Stochastic Surface Effects on Nanobeams Behavior: A SMART Approach

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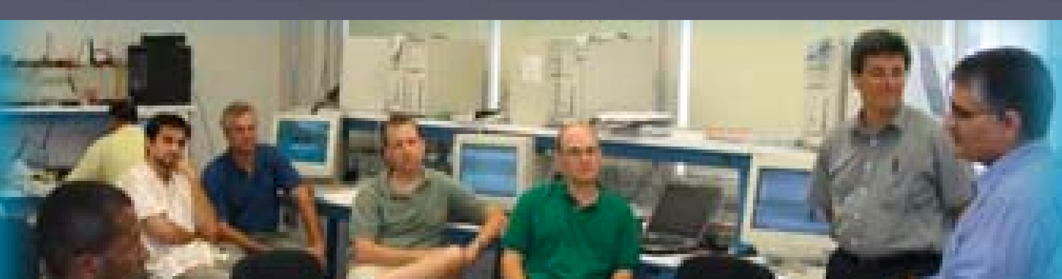
August, 2010



SMART

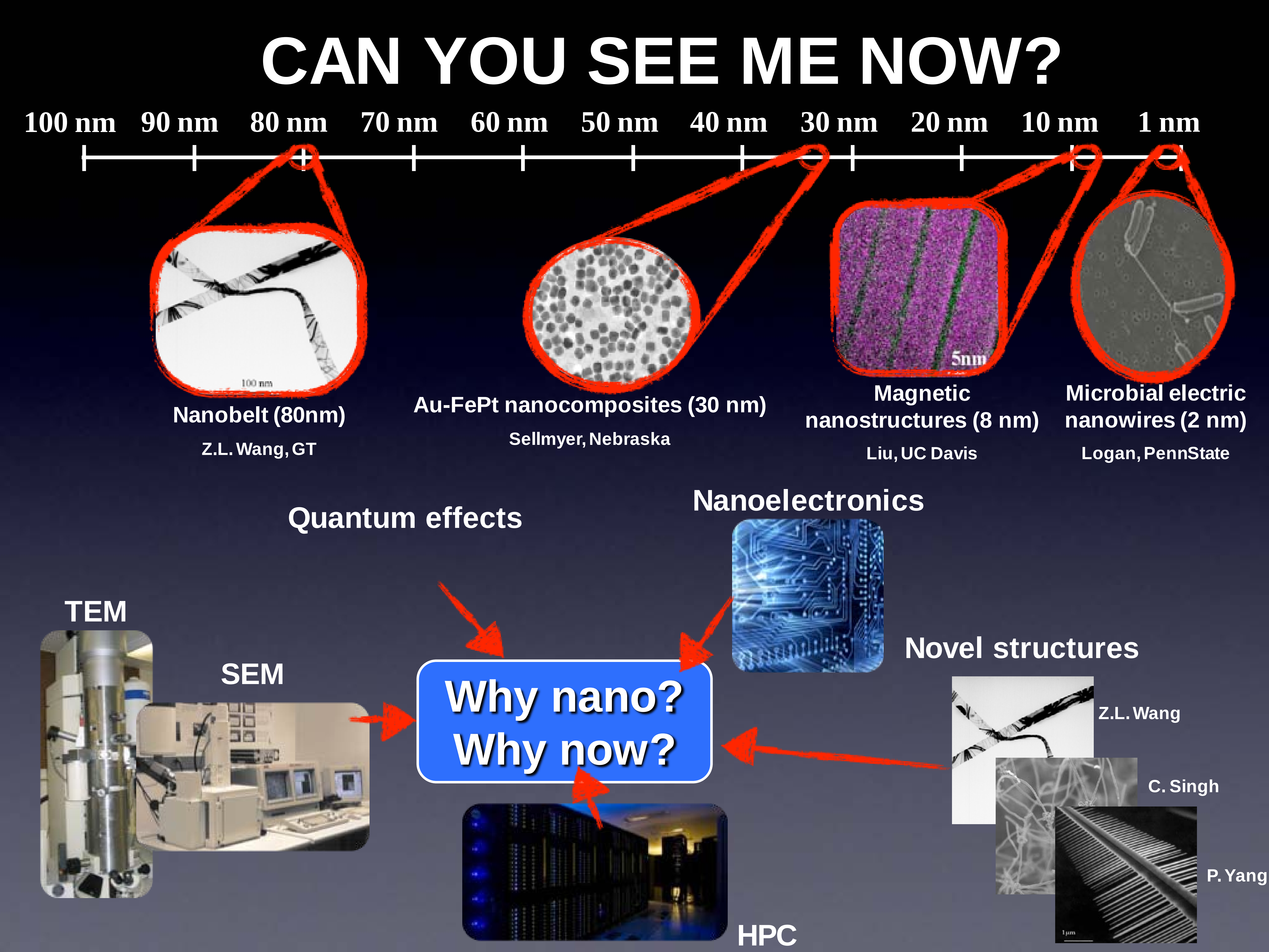
Science and Mechatronics Aided Research for Teachers :
A Research Experience for Teachers (RET) Site

OVERVIEW

- Objectives
- Introduction
- Background Information
- Research Process
- Application
- Action Plan
- Acknowledgment

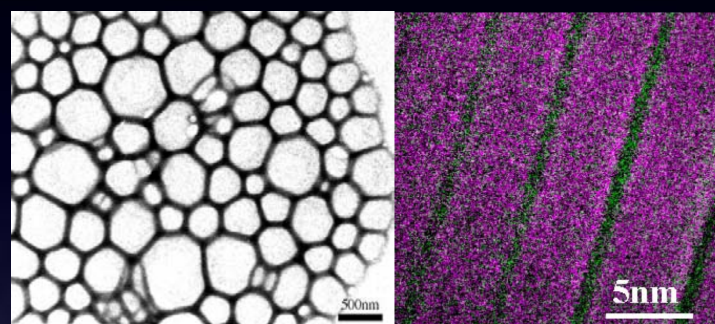
OBJECTIVE

- **Study stochastic behavior on the effective properties of nanowires**
  For this we need:
  - **Use Matlab (numerical/math software)**
  - **Reproduce and validate fundamental methodology(Altus'work)**
- **Utilize research as foundation in class to teach statiscal concepts**


CAN YOU SEE ME NOW?
100 nm
90 nm
80 nm
70 nm
60 nm
50 nm
40 nm
30 nm
20 nm
10 nm
1 nm
Nanobelt (80nm)
Z.L. Wang, GT
Au-FePt nanocomposites (30 nm)
Sellmyer, Nebraska
5nm
Magnetic nanostructures (8 nm)
Liu, UC Davis
Microbial electric nanowires (2 nm)
Logan, PennState
Quantum effects
Nanoelectronics
TEM
SEM
Why nano?
Why now?
Novel structures
Z.L. Wang
C. Singh
P. Yang
HPC

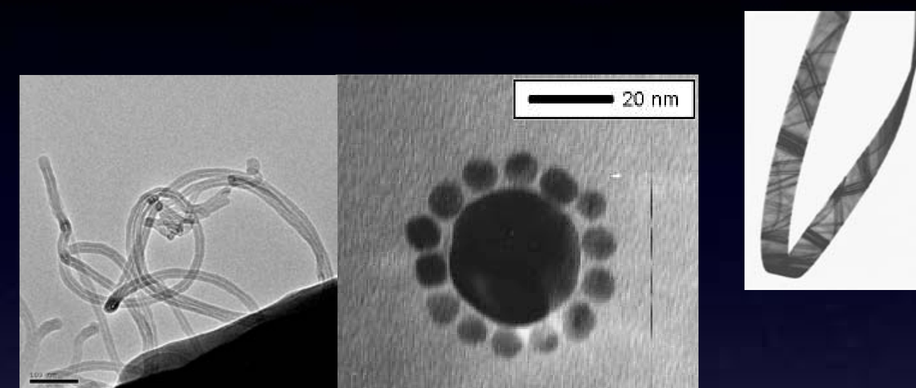
A FUNDAMENTAL DIFFERENCE AT THE NANOSCALE

Nano-structured materials



[Pileni (Pierre et Marie Curie)/Kai (UC)]

Nano-sized structural elements



[Wegrowe (Ecole Polytechnique)/Mirkin (NU)/ Wang (GT)]

Differences between "conventional" and "nano"

– Geometric: the characteristic length (grain or particle size) of the microstructure.

– Physical: the amount of grain boundaries per unit volume.

WHAT IS THE EFFECT OF SURFACE ON THE BEHAVIOR OF SUCH MATERIALS?

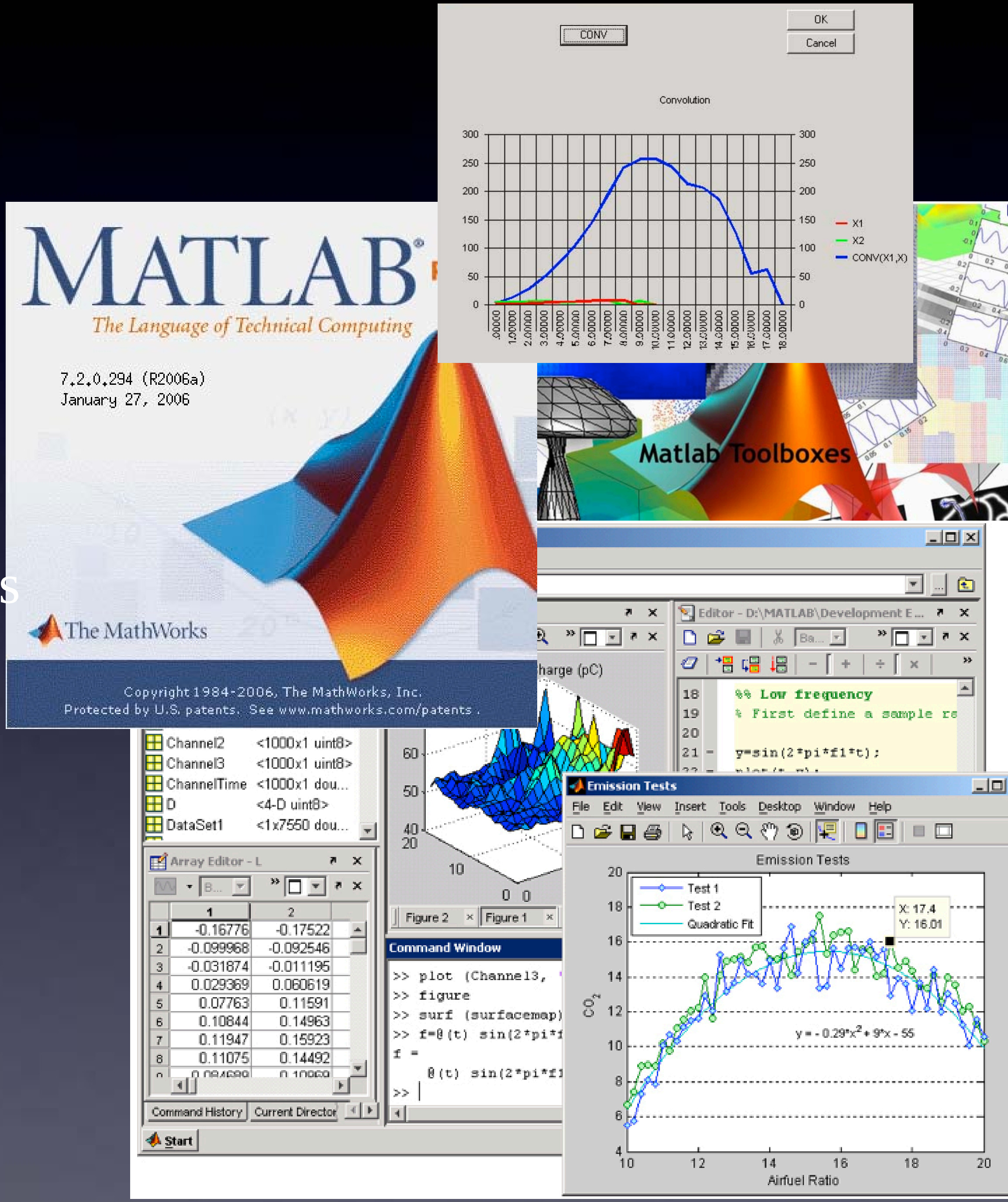
Especially impact of random events occuring at the surface of such devices…

Main tool: MATLAB

What is MATLAB?

- A software package for engineering analysis that does just about anything an engineer could desire. *(www.silcom.com)*

-Lots of graphics capability, full kit of analysis tools *(www.silcom.com)*



-MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other computer languages *(en.wikipedia.org)*

- Began as a high-level programming language for working with matrices. Over time it has expanded to become a fairly general-purpose language. *(mindhive.mit.edu)*

BACKGROUND

Microstress estimate of stochastically heterogeneous structures by the functional perturbation method: A one dimensional example *(Eli Altus, 2006)*

Solving for Var(u)

$$\left\langle u'^2 \right\rangle = \sum_{i=1}^{4} I_x^{(i)}$$

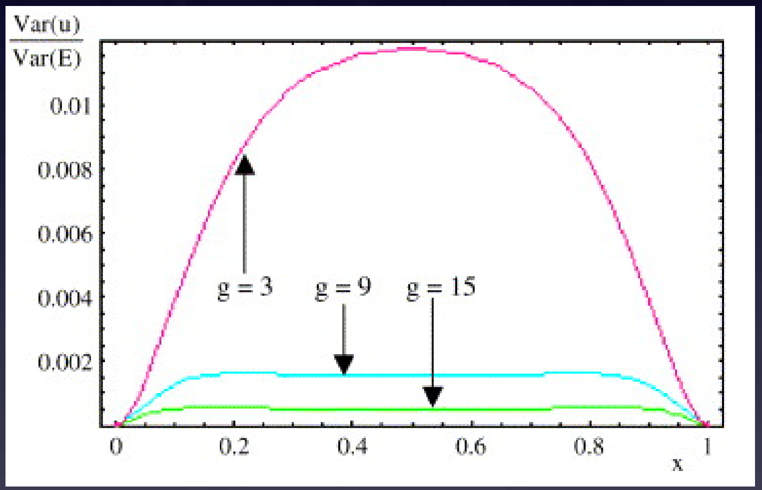
With these conditions:

$$I_x^{(1)} = (\sinh(gx) \cdot \cosh(g(1-x_1))) \times \mathop{*}_{x_1=0}^{x} \langle E_1' E_2' \rangle \mathop{*}_{x_2=0}^{x} (\sinh(gx) \cdot \cosh(g(1-x_2)))$$

$$I_x^{(2)} = (\sinh(g(1-x)) \cdot \cosh(gx_1)) \times \mathop{*}_{x_1=x}^{1} \langle E_1' E_2' \rangle \mathop{*}_{x_2=x}^{1} (\sinh(g(1-x)) \cdot \cosh(g(x_2)))$$

$$I_x^{(3)} = -(\sinh(gx) \cdot \cosh(g(1-x_1))) \times \mathop{*}_{x_1=0}^{x} \langle E_1' E_2' \rangle \mathop{*}_{x_2=x}^{1} (\sinh(g(1-x)) \cdot \cosh(gx_2))$$

$$I_x^{(4)} = -(\sinh(g(1-x)) \cdot \cosh(gx_1)) \times \mathop{*}_{x_1=x}^{1} \langle E_1' E_2' \rangle \mathop{*}_{x_2=0}^{x} (\sinh(x) \cdot \cosh(g(1-x_2))) .$$



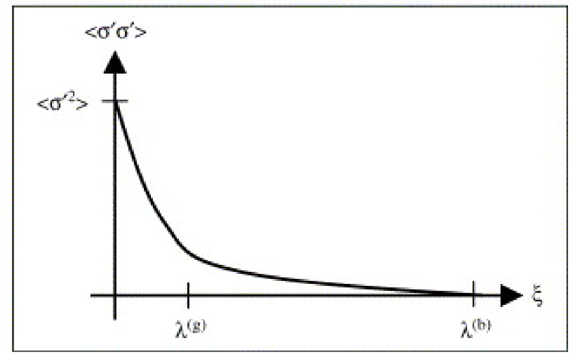


Fig. 2. Var(u) as a function of x for λ=0.1 and different g.

-Altus devised an explicit method in calculating characteristics of a non-uniform, stochastic field of a one dimensional heterogeneous structure

-The analytical result permits an insight to morphology related effects on displacement and stress fields

BACKGROUND

Stochastic surface effects in nanobeam sensors

(B. Bar and Eli Altus, 2006)

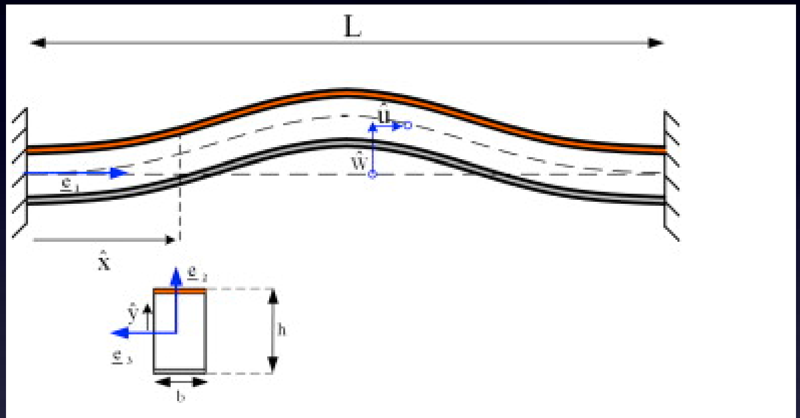


Fig. 1. Schematic description of centerline displacements in a 1D beam.

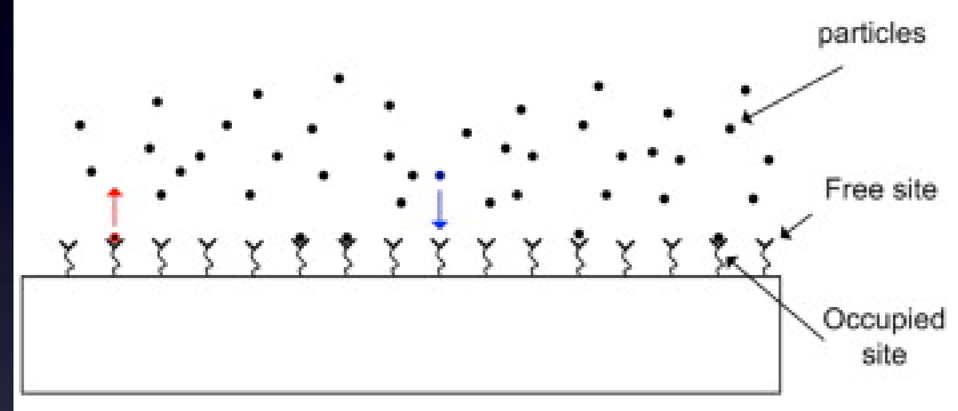


Fig. 3. Schematic description of surface–particle interactions via the Langmuir model.

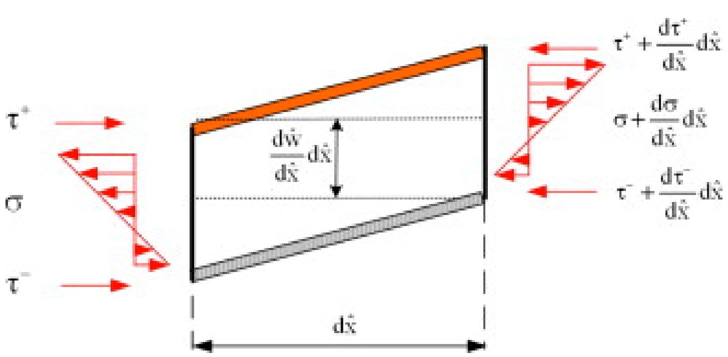


Fig. 2. Free body diagram on a nanobeam segment.

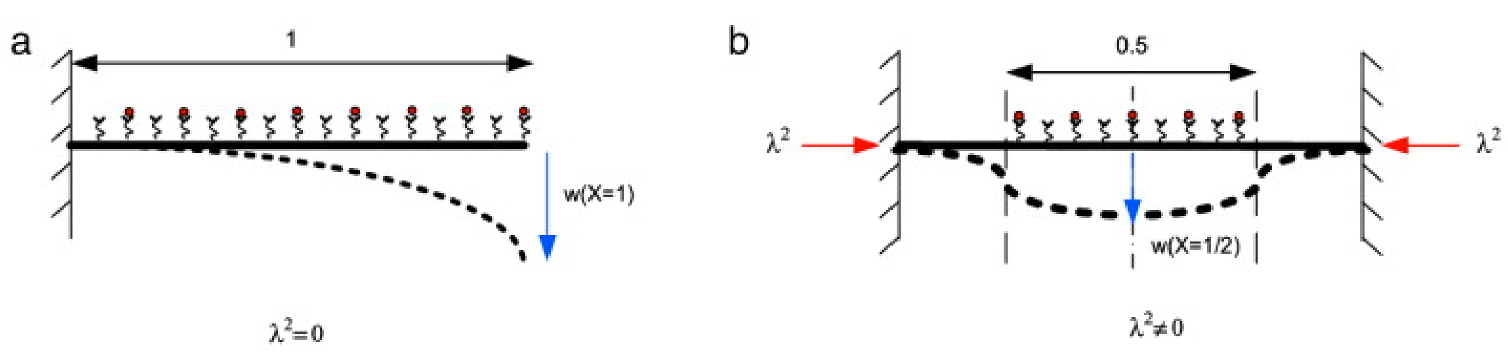


Fig. 4. A cantilever beam (a) under one-sided adsorption and a clamped beam (b) under partial one-sided adsorption ($0.25<x<0.75$).

DEFINITION OF TERMS

STOCHASTICITY

- Random events or behaviors that are not deterministic

NANOBEAMS

- Small structural beam with characterictic length in the nanometer

SURFACE EFFECT

- Mechanical behavior different than the “bulk”

CHEMOTAXIS

- Movement by a cell or organism in reaction to a chemical stimulus

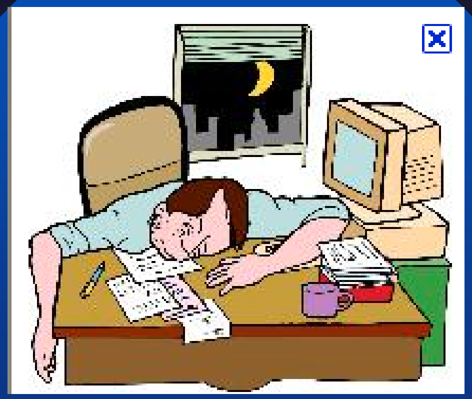
PERTURBATION METHOD

- Mathematical methods used to find an approximate solution to a problem which cannot be solved exactly

RESEARCH PROCESS

APPLICATIONS

-Chemotaxis
- Nanosensors



Researcher

THEORY

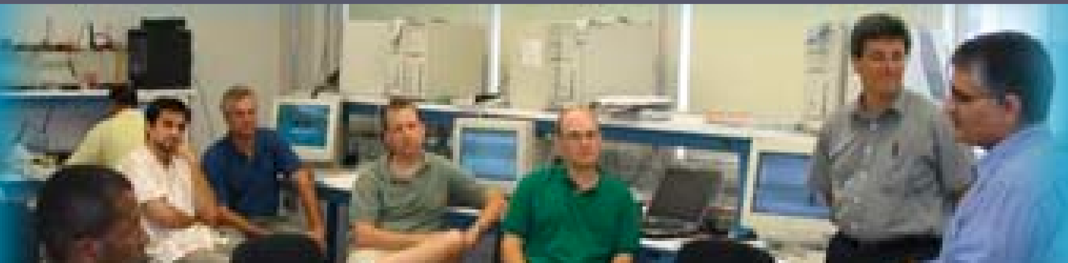
-Stochasticity
-Surface Effects
-Nanobeams

METHODS

-Perturbation method
-Computational Foundation
-Mechanical Model

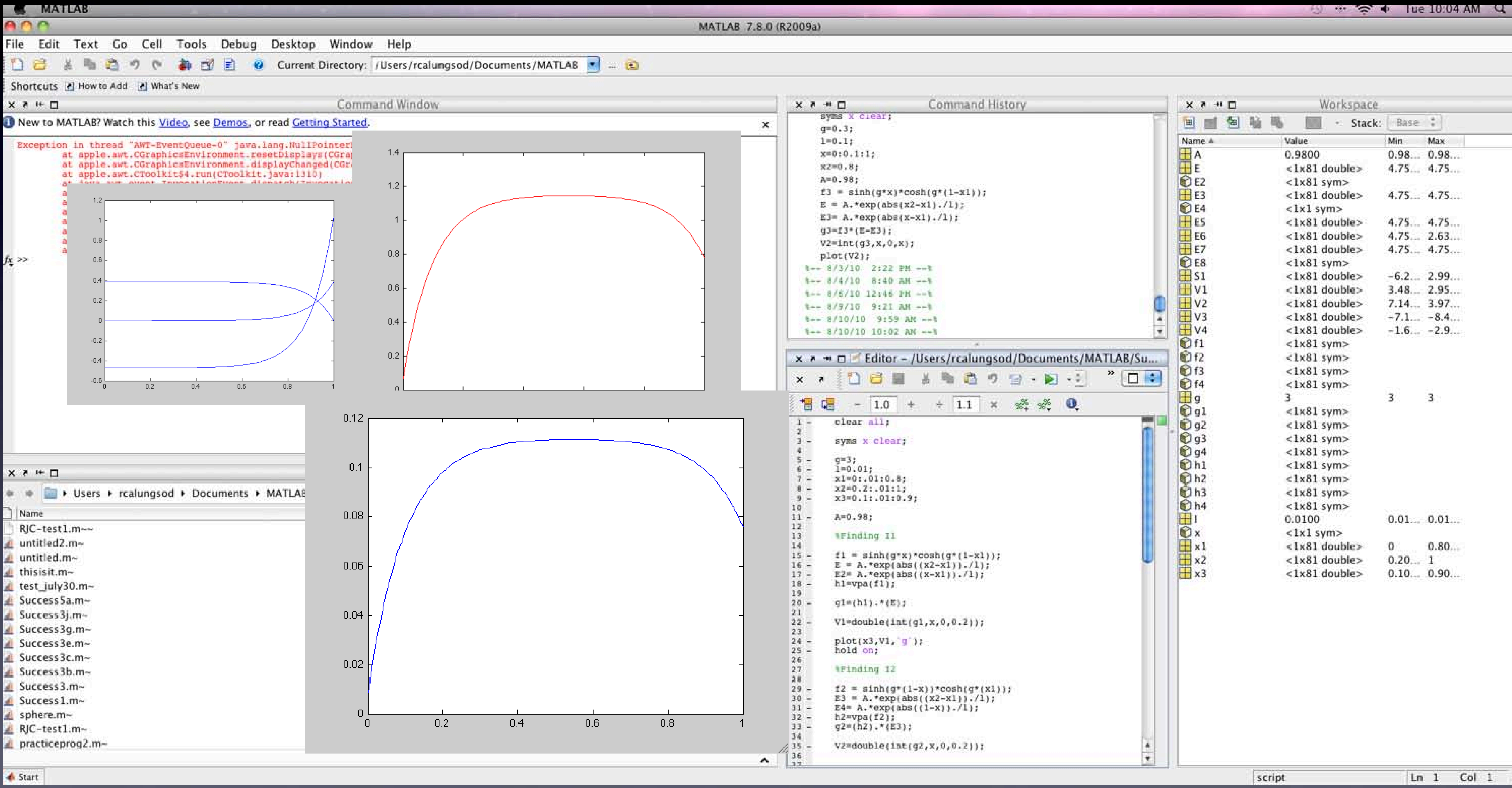
RESEARCH QUESTION

Does stochastic surface behavior on nanoparticles significantly affect its effective properties?



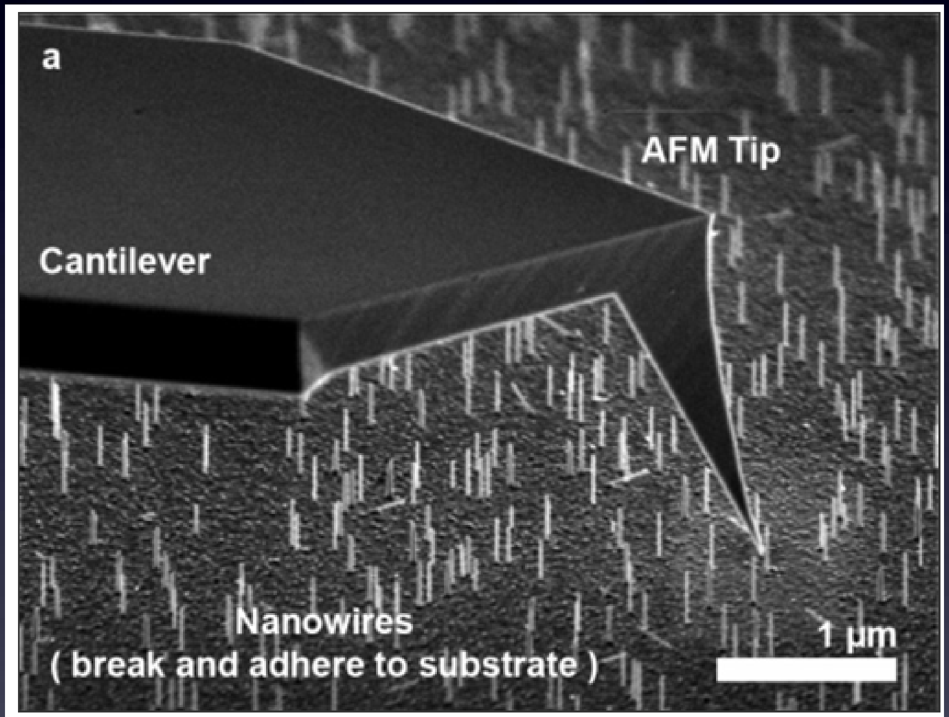
WORK IN PROGRESS...

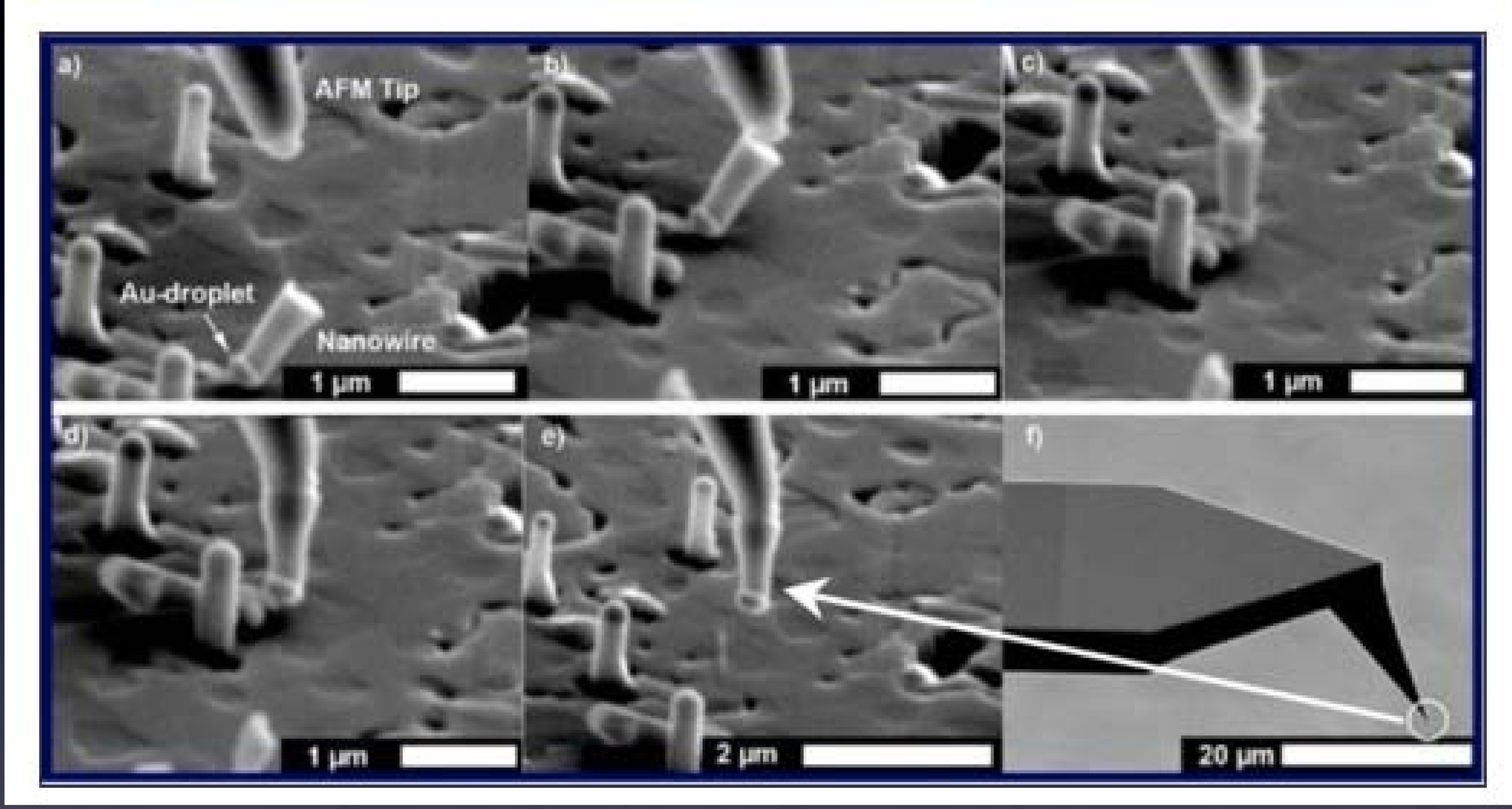
Using Matlab to replicate Altus 2006



APPLICATION

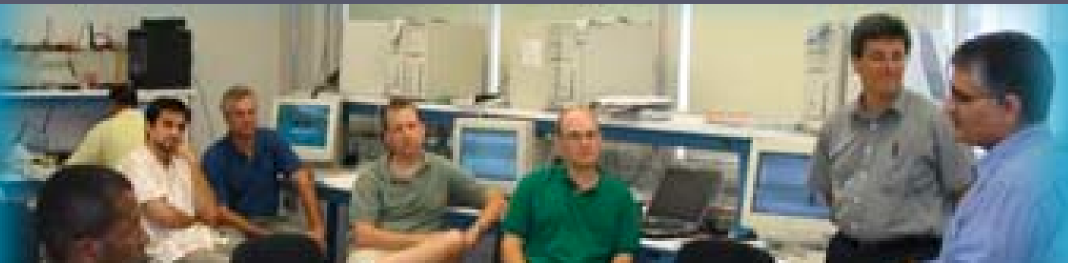
AT PRESENT:





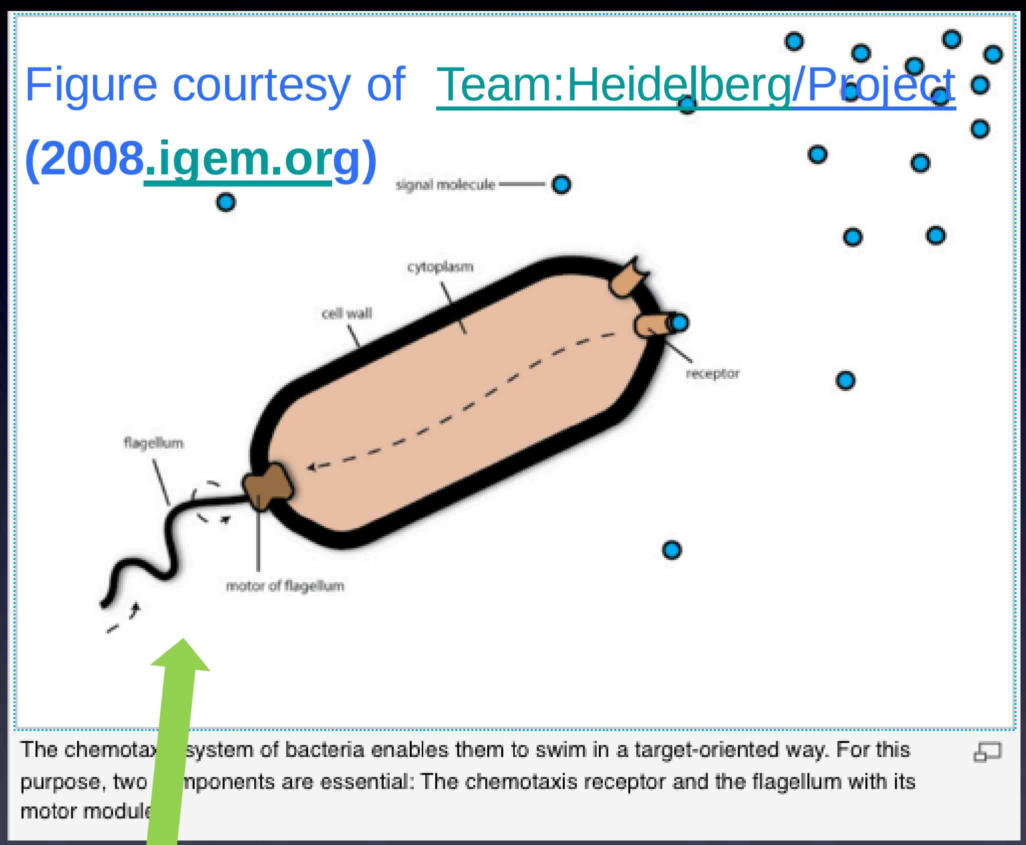
Nanomanipulation sequence for the attachment of an up-side-down nanowire onto an AFM tip; a) Mechanically, some nanowires are broken off the substrate by the movement of an AFM tip; b) A nanowire that lies on the substrate surface is brought into contact with the AFM tip; c) The nanowire is moved into the desired position; d) Welding of the nanowire to the AFM tip by electron beam induced contamination; e) Retraction of the AFM tip; f) Cantilever with tip and welded nanowire assembled to be used as a TERS probe.

htwww.mpi-halle.mpg.de/

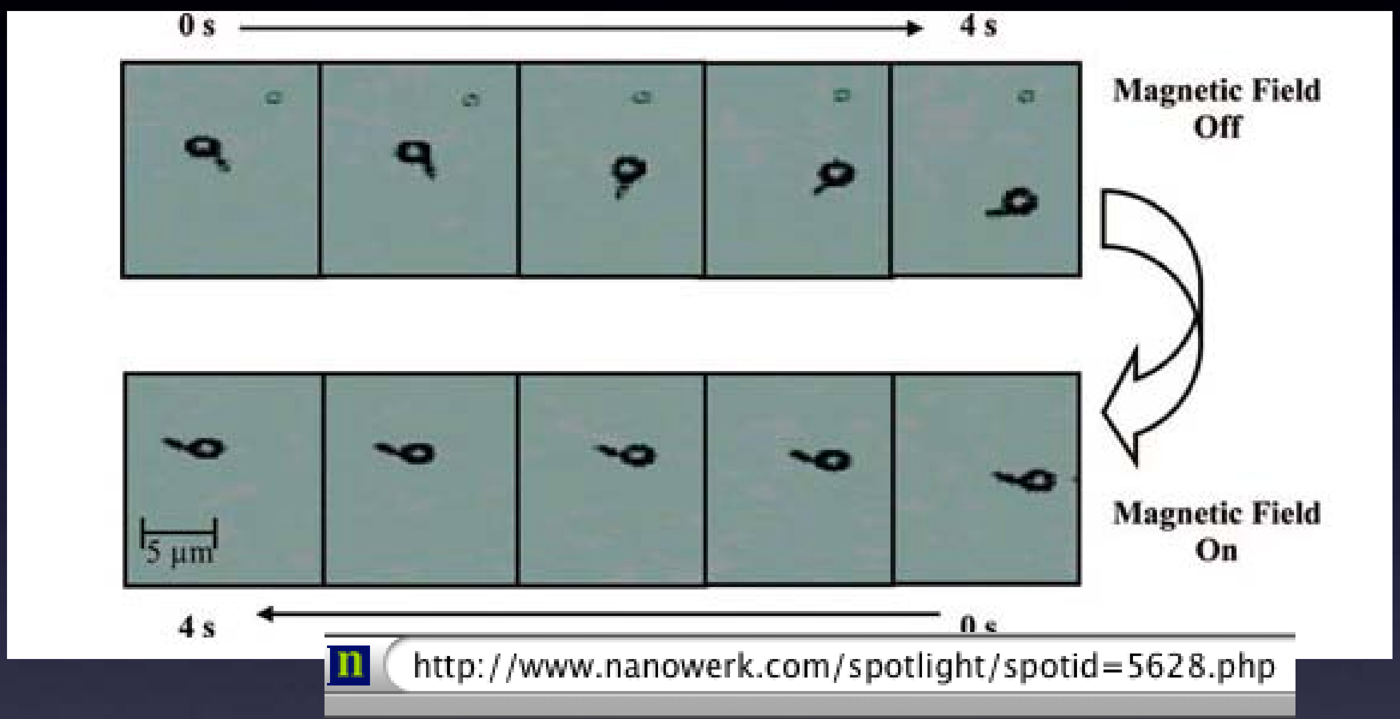


APPLICATION

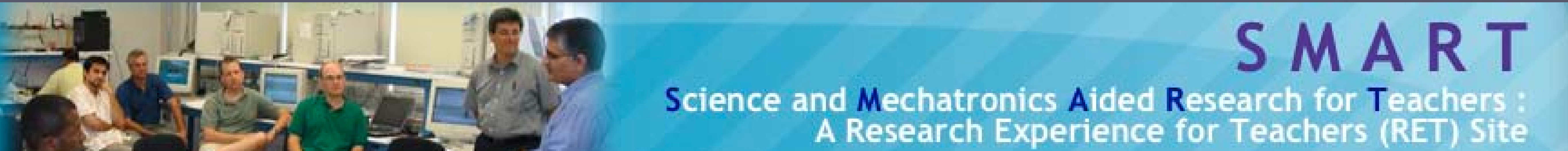
CHEMOTAXIS



Nanowires

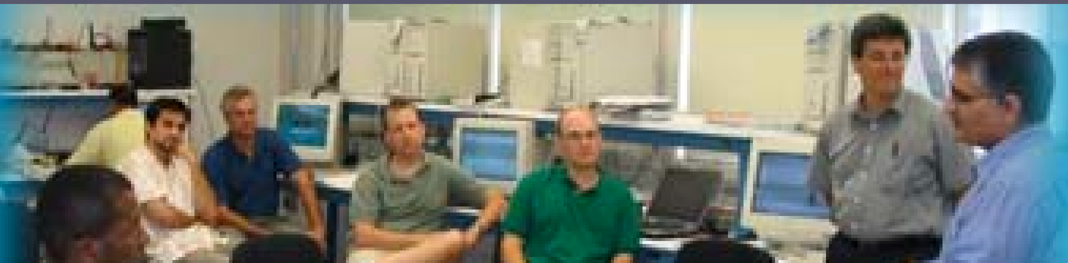


Chemotaxis (or a combination of two or more) traveling in a straight path may be able to produce longer, straighter and cheaper alternative methods in harnessing nanowires in shorter time period.



FUTURE PERSPECTIVE

1. Sustain the computational momentum to validate perturbation method for surface effect
2. Establish the mechanical model of stochastic effects for nanostructural devices
3. Produce lab results (hopefully) to reproduce the theoretical at a bigger length scale..
4. Publish research
5. Incorporate some of the concepts used into classroom to teach some key material in statistics



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ACKNOWLEDGMENTS

- The National Science Foundation
- SMART Program
- Research Experience for Teachers (RET)
- NYU-Poly Mechatronics Department
- Prof. Vikram Kapila, Project Director
- Prof. Remi Dingreville, Research Advisor
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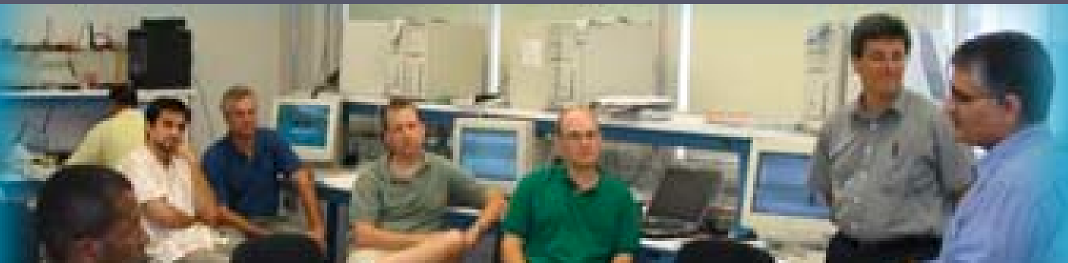
Special mentions:
Nichole, Ankur, Leo, Muhammad, and all the people who helped in their own ways



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