

NAC-Winstead Colloquium

Monday, June 24, 2006

Nano Technology:

**nano is not size,
size is nano!**

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The Trybula Foundation, Inc.

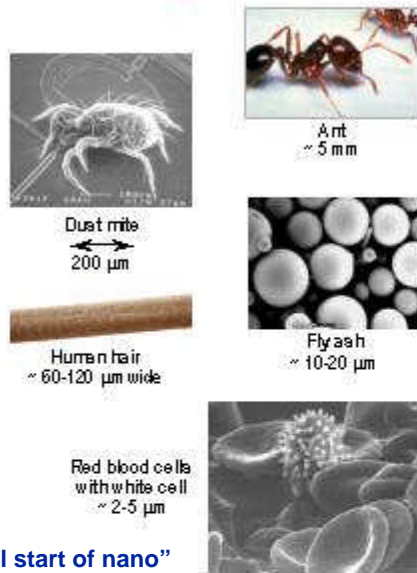
Structure of Presentation

- **Why is nano not size?**
- **Nano Technology**
 - Material properties – some examples
- **Projected applications**
 - Examining properties of “nano” products
- **Business Implications**
- **Summary**

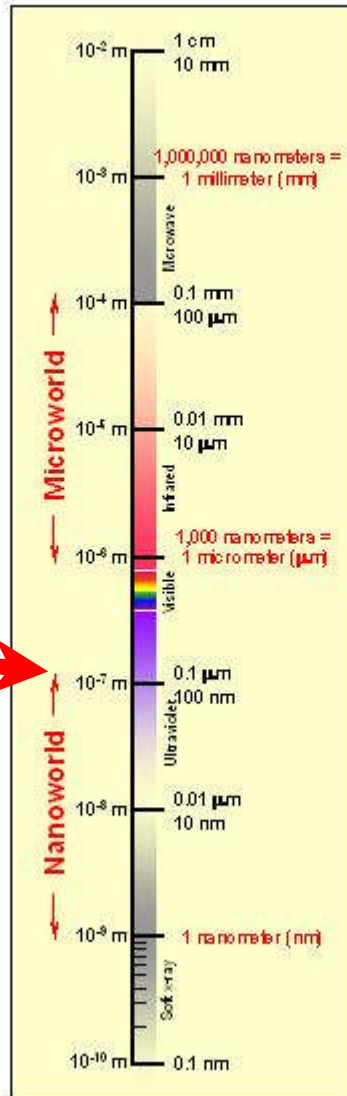
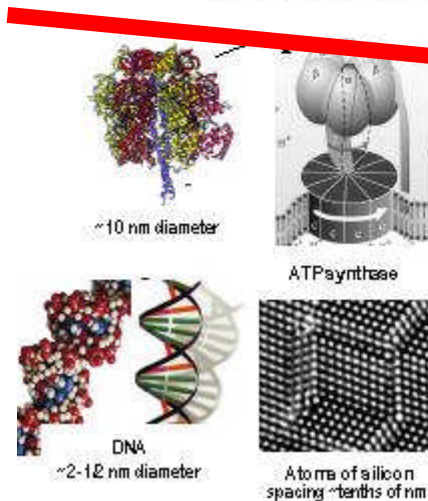


The Scale of Things – Nanometers and More

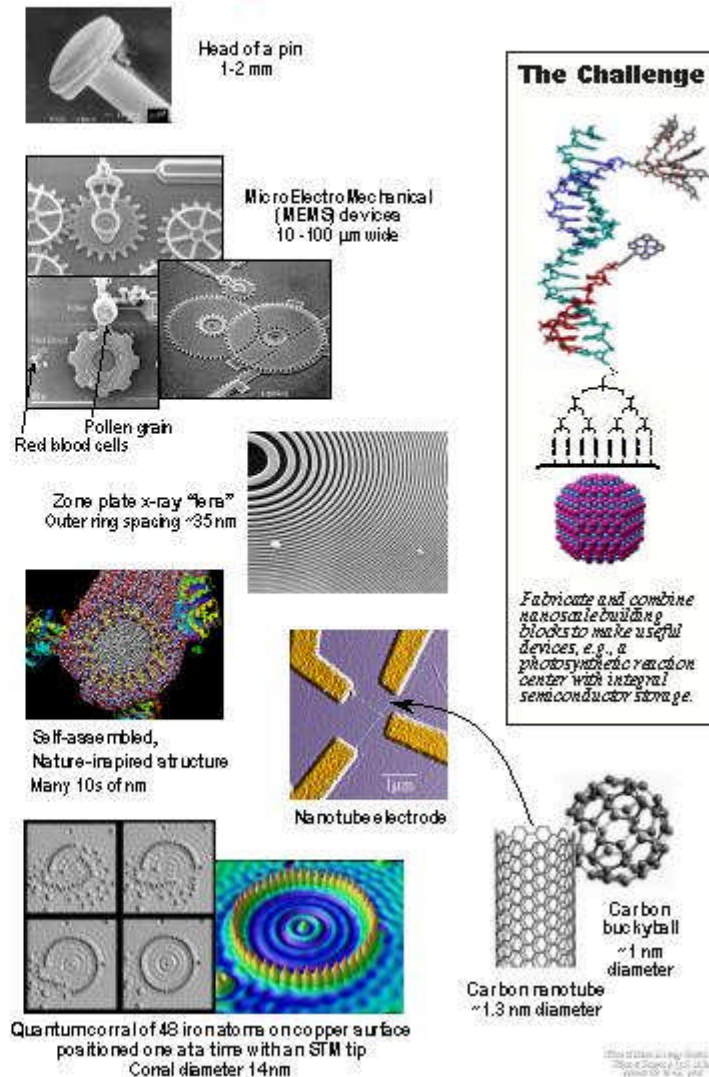
Things Natural



“Traditional start of nano”



Things Manmade



Courtesy Office of Basic Energy Sciences,
Office of Science, U.S. Department of Energy

Nano is not size

Example from Semiconductors

- **Current technology is 90nm node**
 - For logic (microprocessors):
 - Half pitch is 130nm (minimum line width)
 - For memory:
 - Half pitch is 90nm (minimum line width)
- **If nano is size, then memory semiconductors should have different properties from logic ones based on the difference in the size of the conductors (lines).**
- **Both circuits perform the same way. So nano is not size. There are numerous other examples, like Cu conductivity at 40nm or particle cleaning at 50nm.**

Definition of Nanotechnology

Nanotechnology refers to research and technology development at the atomic, molecular, and macromolecular levels aimed at creating and using structures, devices, and systems that have novel properties and functions because of their small size.¹

¹ Nanotechnology Standards Panel of ANSI

Nano

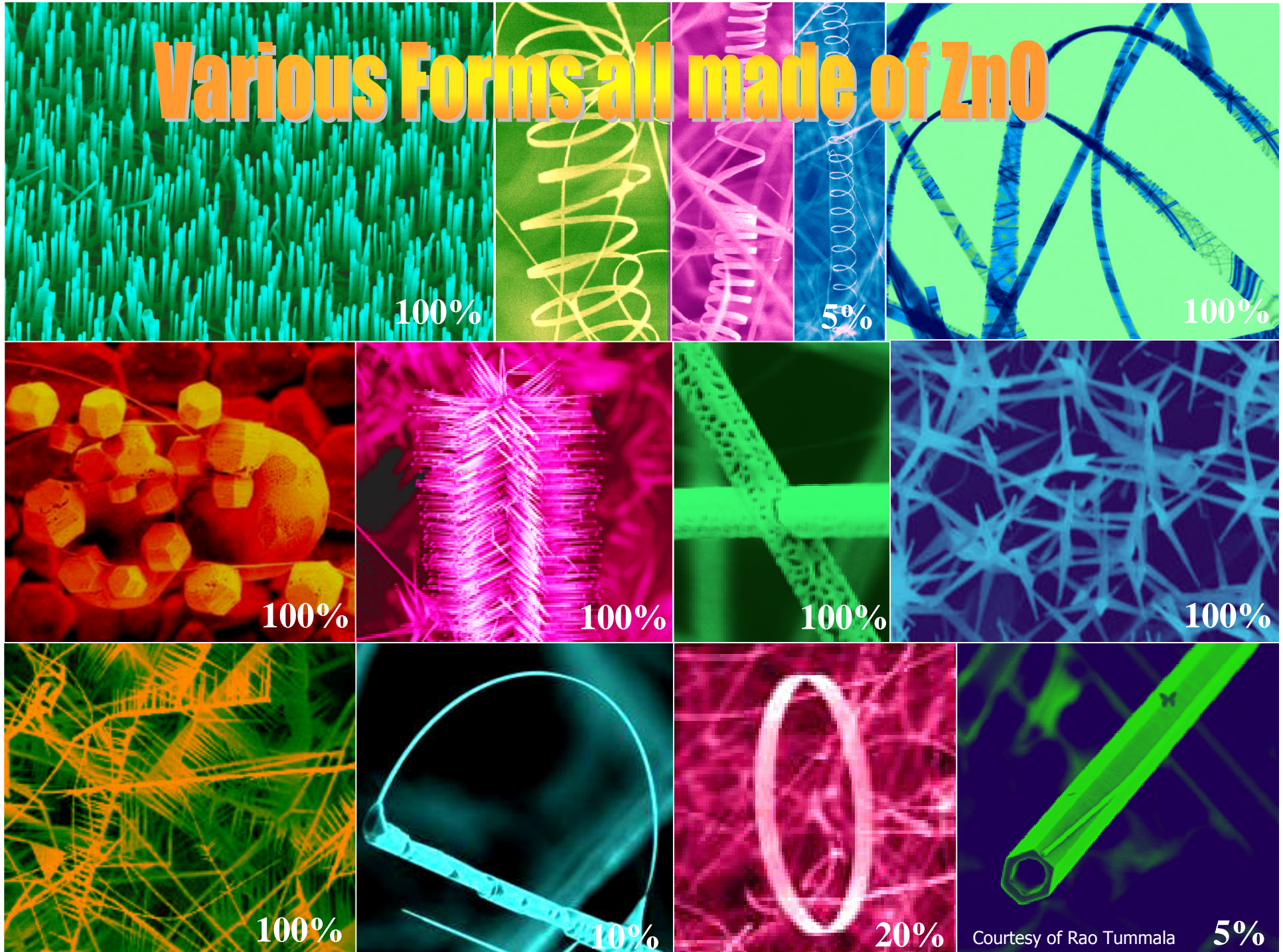
This is a new world

- **Some things will be familiar**
- **Others will be totally unknown or unexpected**
- **Caution will be required before proceeding rapidly forward**

Let's explore some examples of materials



Various Forms all made of ZnO



100%

5%

100%

100%

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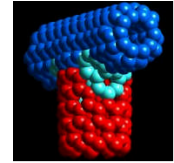
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Courtesy of Rao Tummala

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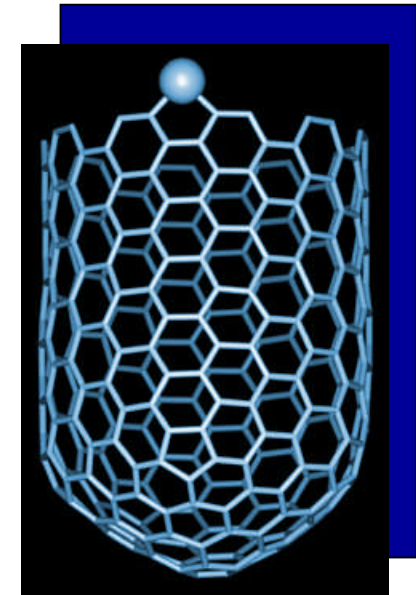
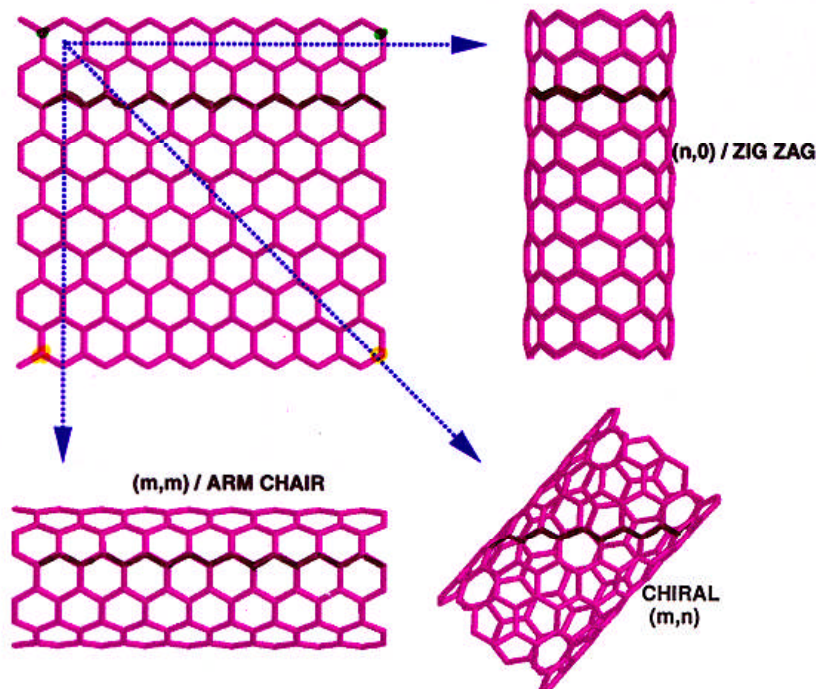
Carbon Nanotube



CNT is a tubular form of carbon with diameter as small as 1 nm.
Length: few nm to microns.

CNT is configurationally equivalent to a two dimensional graphene sheet rolled into a tube.

- STRIP OF A GRAPHENE SHEET ROLLED INTO A TUBE

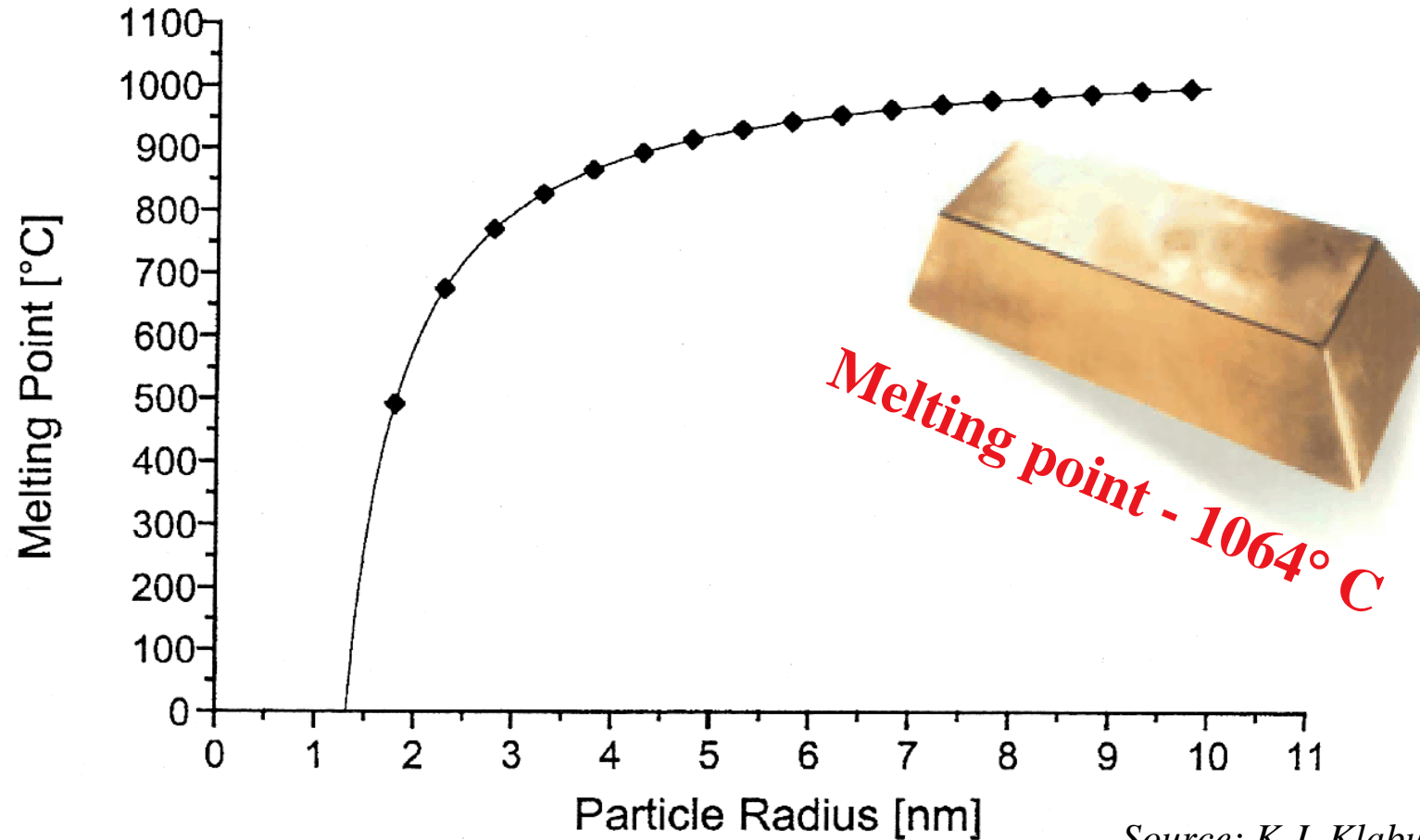


CNT exhibits extraordinary mechanical properties: Young's modulus over 1 Tera Pascal, as stiff as diamond, and tensile strength ~ 200 GPa.

CNT can be metallic or semiconducting, depending on chirality.

Melting Point is not Constant!

Melting Point is Dependent on Particle Size



Source: K.J. Klabunde, 2001

NASA Ames

Color is size dependent!



Quantum Dot Rainbow

Source: Andrey Rogach

References:

Yu. P. Rakovich, J. F. Donegan, S. A. Filonovich, M. J. M. Gomes, D. V. Talapin, A. L. Rogach, A. Eychmüller. "Up-Conversion Luminescence via a Below-gap State in CdSe/ZnS Quantum Dots." *Physica E*, 17, 99-100.2003

Description:

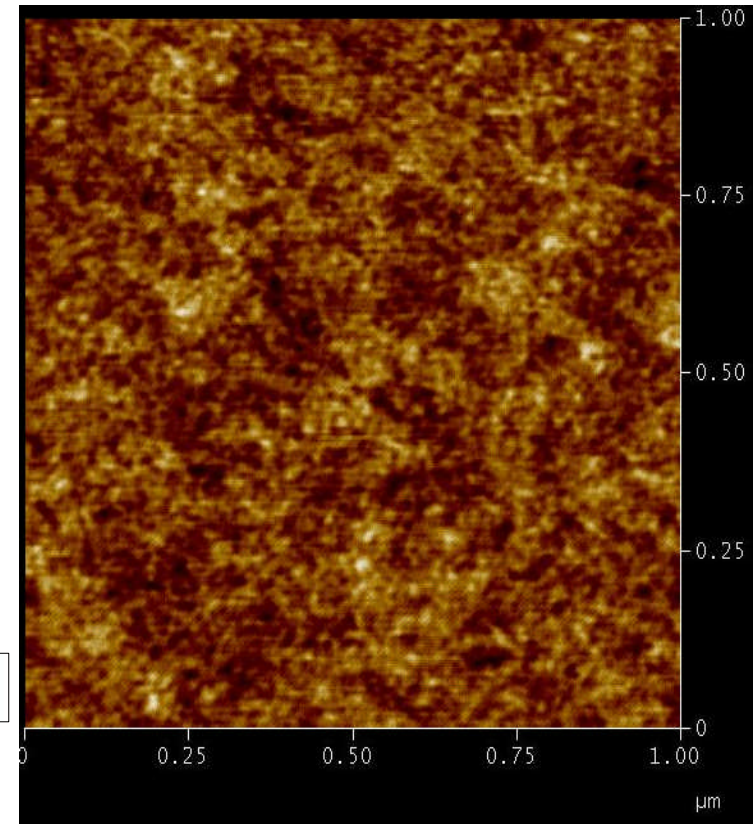
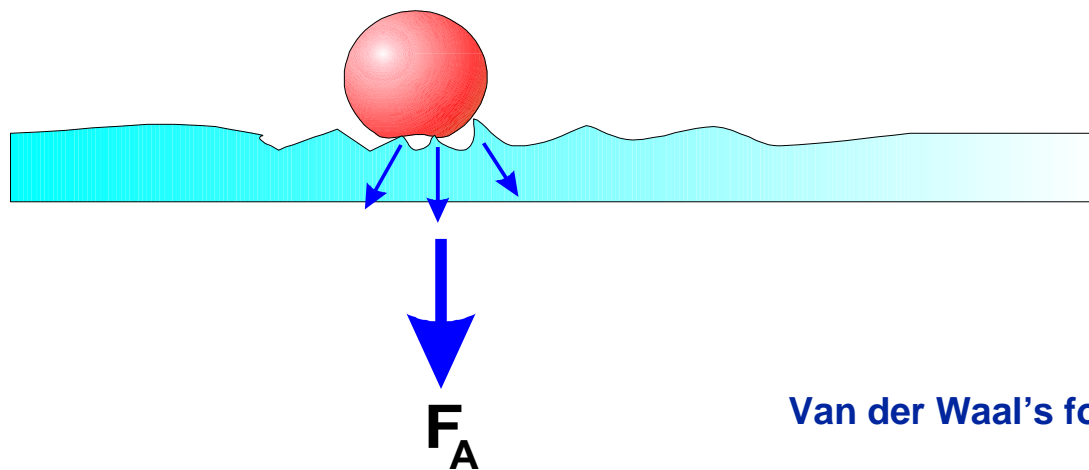
Semiconductor nanocrystals, also called colloidal quantum dots, typically have a size between ~1 and 10 nm and lie in the transition regime between bulk solids and molecules. A demonstration of the size-dependent properties of semiconductor nanocrystals is the continuous change of their emission color as shown by the range of CdSe nanocrystal emission spectra.

A fascinating application for this type of property is to attach the particles to specific molecules that are attracted to cancerous sites. When a surgeon operates and illuminates the area with UV light, the cancerous cells are highlighted by the glowing particles. The surgeon can ensure that the cancerous cells are removed.



Cleaning Nano is different!

- Multiple contact points
- Reduces the total adhesion forces
- Higher roughness leads to higher available surface



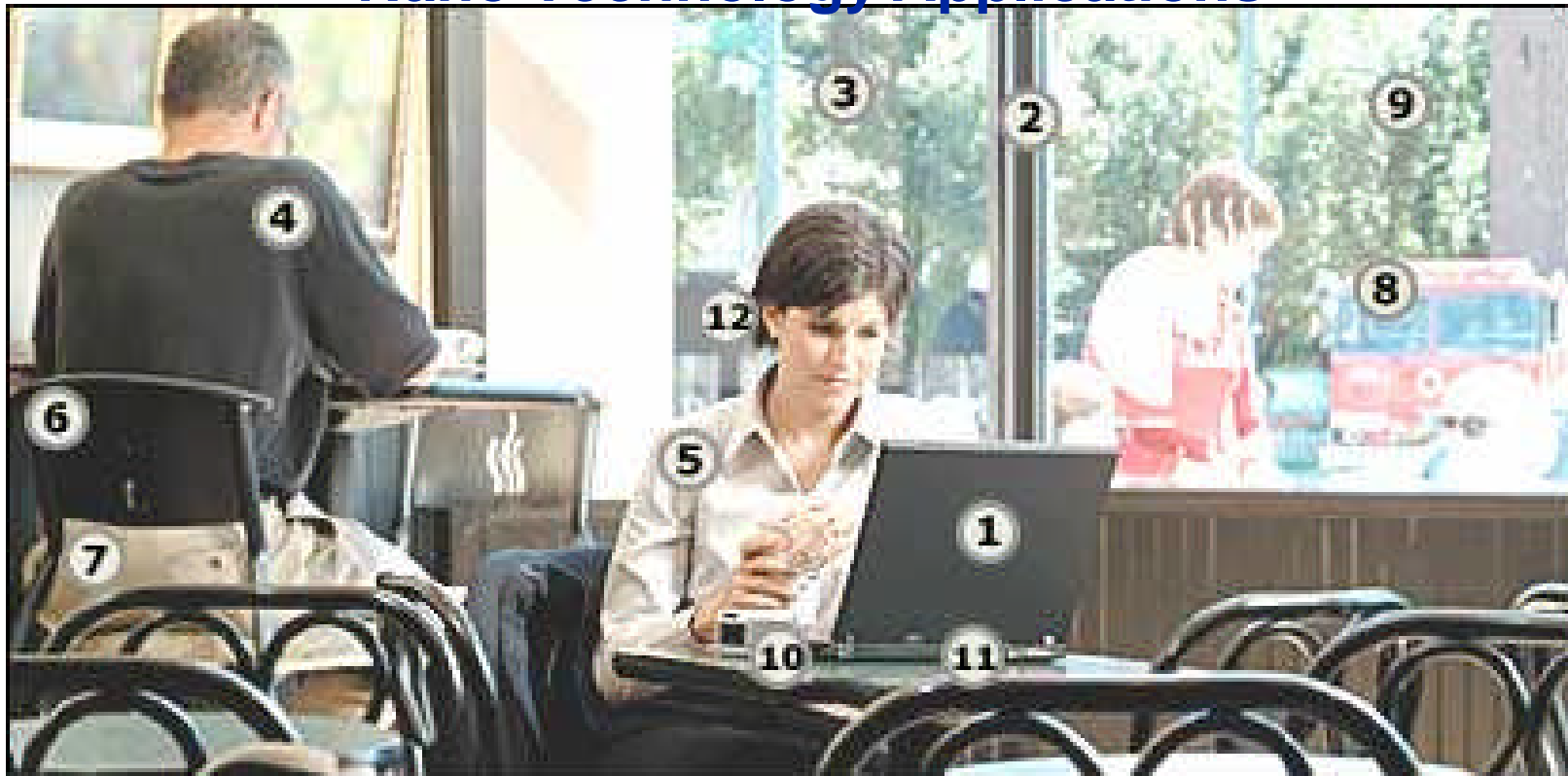
Van der Waal's forces become the dominant about 60nm.

Nano Technology Applications?

- **In the next slide, there is a picture that shows 12 “nano” technology applications identified in 2004.**
- **Examples of each of the selected items will be discussed and identified as nano or not nano.**
- **Additionally, each of the nano applications will be identified by difficulty of manufacturing into the following categories:**
 - Properties where anything is acceptable
 - Properties but requiring some precision of assembly
 - Size dependent properties but no precision assembly needed
 - Size dependent properties with precision of assembly required



Nano Technology Applications



1 - Organic Light Emitting Diodes (OLEDs) for displays

3 - Scratch-proof coated windows that clean themselves with UV

5 - Intelligent clothing measures pulse and respiration

7 - Hipjoint made from biocompatible materials

9 - Thermo-chromic glass to regulate light

11 - Carbon nanotube fuel cells to power electronics and vehicles

2 - Photovoltaic film that converts light into electricity

4 - Fabrics coated to resist stains and control temperature

6 - Bucky-tubeframe is light but very strong

8 - Nano-particle paint to prevent corrosion

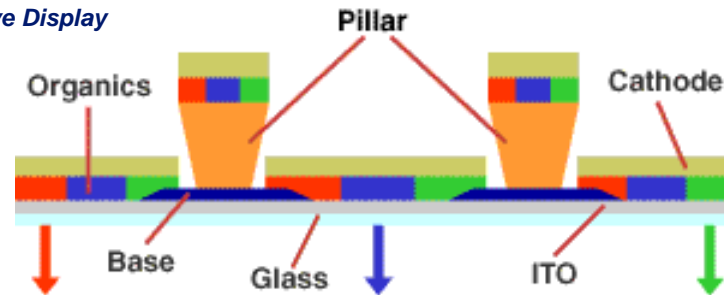
10 - Magnetic layers for compact data memory

12 - Nano-engineered cochlear implant

Compiled by Jo Twist, BBC News On-Line, July 28, 2004

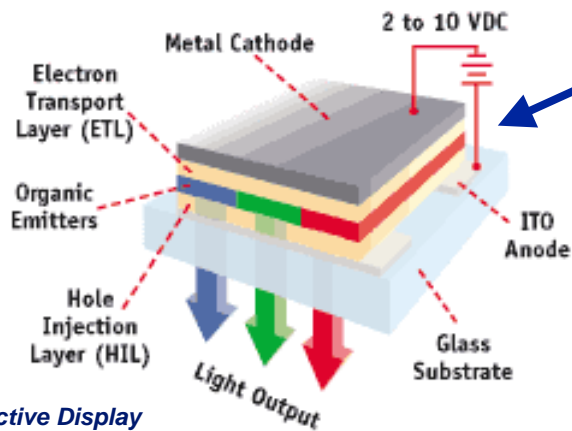
Organic Light Emitting Diodes

Passive Display



Emitter Layer ~100nm

OLED Structure



Active Display

OLED, unlike LCD, are self luminous. Consequently, they do not required backlighting, diffusers, or polarizers. There are two types of OLEDs.

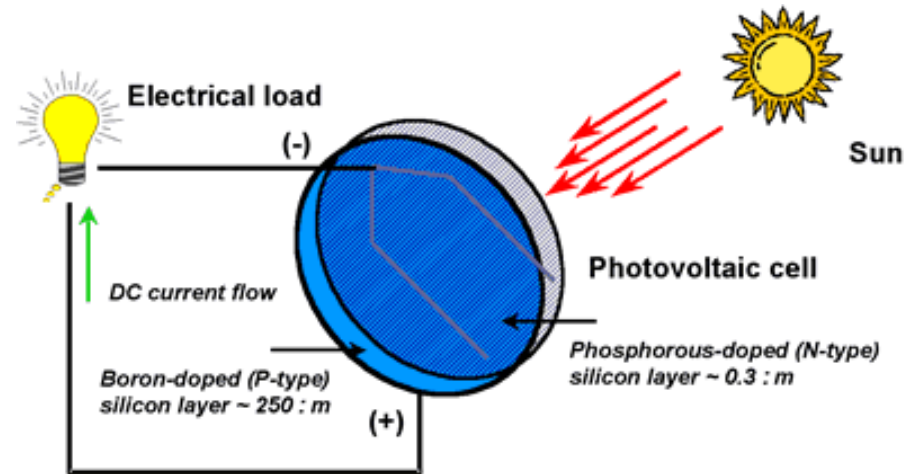
The passive matrix OLED display is an array with pixels connected by intersecting conductors. This structure can be readily applied to existing high volume manufacturing.

The active matrix OLEDs have electronics incorporated into the back plane, which enables it to be used in high-resolution applications.

Figures from <http://komar.cs.stthomas.edu/qm425/01s/Tollefsrud2.htm>



Photovoltaic film



A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact, called the P-N junction.

When sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the solar cell is connected to an electrical load. The voltage is constant, between 0.6 and 0.5 volts, but the total power is a function of size. Cells can be connected in either parallel or series to produce higher voltages, or higher current.

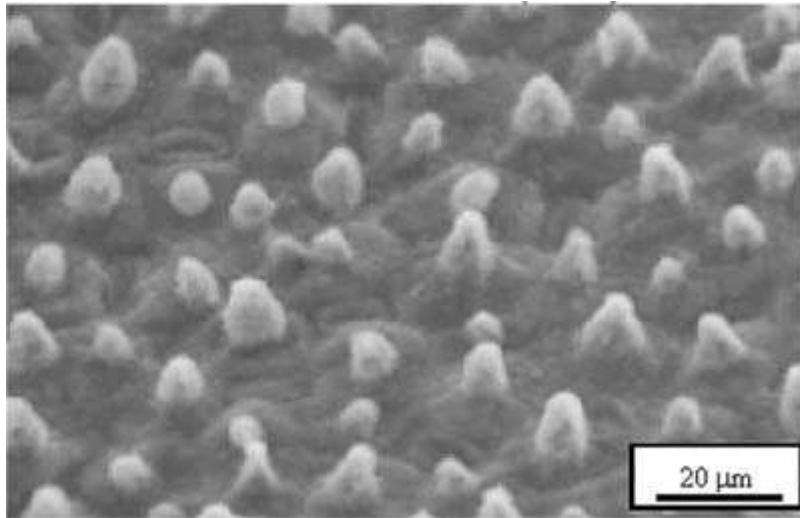
Thin film photovoltaic cells use layers of semiconductor materials only a few micrometers thick, attached to an inexpensive backing such as glass, flexible plastic, or stainless steel. Semiconductor materials for use in thin films include [amorphous silicon \(a-Si\)](#), [copper indium diselenide \(CIS\)](#), and [cadmium telluride \(CdTe\)](#)

Constant changes

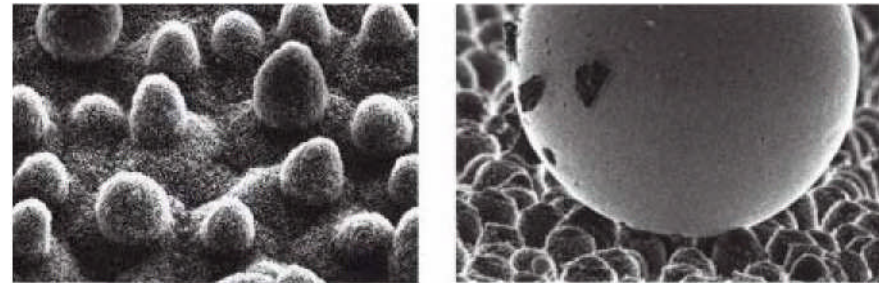
<http://www.fsec.ucf.edu/pvt/pvbasics/>



Window coatings



SEM image of lotus leaf



SEM image of self-cleaning glass

Ref: Dr. Helmut Hohenstein of Institut fur Fenstertechnik

There is a great interest in the design and development of the so-called “hygienic surfaces”, referring to surfaces that not only provides biocidal activity but also to those that are easy to clean and even self-cleaning.

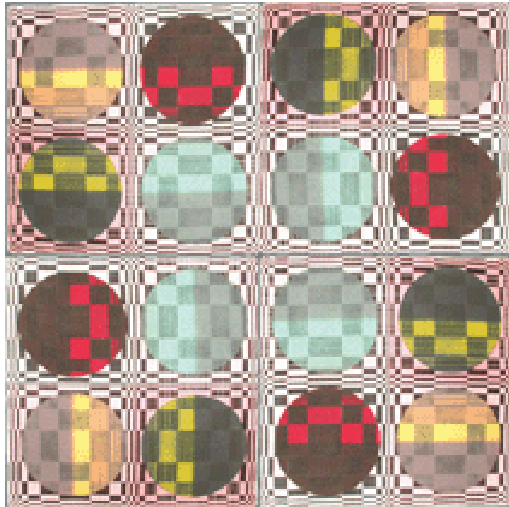
Achieving these properties on a surface is possible by means of coatings and treatments on specific surfaces, and in which nanotechnology plays a key role. Most of these coatings acquire their biocidal/self-cleaning capacity by incorporating specific nanoparticles: basically silver (Ag) and titanium oxide (TiO₂).

Ref: Nano Tsunami - Hygienic surfaces, biocidal and self-cleaning coatings



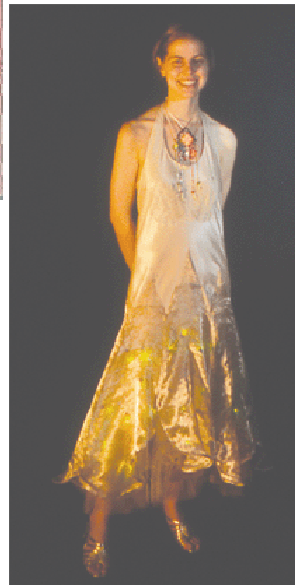
Smart fabric

Interactive fabric



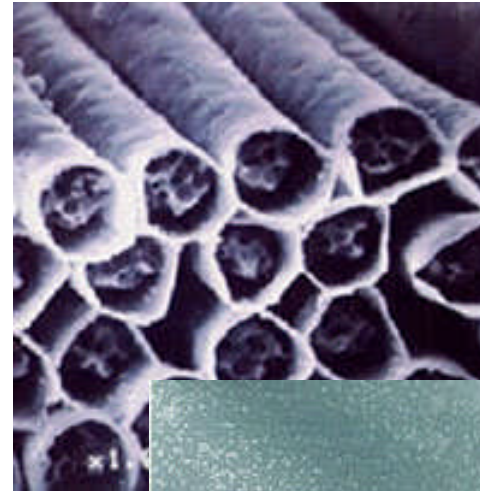
Electric Plaid: a handwoven, color-changing textile. Photo by International Fashion Machines.

Journal of Materials
Vol.57, No. 7



Firefly dress

Passive fabric

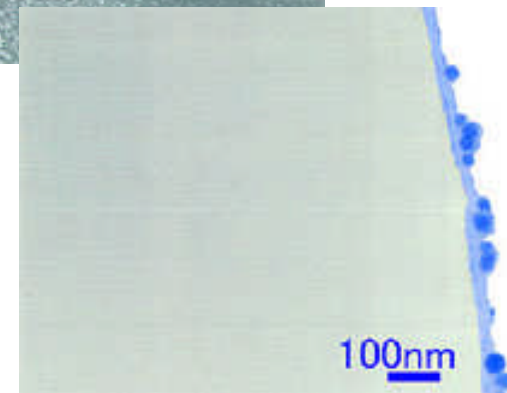


SEM photograph of functional material coating on polyester fiber surface



SEM photograph of the fiber surface coated with functional material

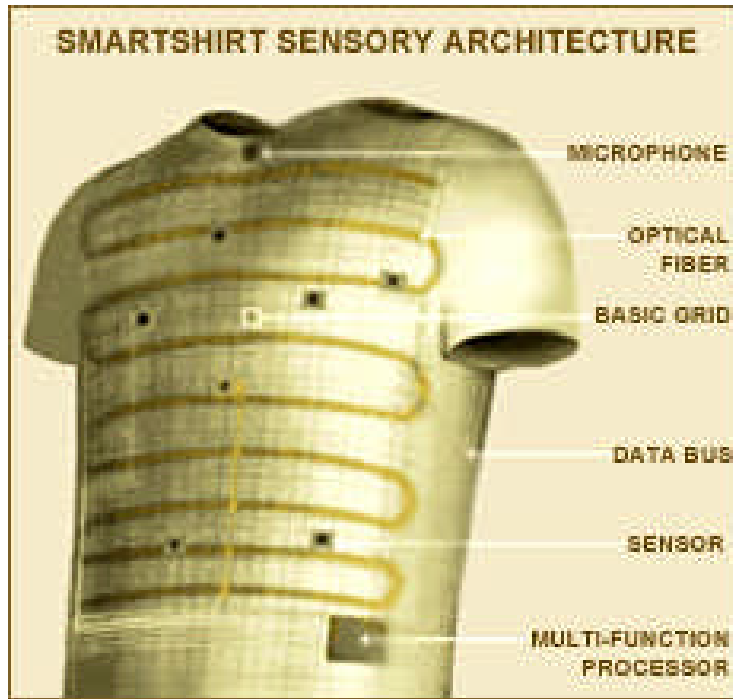
TEM photograph of a cross-section of fiber coated with functional material



Ref: Toray Institute



Med-bio monitoring



http://www.fibre2fashion.com/news/NewsDetails.asp?News_id=11705



Untethered signal transmission permits remote monitoring

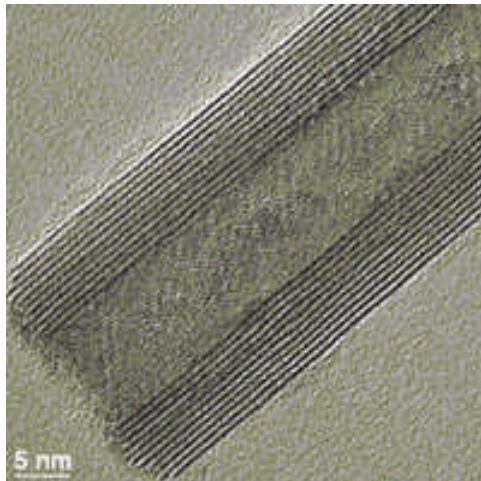
Dietary tracking with remote sensing



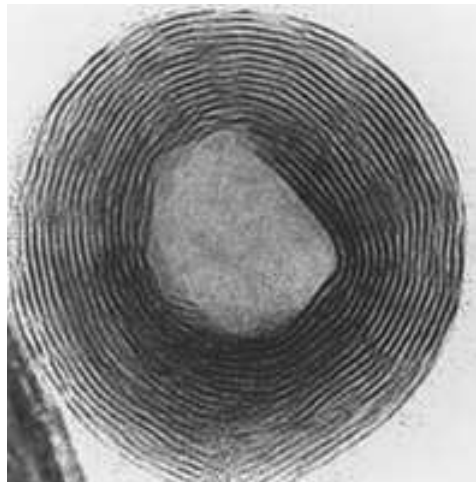
Ref. http://www.cs.indiana.edu/surg/Projects/TRIGGERS_S

Stronger materials

IsraCast has recently tested one of the most shock-resistant materials known to man. Five times stronger than steel and at least twice as strong as any impact-resistant material currently in use as protective gear.



Certain inorganic compounds such as WS₂, MoS₂, TiS₂ and NbS₂ that normally occur as large flat platelets can be synthesized into much smaller nano-spheres and nano-tubes which they named inorganic fullerene-like nanostructures (IF)



The "Onion like" nano-structure of the IF materials, is the result of a sophisticated manipulation on the original layered material. This unique structure is responsible for its remarkable strength and durability



The material withstood the shock pressures generated by the impacts of up to 250 tons per square centimeter. The rendering above is of a possible armor vest. (Material production is currently a few kilograms per day.

Ref. http://www.isracast.com/tech_news/091205_tech.htm

Med-bio prosthetics



Ref: http://www.defensetech.org/archives/cat_medic.html

Requirements:

Breakthroughs in

- neural control,
- sensory input,
- advanced mechanics and actuators, and
- prosthesis design and integration (Ref.)

Other Requirements:

Significantly enhanced computing power

Reduced power consumption

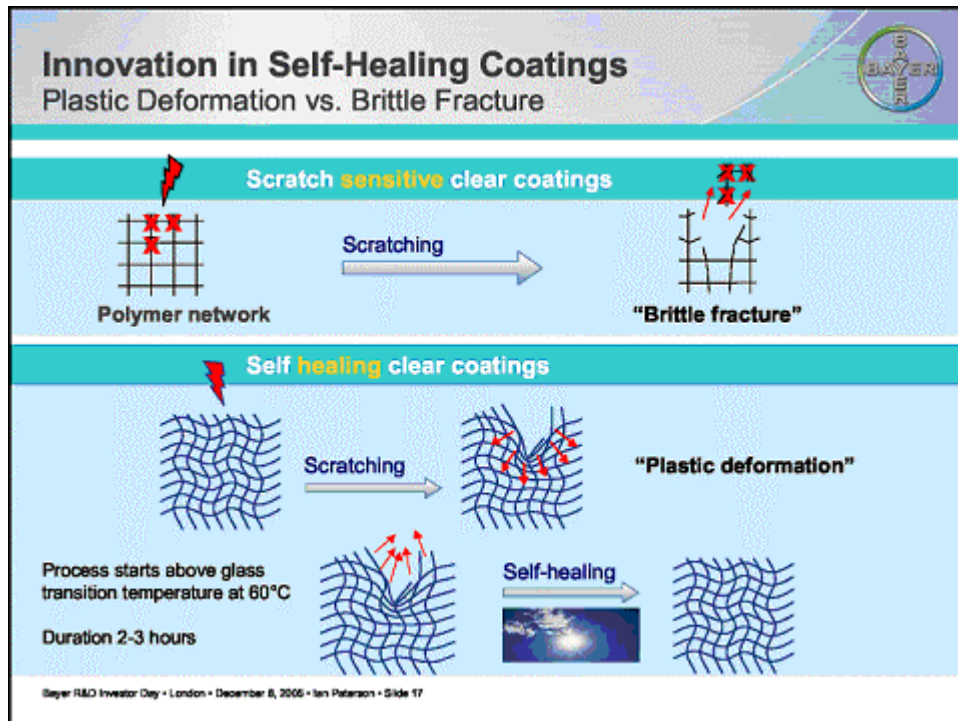
New electronic interfaces

- Analog to neural converters (A to N)
- N to A converters
- Digital to neural converters (D to N)
- N to D converters

Note: DARPA is also working on complete arm replacements with neural control.

Self healing paints

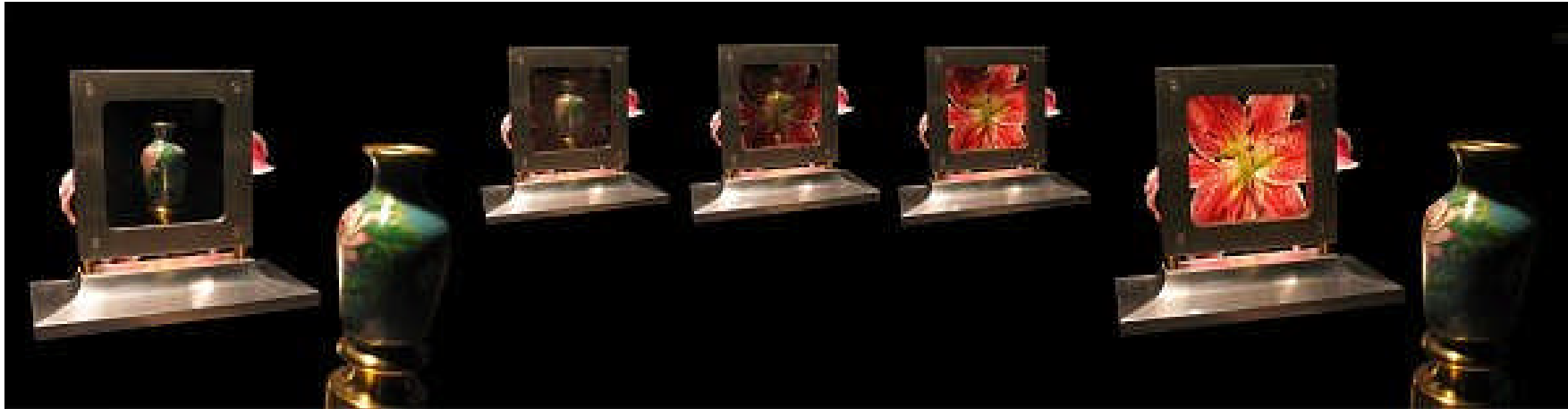
Nissan will start offering a self-healing paint. After an encounter that creates scratches to the paint, the paint starts to reform itself over the scratch. An overnight reformulation should occur over night.



Ref. <http://www.timesonline.co.uk/article/0,,3-1901520,00.html>

Ref. http://www.bayer.com/medien/pages/4248/20051208rdinvestordaypaterson_automotive.pdf

Thermo-chromic glass



Chromogenic materials are glazing materials that selectively control the spectral aspect of radiation. Low-emittance coatings suppress infrared radiation transfer thereby imparting additional thermal insulation. Modified low-emittance coatings can also reject unwanted heat gain due to solar infrared. It is possible to provide a controlling set point for the transparency to change automatically.

Ref. <http://windows.lbl.gov/materials/chromogenics/default.htm>



Nano based memory devices

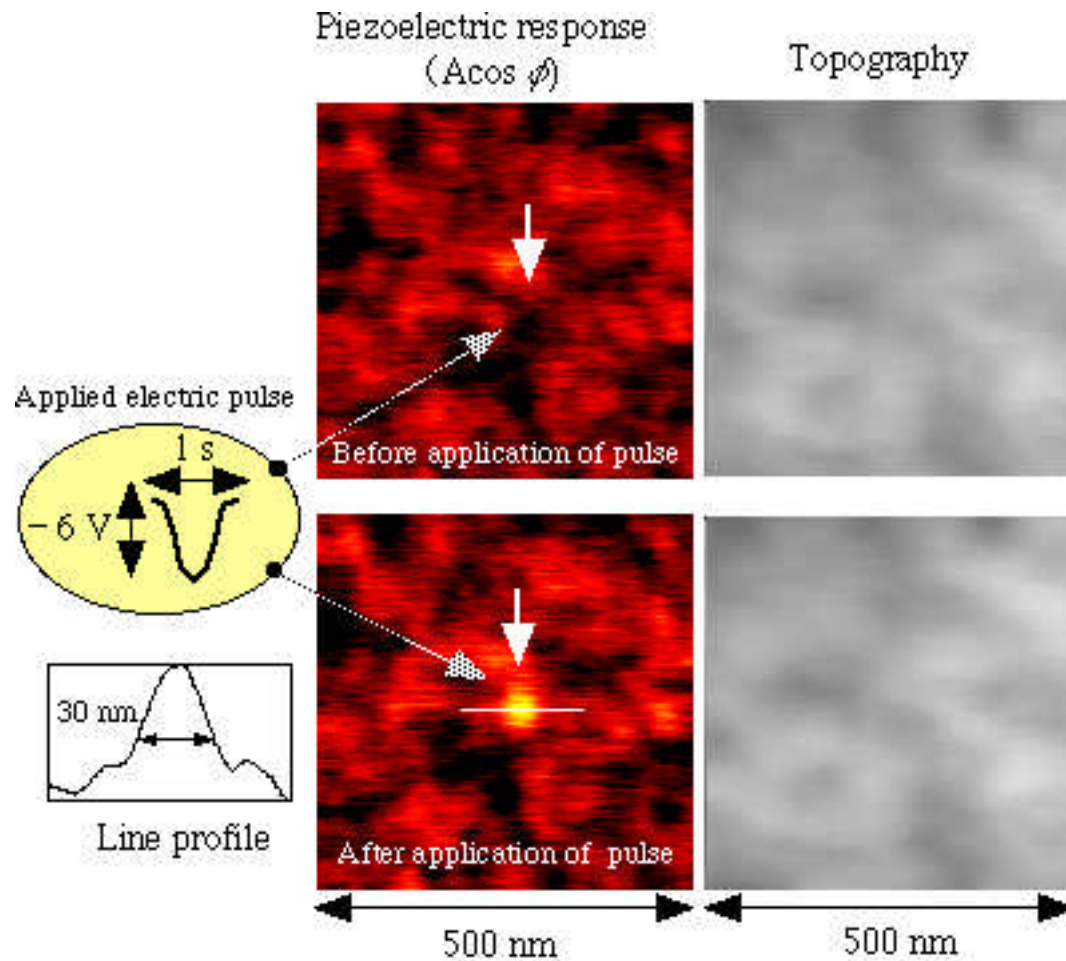
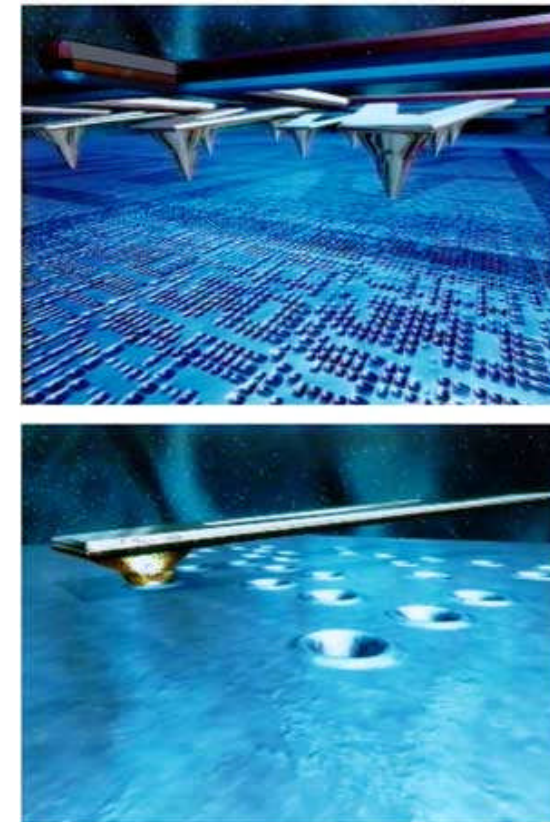


Figure 4. Piezoelectric response and topographic images of the ferroelectric copolymer film observed before and after the application of electric pulse.

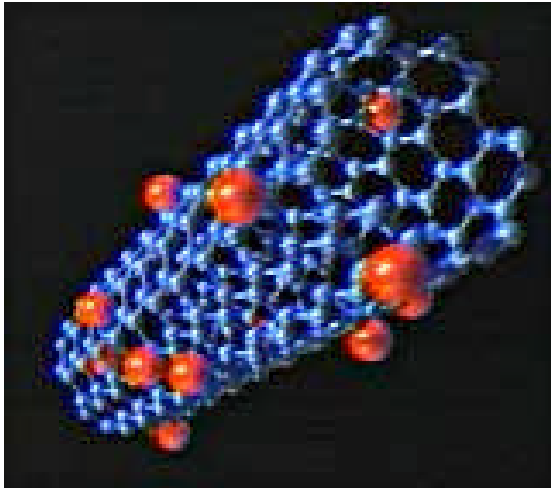
<http://www foresight.org/Conferences/MNT05/Papers/Matusige/>



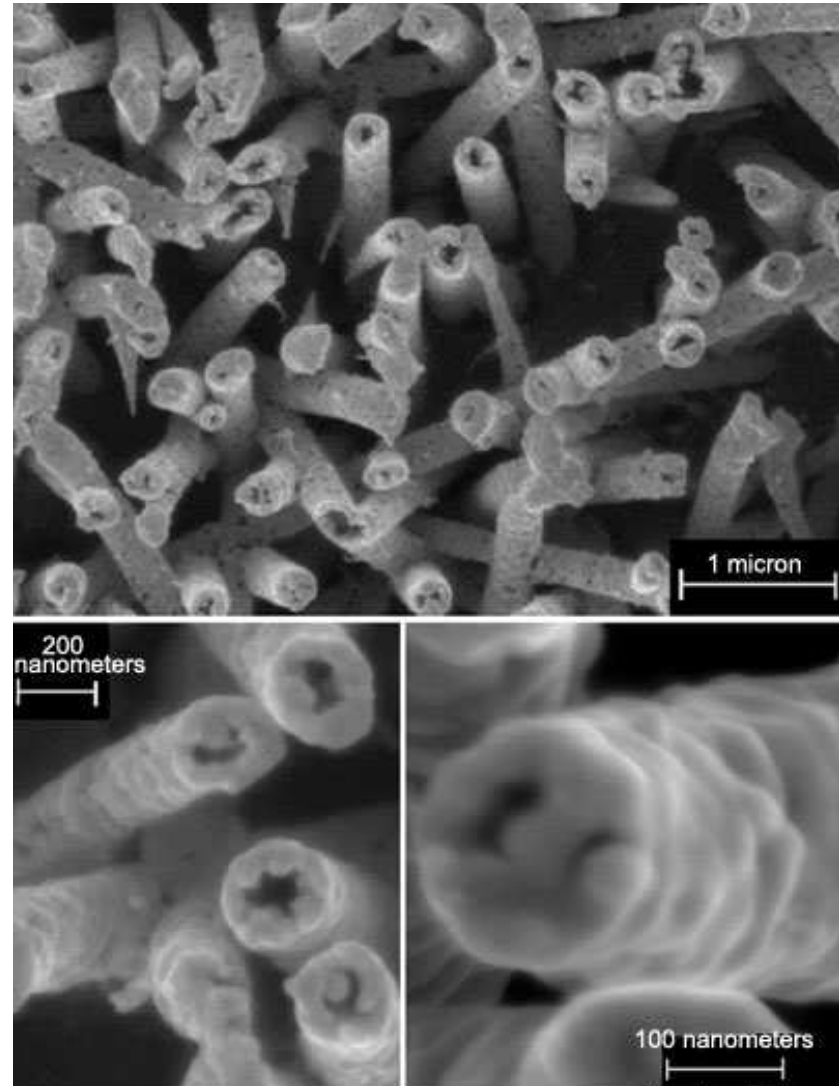
IBM Millipede Memory. 2D multistack architecture with multibits per cell. Requires uniform thin polymer thickness for high density. Rewritable with no wear on polymer after 106 cycles. Multi-tip provides fast speed, but the initial cost will not be inexpensive.

Ref. <http://www.ieee-virtual-museum.org/collection/tech.php?id=2345954&lid=1>

CNT fuel cells



http://www.pbs.org/newshour/bb/science/july-dec03/hydrogen_10-20.html



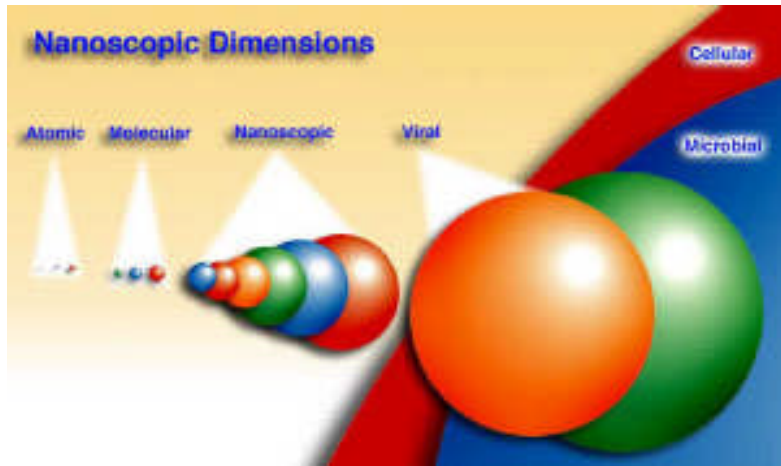
Source: University of Wisconsin

http://www.trnmag.com/Stories/2004/092204/Fuel_cell_converts_waste_to_power_092204.html



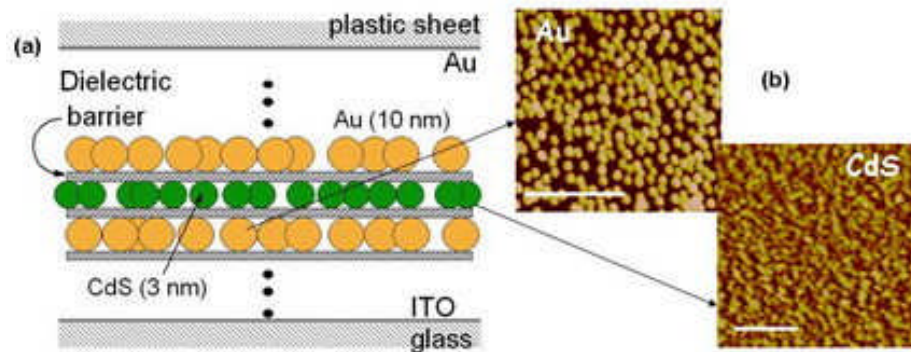
The Trybula Foundation, Inc.

Med-bio active devices



Ref: <http://nano.med.umich.edu/projects/dendrimers.html>

Artificial sense of touch



Ref: <http://www.physorg.com/news69155876.html>

Cochlear Implants



Tissue compatibility coatings
Finer electrodes
On-board signal processing
Very low power

Ref: Deb Newberry

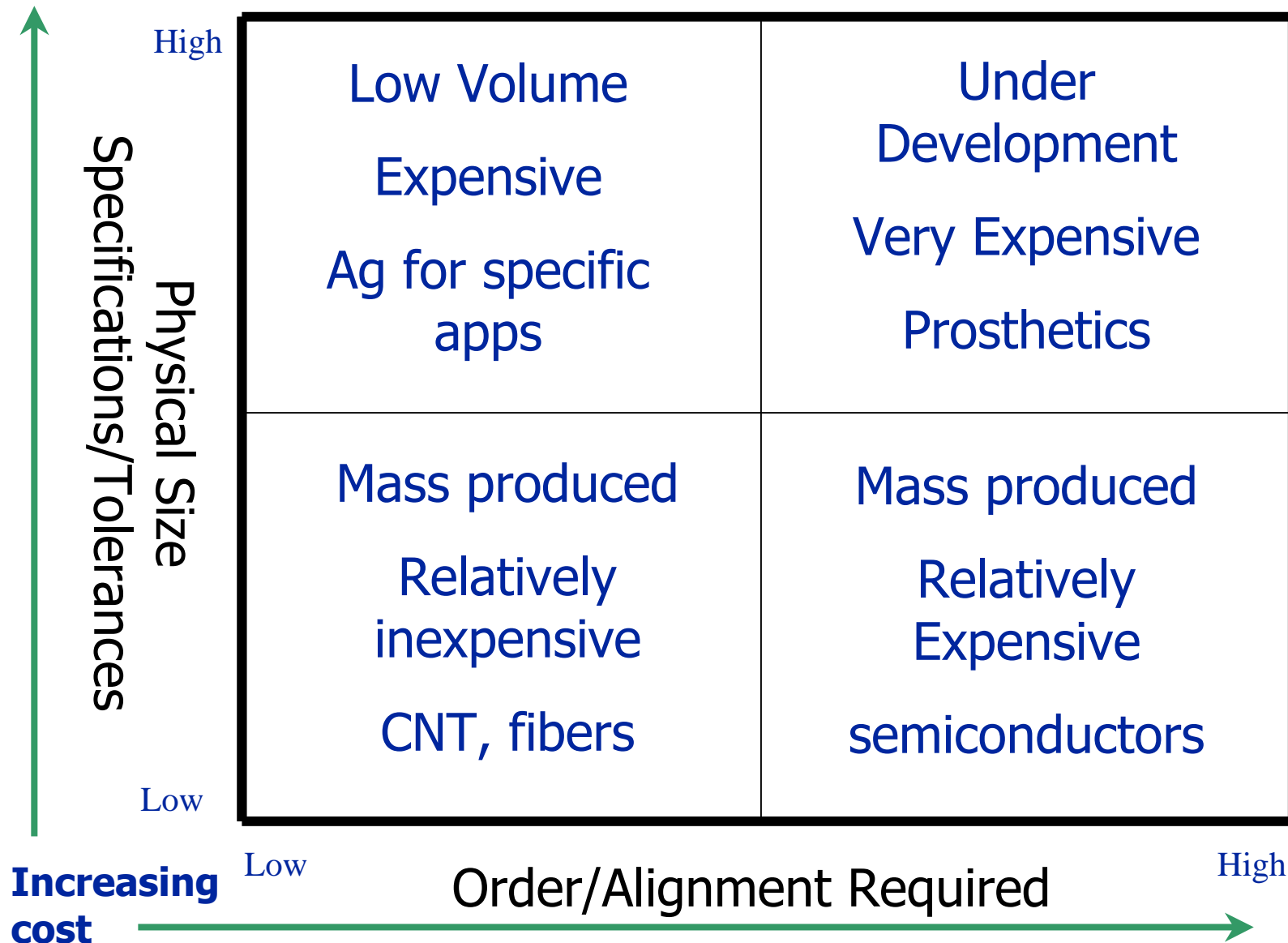


Nano Everywhere

- There are hundreds of available consumer products being spawned as companies manipulate matter at the atomic level, according to The Project on Emerging Nanotechnologies, a Washington, D.C. initiative associated with the Woodrow Wilson International Center for Scholars.
- The group released a products inventory containing descriptions of more than 200 consumer goods purportedly made with some type of nanotech process or nanomaterial.
- Link to Nanotechnology Consumer Products Inventory - <http://www.nanotechproject.org/index.php?id=44&action=view>



Opportunities and Challenges of nano



Summary

- **Nano Technology is all about properties and not size → nano is not size.**
- **Employing novel properties will permit development of devices with novel functions that are impossible as the macro scale → size is nano.**
- **The existing materials property handbook does not apply in the nano realm. We need to develop an entirely new handbook.**
 - Without this fundamental information on materials, novel developments will be challenging.



Something to think about

Nano Technology

First “beneficial” applications – Med-bio?

Effectively a new “plastic-type” revolution?



Opportunities

**“The Future Ain’t What
It Used to Be...”**

- Yogi Berra



“It’s a whole lot more!” - Walt

