Introduction to Nanotechnology and Nanoscience – Class#1

Liwei Lin

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ME118/ME218N
Starts at 9:40am
Berkeley Time

Inclusive Classrooms

- **Inclusion**: We are committed to creating a learning environment welcoming of all students that supports a diversity of thoughts, perspectives and experiences, and respects your identities and backgrounds (including race/ethnicity, nationality, gender identity, socioeconomic class, sexual orientation, language, religion, ability, etc.)

https://lwlin.me.berkeley.edu/me118/Inclusive2021.pdf

Berkeley Honor Code

- Everyone in this class is expected to adhere to this code: “As a member of the UC Berkeley community, I act with honesty, integrity, and respect for others.”

Mental Health and Wellness: All students — regardless of background or identity — may experience a range of issues that can become barriers to learning. These issues include, but are not limited to, strained relationships, anxiety, depression, alcohol and other drug problems, difficulties with concentration, sleep, and eating, and/or lack of motivation. Such mental health concerns can diminish both academic performance and the capacity to participate in daily activities. In the event that you need mental health support, or are concerned about a friend, UC Berkeley offers many services, such as free short-term counseling at University Health Services.

An excellent campus website having links to many resources is: http://recalibrate.berkeley.edu/. Another campus website addressing mental health services in specific reference to this time of the coronavirus pandemic is: https://uhs.berkeley.edu/coronavirus/student-mental-health

Remember that seeking help is a good and courageous thing to do — both for yourself and for those who care about you.

Outline

- Course Administrative Issues
- Course Overview
- Brief History of Nanoscience
- Why take this course?
  "Nanoscience & ME"

Next class:

- Nanoscale properties & devices
- Intro to nanofabrication

Course Objectives

- ☐ ***To introduce concepts in nanoscience and nanotechnology***

What is "nano" and why does anyone care?

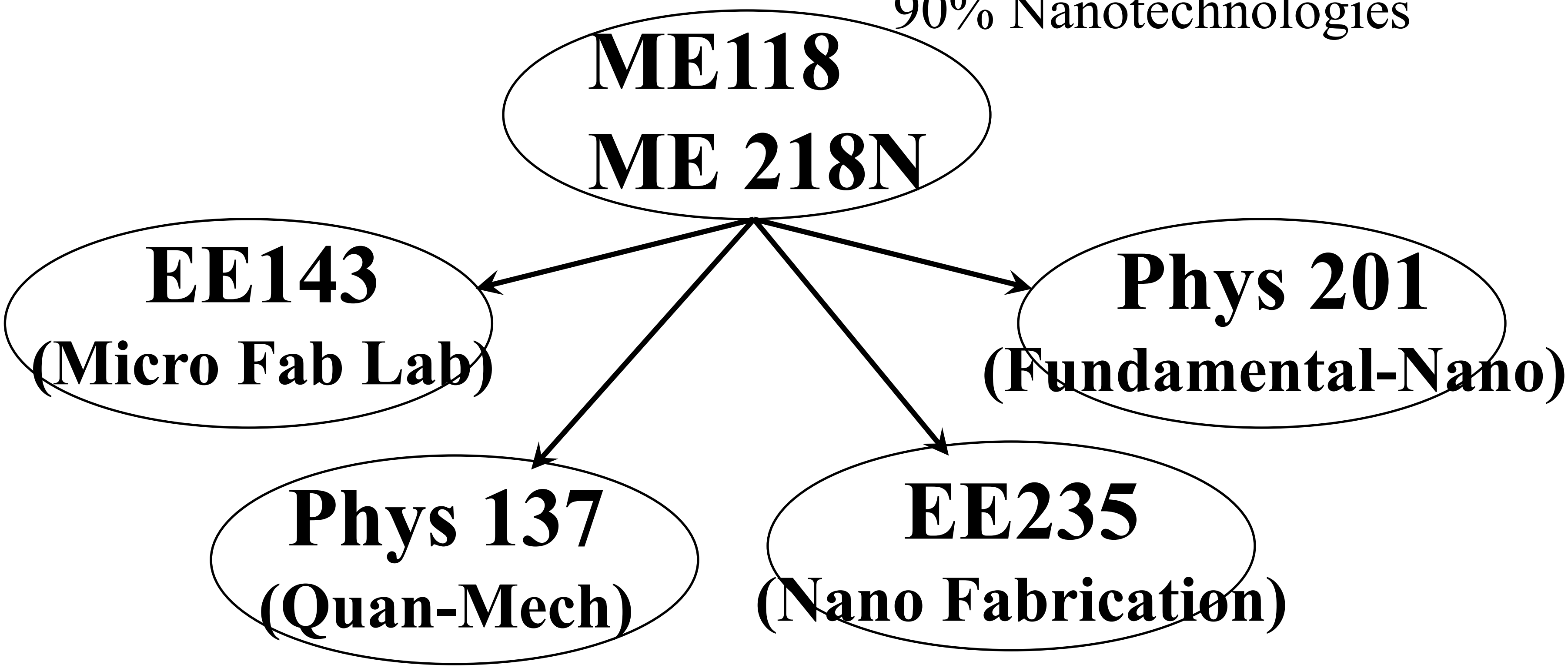
How can you achieve or access the "nano" regime?

Do materials properties behave like the bulk in the nano regime?

- ☐ ***To demonstrate technological relevance (in science, engineering, and industry)***
- ☐ ***To discuss issues surrounding nanotechnology including societal impact (environmental & health, for instance)***
- ☐ ***Hands-on Experiences – Nanofibers & Sensing Systems***

UCB Partial Nano Courses

10% Micromachining
90% Nanotechnologies



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ME118/ME 218 N
Spring 2024

Introduction to Nanotechnology and Nanoscience

Instructors:

- Prof. Liwei Lin, Room 5135 Etcheverry, (510)643-5495, lwlin@me.berkeley.edu
- Teaching Assistant, Kamyar Behrouzi, kbehrouzi@berkeley.edu

Class Meetings:

- *Lecture*, Tuesday and Thursday at 247 Cory Hall, 9:30 - 11:00am
- *Office Hours*, Tuesday 1-2pm
- *TA Office Hours*, tbd, SDH 668

https://lwlin.me.berkeley.edu/me118/2024.html

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Course Descriptions:

Nanofabrication technology (how one achieves the nanometer length scale, including "bottom up" and "top down" technologies), interdisciplinary nature of nanotechnology and nanoscience (including areas of chemistry, material science, physics, and molecular biology), examples of nanoscience phenomena (the crossover from bulk to quantum mechanical properties), and applications (from integrated circuits, quantum computing, MEMS, and bioengineering). Students are asked to read and present a variety of current journal papers to the class and lead discussions on various works.

Prerequisite: Chemistry 1A, Physics 7B,

Text Books:

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Projects:

A small project abstract based on nanowires/nanotubes will be collected at the middle of the semester. A final project is required, including oral project presentation to be held at the end of the semester and a written report. For ME218N students, an additional requirement is to conduct numerical simulations for the final project.

Grading:

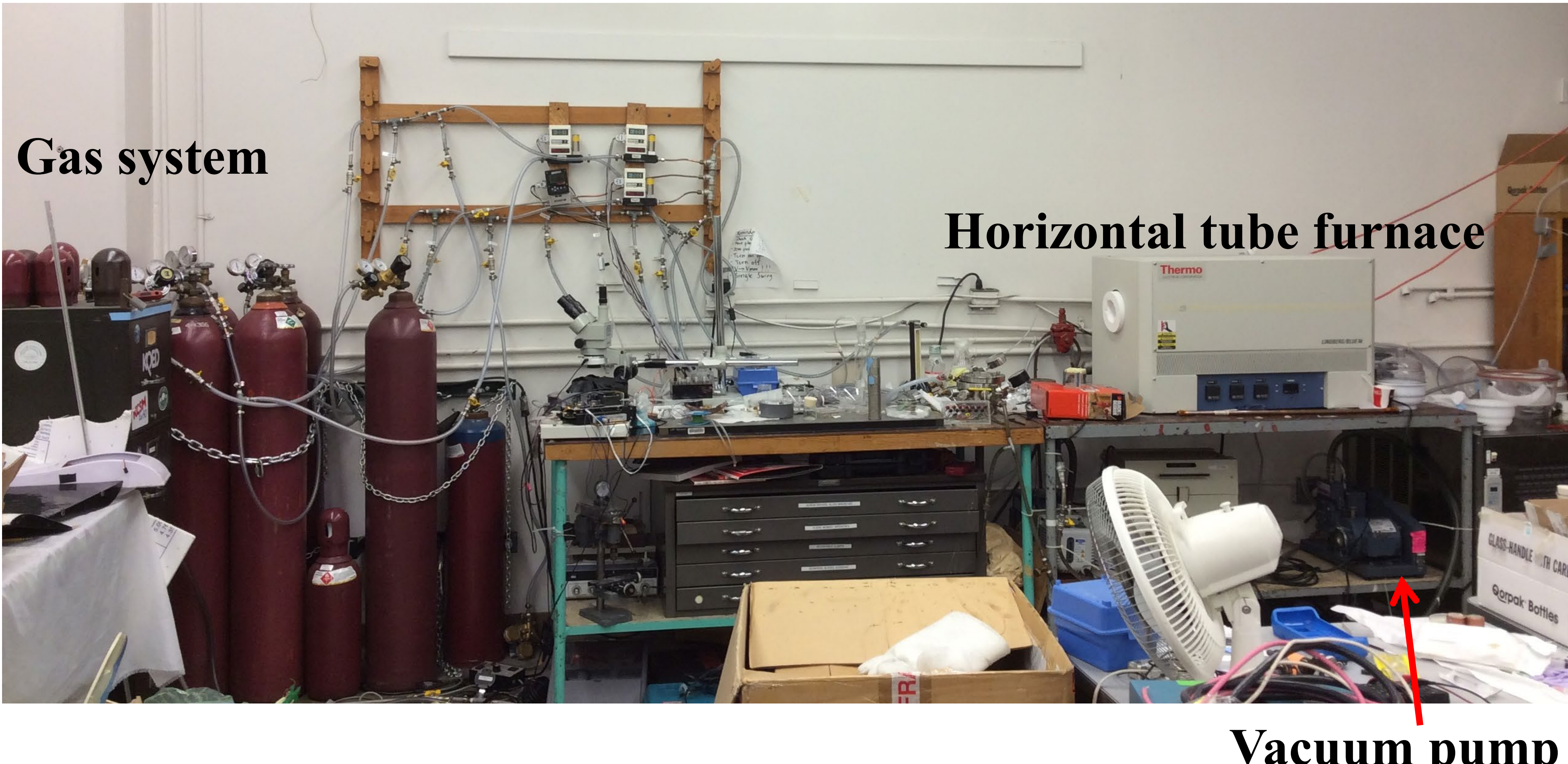
- 25% homework and participation (including participation)
- 10% small project (one-page project abstract based on nanowires/nanotubes)
- 30% 2 exams (10% Quiz I, 20% Quiz II)
- 35% final project (concept 10%, oral presentation 10%, written report 15%)

Selected Papers

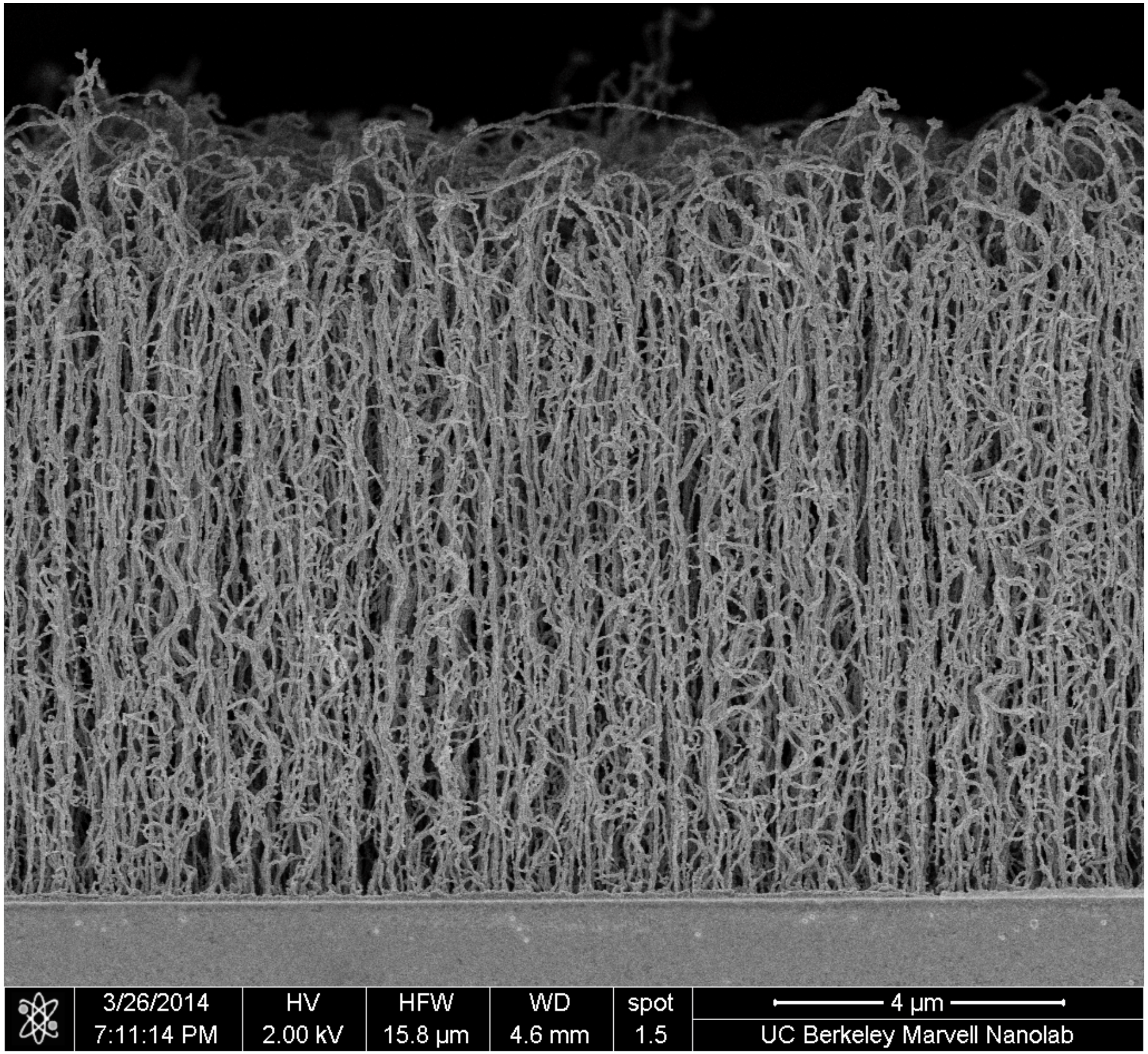
Selected Papers(Tentative)

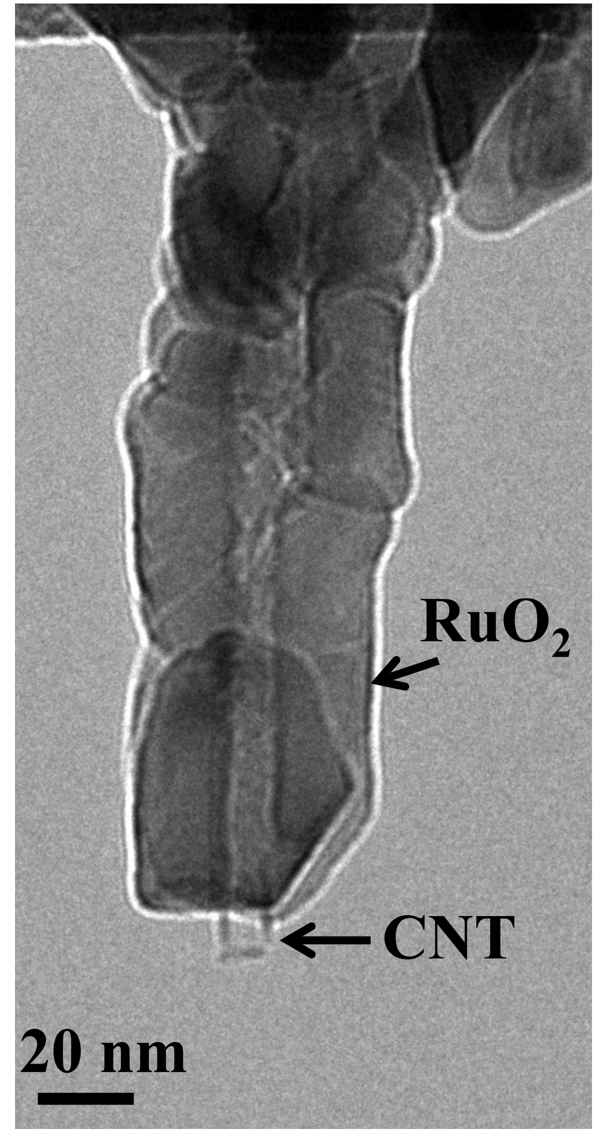
Paper	Authors	Title	Journal	Volume,Page	Year
1	S. Iijima	Helical Microtubules of Graphitic Carbon	Nature	Vol. 354, pp. 56-58	1991
1+	S. Iijima and T. Ichihashi	Single-shell Carbon Nanotubes of 1-nm Diameter	Nature	Vol. 363, pp. 603-605	1993
2	O. Englander, D. Christensen, and L. Lin	Local Synthesis of Silicon Nanowires and Carbon Nanotubes on Microbridges	Appl. Phys. Letters	Vol. 82, pp.4797-4799	2003
2+	L. Lin, and M. Chiao	Electrothermal Responses of Lineshape Microstructures	Sensors and Actuators - A	Vol. A55, pp.35-41	1996

Old Lab #1: Carbon Nanotubes

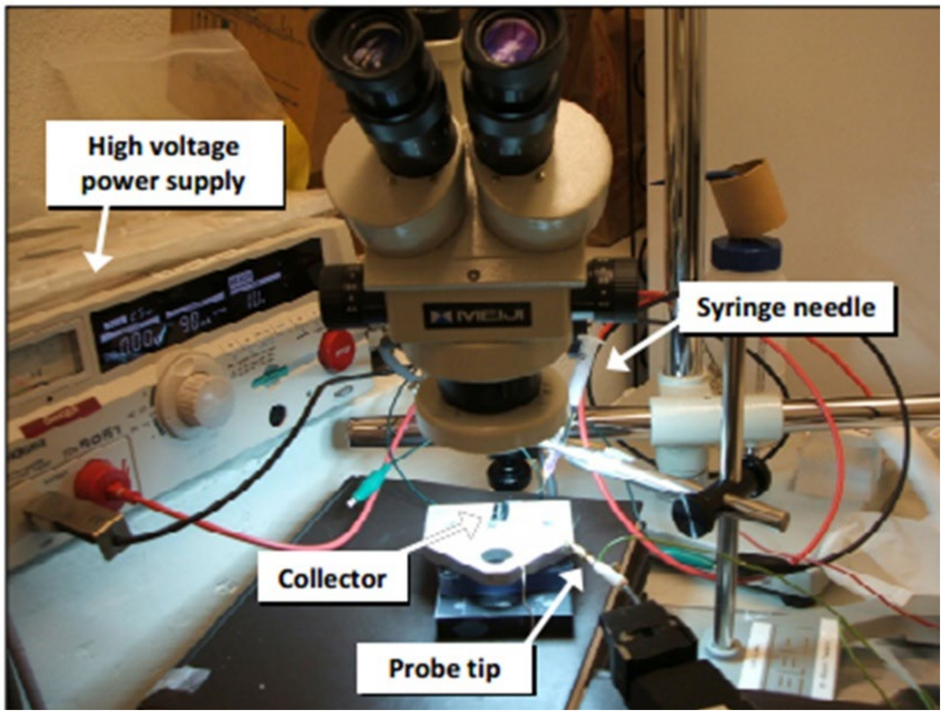


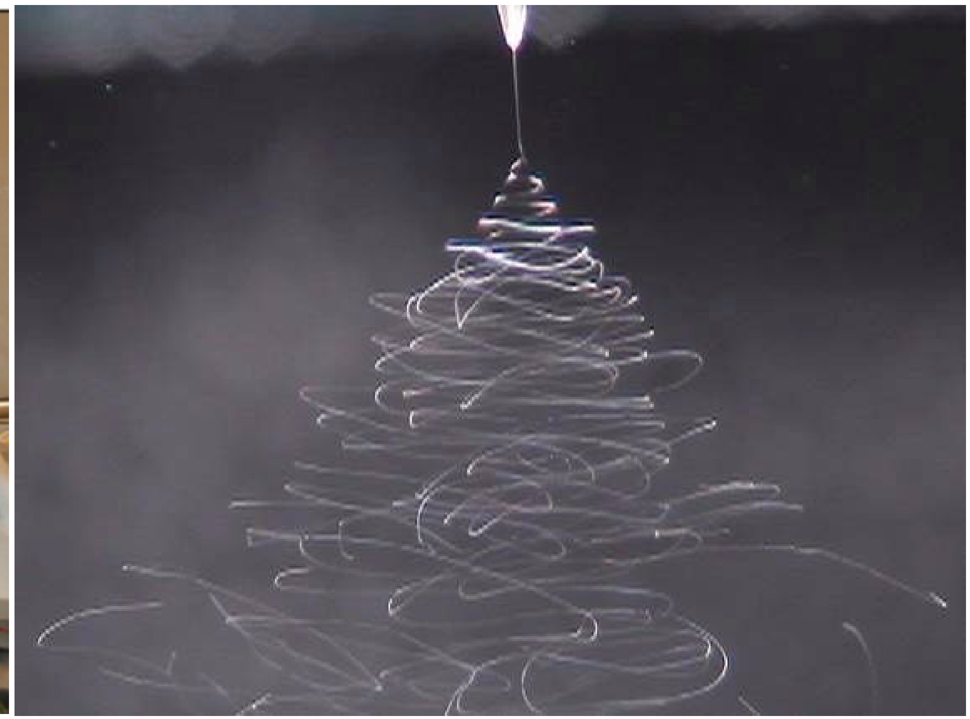
Old Lab #1: Carbon Nanotubes





Lab #2 Electrospinning





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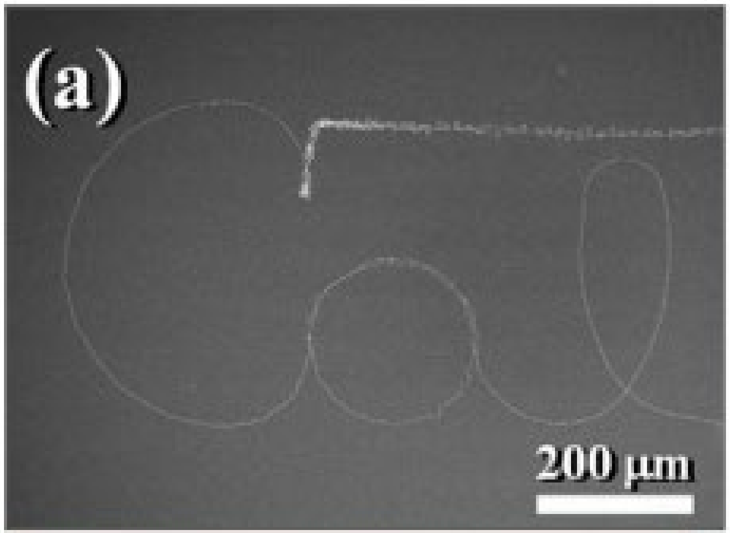
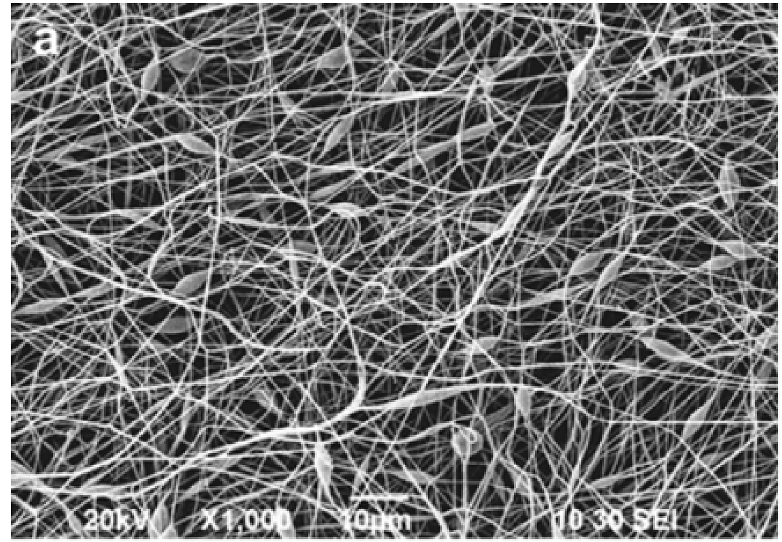
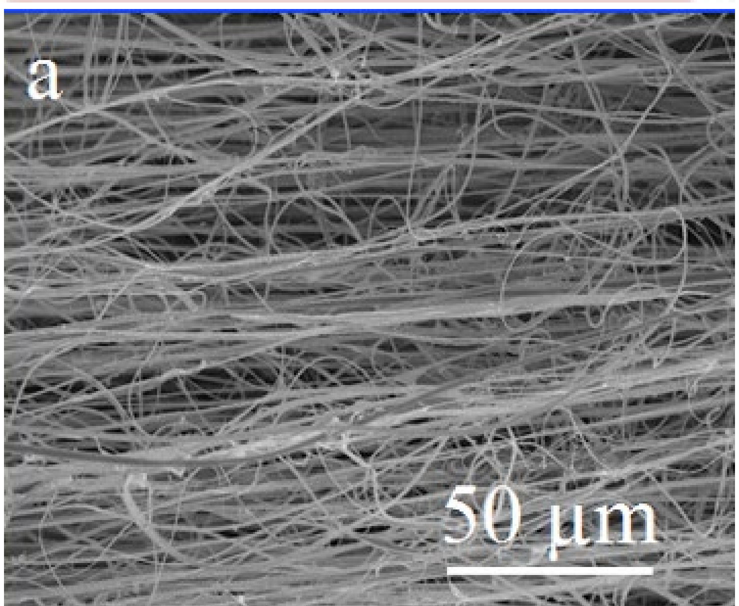
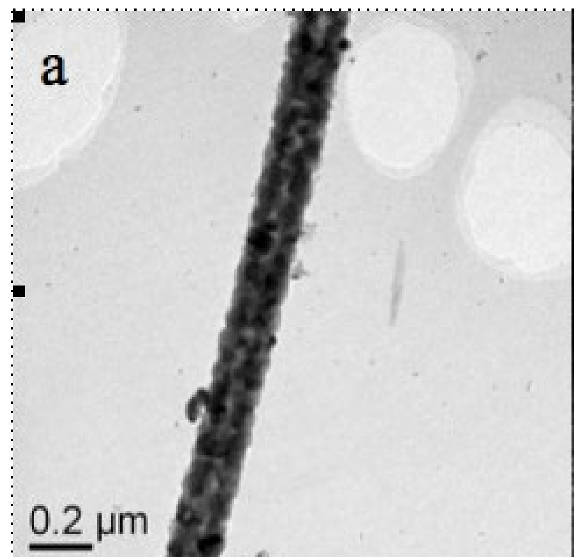






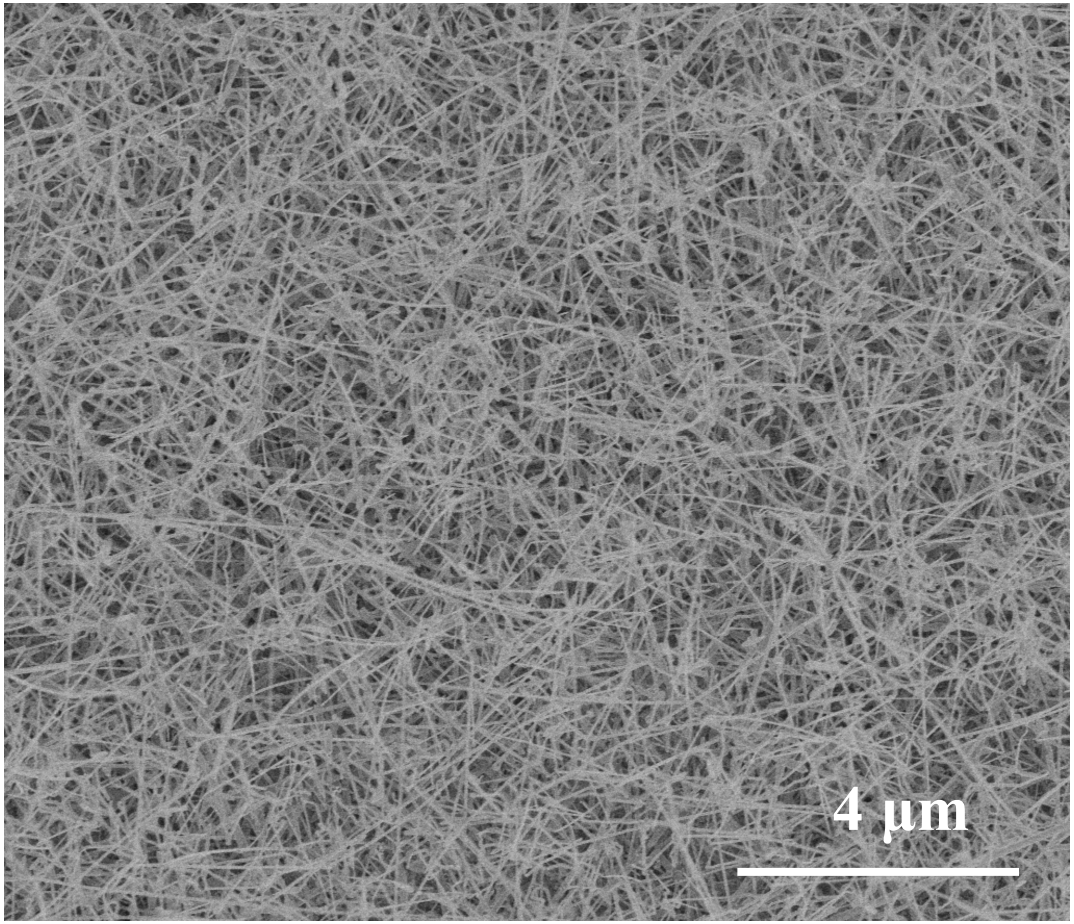


Projects

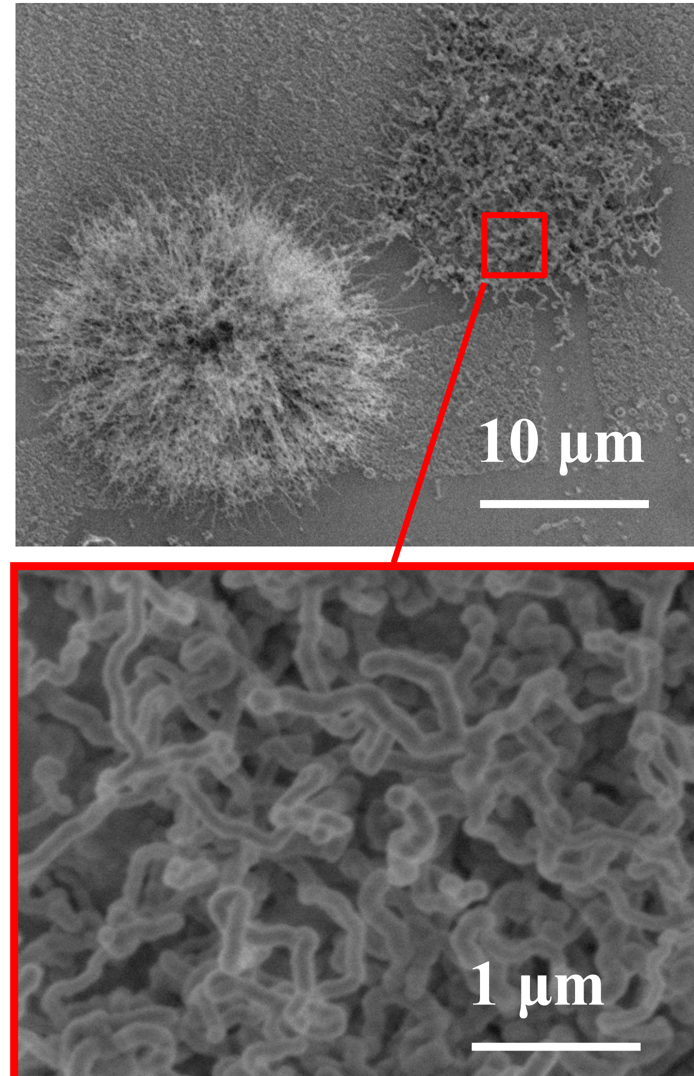
- **One-page Small Project: Engineering Applications of Nanowires/Nanotubes**
  The purpose of this project is to use the knowledge you have learned in the class on nanowires/nanotubes toward engineering applications. Your one-page project report will include (1) a schematic diagram of your structure/device/system, (2) brief explanation on the uniqueness of your structure/device/system, and (3) assumptions you may have to make in order to claim the functionality in (2). You are encouraged to do a different design (a new nano structure of your own) and your grade will be judged on the effort and innovation you put into the design.
- **Final Project: Design and Analysis of Nano Structure/Device/System**
  The purpose of this project proposal is to exercise your knowledge and imagination of nanoscience and nanotechnology toward engineering applications with detailed justifications. You will need to draw a diagram of your nanostructures to illustrate your concept and specific applications into nanoscience and nanotechnology. You can continue working on the small project by using nanowires/nanotubes. Or you can change your topic to have different nanostructures such as nanofibers, quantum dots or other nanostructures. You are encouraged to use new concept, design new nanostructures. Reports that only discuss things we have covered in the class generally get lower grades. Final presentations are in the last week of the class.

Nanowires

ZnO



Ta_2O_5



What is a nanometer?

1000 kilometers

(After Mark Ratner, Northwestern)

100 kilometers

Northwest Florida

10 kilometers

Tallahassee

1 kilometer

National Magnet Lab

100 meters

Lake, oaks

10 meters

Oak tree top

1 meter

Oak branch and leaves

100 millimeters

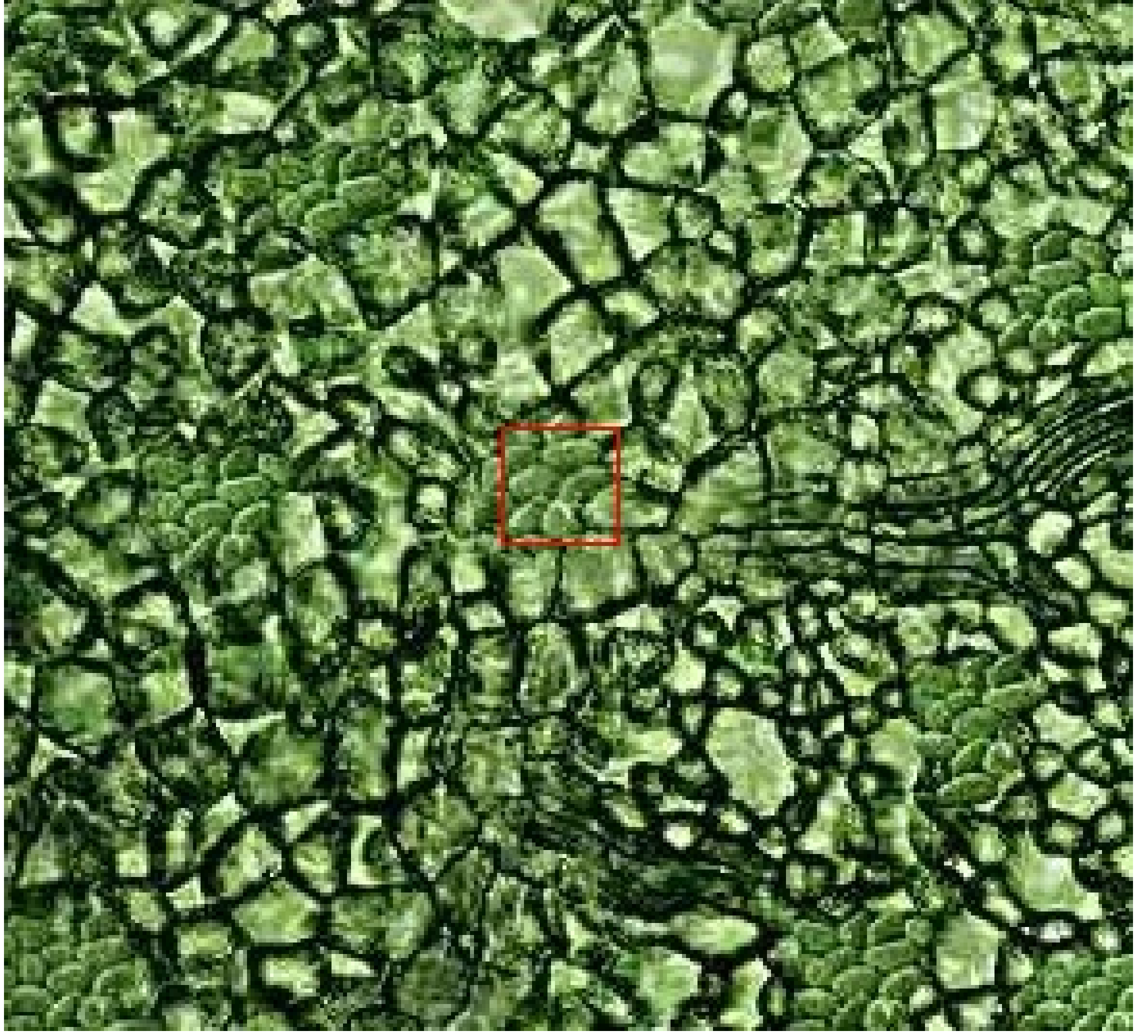
Oak leaf (actual size)

10 millimeters

Leaf surface, 10x enlarged

1 millimeter

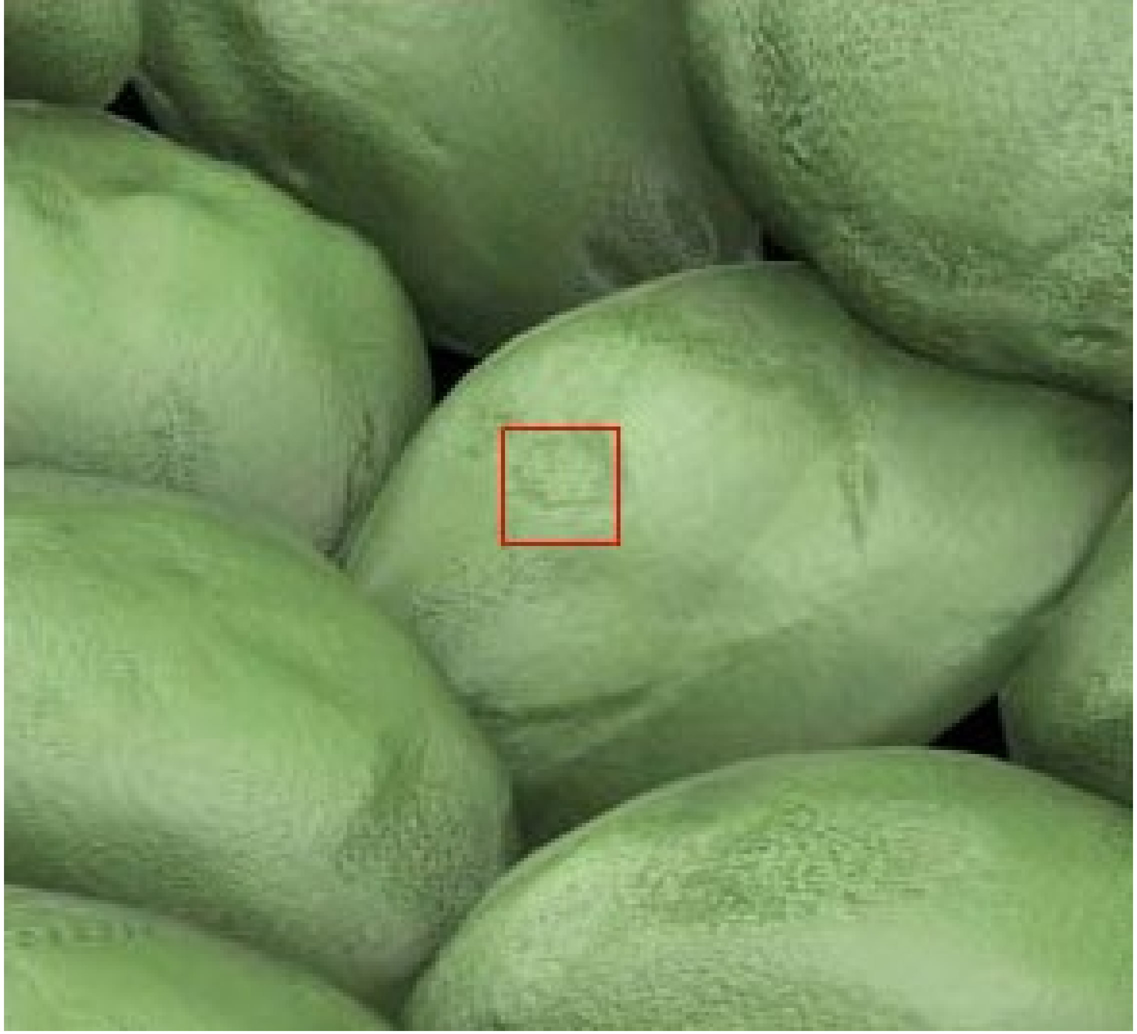
Leaf surface, 100x enlarged



100 microns

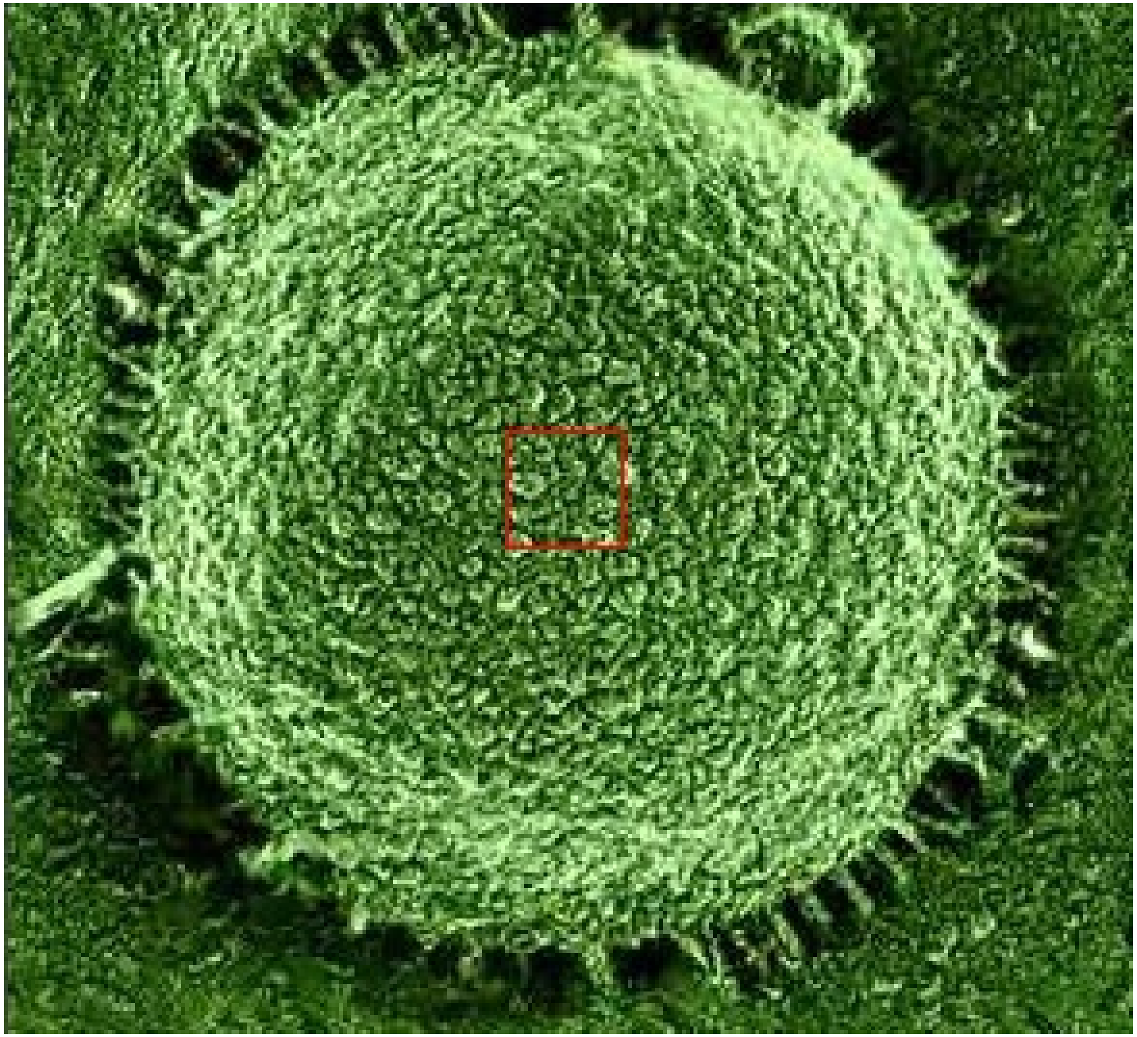
Many cells

HUMAN HAIR



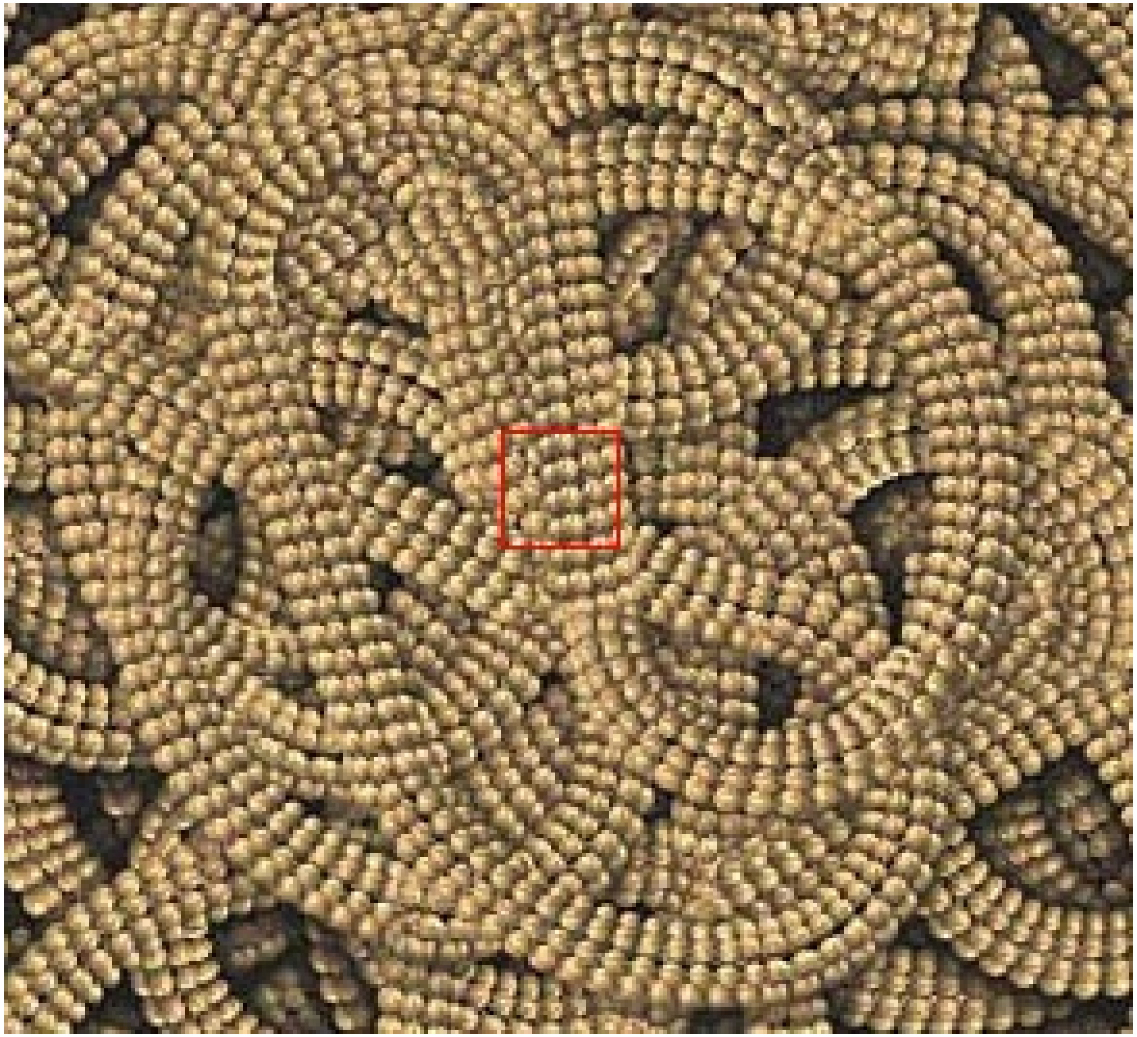
10 microns

Individual cells



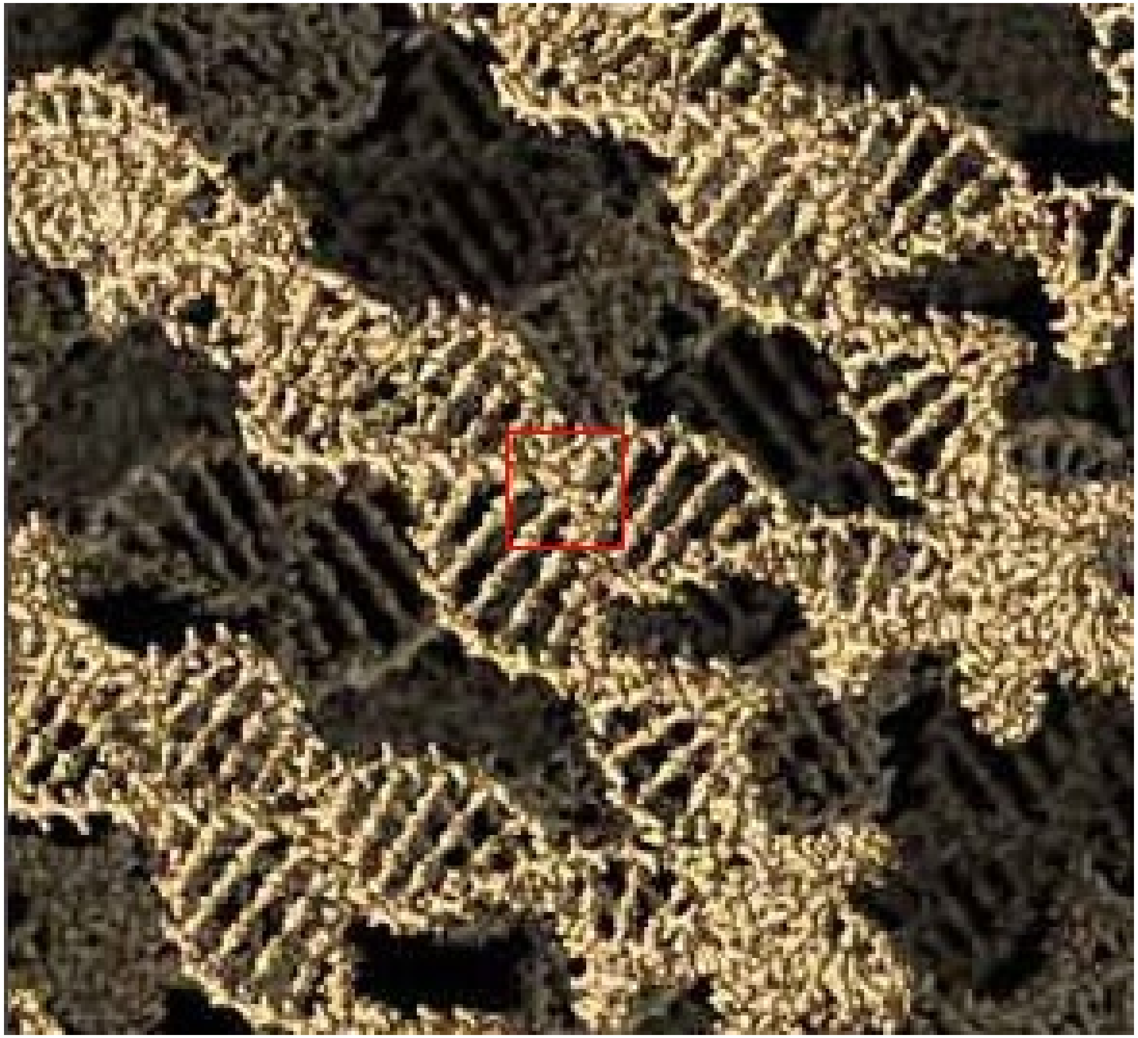
1 micron

Cell nucleus



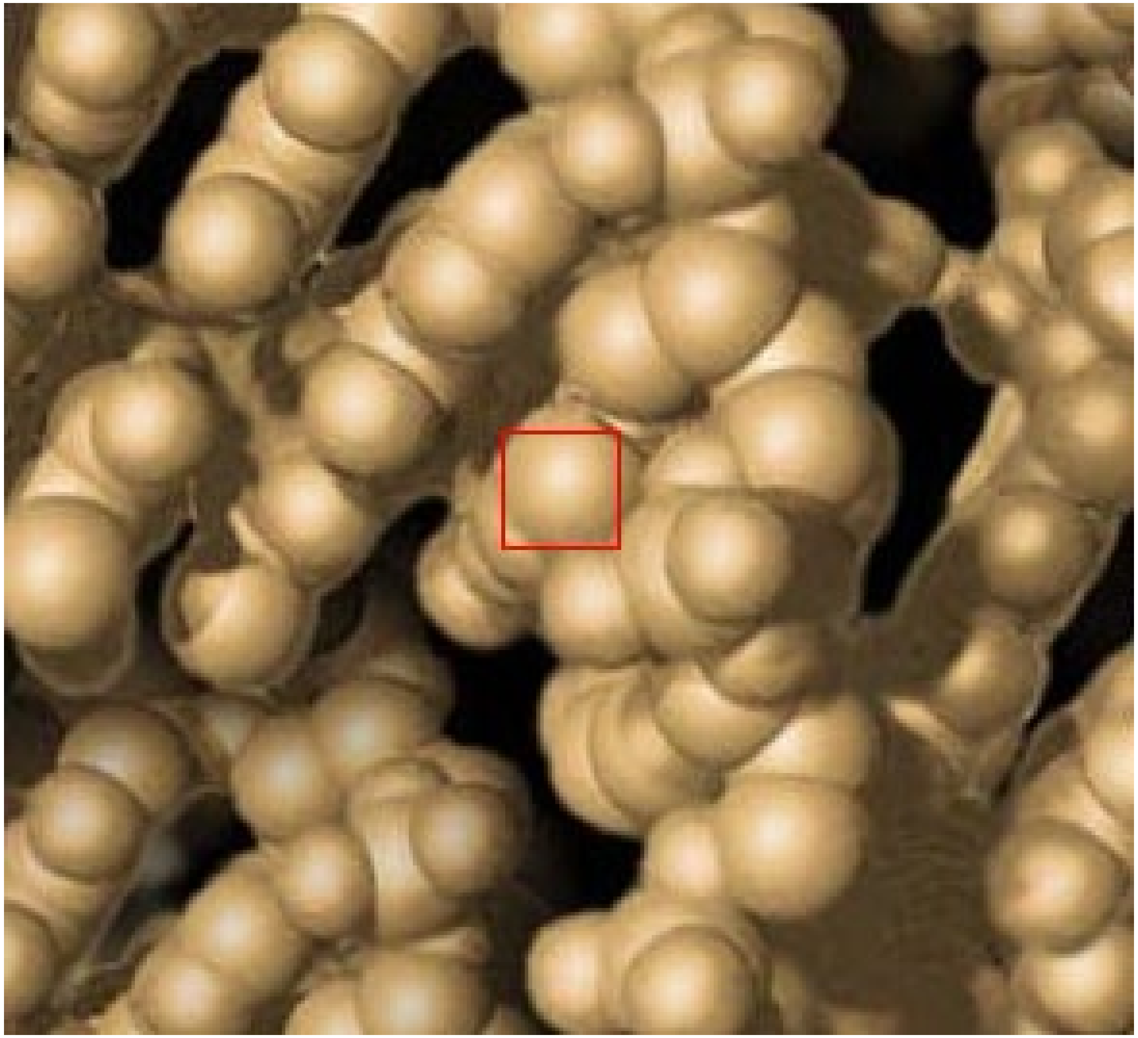
100 nanometers

Chromatin structure



10 nanometers

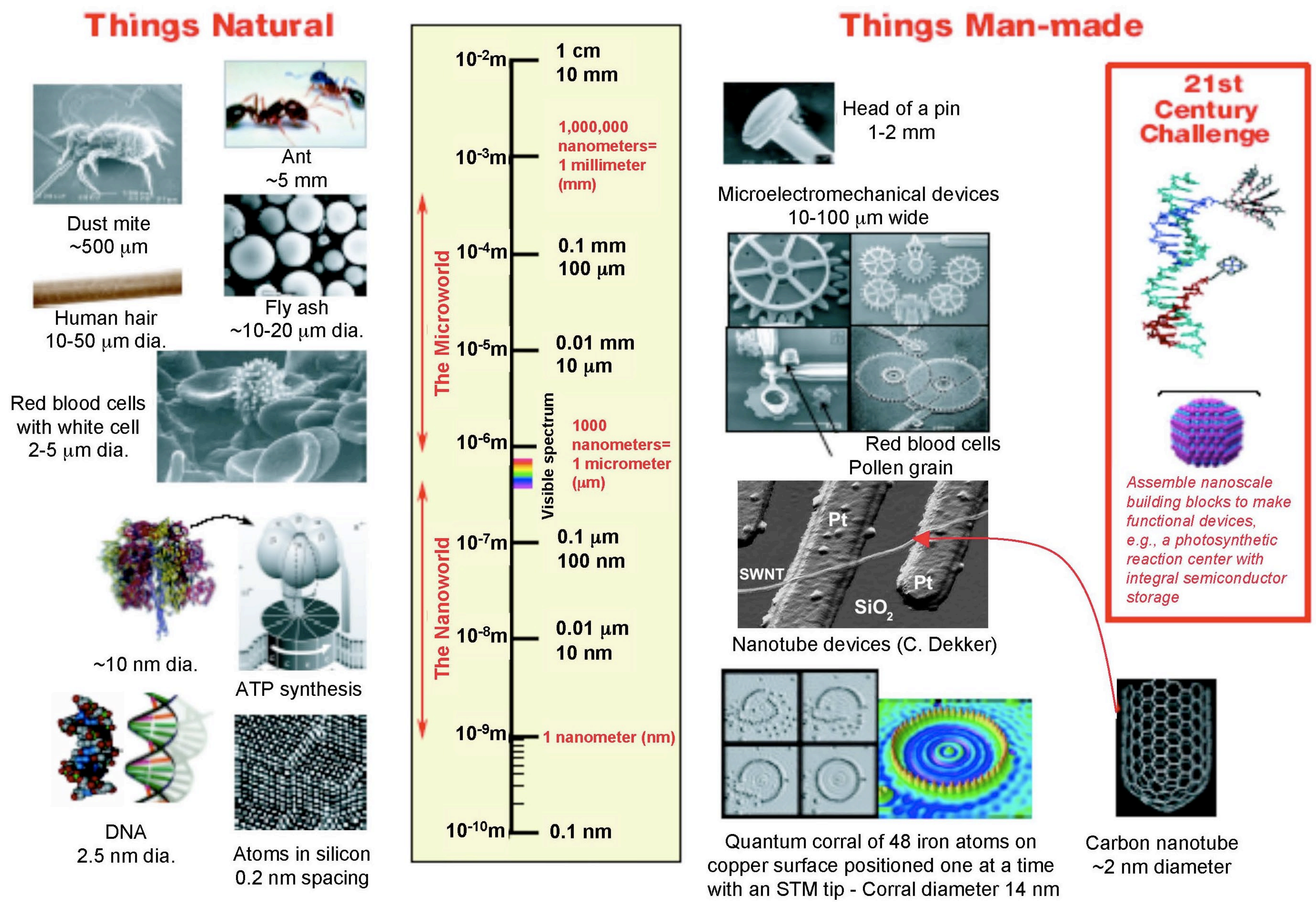
DNA double strands



1 nanometer

Individual molecules and atoms

What is a Nanometer?

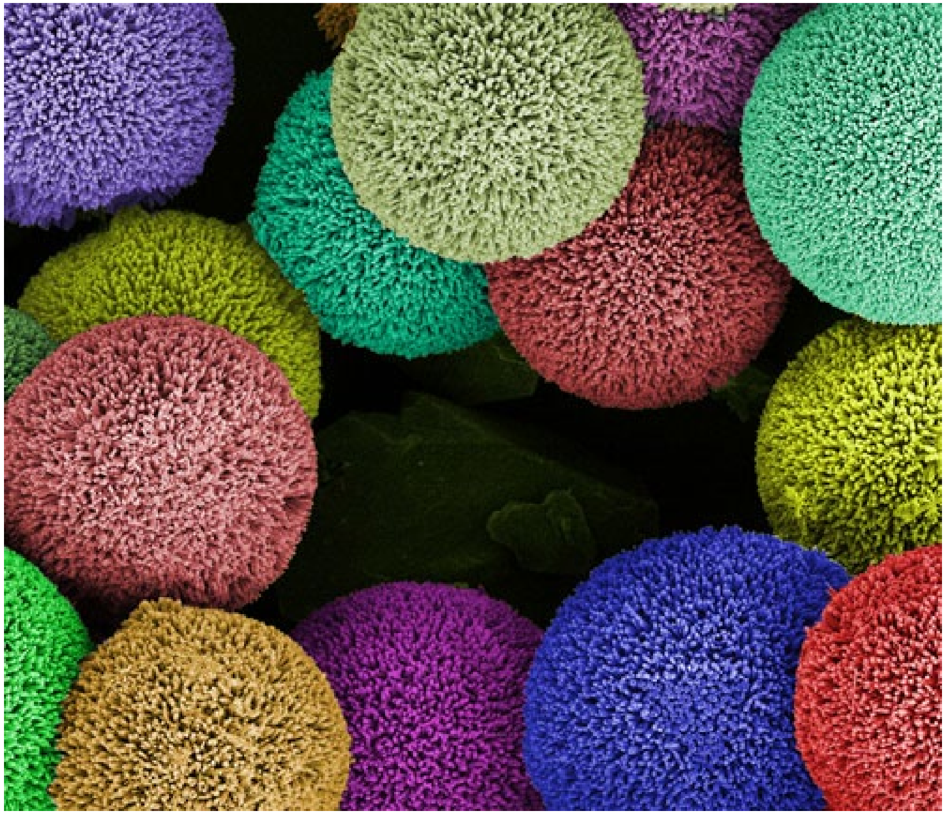


MRS: "Science As Art"

"Playful Hedgehog Particles"

The "Hedgehog" particles with nano-scale corrugation are sculpted by interfacial growth of rigid ZnO nanowires on polymeric microspheres.

- Joong Hwan Bahng, University of Michigan-Ann Arbor



Spring 2013

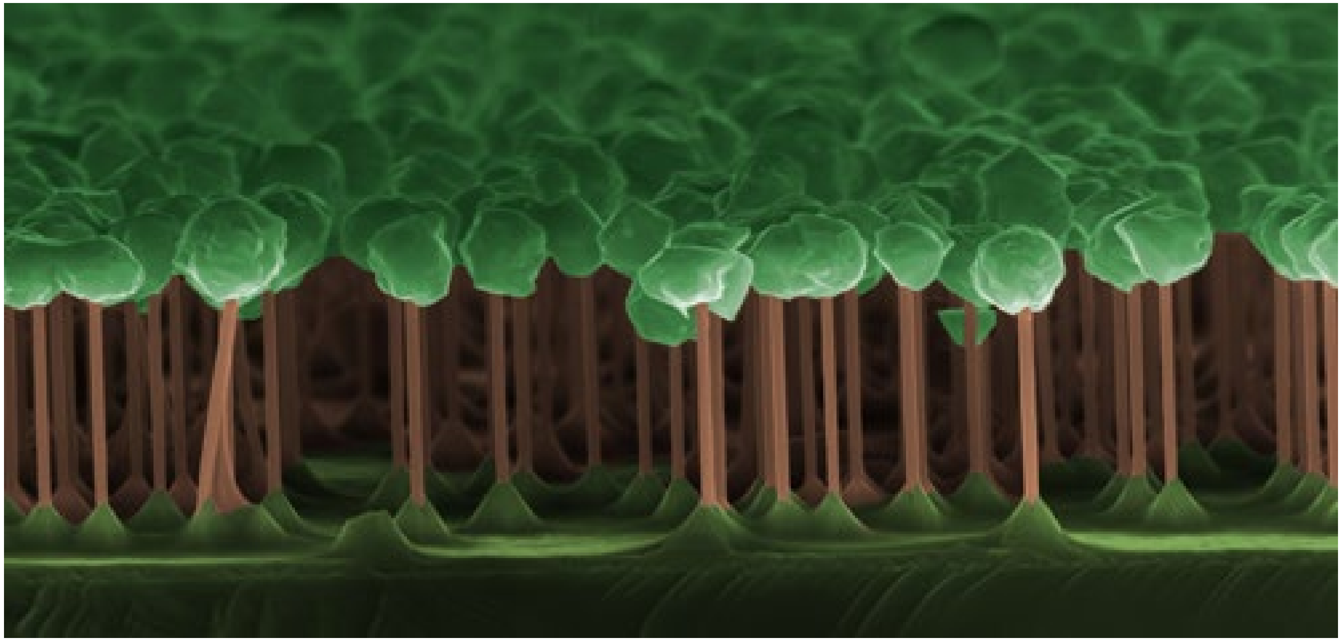
http://www.mrs.org/science-as-art/

MRS: "Science As Art"

"The Dark Forest of GaAs/GaInP Nanowires"

The nanowires were grown in two steps: first the GaAs stem using an Au particle as seed particle in MOVPE. The sample was removed from the reactor and a layer of HSQ resist was applied by spinning, forming a thin layer of moss. When the GaInP was grown during a second MOVPE step, the resist prevented growth on the substrate and sidewalls of the GaAs stems.

- Daniel Jacobsson, Lund University



Spring 2012

http://www.mrs.org/science-as-art/

MRS: "Science As Art"

"Nano Spaghetti & Meatballs"
The 'spaghetti' is a collection of electrodeposited Au nanowires, 100 nm in diameter, that have released from the substrate and bundled together (Thomas Cornelius – GSI Darmstadt). The 'meatballs' are Si nanoparticles, ~1.5 um in diameter, with Au nanocrystals on the surface that were grown on carbon-coated substrates using ultra-high vacuum molecular beam epitaxy (Gunther Richter – MPI Stuttgart)

Spring 2009

http://www.mrs.org/science-as-art/

Stained Glass

Historical Use of Nanoparticles

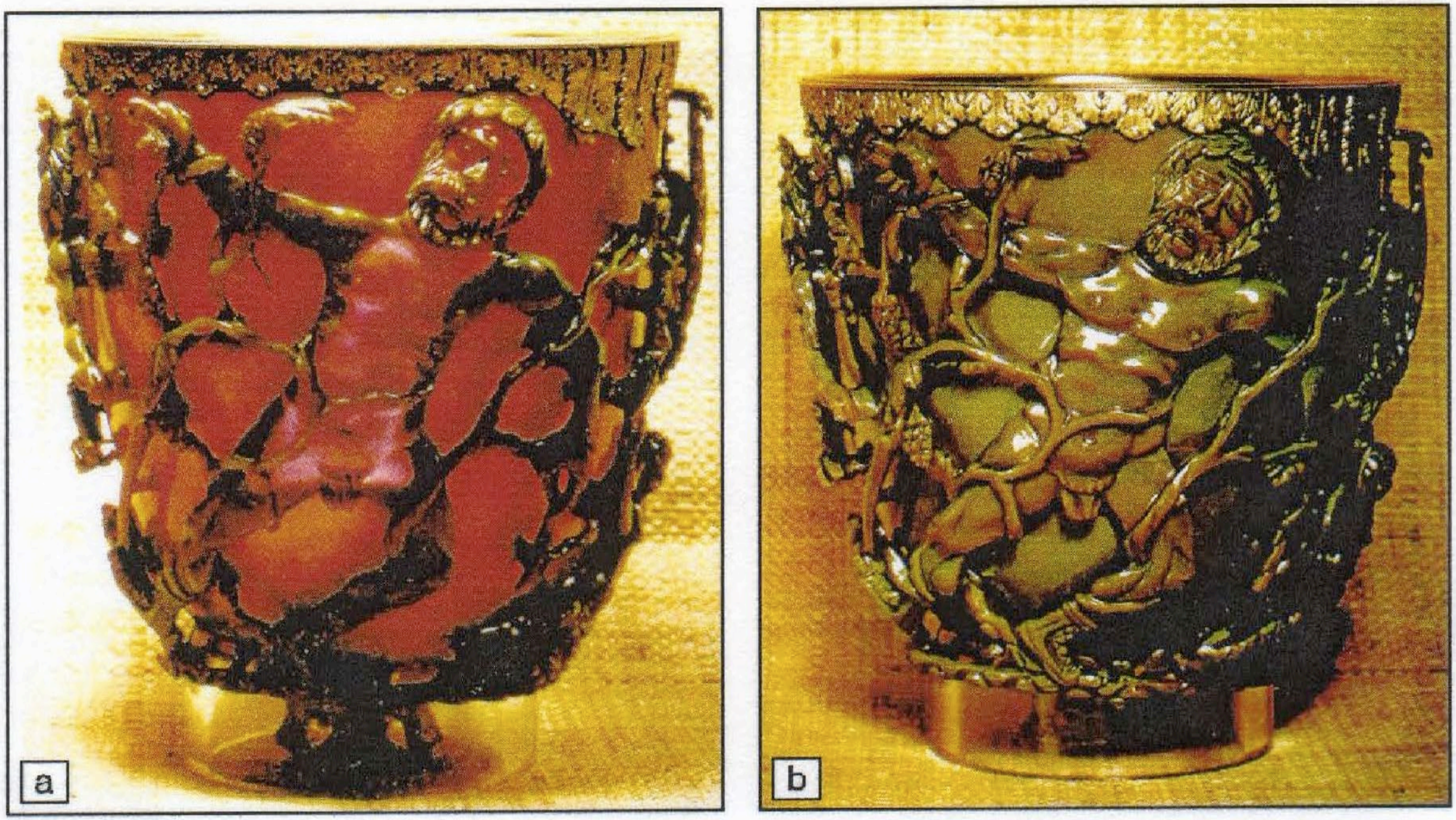


Figure 2. The Lycurgus Cup, dating from the 4th century A.D., is made from glass impregnated with gold nanoparticles; seen in (a) transmitted light and (b) reflected light.

Richard Feynman

A Man Before His Time…

In a 1959 talk entitled, *There's Plenty of Room at the Bottom: An Invitation to Enter a New Field of Physics*, Feynman discussed the potential benefits of making devices on the nanoscale:

> *What I want to talk about is the problem of manipulating and controlling things on a small scale….People tell me about miniaturization, and how far it has progressed today. They tell me about electric motors that are the size of the nail on your small finger. And there is a device on the market, they tell me, by which you can write the Lord's Prayer on the head of a pin. But that's nothing; that's the most primitive, halting step in the direction I intend to discuss. It is a staggeringly small world that is below. In the year 2000, when they look back at this age, they will wonder why it was not until the year 1960 that anybody began seriously to move in this direction.*

Richard Feynman

A Man Before His Time…

Feynman also posed this question:

Why cannot we write the entire 24 volumes of the Encyclopedia Brittanica on the head of the pin?

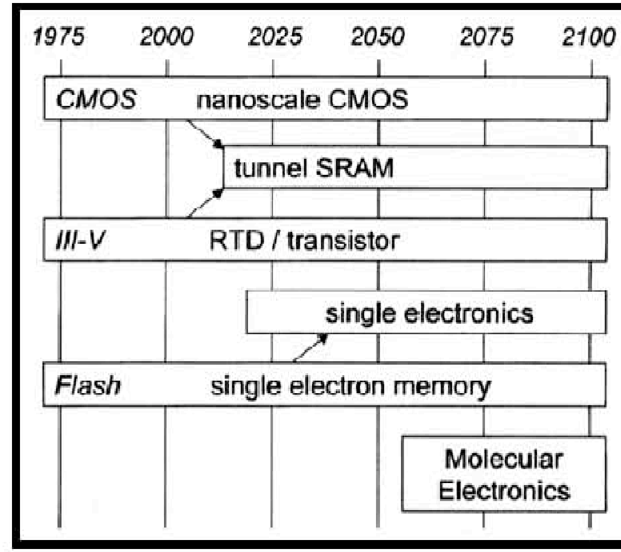
This goal requires patterning at the 10 nanometer length scale!

Molecular Electronics

The Future?

Projected timeline for the electronics industry:

A. C. Seabaugh, P. Mazumder,
***Proceedings of the IEEE*, 87, 535 (1999).**



President William J. Clinton
State of the Union Address
January 27, 2000

"Soon researchers will bring us devices that can translate foreign languages as fast as you can talk; materials 10 times stronger than steel at a fraction of the weight; ***and -- this is unbelievable to me -- molecular computers the size of a tear drop with the power of today's fastest supercomputers.***"

National Nanotechnology Initiative

- Even though nanoscience & nanotechnology had existed for many years, it was Pres. Bill Clinton in January 2000 who catapulted (for better or for worse) the field into mainstream science & engineering and society

  —Proposed the NNI which has now become a multibillion dollar investment in the US

  —see http://www.nano.gov for history and current info. on the NNI

- Estimated world-wide investment on nanotechnology and nanoscience is $8.6B in 2004