Nano Science and Nano Technology at Argonne

Axel Hoffmann

International Workshop on Nanocomposites: Materials, Neutrons, and Data Interpretation

March 28-30, 2002

Argonne National Laboratory

Materials Science Division

Outline

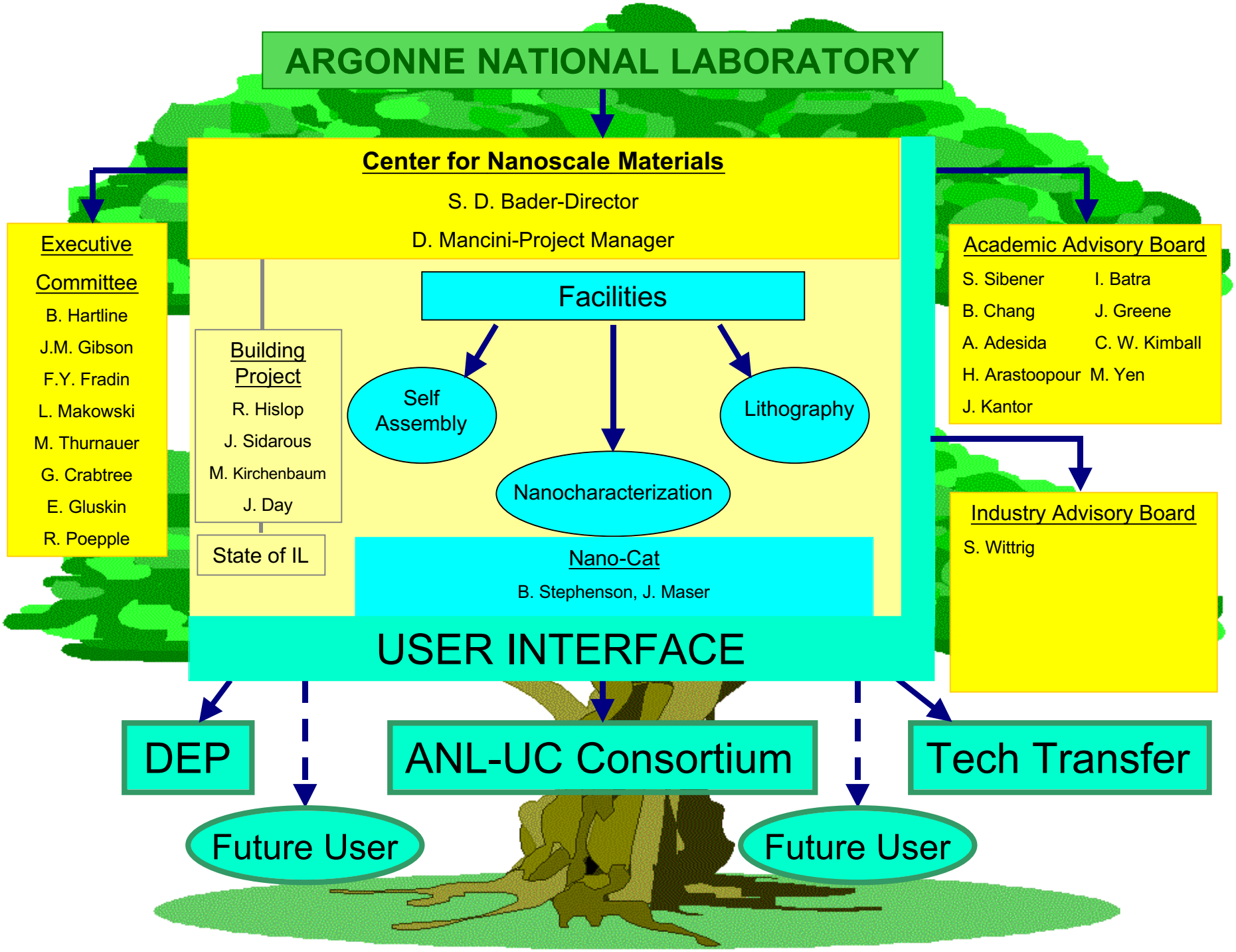
- Center for Nanoscale Materials
  - Concept
  - Current Status
- Nanoscience at ANL
  - Research Examples:

    From **Top-Down** : Lithography

    to **Bottom-Up** : Self-Assembly

CENTER FOR NANOSCALE MATERIALS

Sam Bader, Director
Argonne National Laboratory


ARGONNE NATIONAL LABORATORY
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D. Mancini-Project Manager
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F.Y. Fradin
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USER INTERFACE
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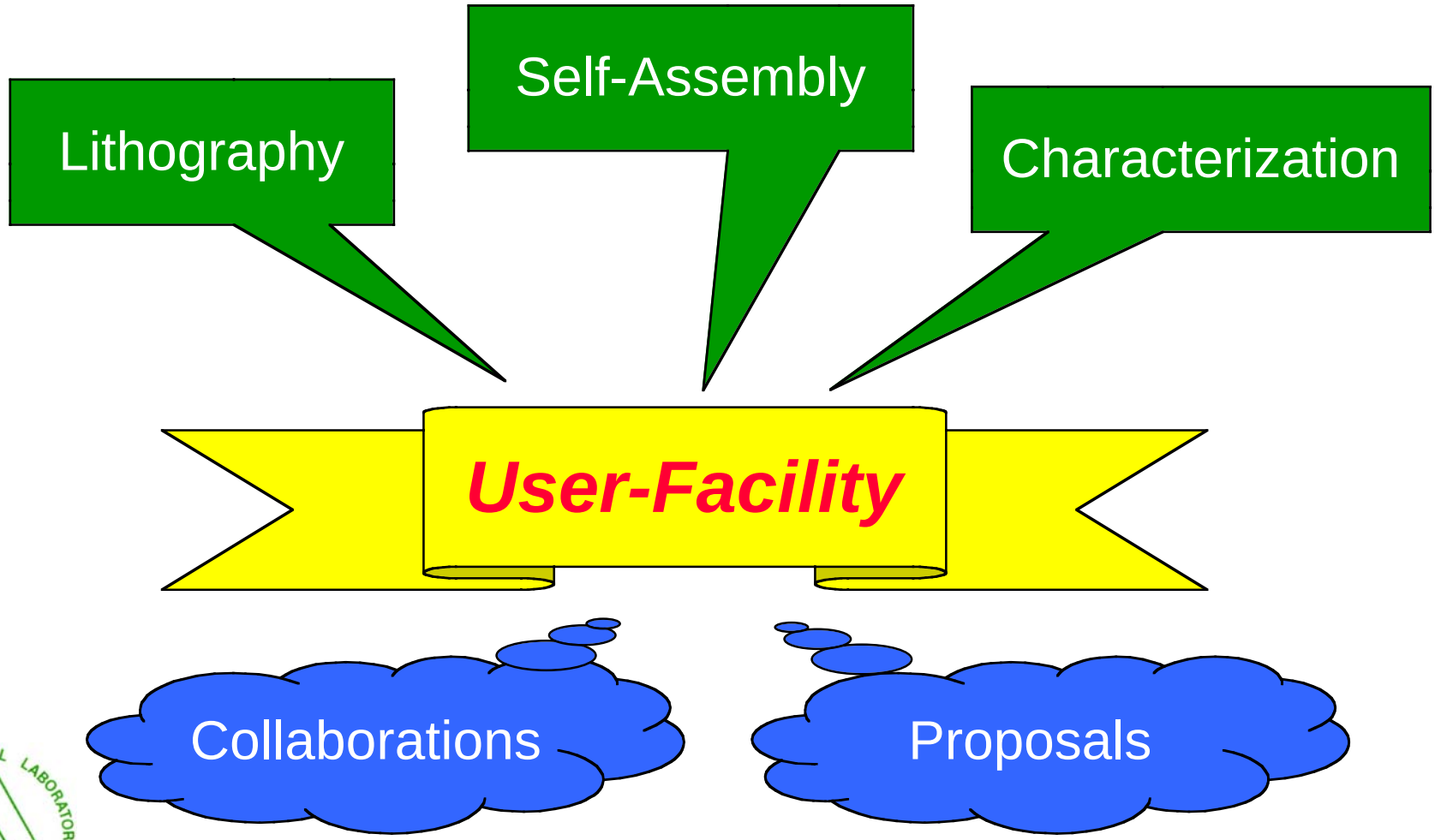
ANL-UC Consortium
Tech Transfer
Future User
Future User

Center for Nanoscale Materials



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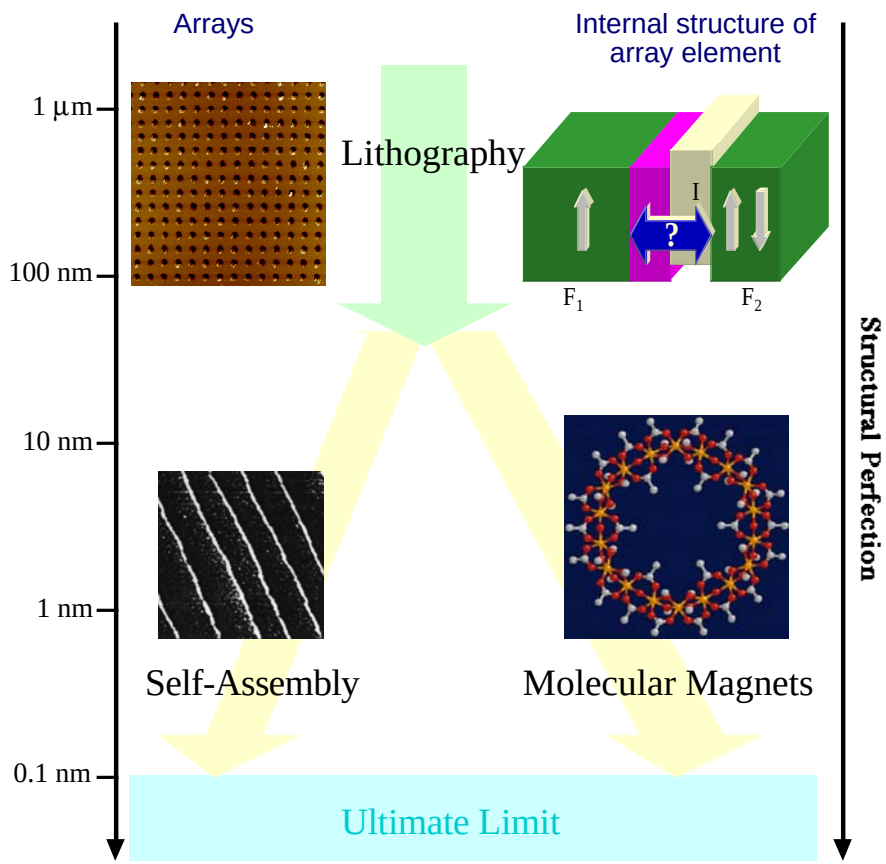
Current Status as of March '02

- ***Building***
  - ✓ State of Illinois Approved $36M Funding
    FY02: $2M, FY03: $17M, FY04: $17M
  - Start of Construction in FY03!
- ***X-ray Nanoprobe*** (at Advanced Photon Source)
  - ✓ Proposal approved by DOE
  - $14M requested, completion expected FY05
- ***Center for Nanoscale Materials***
  - ⌛ Proposal submitted to DOE in January '02
    Oral Defense: April 16th
  - Requested FY04: $60M for Instrumentation
    FY05…: $17M/year for Operation

Nanoscale Materials



Top-Down

Bottom-Up

Bottom-Up

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Top-Down: Lithograpy

Exquisite Control of Shape, Geometry, etc.

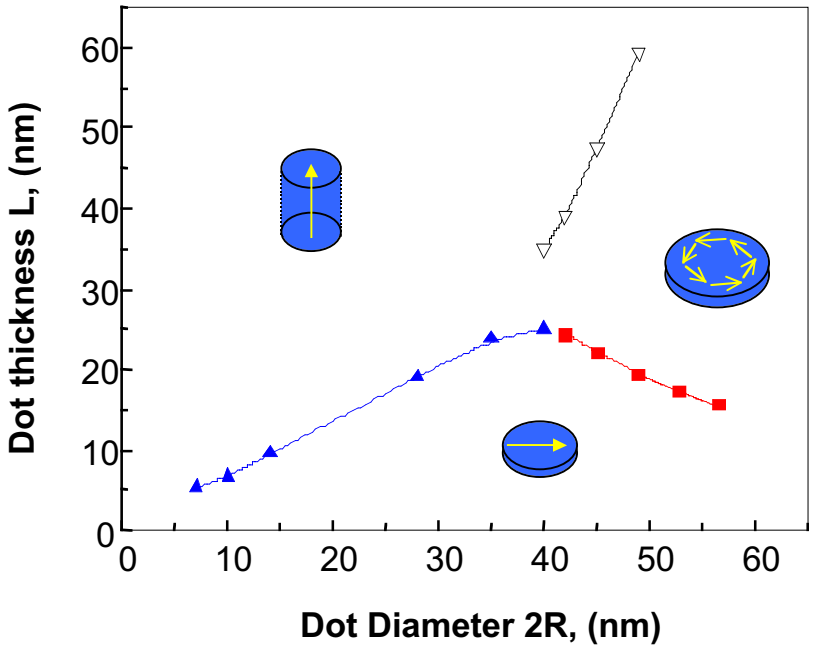
Important for:

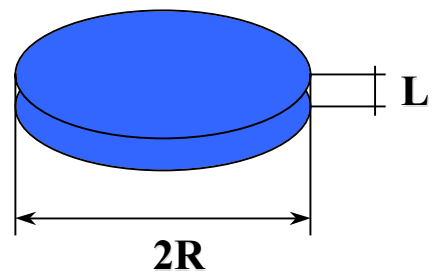
- Electronic Circuitry
- Nano-photonics
- Magnetism!
- …

Circular Ferromagnetic Dot: magnetic phase diagram

V. Novosad

(permalloy)





Important parameters:

- geometry: L and R
- material: A and M_s

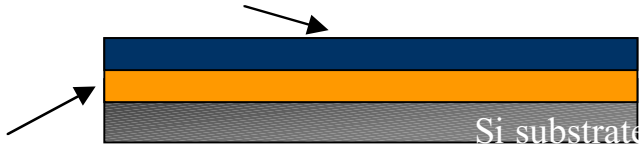
Thin circular dot with submicron diameter supports vortex magnetic state in remanence.

Micro-fabrication

V. Novosad

Double Layer Resist Spin-coating

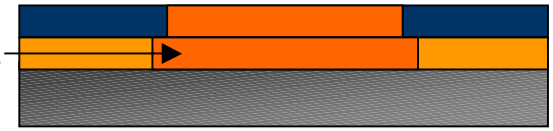
ZEP 520 Resist (5000 min^{-1} / 3 min; 180 C / 20 min)



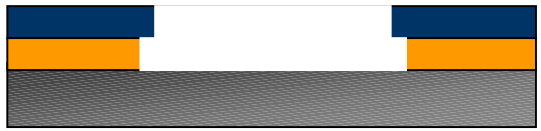
PMGI Resist (5000 min^{-1} / 3min; 250 C / 30 min)

EB Patterning (30-500 pA)

Exposed Areas



Resist Development

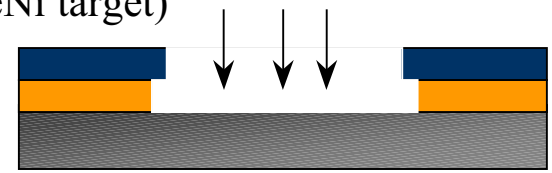


Xylene 3-5 min + 15 sec rinsing

PMGI developer 5-10 min,
+ H2O rinsing

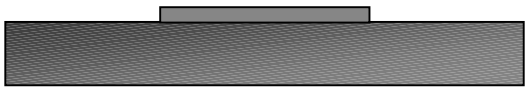
EB Deposition (1 A/sec)

(FeNi target)



Lift-off process

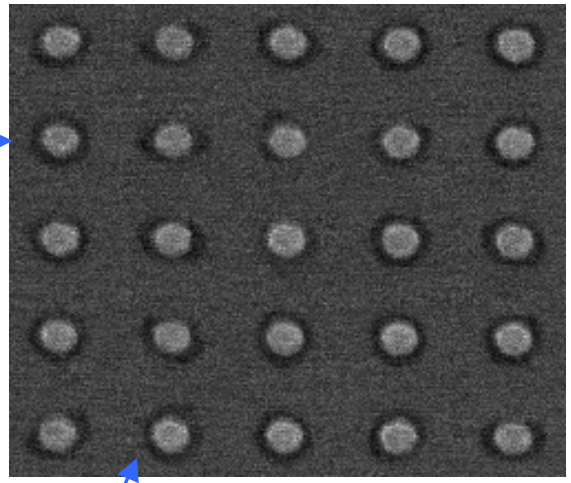
FeNi circular dot

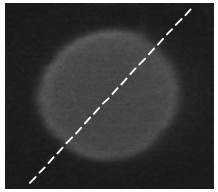


Methyl-**E**thyl-**K**etone (**MEK**, for ZEP520)
1-Methyl **2-P**yrolidone (for **PMGI**)

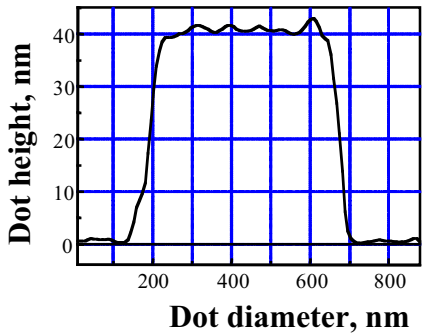
Obtained circular dot array (SEM image)

∅ 0.4 µm
(0.2..1.0 µm)





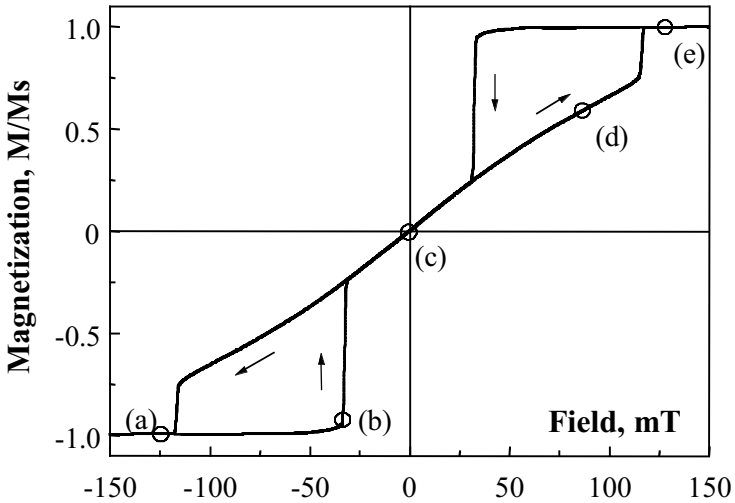
AFM profile

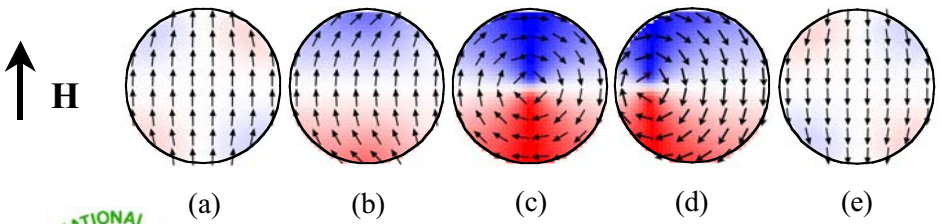


Magnetic Vortex State in Permalloy Disk

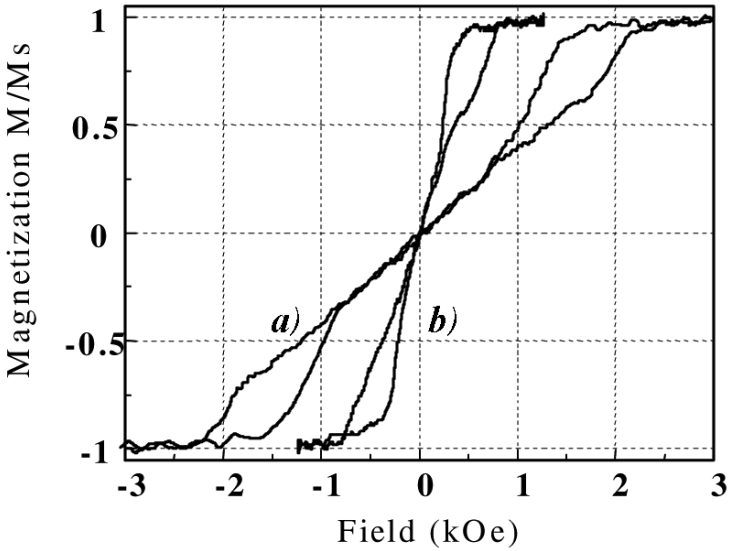
V. Novosad

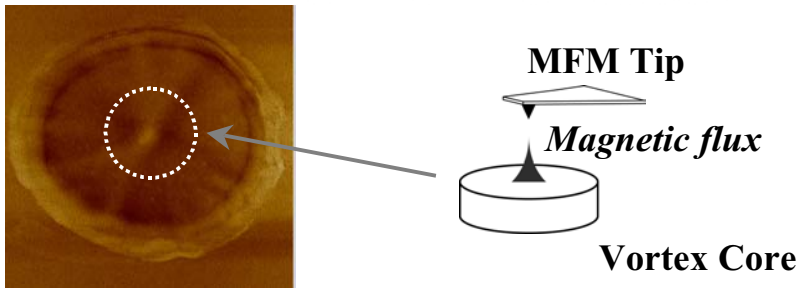
Micromagnetic Simulation





Experimental Results





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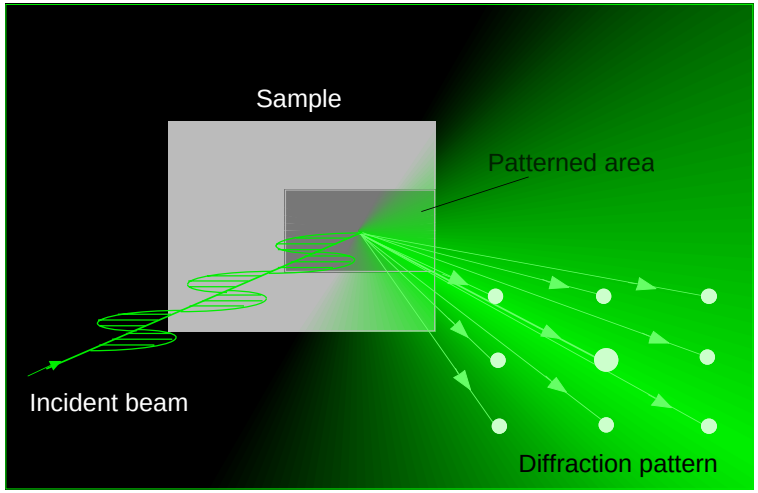
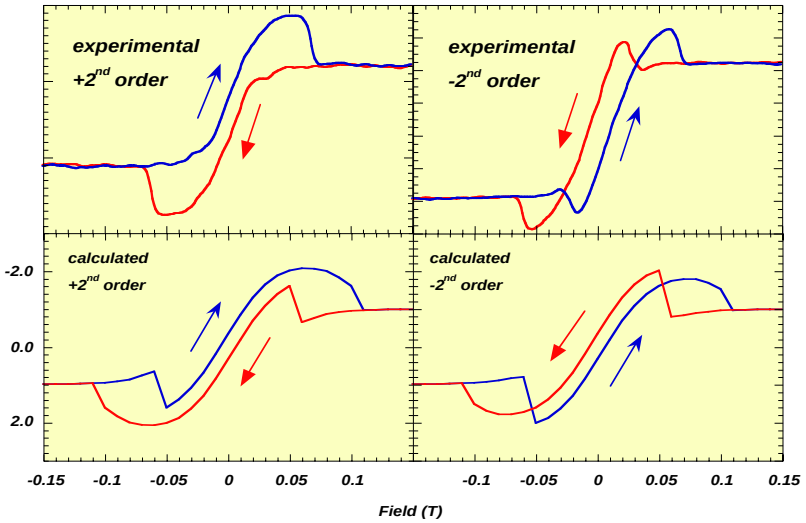
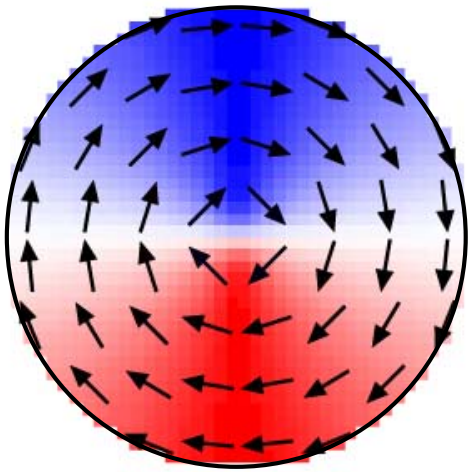
New Tools: Diffracted MOKE



Concept of Diffracted MOKE



Experimental and calculated D-MOKE loops from a vortex array.



Schematic of a magnetic vortex state

Diffracted MOKE allows further insight into magnetization structure of periodic arrays:

i.e. chirality of vortex state

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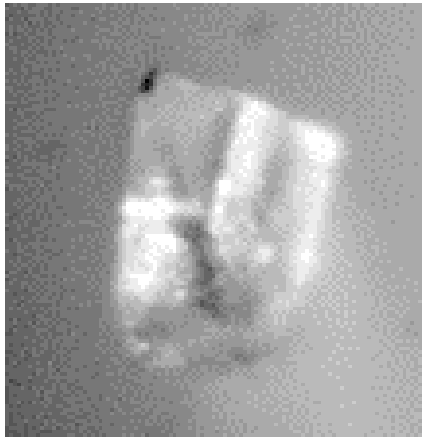
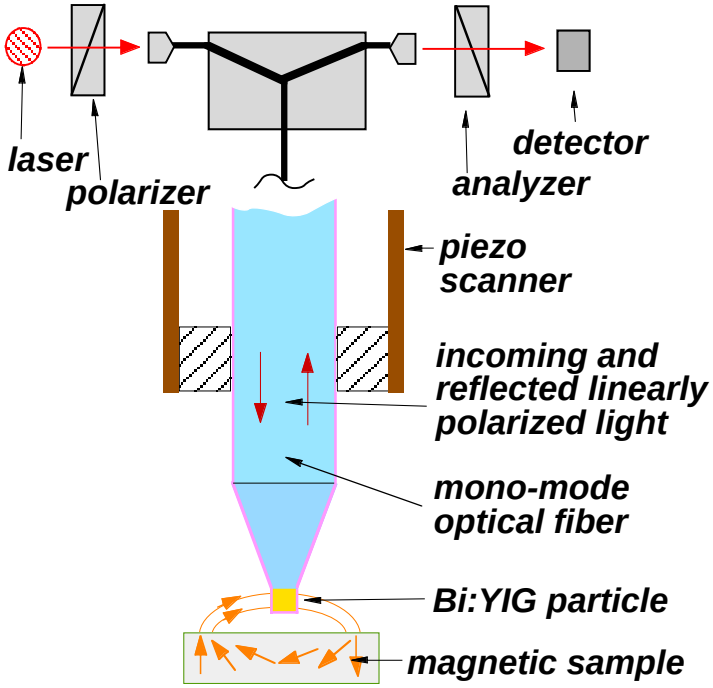
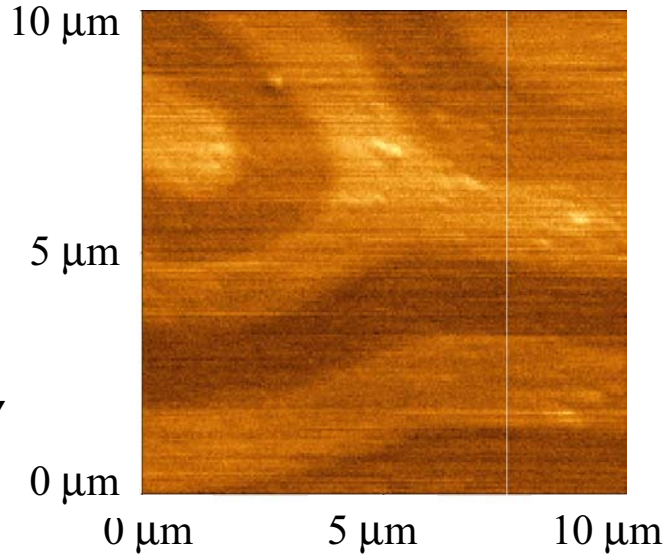
U. Welp

New Tools:
Near Field Magneto-Optic Scanning Microscope



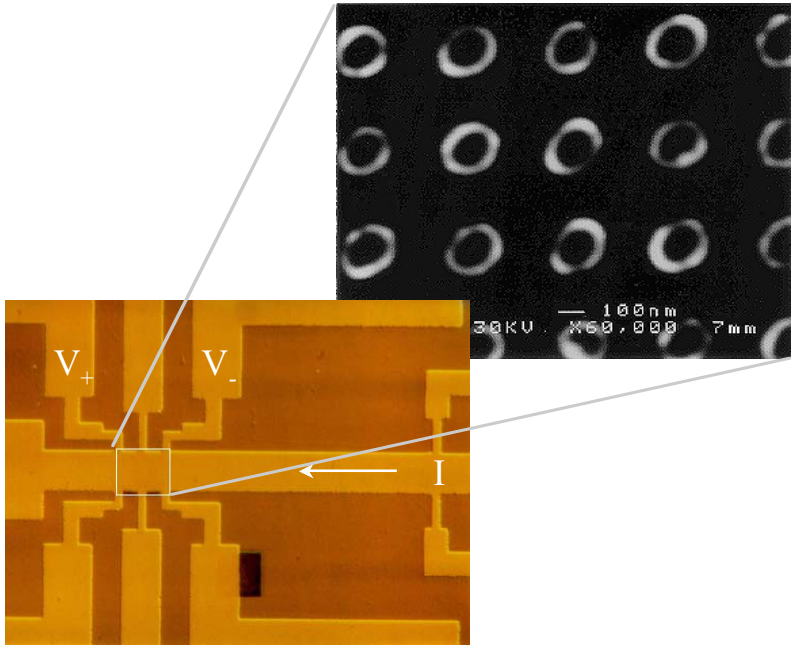
Garnet particle
at tip of a fiber

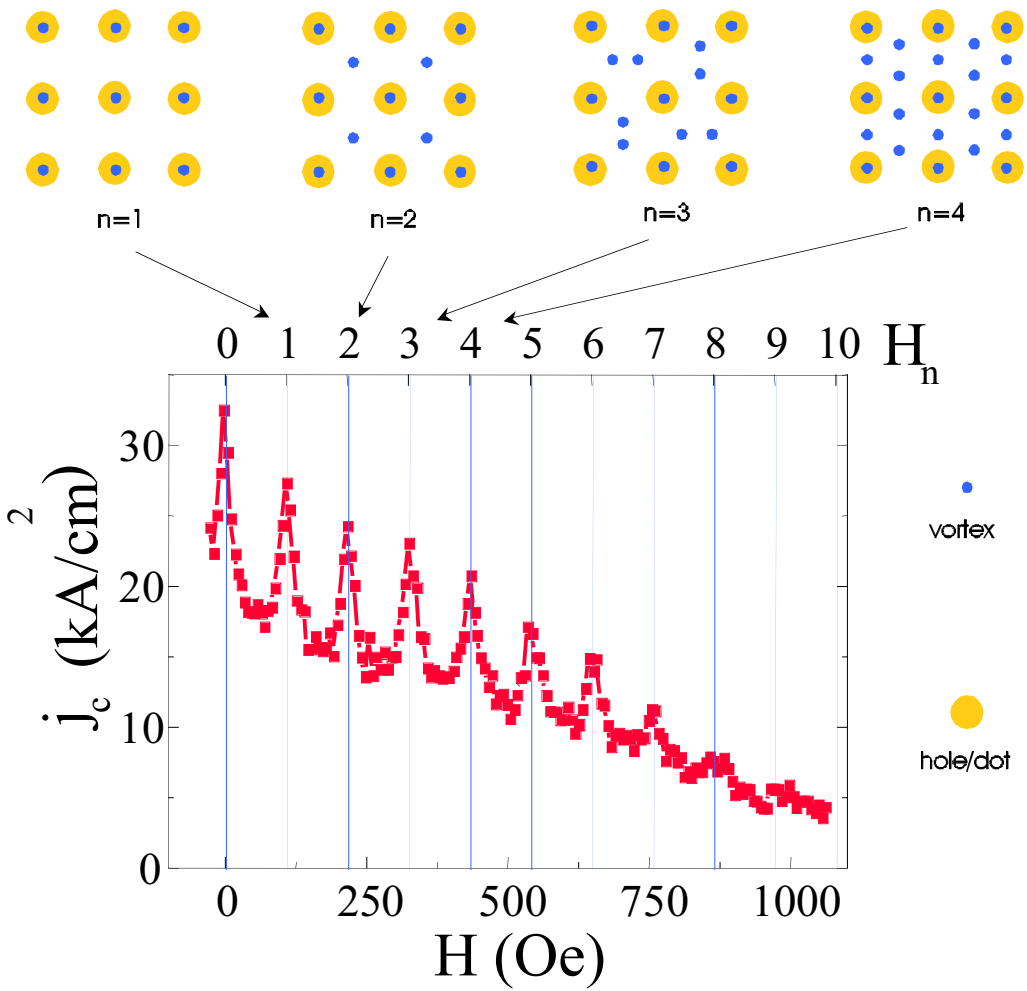




Labyrinth domains
in YIG

Lithography combined with Self-Assembly: Periodic Pinning as a Model System





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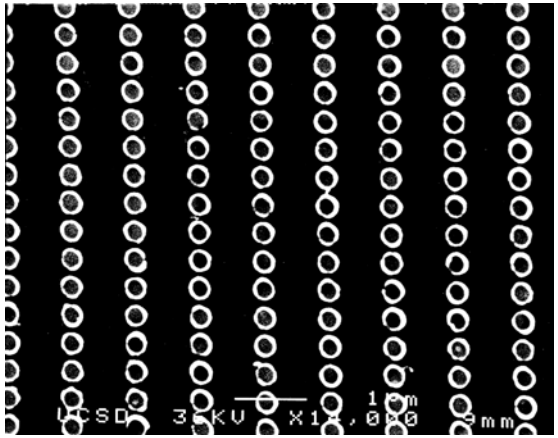
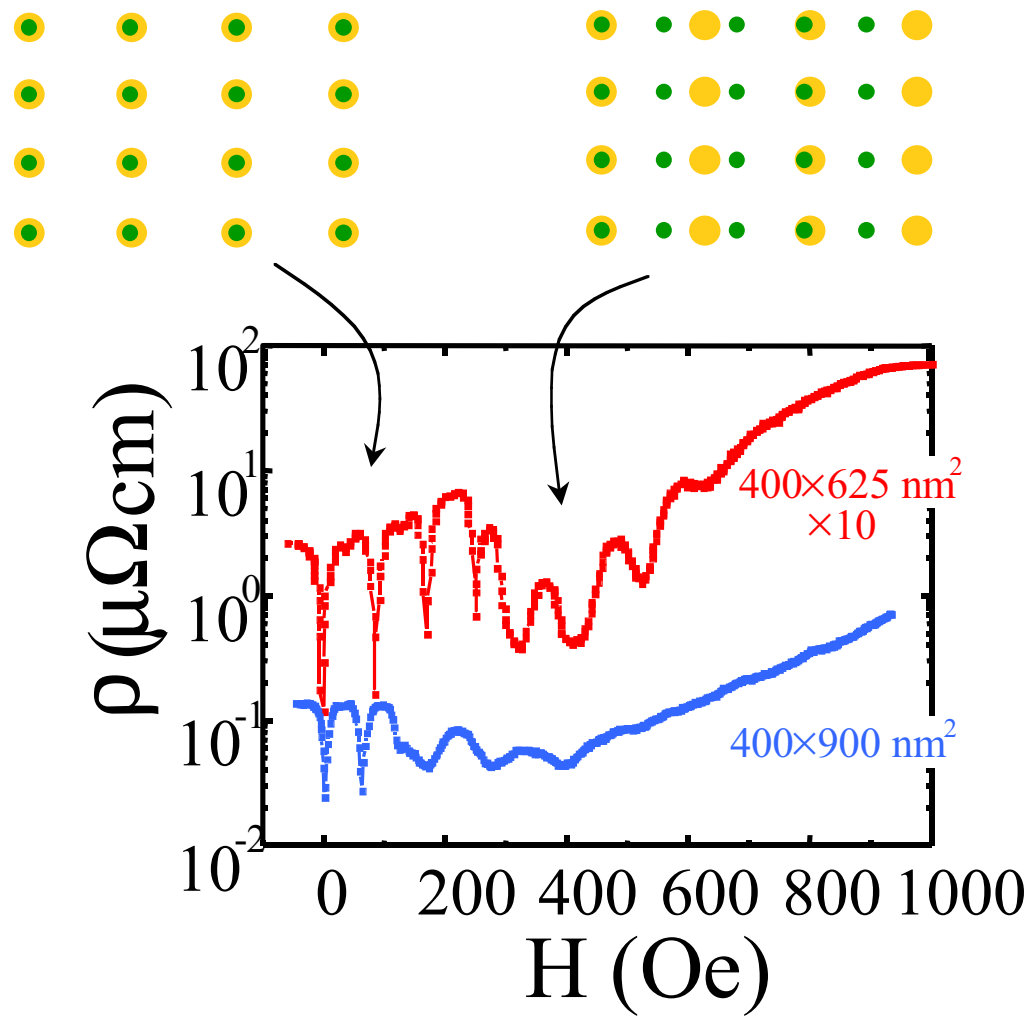
Elastic Limitations to Deformation of Self-Assembly





Geometric Transformation for

$E_{elastic} > E_{Pinning}$

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Bottom-Up:Self-Assembly

Generally easily scalable

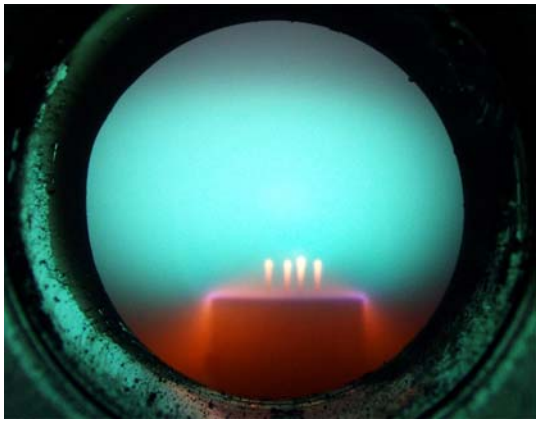
Ideally suited for

- Neutron Scattering

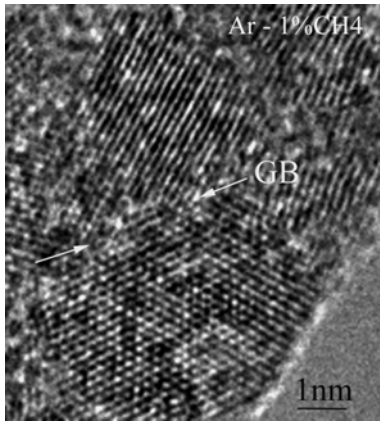
Ultrananocrystalline Diamond (UNCD)

O. Auciello and J. Carlisle

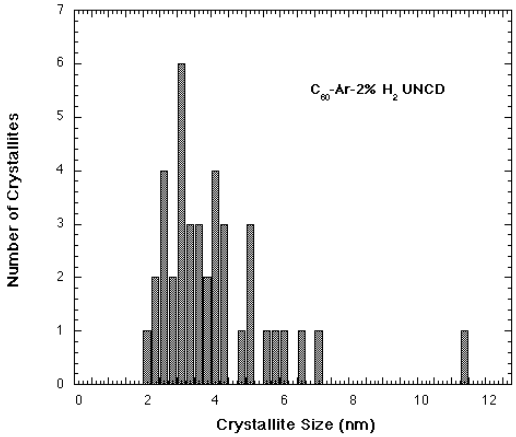
- Ar/CH_4 MPCVD: C_2 dimer growth
- 2-5 nm grain sizes; atomically-abrupt grain boundaries
- Phase-pure (<3% sp^2-bonded carbon)
- Conformal coating, low stress
- Materials Properties:
  - ***Mechanical*** (high hardness and fracture strength)
  - ***Tribological*** (low friction, thermal conductance)
  - ***Transport*** (electronic, thermal)
  - ***Electrochemical*** (wide working potential window)
  - ***Electron Emission*** (low, stable threshold voltage)
- 2000 MRS Award



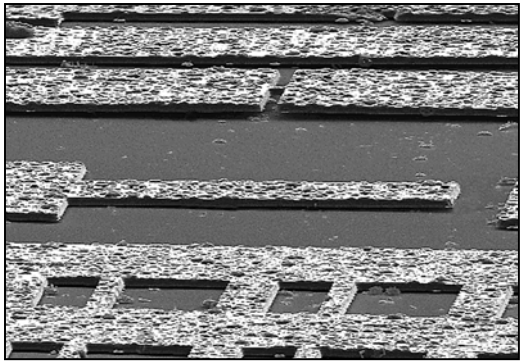
Ar/CH_4 plasma coating W microtips



HRTEM



2-5 nm Grain Sizes



UNCD-MEMS

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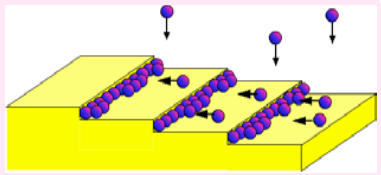
Self-Assembled Magnetic Wires and Nanodots

D. Li

Fe Nanowires by step decoration

Monolayer thick
10^0 nm wide



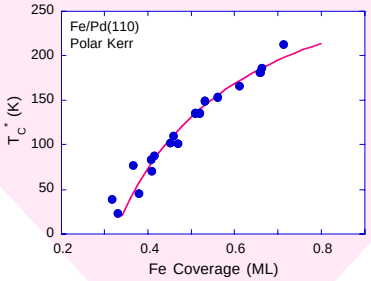
2D: *Heisenberg, X Ising, ✓*

?

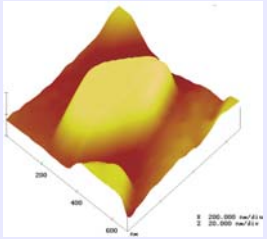
1D: *No spontaneous order > 0K*

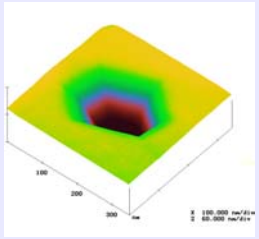
finite size scaling

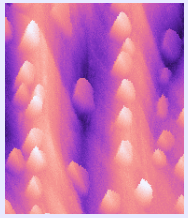
T_C shift: $T_C(w) = T_{C0}[1-(w/w_0)^{-\lambda}]$



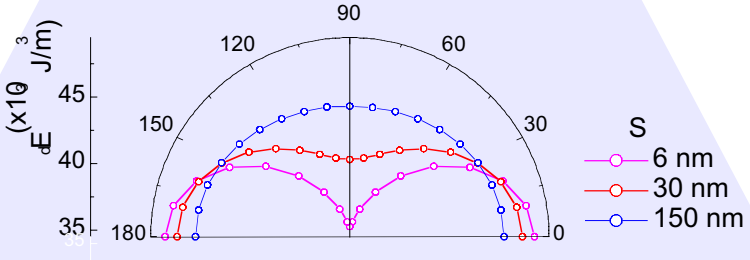
Co dots, antidots, dot chains, and stripes by strain relaxation

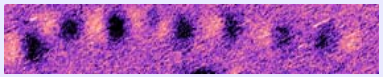






10^0 nm thick
10^2 nm wide





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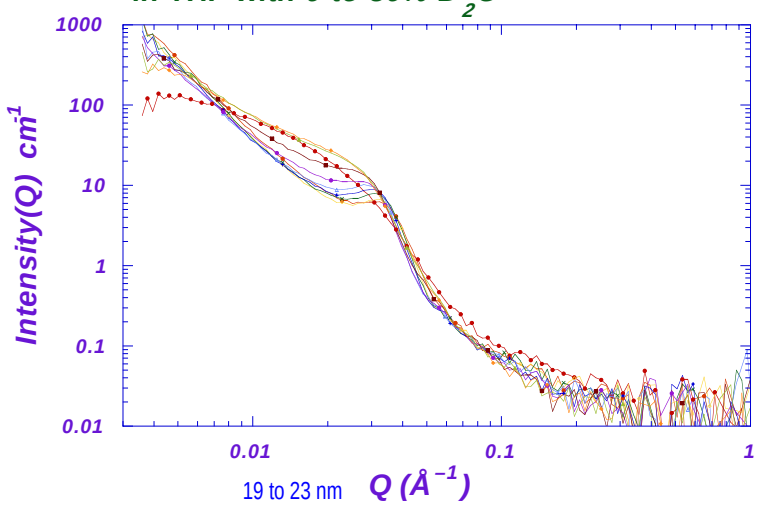
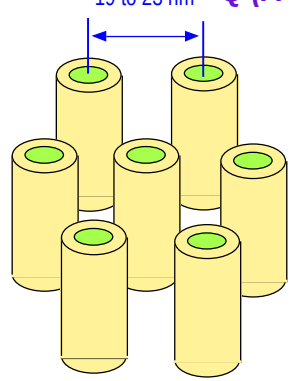
Using Self-Assembly as a Template

H.-H. Wang

Block Copolymers

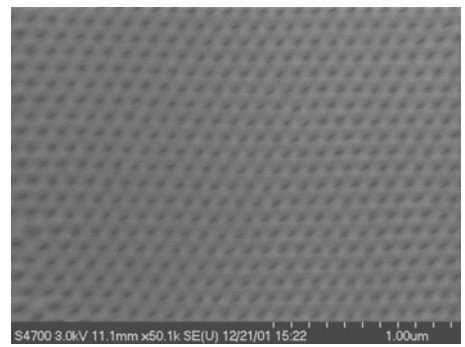
SANS studies of OPV-PEG nanofibers in THF with 0 to 30% D_2O



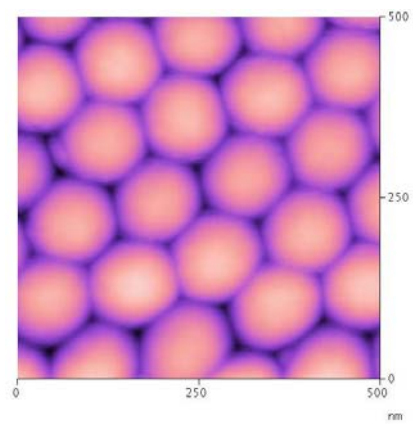


Packed OPV-PEG fibers in THF/H_2O

Anodized Aluminum Oxide (AAO)



SEM



AFM

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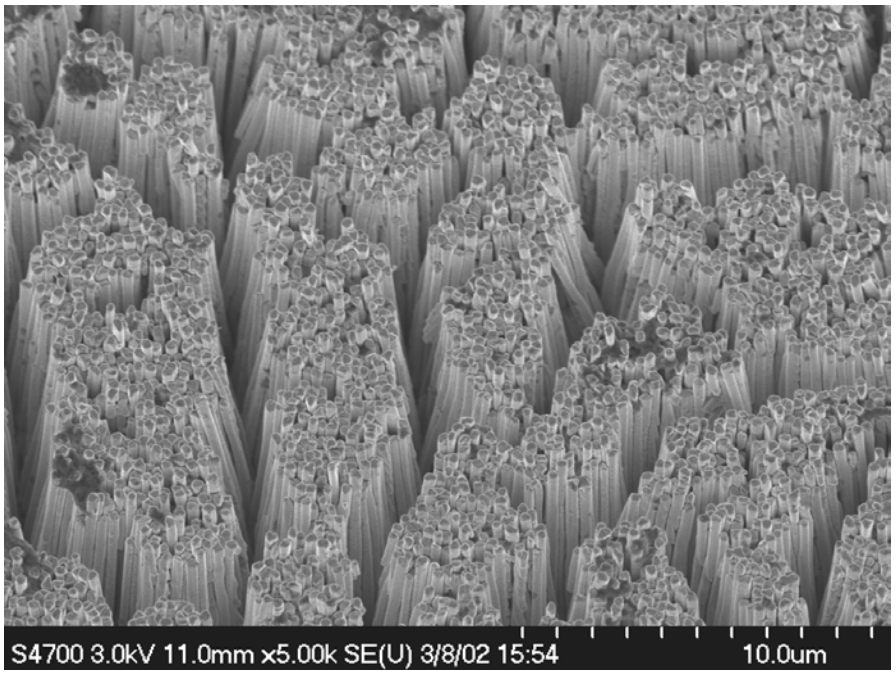
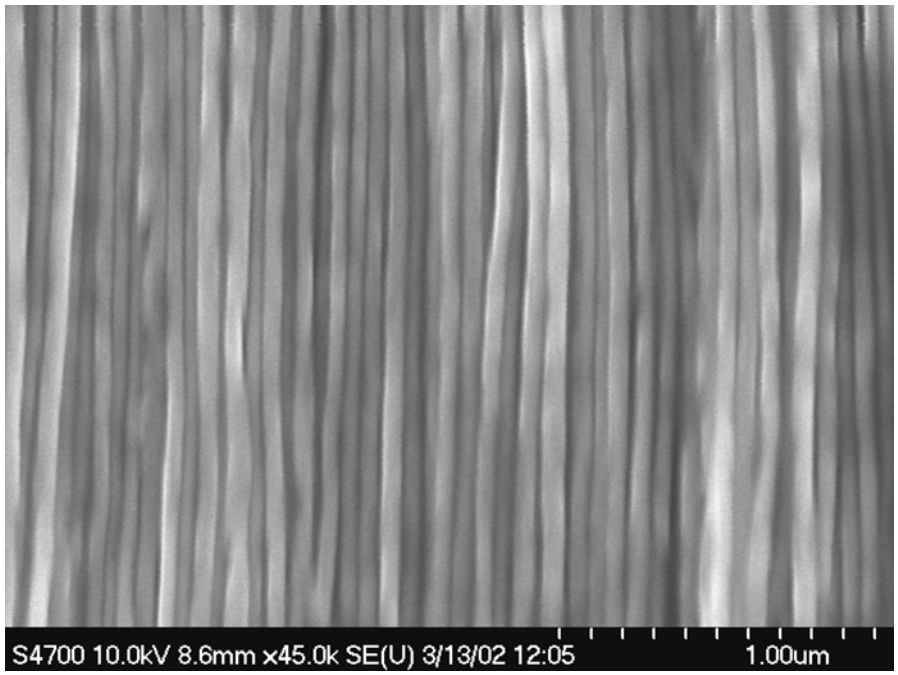
Ni wires from AAO Templates

H.-H. Wang





∅ 200 nm
partial removal
of AAO

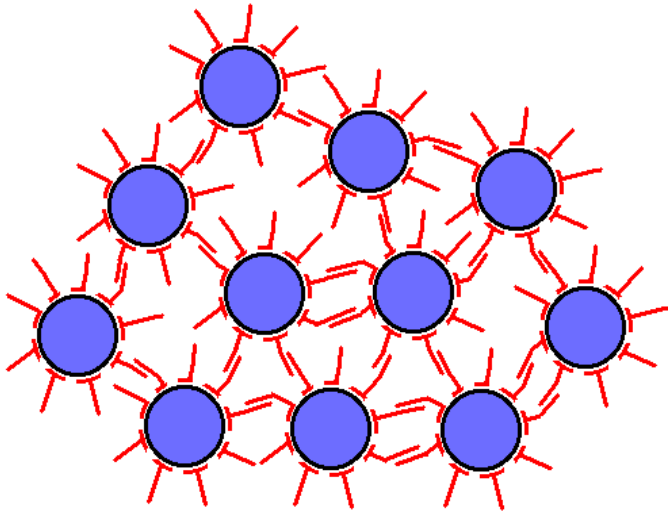
∅ 60 nm
complete removal
of AAO

Wires grown by electrodeposition

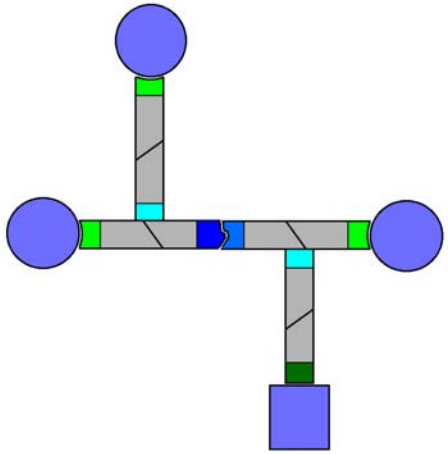
Using Biological Templates

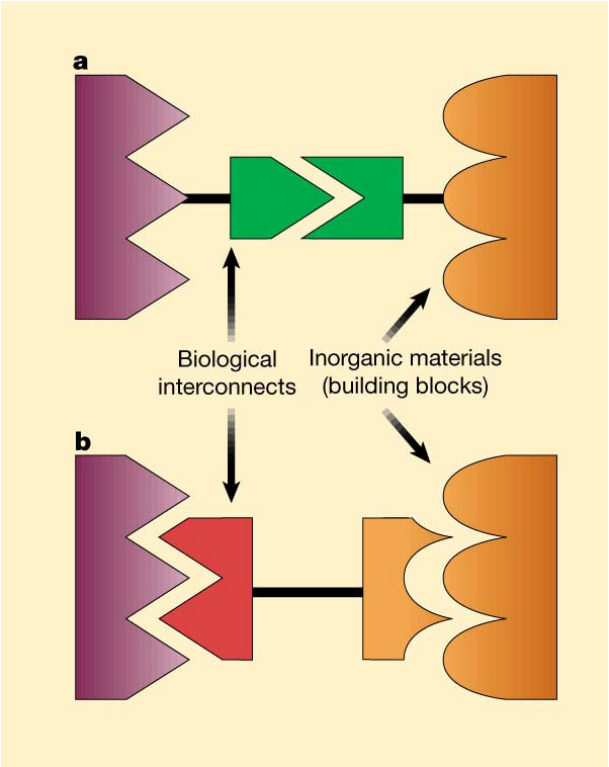
B. Kay and L. Makowski, Bioscience

Nanostructured Material



Nanodevice





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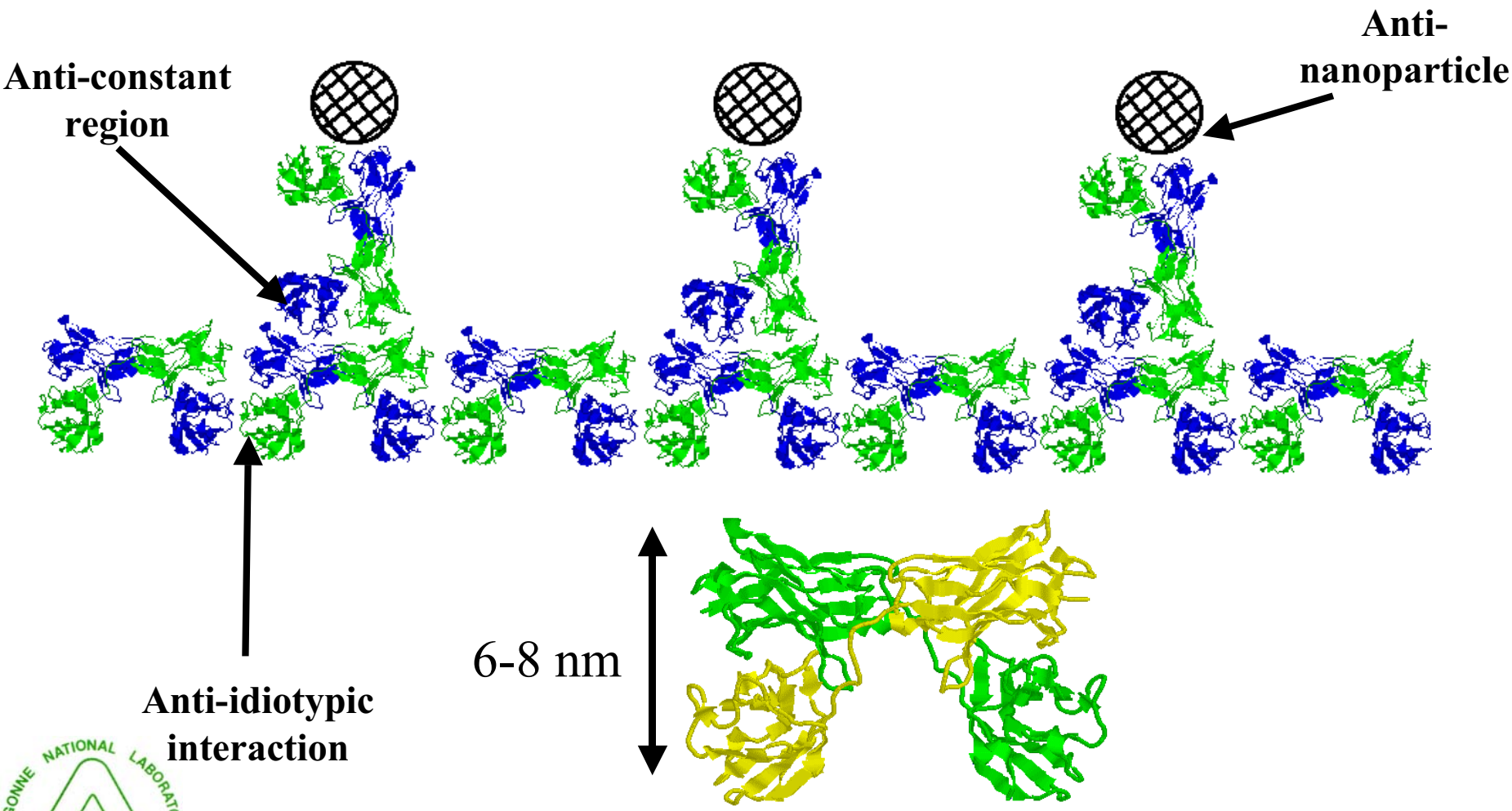
Array of nanoparticles with Antibody framework

L. Makowski,
Bioscience



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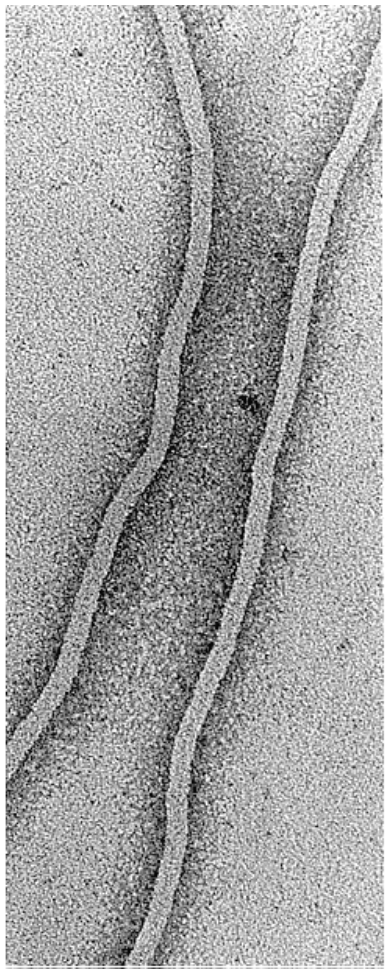
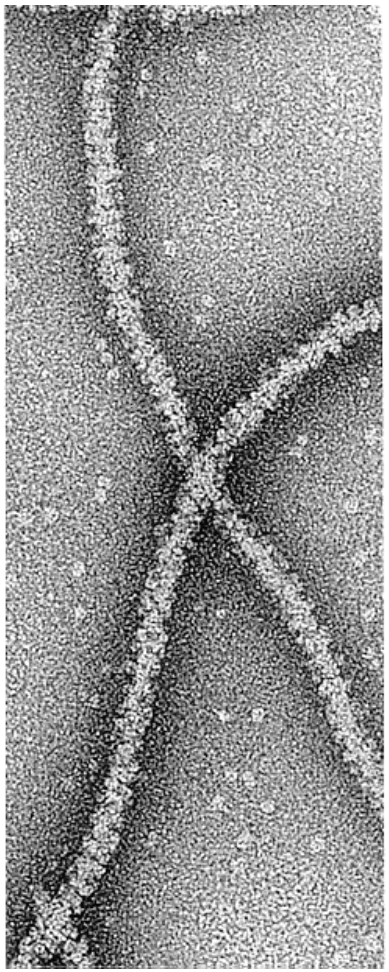
Example of a wire on a rod-shape protein

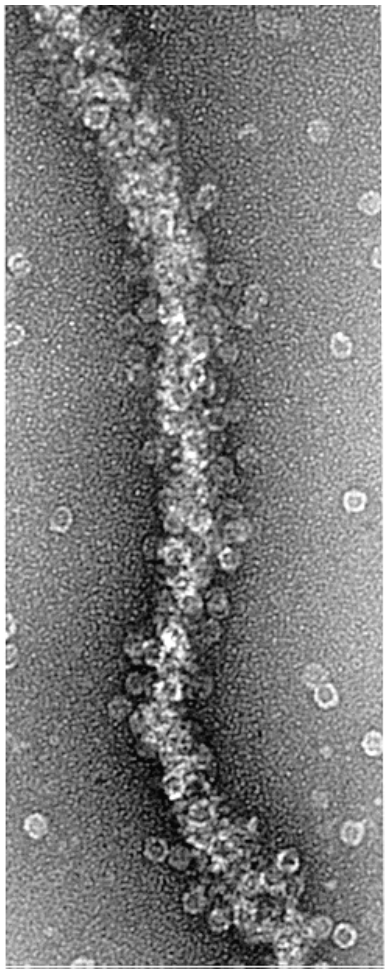
L. Makowski, Bioscience



Biotinylated M13



+ streptavidin

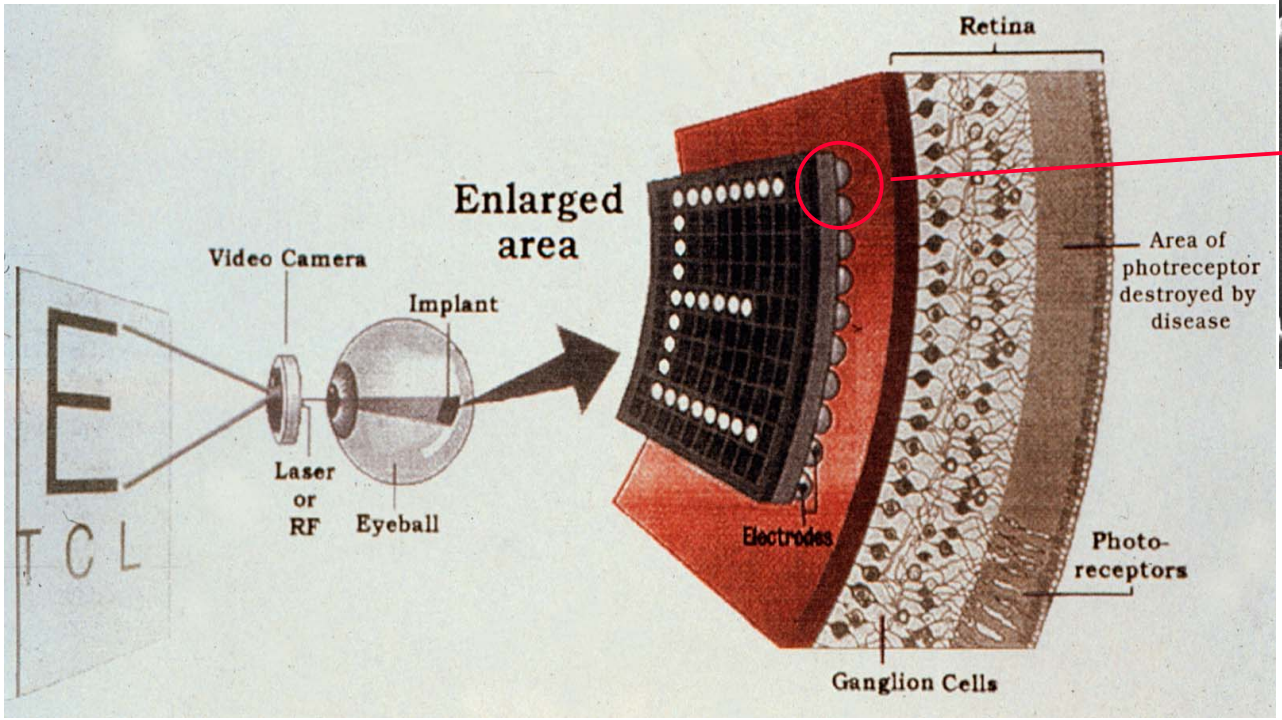


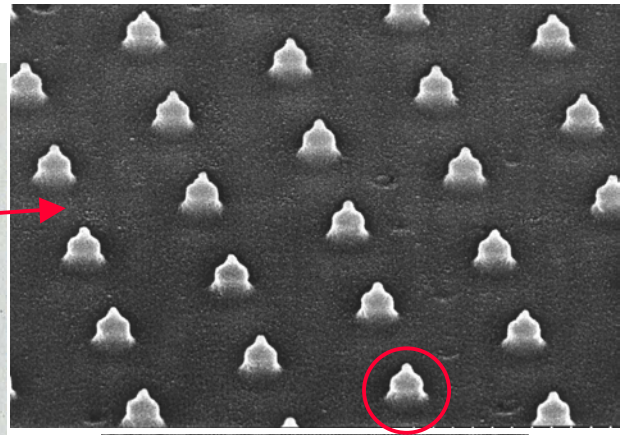
+ ferritin

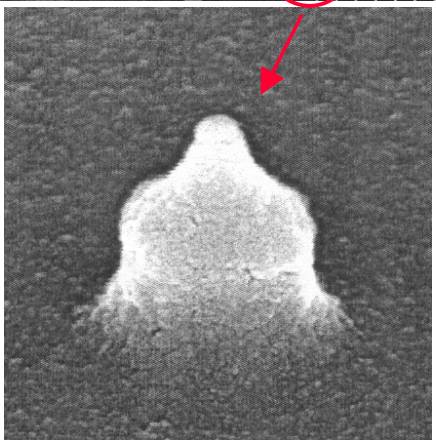
View of the Future

O. Auciello and J. Carlisle

Artificial Retina Project [DOE Biomedical Engineering]







UNCD Electrodes

Materials Science Division

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