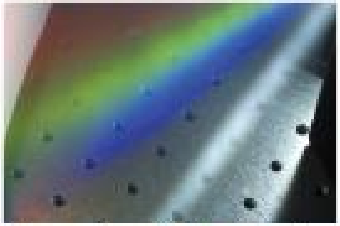
Berger
Vavassori

Design, fabrication and characterization of nanomagnetic and spintronic structures and devices.

Nanodevices

Nanofabrication of devices and its impact on nanobiotechnology, nanomagnetism and nanomechanics.

Nanooptics



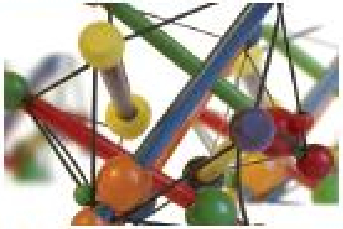
Hillen-
brand

Advanced near-field optical microscopy.
Nanophotonic structures and devices.

Nanoscale Imaging

Scanning probe microscopy.
Electron microscopy.

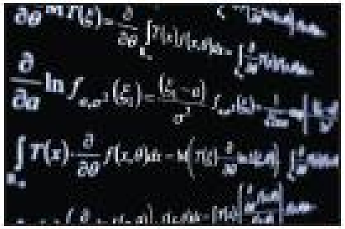
Self-assembly



Bittner

Synthesis, functionalization and processing of nanomaterials.
Self-assembly of complex structures.

Theory & Simulation



Theoretical methods and computational tools for the study of the nanoscale.

Nanobiotechnology

Nabiev

Biofunctional nanoparticles, non-bio/bio interfaces, and nanobioassemblies.