Introduction to Nanotechnology

134.152
Wednesday, 16:00ct, SEM134 (Freihaus, 5th floor, yellow area)
Lecturer: Univ. Ass. DI Dr. techn. Ille Gebeshuber

- Introduction to nanotechnology
- Nanostructures, micro- und nanofabrication and micro- und nanodevices
- Scanning probe microscopy (with demonstrations)
- Nanotribology and nanomechanics
- Molecularly thick films for lubrication
- Industrial applications and microdevice reliability
- Social und ethical implications

IAP

TU WIEN

Technische Universität Wien

Vienna University of Technology

Recommended Literature

Springer Handbook of Nanotechnology with CD ROM (Editor B. Bhushan, Springer Verlag 2004, 1221 pages)

ISBN 3540012184

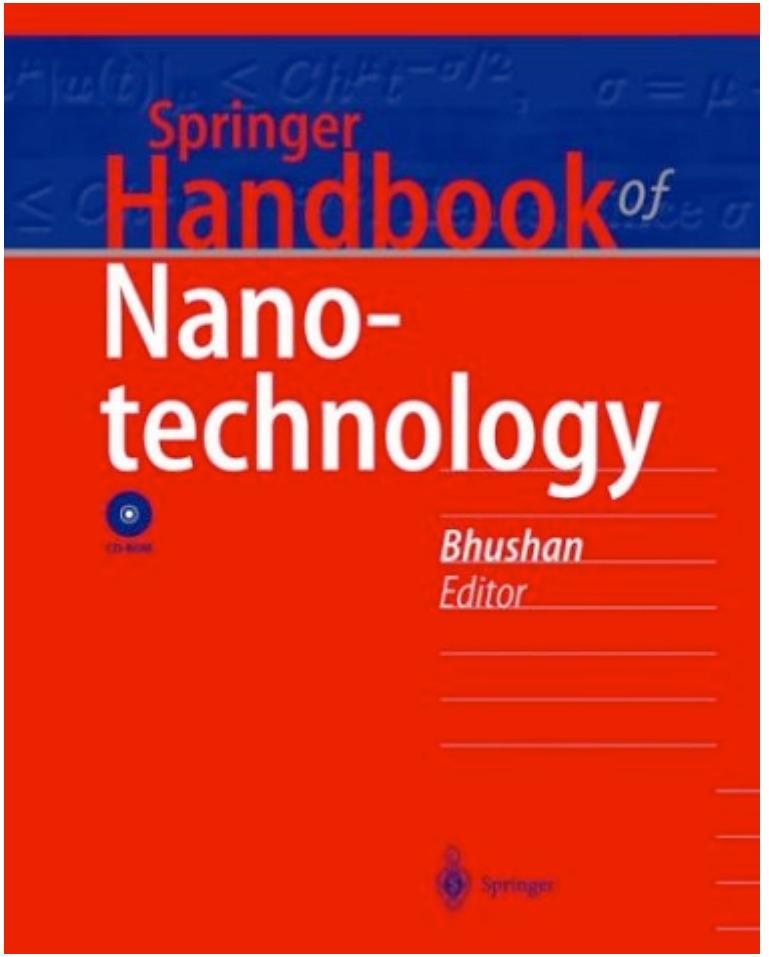
EUR 266,43 @ amazon.de

(used from 142,86

$ 160 @ amazon.com

special price @ my dealer

pdf files (selected chapters) on Ille.com (username & password required)



Recommended Literature

Travels to the Nanoworld: Miniature Machinery in Nature and Technology
by Michael Gross
(Perseus Publishing, 272 pages)
ISBN 0738204447
EUR 15,50 @ amazon.de
$ 11.90 @ amazon.com
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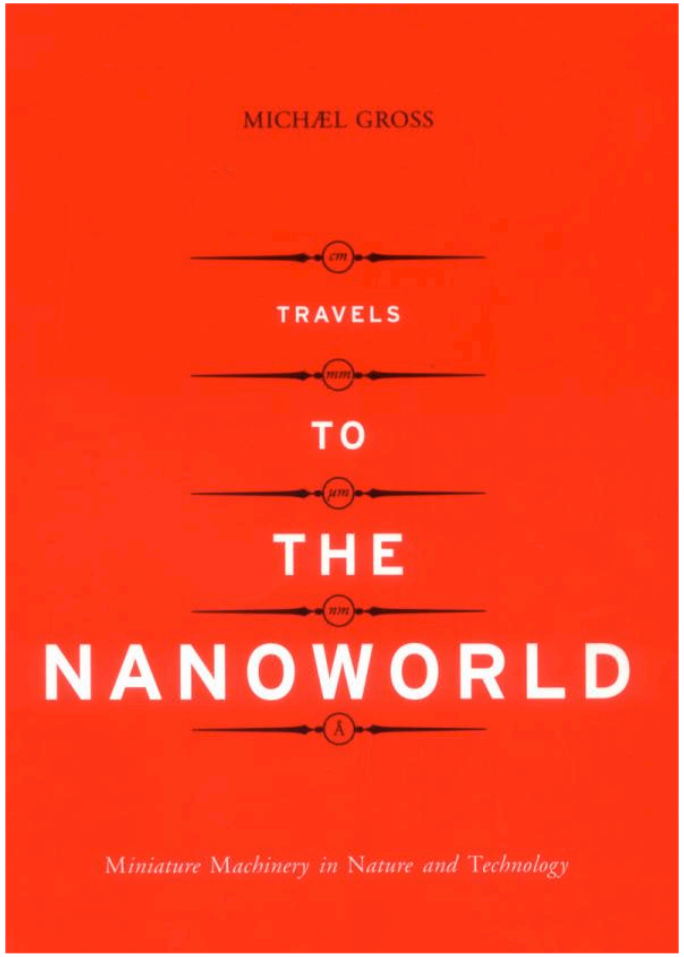


Recommended websites

Molecular nanotechnology, many links:

http://www.zyvex.com/nano/

http://www.foresight.org/

The institute of nanotechnology (UK):

http://www.nano.org.uk/

IBM (USA):

http://www.research.ibm.com/nanoscience/

Richard P. Feynman´s famous after dinner speech:

http://www.zyvex.com/nanotech/feynman.html

Material online

Go to www.ille.com and follow the link to
Supplementary Material for Nanotechnology lecture.

10890790-C-1.PDF, 292 Kb, Wed Oct 12 12:21:48 2005
10890790-C-2.PDF, 913 Kb, Wed Oct 12 12:21:48 2005
10890790-P-1.PDF, 208 Kb, Wed Oct 12 12:21:48 2005
BILDER/
FEYNMAN_PLENTY_OF_ROOM_AT_THE_BOTTOM.DOC, 70 Kb, Wed Oct 12 12:21:48 2005
NANOTECHNOLOGIE_INNO_FUER_DIE_W.PDF, 2264 Kb, Wed Oct 12 12:21:48 2005

Introduction to Nanotechnology

Background and Definition of Nanotechnology

- 1959 **Feynman**´s famous after dinner speech.
- Nanotechnology literally means any **technology performed on a nanoscale** that has applications in the real world.
- Nanotechnology encompasses the **production and application of physical, chemical, and biological systems** at scales ranging from individual atoms or molecules to submicron dimensions, as well as the integration of the resulting nanostructures into larger systems.
- It is widely felt that **nanotechnology will be the next industrial revolution**.

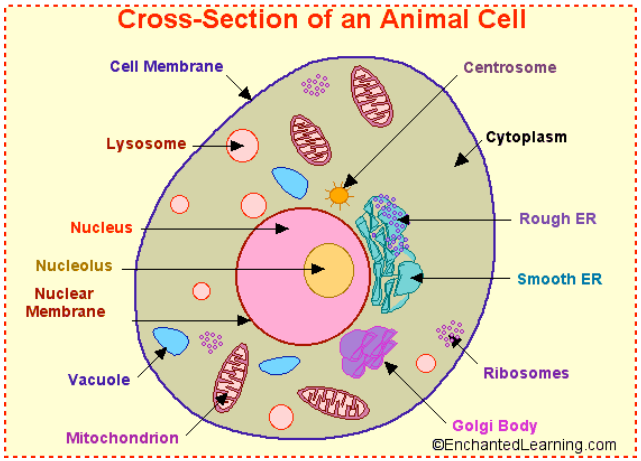
US Nanotechnology Intitiative

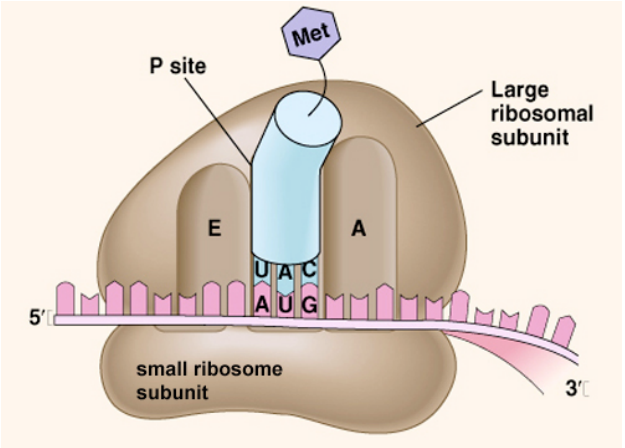
- The US NTI was announced by president Clinton in the year 2000.
- Budget for 2001: **497 million US$.**
- The objective of this initiative was to form a broad-based coalition in which academia, the private sector, and local, state, and federal governments would work together to push the envelope of nanoscience and nanoengineering to harvest nanotechnology's potential social and economic benefits.

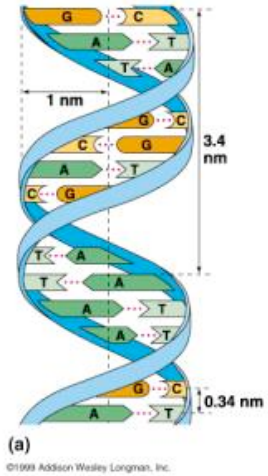
Cells - biological nanomachines

A biological system can be exceedingly small. Many of the cells are very tiny, but they are very active; they manufacture various substances; they walk around; they wiggle; and they do all kinds of marvelous things – all on a very small scale. Also, they store information. Consider the possibility that we too can make a thing very small which does what we want – that we can manufacture an object that maneuvers at that level.

(Richard P. Feynman, 1959)

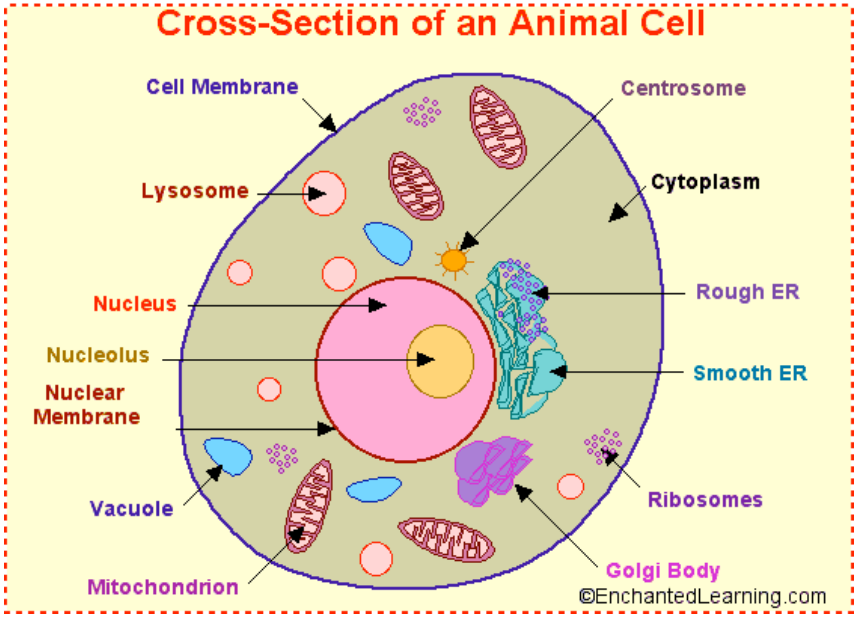






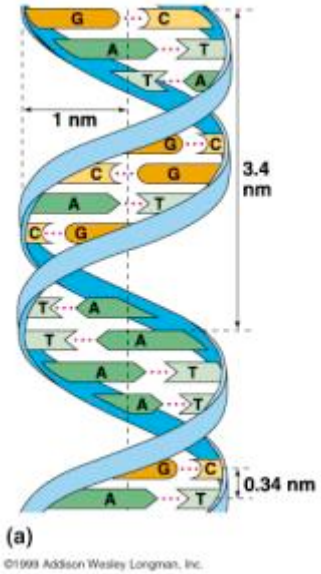
Living cells

- Nanomechanical machines
- Diameter about **1µm**
- Smallest free living organism (*Mycoplasma genitalium*): diameter 0.2 to 0.3 µm



DNA

- A human cell's DNA has about three meters in length.
- 10 base pairs per turn (3.4nm)
- Distance between base pairs 0.34nm.



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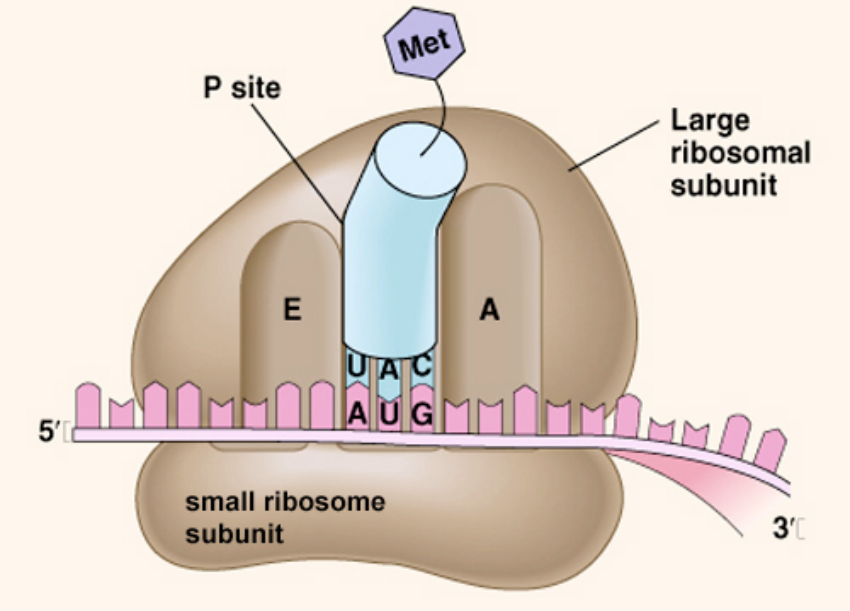
Ribosome

- 17 to 23nm diameter



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Viruses

- Diameter 0.02 to 0.3μm
- Parvoviruses have only **18nm** diameter.
- The smallest virus codes for 3-10 proteins.

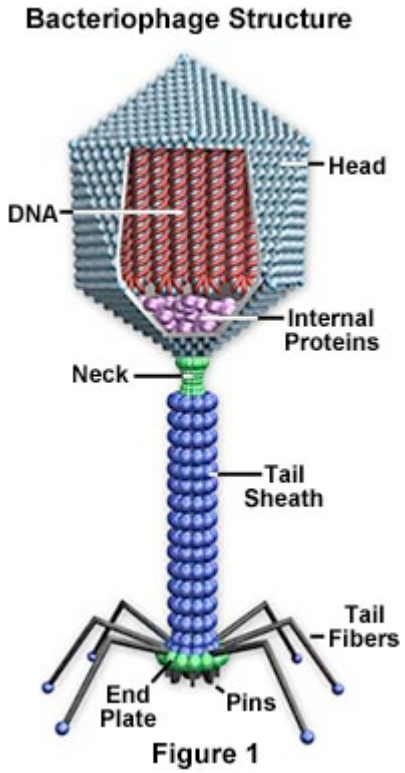
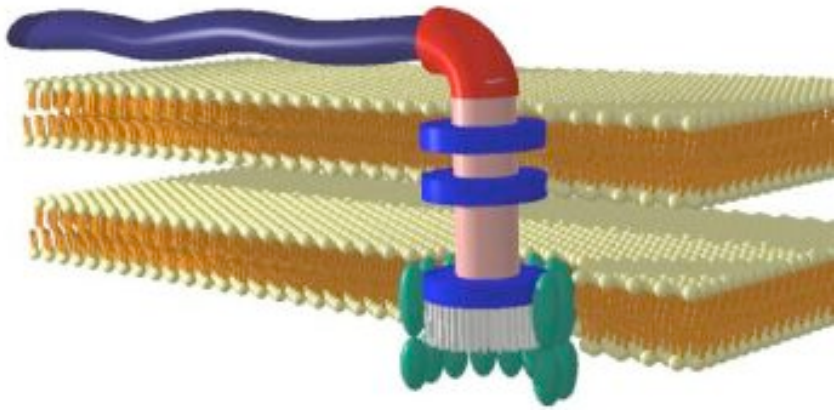


Figure 1

Lessons from Nature

- Photosynthesis
- Selfcleaning surfaces (lotus leaf)
- Bacterial flagellum (10 000 rotations per minute, bearing 20-30nm, clearance 1nm)

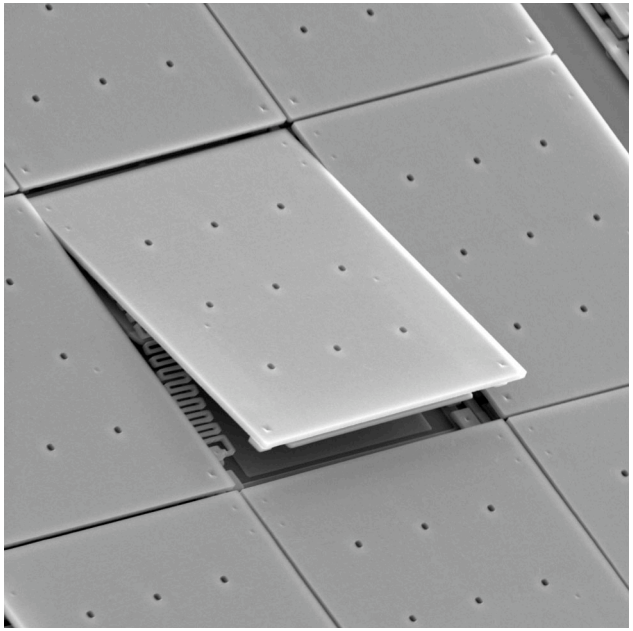


Man-made nanotechnology

Science and technology continue to move forward in making the fabrication of micro/nanodevices and systems possible for a variety of industrial, consumer, and biomedical applications.

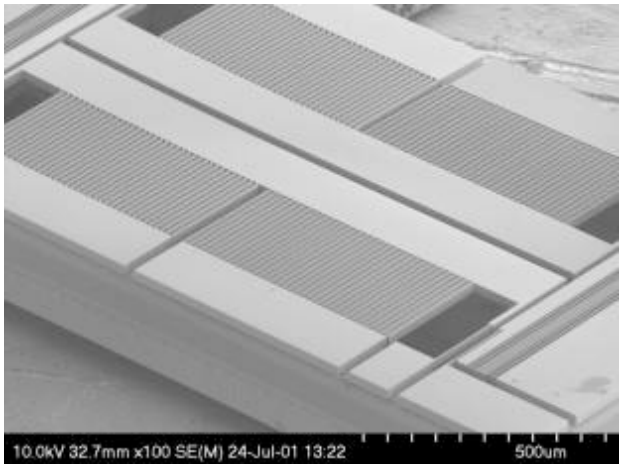
Applications in different fields

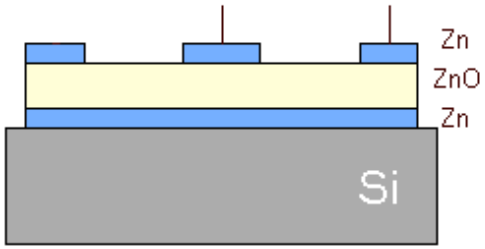
- MEMS (micro electro mechanical systems)
  - US$ 400 million **digital micromirror** devices sold in 2001 (launched in 1996 by Texas Instruments)



Applications in different fields

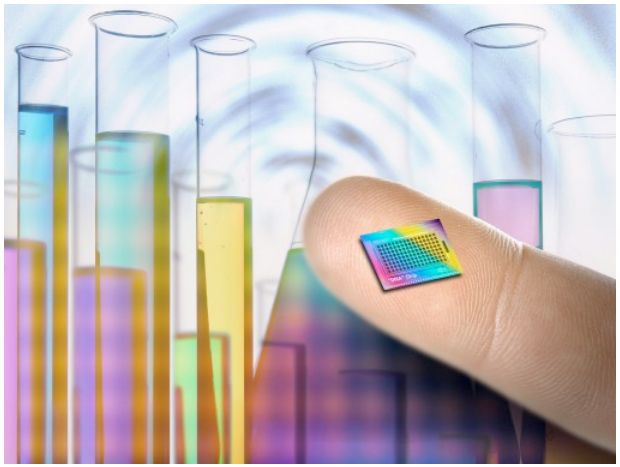
- MEMS
  - 85 million **accelerometers** sold in 2002 (Analog Devices, Bosch, Motorola, etc.)





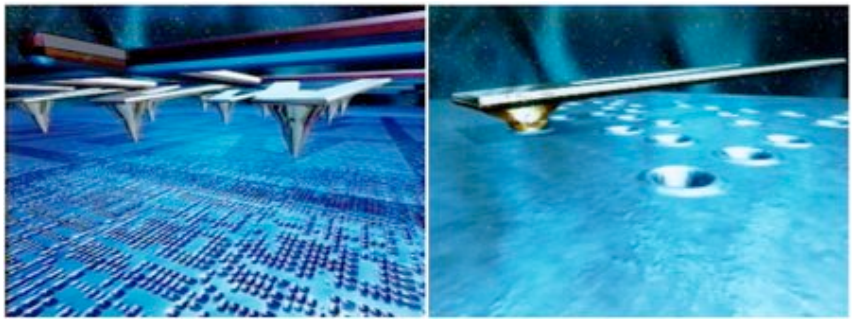
Applications in different fields

- BIOMEMS
  - **Lab-on-a-chip** (20 million units sold in 2002)
  - a biochip can perform thousands of biological reactions, such as decoding genes, in a few seconds.



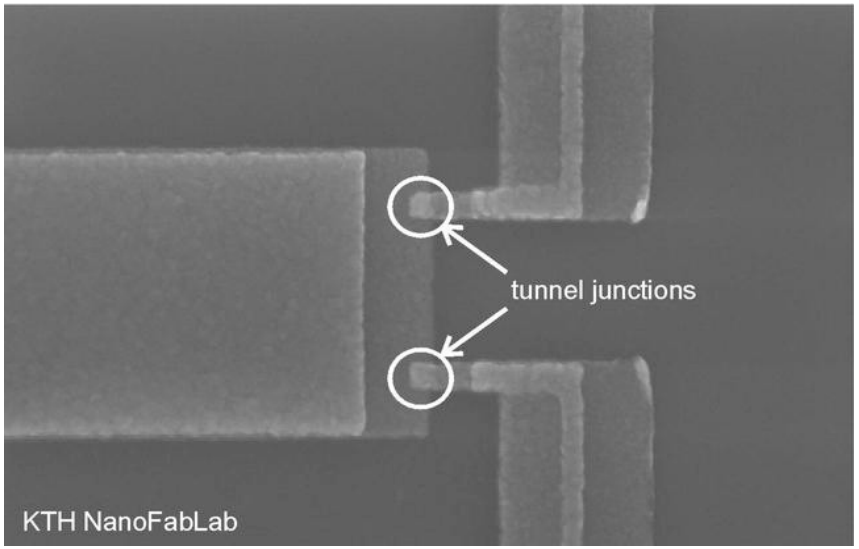
Applications in different fields

- NEMS (nano electro mechanical systems)
  - **AFM Millipede:** more than 4,000 tips (0.5μm thick and 70μm long) working simultaneously over a 7 mm^2 field
  - 0.5 gigabytes in an area of 3 mm^2



Applications in different fields

- NEMS
  - **Single electron transistor (SET)**



Reliability Issues of MEMS/NEMS (1/3)

- There is an increasing need for a multidisciplinary, system oriented approach to **manufacturing micro/ nanodevices that function reliably**.
- Common potential **failure mechanisms** for MEMS/NEMS that need to be addressed in order to increase reliability are: **adhesion, friction, wear, fracture, fatigue, and contamination**.

Reliability Issues of MEMS/NEMS (2/3)

- **Mechanical properties** are known to exhibit a **dependence on specimen size**.
- Mechanical property evaluation of nanometer-scaled structures is carried out to help design reliable systems, since good mechanical properties are of critical importance in such applications.

Reliability Issues of MEMS/NEMS (3/3)

- Some of the properties of interest are: Young's modulus of elasticity, hardness, bending strength, fracture toughness, and fatigue life.
- **Finite element modeling** is carried out to study the effects of surface roughness and scratches on stresses in nanostructures.
- When nanostructures are smaller than a fundamental physical length scale, **conventional theory may no longer apply, and new phenomena may emerge.**
- **Molecular mechanics** is used to simulate the behavior of a nano-object.

End of the Introduction

Nanostructures, Micro-/Nanofabrication and Micro-/Nanodevices

Part A: Nanostructures, micro-/nanofabrication and micro-/nanodevices

Nanomaterials synthesis and applications: molecule based devices

- **top-down** vs. **bottom-up** approach
- **Nature relies on chemical strategies** to assemble nanoscaled biomolecules.
- mimicking Nature´s bottom-up approach→ first man-made nanohelices, nanotubes, molecular motors
- molecule based devices