# NANOTECHNOLOGY AND WHY FOR DEVELOPING COUNTRIES

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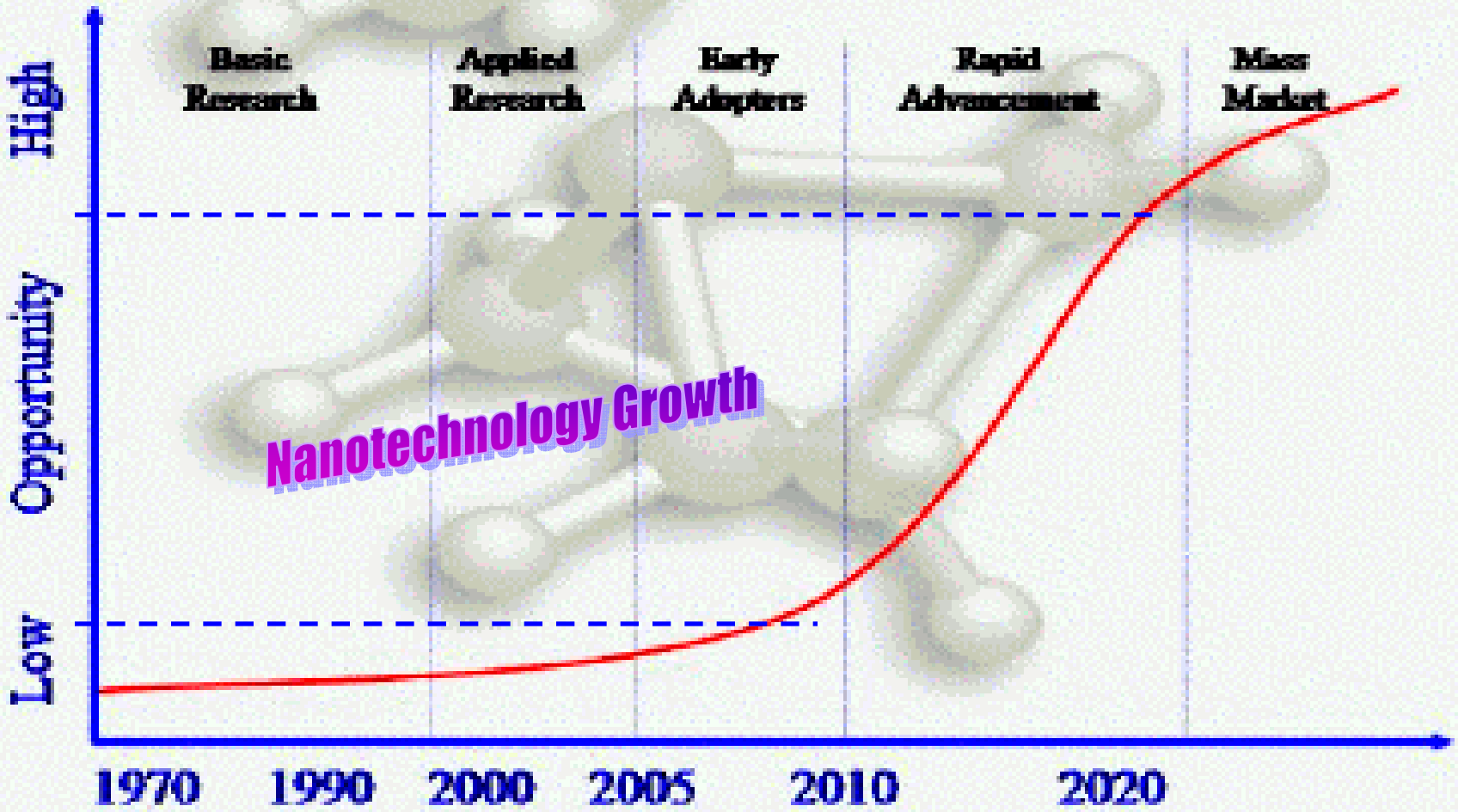
# 1. Importance of Materials

# Importance of Materials

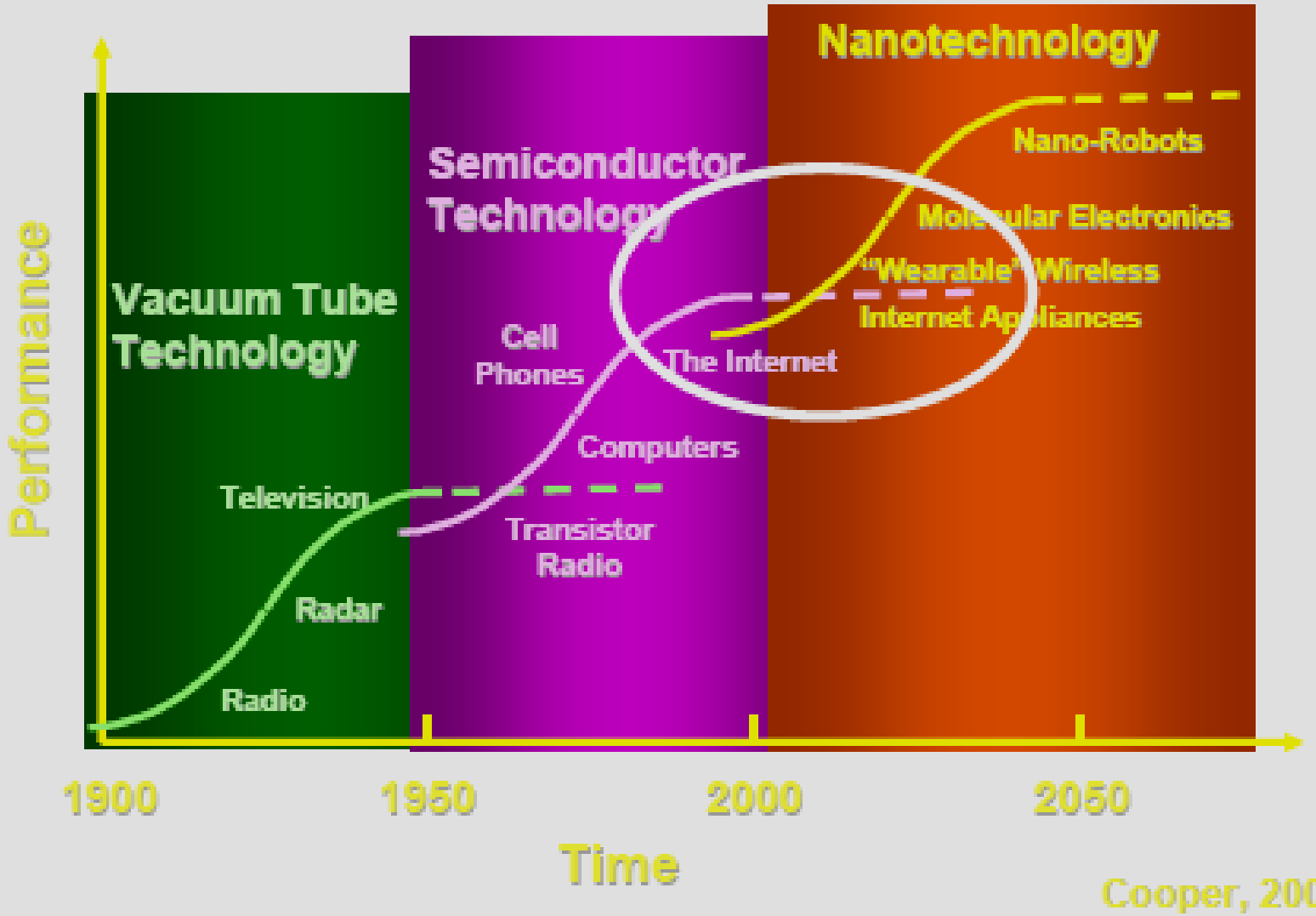
- The rise and fall of the different human groups and nations is strongly connected with the type of materials under their use.
- Another way to look at the importance of materials in human life is to see eye to eye with the historians who have divided the annals of human history into different phases, depending upon the type of materials used, such as, Stone Age, Bronze Age, Iron Age, Steel Age, Semiconductor Age, and the Advanced Materials Age (composites, ceramics, polymers, and nano-crystalline).
- Among these ages, the one of current importance and future dominance is the age of Nanotechnology of materials.

# The Evolution of NanoTechology




**Source:** http://www.directionsmag.com

# Evolution of Technologies



# 2. Richard Feynman's Lecture, December 1959

## "There's Plenty of Room at the Bottom"
## Richard P. Feynman December 1959

The classic talk that Richard Feynman gave on December 29th 1959 at the annual meeting of the American Physical Society at the California Institute of Technology (Caltech)

- The problem of manipulating and controlling things on a small scale
- Why can't we write the entire 24 volumes of the Encyclopedia Britannica on the head of a pin?

60 nm

As soon as I mention this, 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.

400 nm

Richard P. Feynman, 1960

The founding speech of Nanotechnology – written at the nanoscale.
Courtesy of the Mirkin Group Northwestern University

# 3. Introduction to Nanotechnology

# Milestones (Summarized)

- 1959 Feynman's lecture on "Plenty of room at the bottom"
- 1974 First patent filed on Molecular Electronic Device
- 1981 Scanning Tunneling Microscope (STM) invented
- 1985 Bukyballs discovered
- 1986 Atomic Force Microscope (AFM) invented
- 1987 First single-electron transistor created
- 1988 First 'designer protein' created
- 1991 Carbon nanotubes discovered
- 1993 First nanotechnology lab in the US
- 1997 DNA-based nanomechanical device created
- 1999 Molecular-scale computer switch created
- 2000 US launches National Nanotechnology Initiative (NNI)
- 2001 Logic gate made entirely from nanotubes
- 2002 EU program focuses heavily on Nanotechnology in Health Care
- 2003 US president Bush signs Nanotechnology Act

# Nanotechnology

A nanometer (nm) is one billionth ($10^{-9}$) of a meter

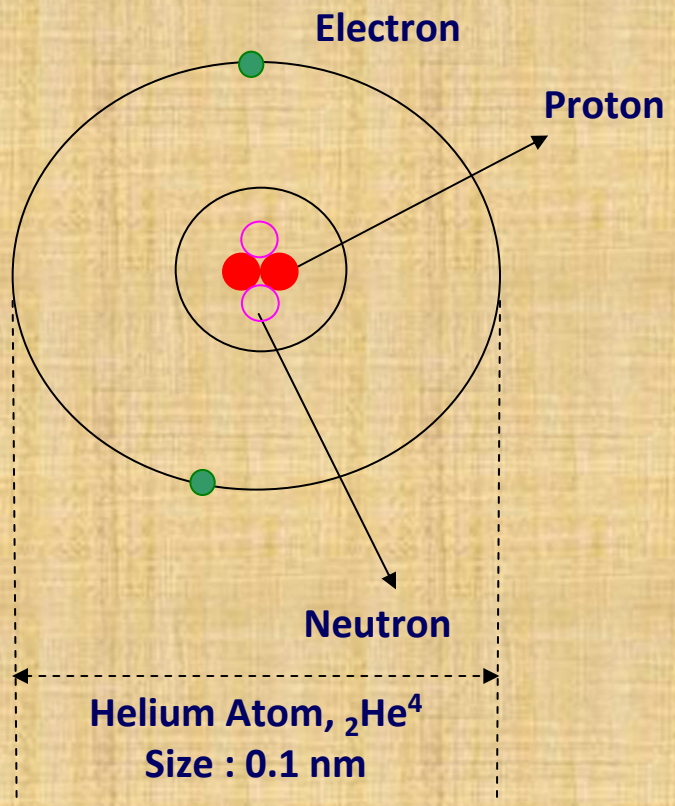
Thickness of a human hair ~ 80,000 nm

Nanometer: $10^{-9}$ m = 10 x $10^{-10}$ m = 10 atoms in a line

(one atom, $_2He^4$ ~ $10^{-10}$ m ~ 0.1 nm)

## Sub-Nanometer Sizes:

- Electron ~1.986 x $10^{-18}$ m
  ~ 2 x $10^{-9}$ nm
- Proton ~$10^{-15}$ m ~ $10^{-6}$ nm
- Neutron ~ $10^{-6}$ nm
  ~ 1/1,000,000 nm)



# The Scale of Things -- Nanometers and More

## Things Natural

Dust mite

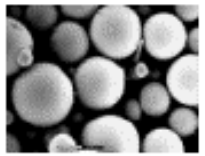
200 µm

Ant

~ 5 mm

Human hair

~ 10-50 µm wide

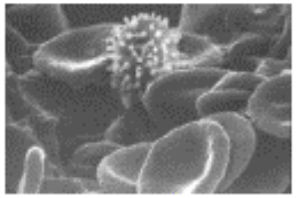


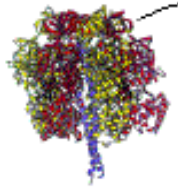
Fly ash

~ 10-20 µm

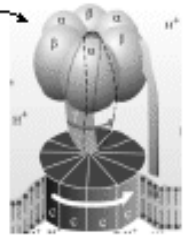
Red blood cells with white cell

~ 2-5 µm

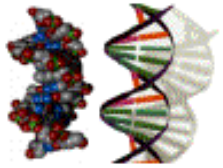




~10 nm diameter



ATPsynthase

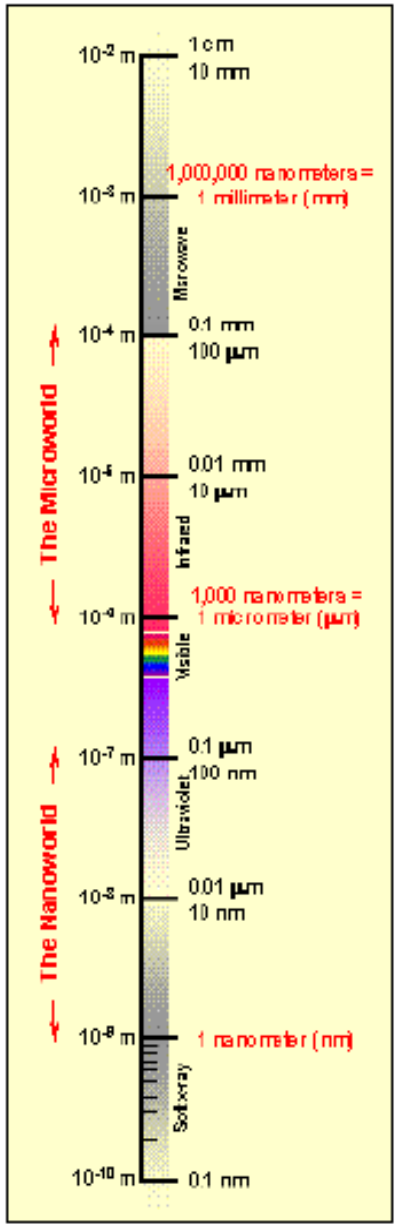


DNA

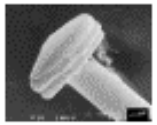
~2-12 nm diameter

Atoms of silicon

spacing ~tenths of nm




## Things Manmade

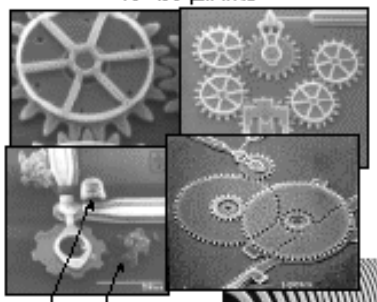


Head of a pin

1-2 mm

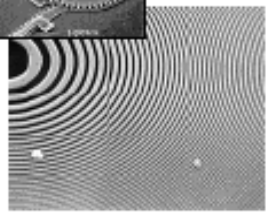
MicroElectroMechanical devices

10 - 100 µm wide



Red blood cells

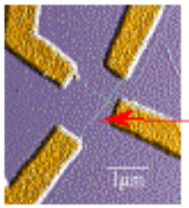
Pollen grain



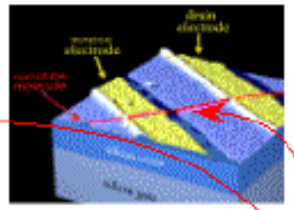
Zone plate x-ray "lens"

Outermost ring spacing

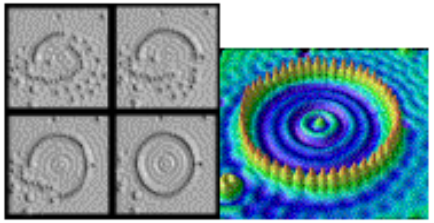
~35 nm



Nanotube electrode



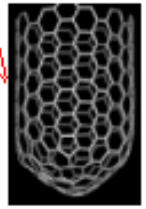
Nanotube transistor



Quantum corral of 48 iron atoms on copper surface

positioned one at a time with an STM tip

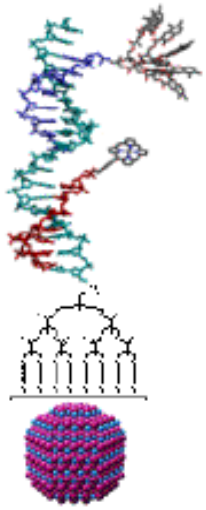
Corral diameter 14nm



Carbon nanotube

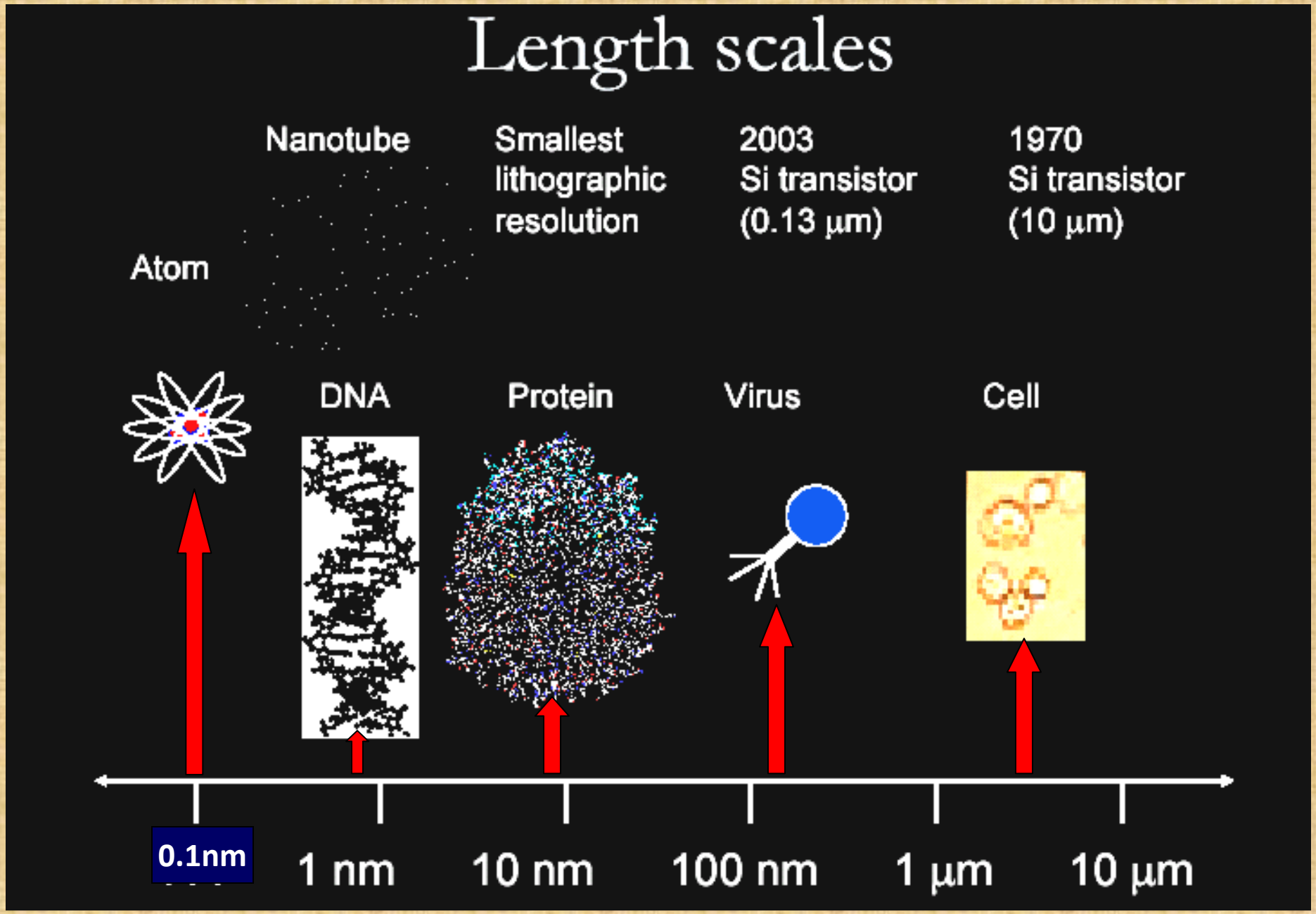
~2 nm diameter

### 21st Century Challenge



*Combine nanoscale building blocks to make novel functional devices, e.g., a photosynthetic reaction center with integral semiconductor storage*

# Length scales



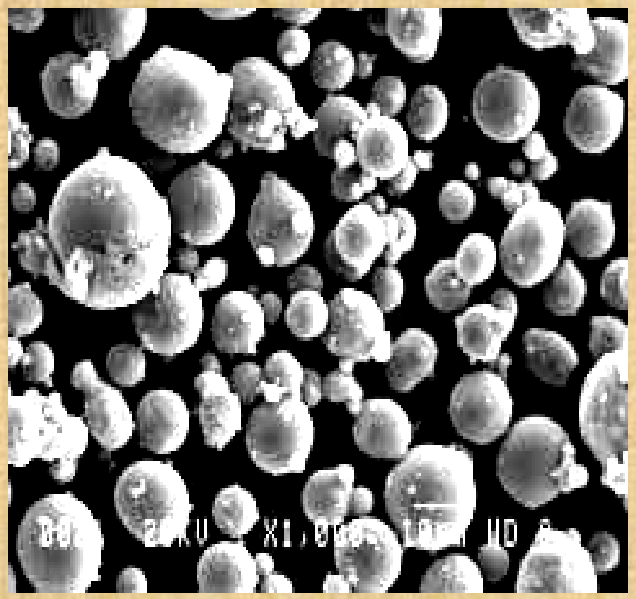
# Nanoscale

| No. | Item | Size (Approx.), Scaling down μm to nm | Size (Approx.), on nm Scale |
|---|---|---|---|
| 1. | Human hair (diameter) | 60 – 120 μm | 60,000 – 120,000 nm |
| 2. | Pollen | 10 – 100 μm | 10,000 – 100,000 nm |
| 3. | Asbestos fibers (diameter) | < 3 μm | < 3,000 nm |
| 4. | Diesel exhaust particles | < 100 nm – 1 μm | < 100 nm – 1000 nm |
| 5. | Soot | < 10 nm – 1 μm | < 10 nm – 1000 nm |
| 6. | Quantum dots | 2 – 20 nm | 2 – 20 nm |
| 7. | Nanotubes (diameter) | ~1 nm | ~ 1 nm |
| 8. | Fullerenes | ~ 1 nm | ~ 1 nm |
| 9. | Atoms | 1-3 Å ~ 0.1 nm | 1-3 Å ~ 0.1 nm |

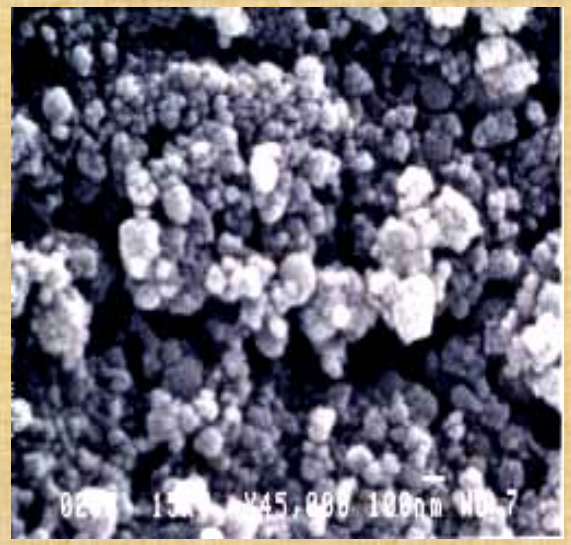
# Why nano will change the properties of materials?

Example: Smaller size means larger surface area

10 µm diameter
0.22 $m^2/g$



50 nm diameter
44 $m^2/g$

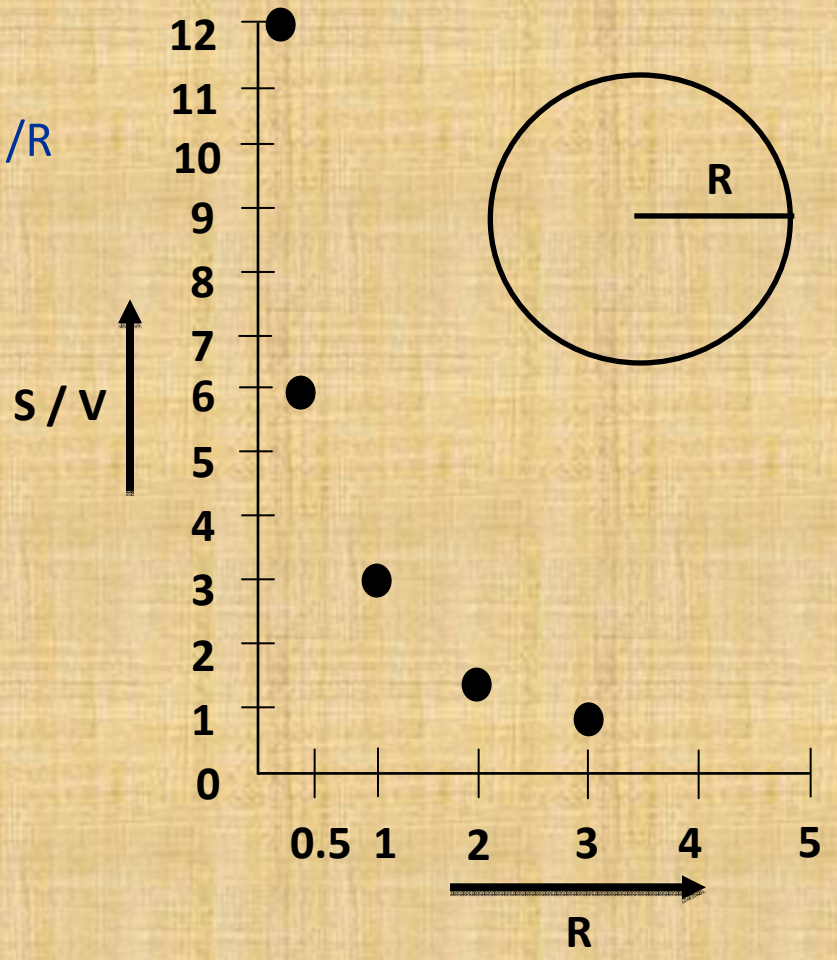


# Why nano will change the properties of materials?

**Sphere**

- Volume, $V = 4/3\ \pi R^3$
- Surface Area, $S = 4\pi R^2$
- Ratio $(S/V) = (4/3)\pi R^3/4\pi R^2 = 3/R$
  $\alpha\ 1/R$

| R | S/V |
|---|---|
| 3 | 1 |
| 2 | 1.5 |
| 1 | 3 |
| 0.5 | 6 |
| 0.25 | 12 |
| 0.125 | 24 |



# 4. International Importance of Nanotechnology: Statements by World Leaders

# President Clinton, 2000

## The National Nanotechnology Initiative

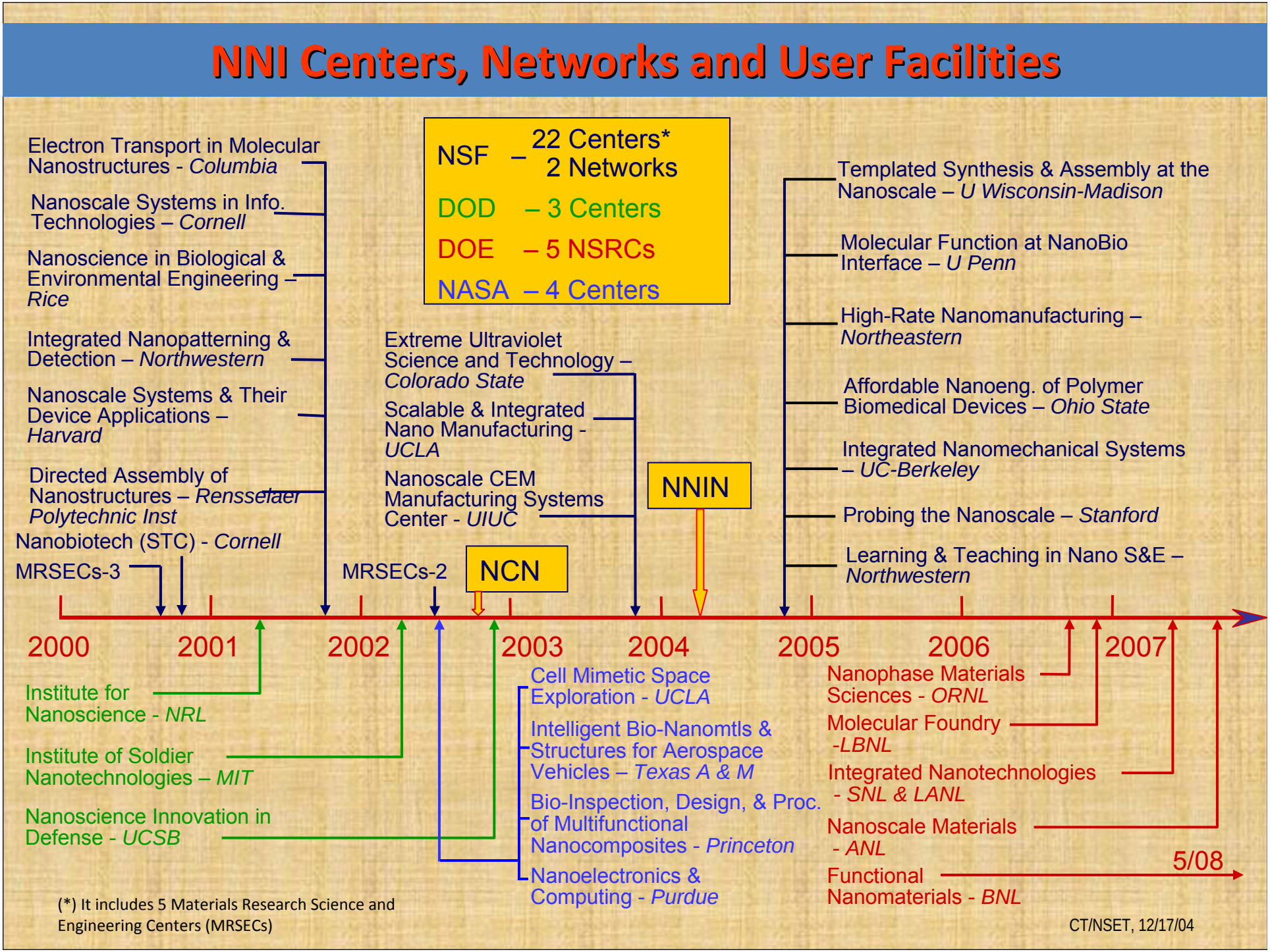
**In his speech proposing the NNI, President Clinton (2000) invoked this vision on Feynman's home ground:**

**My budget supports a major new National Nanotechnology Initiative, worth $500 million. Caltech is no stranger to the idea of nanotechnology —the ability to manipulate matter at the atomic and molecular level. More than 40 years ago, Caltech's own Richard Feynman asked, "What would happen if we could arrange the atoms one by one the way we want them?**

# NNI, USA Funding in the President's 2007 Budget

The US President's 2007 Budget provides over $1.2 billion for the multi-agency National Nanotechnology Initiative (NNI), USA, bringing the total investment since the NNI was established in 2001 to over $6.5 billion and nearly tripling the annual investment of the first year of the Initiative. "This sustained investment is advancing our understanding of the unique phenomena and processes that occur at the nanometer scale and expedite the responsible use of this knowledge to achieve advances in medicine, manufacturing, high-performance materials, information technology, and energy and environmental technologies".

# NNI Centers, Networks and User Facilities




(*) It includes 5 Materials Research Science and Engineering Centers (MRSECs)

CT/NSET, 12/17/04

# Russian Budget for Nanotechnology

The Russian Government would allocate **200 billion rubles ($7.7 billion)** to develop nanotechnology **until 2015** and transfer to the state corporation 130 billion rubles ($5 billion) by the end of this year. As of now, the government has invested about 150 billion rubles ($5.76 billion) in different nanotechnology studies including weapons projects.

In **2007, 12 billion rubles ($461 million)** has been appropriated for the development of nanotechnologies, an incredible sum by Russian standards i.e. more than 5 times allocated for this purpose in 2006. This year's nanotechnologies budget of Russia is comparable to USA, European Union and Japan.

**Source:** http://en.rian.ru/russia/20070723/69482473.html 23rd July, 2007

# India Sees Growth Opportunity through Nanotech

## India's Former President A.P.J. Abdul Kalam

**Within India, nanotechnology is frequently taking a prominent role in presidential speeches.**

***"One of the two technologies which will take India to the level of advanced countries by 2015 is nanotechnology and the other is fuel technology".***

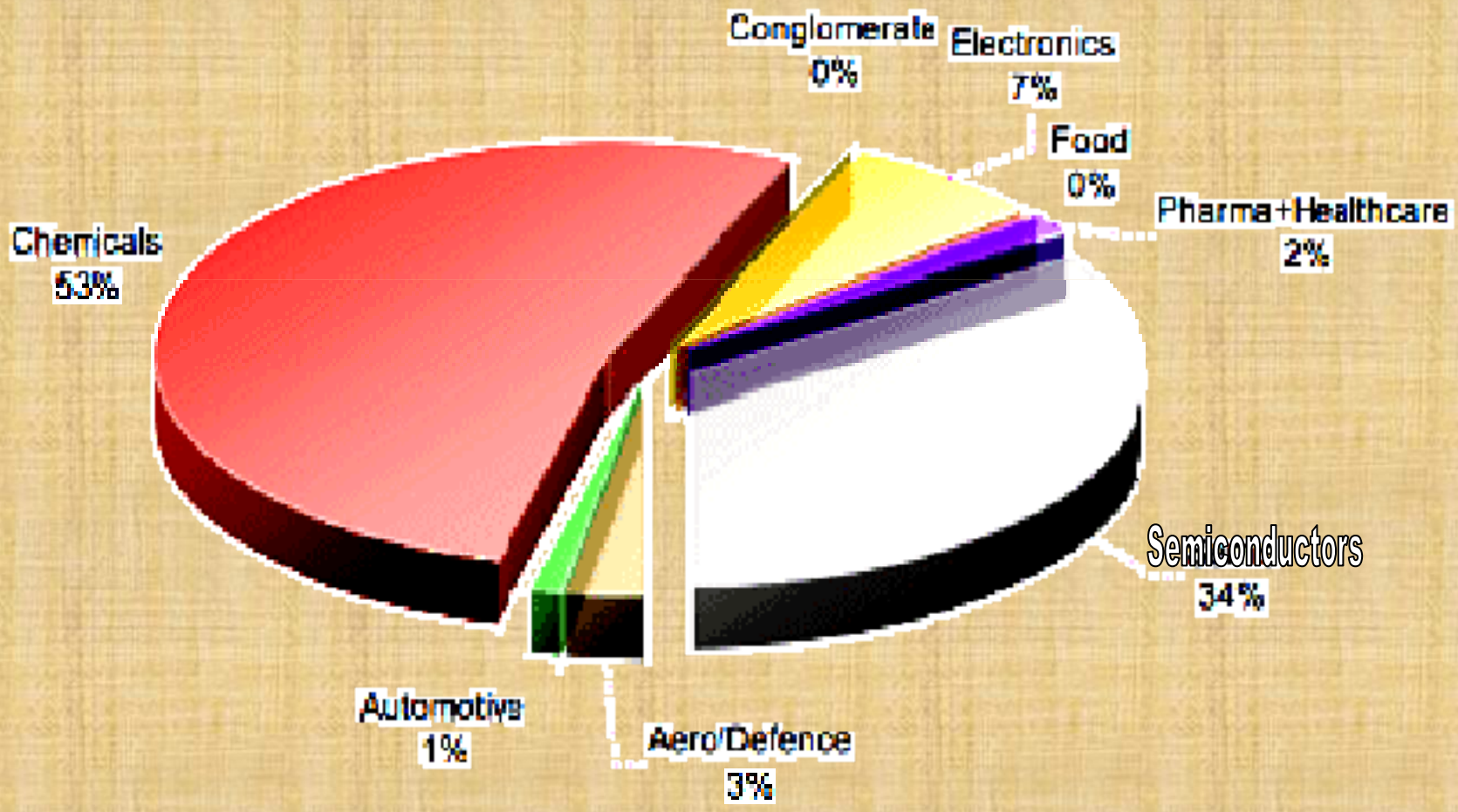
"Nano-technology is knocking at our doors," he said. "It is the field of the future that will replace microelectronics and many fields with tremendous application potential in the areas of medicine, electronics and material sciences".

# 5. Economic Importance

# Funding for Nanotechnology Research in European Union

- The 7th Framework Programme (FP7: 2007-2013)
  - The main EU mechanism to support research
    - Inside the European Union
    - Collaboration with outside countries (including international co-operation with China and Pakistan)
- Budget: ca. € 50 billion
- Official launch of FP7: 7 March 2007


# The Nanotechnology Market in 2007




http://www.nanotechnology.com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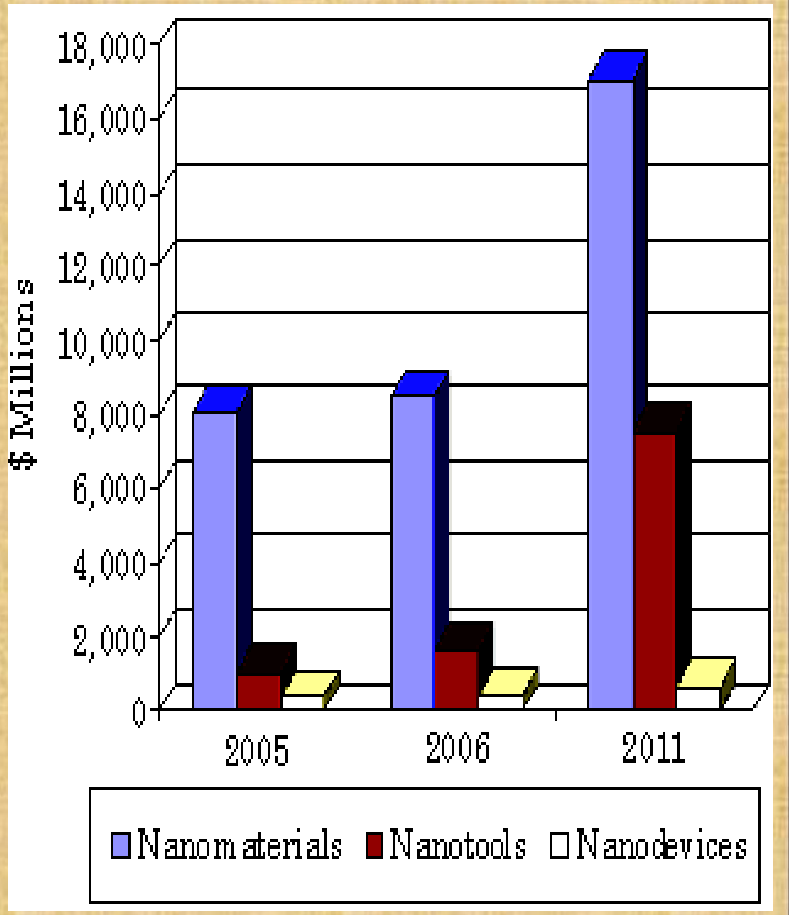
# Nanotechnology
# A Realistic Market Assessment

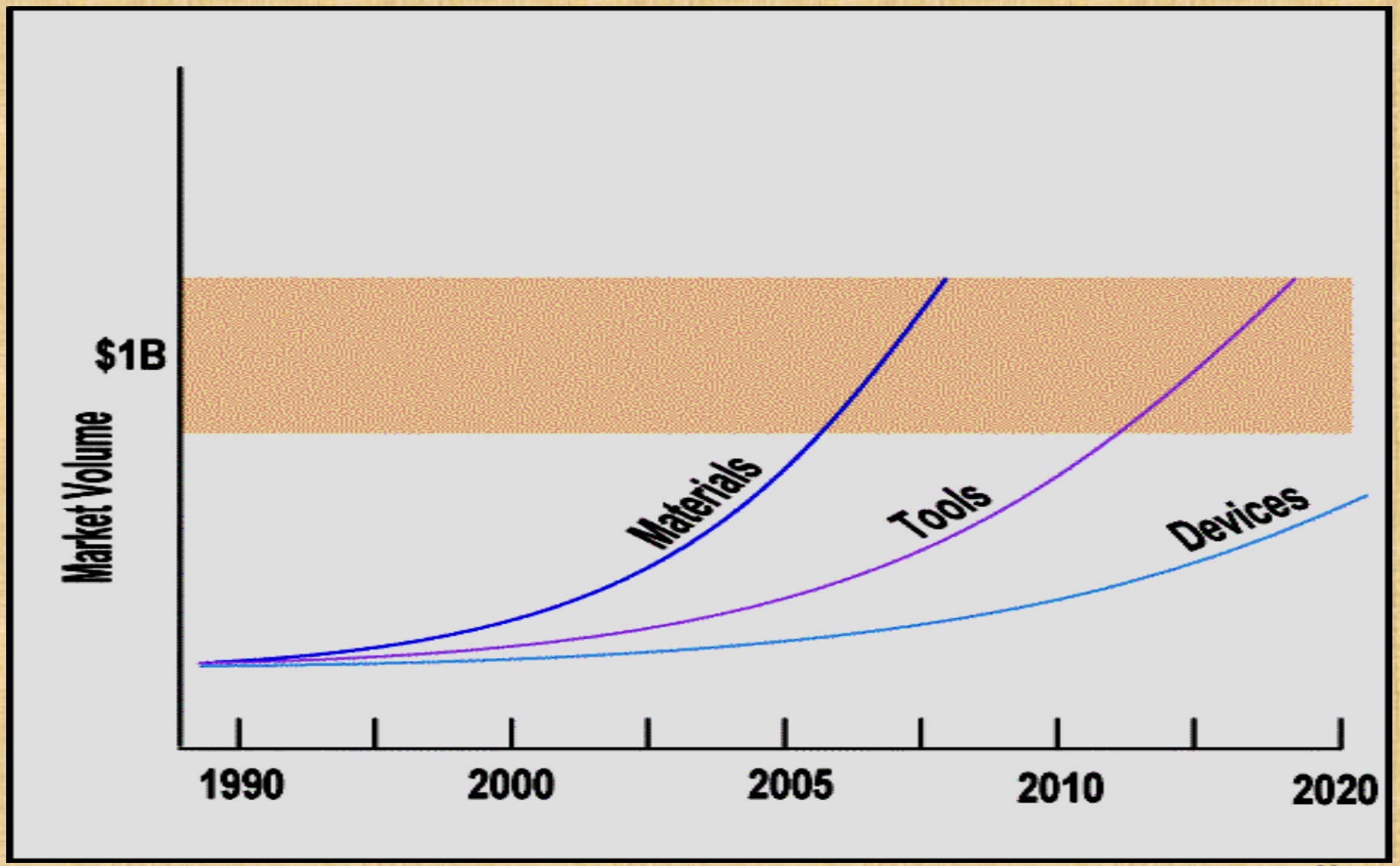
- BCC (Business Communications Company, Inc.) estimates,

  Global market for nanotechnology products ~ $9.4 bn in 2005, over $10.5 bn in 2006, growing to ~ $25.2 bn by 2011 (an AAGR of 19.1% from 2006 – 11)

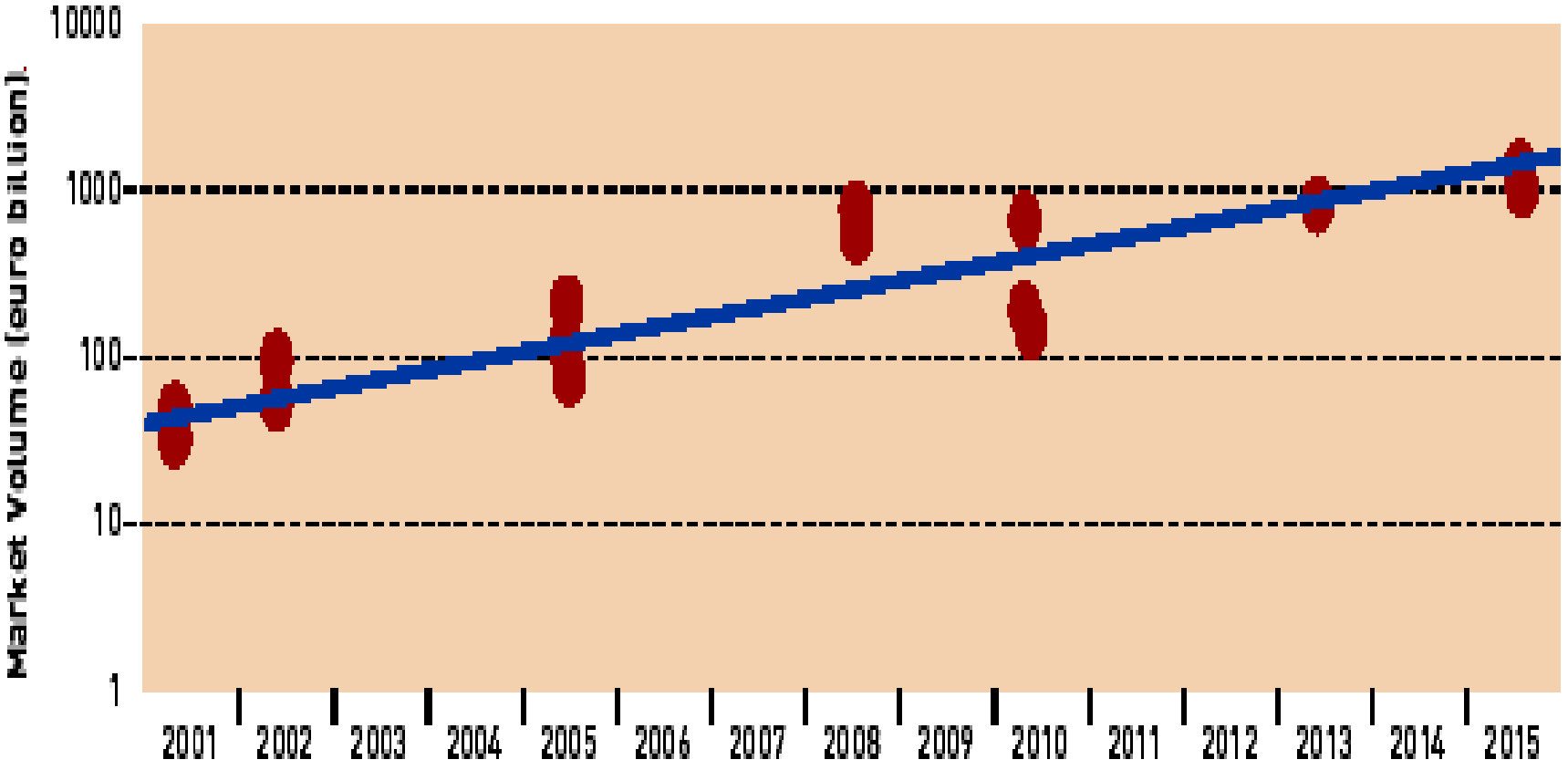
- The bargraph shows established commercial nanomaterial applications, i.e. carbon black filler for inkjet inks, nanocatalyst thin films for catalytic converters, and new technologies: nanoparticulate fabric treatments, rocket fuel additives, nanolithographic tools, and nanoscale electronic memory.



# Projected Nanotechnology Growth



# Market Volume (€ billion)
# Exponential Market Growth for Nanotech Products





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# Market Size Predictions – 2015

| S.No. | Item | Amount $ billion |
|---|---|---|
| 1. | Nano-Materials | 340 |
| 2. | Nano-Electronics | 300 |
| 3. | Pharmaceuticals | 180 |
| 4. | Chemical & Refining | 100 |
| 5. | Aerospace | 70 |
| 6. | Health Care | 30 |
| 7. | Tools | 20 |
| 8. | Sustainable Processes | 45 |
| | Total: | $ 1.1 trillion |

Source: James Murday & Mike Roco,U.S National Nanotech Institute, November 2003

# Investment in Nanotechnology

| Country | Nanotechnology | Amount, € million |
|---|---|---|
| Europe | Nanoelectronics, medicine, materials | 1250 |
| USA | All aspects of nanotechnology | 1200 |
| Japan | Nanoelectronics, nanomaterials, nanotubes | 750 |
| South Korea | High density memory, displays | 250 |
| China | Mass production nanomaterials | 400 |
| Taiwan | Display, optoelectronics | 150 |
| Others | Various | 150 |


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# Investment Impact in Nanotechnology

| Type of Investment | Country | Amount $ | Economic Impact |
|---|---|---|---|
| College of Nanoscale Science and Engineering (CNSE), 2006 | USA | 7 million | $1.1 billion |
| Federal nano investments in 2003 | USA | 700 million | |
| 1997-2004 | USA | 4.0 billion | |
| Projected public and private sector spending on nanotechnology 2006 | South Korea | 150 million | |
| Spending on nano-technology, 2006-2010 | Taiwan | 630 million | Production value US $9.07 billion by 2008 |
| Global R&D, 2006 | | 9.5 billion | Exceeds US $1 trillion<br>7 million jobs by 2015 |


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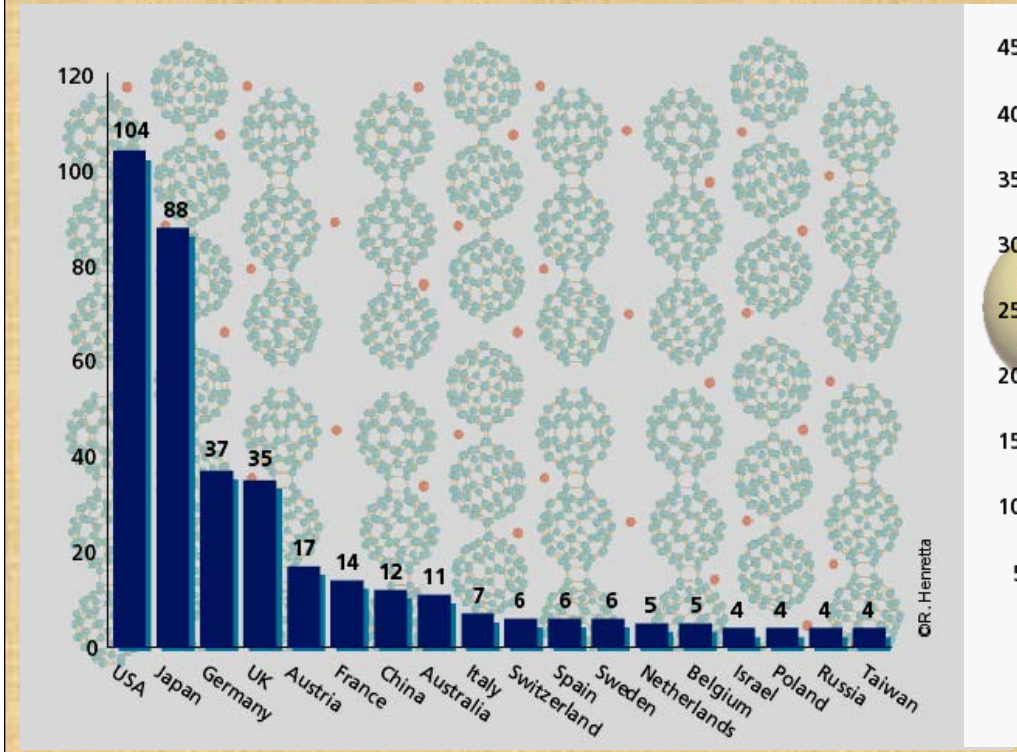
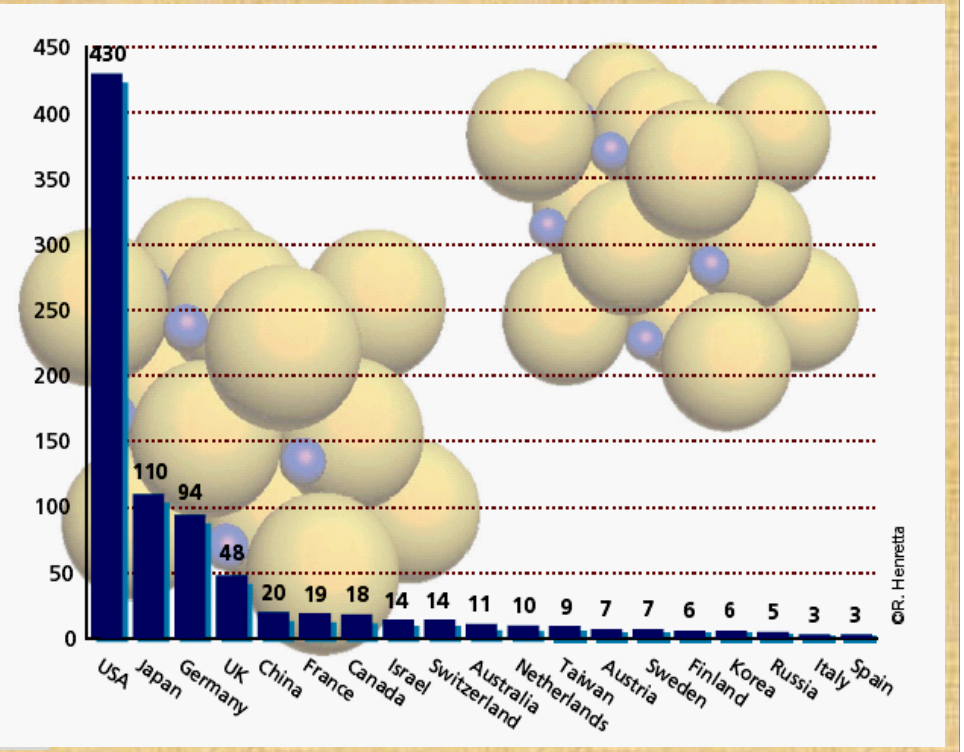
# World Wide Nanotechnology: Universities and Companies



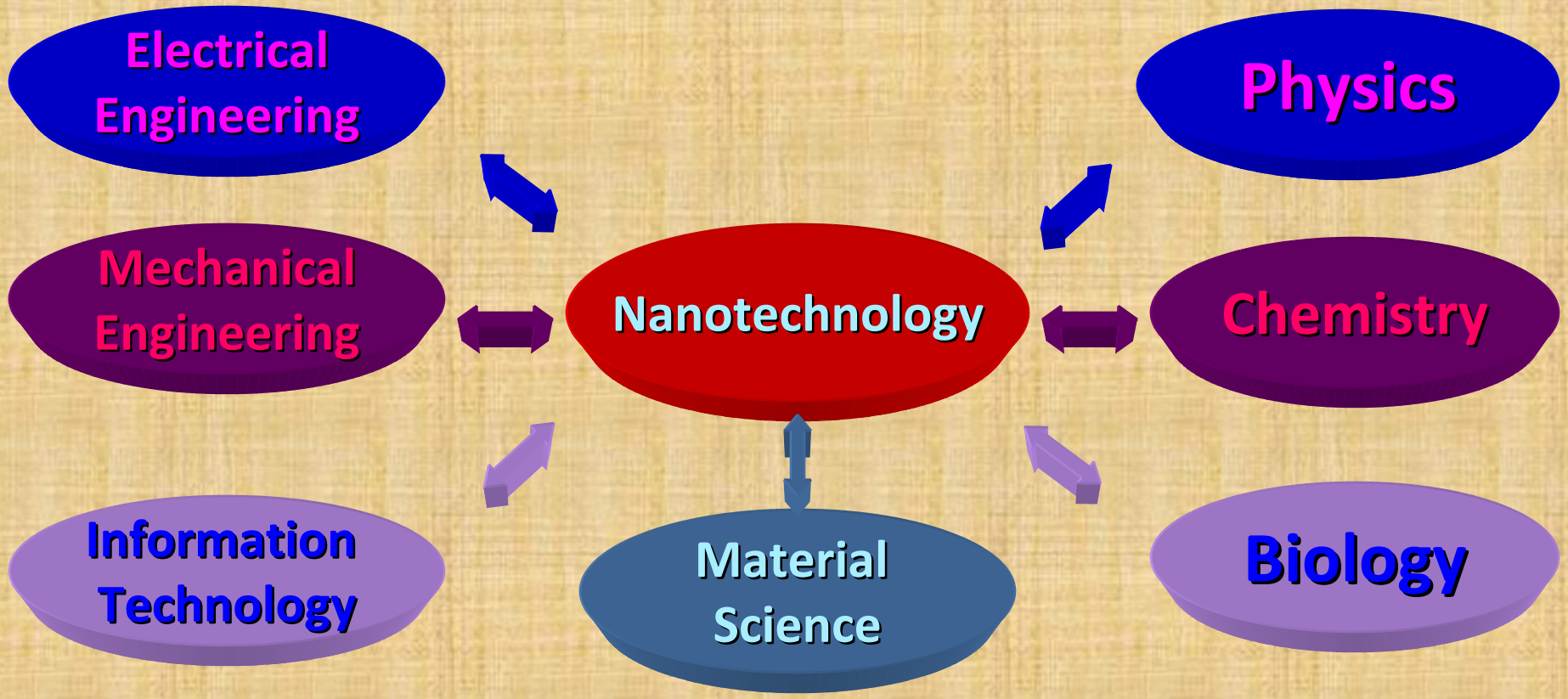

**Nanotechnology Global Universities**

**Nanotechnology Global Companies**

**The number of global universities and company investing in nanotechnology is increasing exponentially these days**

# 6. Nanotechnology as a Multidisciplinary Subject

# Nanotechnology is Multidisciplinary



# 7. Applications of Nanotechnology

# Applications of Nanotechnology

i. Medical / Nanomedicine:
   Anti-cancer drugs, Bio-sensors, Implants, Dental Pastes
ii. Energy:
   Solar, Fuel cells, Bio-fuels, Batteries
iii. Automobiles:
   Lubricants, Glass Coatings, Resins, Phosphors
iv. Industry:
   Ceramics, Insulation Materials, Phosphors, Hard Materials, Mechanical Systems, Spray, Sensors
v. Computer/Information Technology:
   Bio-molecules, Large Memories
vi. Defence:
   Special Materials, Censors, Clothing

# Applications of Nanotechnology Continued

vii. Cosmetics:
Skin Creams

viii. Agriculture:
Food Safety, Quality Assurance, water purification

ix. Environment:
Filters, anti-toxicants

x. Textiles:
Special clothes

xi. Sports:
Sunglasses, Rackets, Tennis and Golf balls

xii. Aerospace:
Communication, High strength light weight materials

xiii. Oil and Gas:
Nanotechnology in Exploration

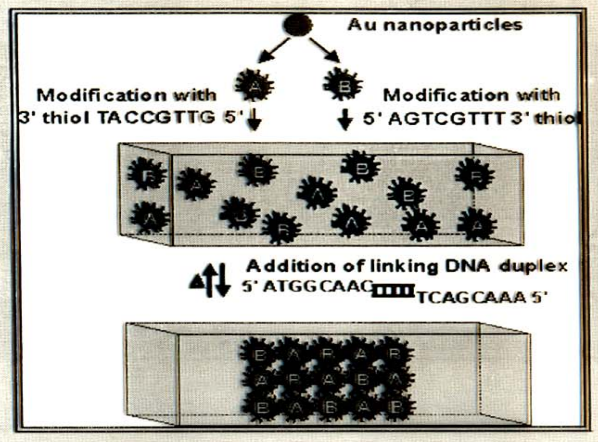
# i. Medical / Nanomedicine

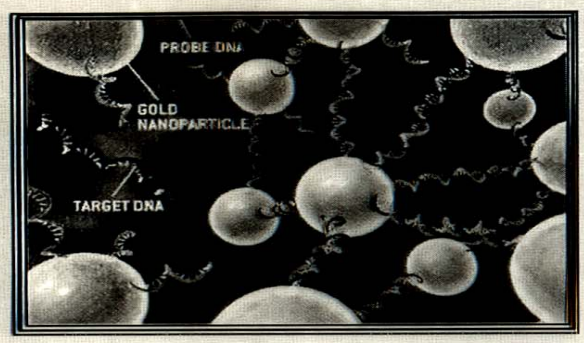
# Biomedical Applications

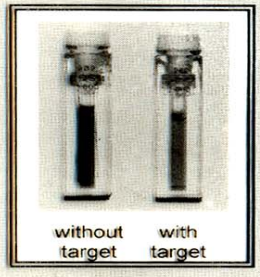
- Competitive technologies' agreement for dental use of nanotechnology bone biomaterial
- Anti-cancer drugs
- Injecting of micro-doses of toxin into cancer cells – true healing at the molecular level
- Anti-microbial encapsulation
- Use of nano-carbon buckyballs and nano-tubes for drug delivery
- Biomimetics: Synthesis products
- Manufacturing of quantum dots of 3 – 5 nm suitable for buildng biomolecules
- Tissue engineering: From MESA+ to replace damaged tissue or provide the missing ones
- Artificial sensor for eye, ear or nerve, bioelectronic interface
- Diagnostic sensors (Easy detection of diseases)
- Longer lasting medical implants
- Immediate mapping of an individual's genetic code
- Instruments for studying individual molecules
- Detection of clothing contact with Anthrax within 20 minutes
- Lab-on-a-chip for blood test and analysis

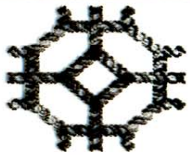
# Identification of Diseases

## DNA Detection by Gold Nanoparticles



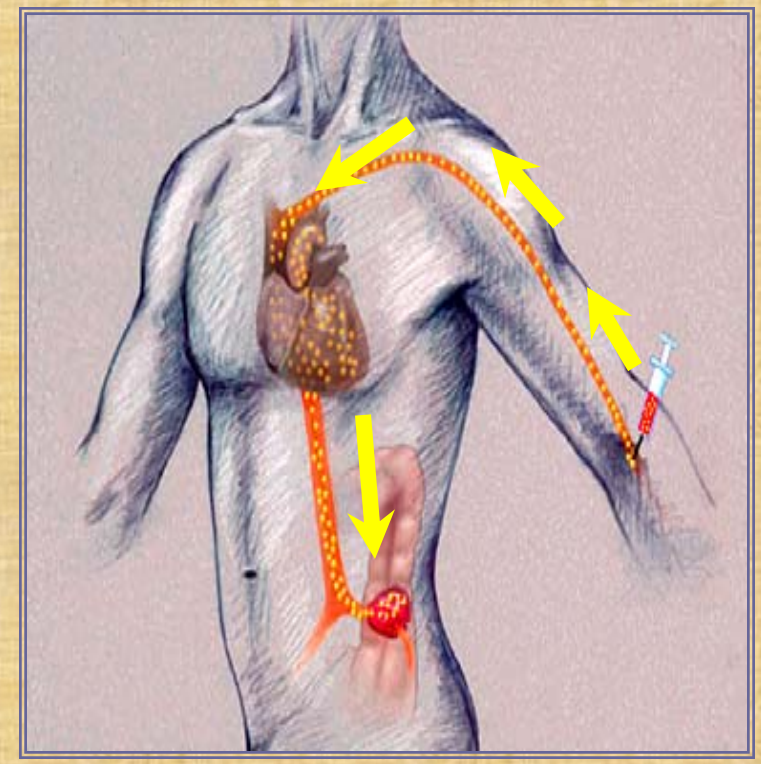



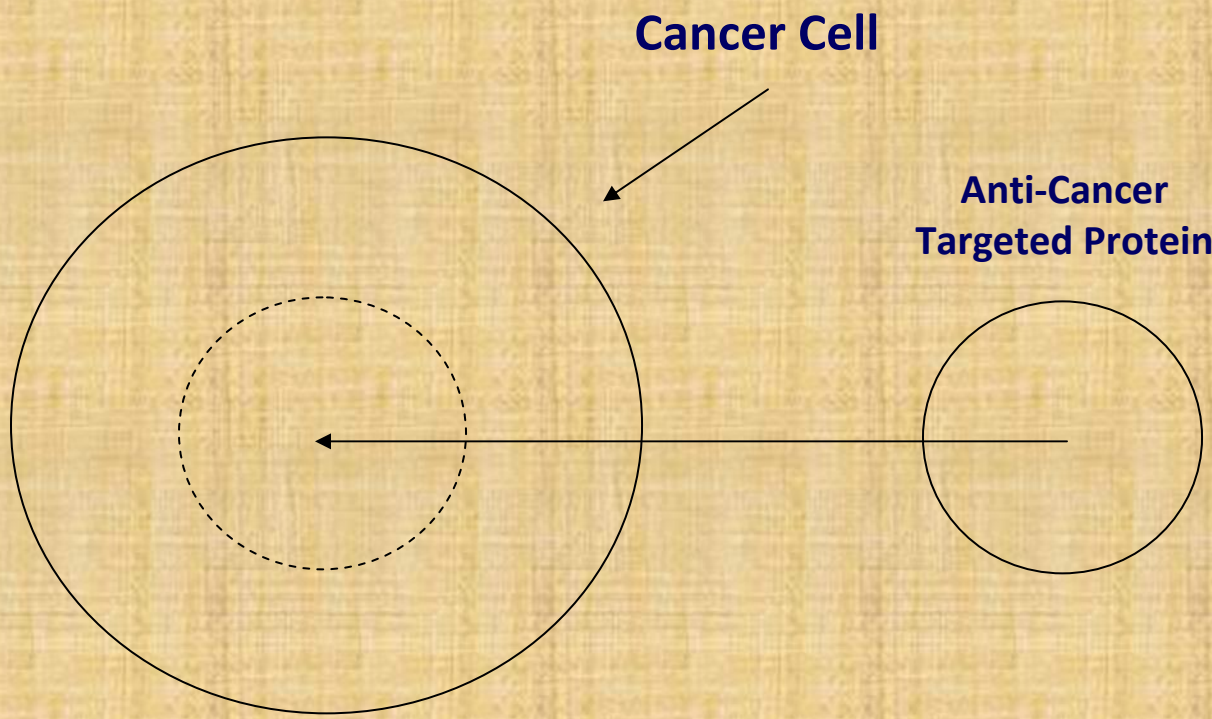
This colorimetric method can be used to detect even a single base pair mismatch in DNA by carefully observing the melting points of the gold nanoparticle's aggregates

# Nano-particles for Drug Delivery

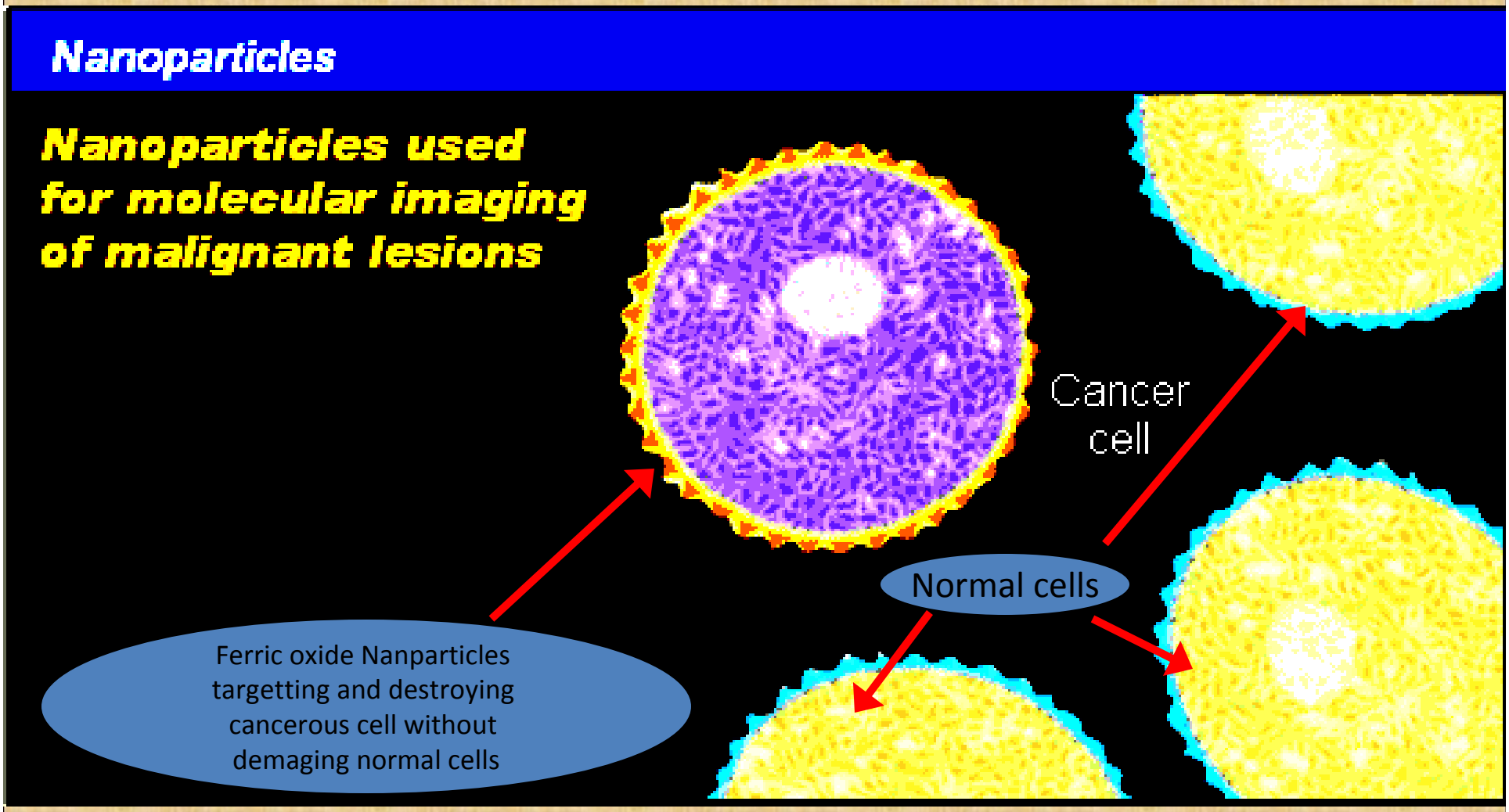
- Gold Nano-particles made it possible to deliver cancer drugs only to the target tumours thus minimizing side effects.
- Gold Nano-particles are being evaluated not only as drug delivery systems but also as cancer monitoring and treatment system.



# Cancer Cell Treatment



# Diagnosis and Destruction of Cancer Cell



# Cancer Treatment with Nanotechnology

- Nanotechnology created particles directly attach to cancer cells with "Lethal payload of drugs"
- Nano-cell, 1/5 of normal cell is tagged with antibodies attracted by cancerous tumours
- Do not flood the body with toxic chemicals
- No usual harmful debilitating side effects such as nausea, hair loss
- No life threatening as chemotherapy
- Trials on lab animals
- Human trials soon

Source: The News, 14th May 2007 (From Australian Scientists)

# Medicine and Health

- Nanorobots could also be programmed to perform delicate surgeries – such nanosurgeons could work at a level, a thousand times more precise than the sharpest scalpel.
- By working on such a small scale, a nanorobot could operate without leaving the scars that conventional surgery does.
- Nanorobots could change your physical appearance. They could be programmed to perform cosmetic surgery, rearranging your atoms to change your ears, nose, eye color or any other physical feature you wish to alter.

# ii. Energy

# Applications in Energy Sector

- Solar energy

  Nanotechnology hike hydrogen production

- Solar Cells

  Nanotechnology-based power cell technology will address power needs in defence, industrial and consumer electronics

- Batteries

  High energy density batteries

# Saving Energy through Advanced Nanomaterials

The most immediate opportunities lie in saving energy through the use of advanced materials and this is already a $1.6 billion dollar market, predicted to rise to$ 51 billion by 2014.

- Despite advances in battery technology, hydrogen storage and fuel cells, energy saving technologies will exhibit faster growth, accounting for 75% of the market for nanotechnologies in 201**4**, up from 62% in 2007
- The adoption of energy generation technologies is highly sensitive to geopolitical factors and consumer acceptance, while energy saving technologies exhibit no such problems
- Solid state lighting, nanocomposite materials, aerogels and fuel borne catalysts will have the greatest impact between now and 2014
- Compound annual growth rates are 64% for energy saving technologies and 90% for energy generation, while energy storage applications show a comparatively lowly 30%
- Applications in transportation will increase to $50 billion by 2014 with a CAGR of 72%

# iii. Automobiles

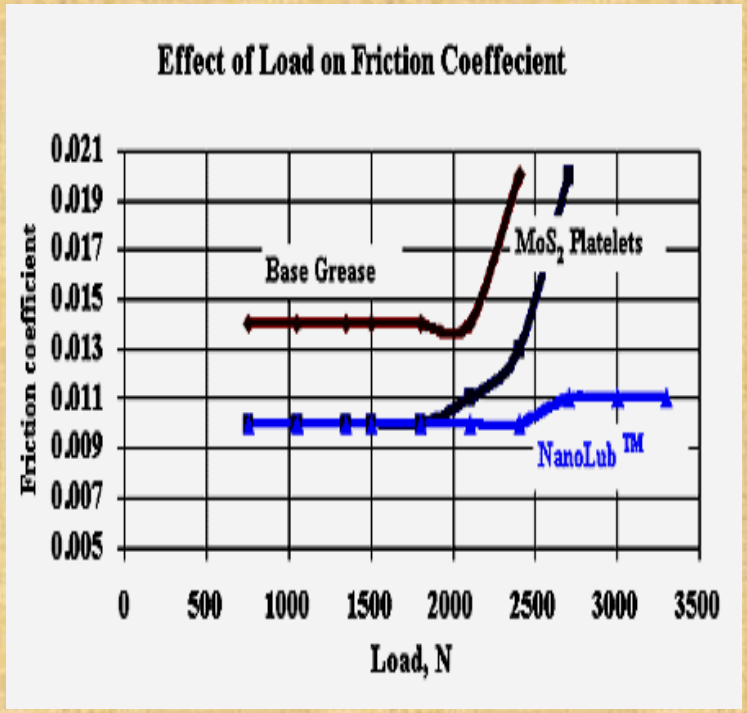
# Applications in Automobile Technology

- World's first commercial nanotechnology based solid lubricant declared non-toxic
- Automobiles with greater fuel efficiency
- Aerospace components with enhanced performance characteristics.
- Dust free mirrors used in recent Nissan cars
- Fog free glass windows for cars: Spray of nano-ceramics on glass
- Carbon atoms arranged in precise diamond-like fashion create a stronger material 100 times strength-to-weight ratio than steel and 6 times lighter than steel (Nanonow, May 2007)

# Nano Lubricants

Nano-Lub™

- Significant reduction in friction and wear
- Better than conventional lubricants especially at high loads
- Prolongs device service life, lowers maintenance costs and downtimes
- Useful in applications ranging: machines, tooling, jets and satellites
- World's first commercial solid lubricant based on spherical inorganic nanoparticles




**Source:** http://www.apnano.com/

# Nano-Sperse Resins

Nano-Sperse resins are powerful tools for the enhancement of product properties.

- Composites: High strength, fracture resistance, flammability resistance.
- Adhesives: Scratch resistant, bond strength, dimensional stability, conductivity.
- Coatings: EMI (Electromagnetic Imaging) / RFI (Radio Frequency Imaging), shielding, antistatic properties and barrier.

These are nanocomposite additives.

**Source:** http://www.nationalpolymerlabs.com/product_applications.htm

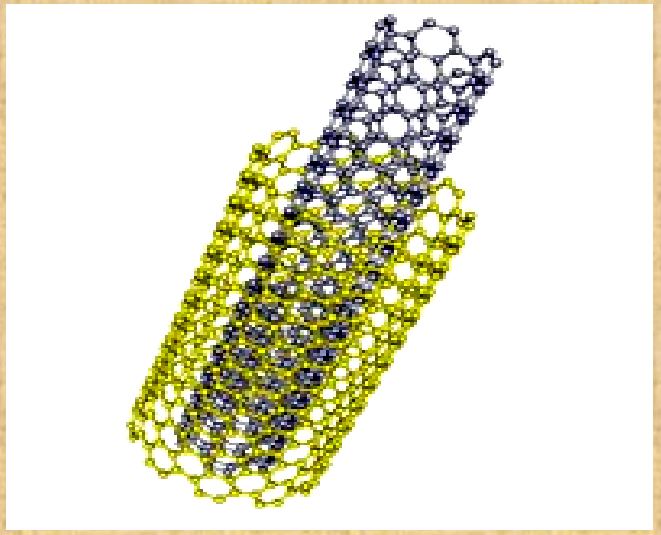
# iv. Industry

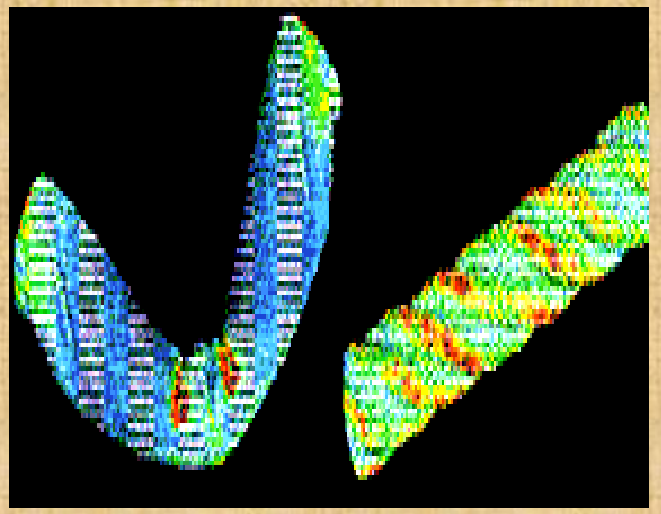
# Industrial Applications of Nanotechnology

- Ductile, machinable ceramics
- Better insulation materials
- Phosphors for high definition TV
- Low cost flat panel displays
- Tougher and harder cutting tools
- Elimination of pollutants
- Polymers, plastics etc with high electrical conductivity, more than copper
- Lightweight high strength materials
- Better ink – inkjet printing
- Nano-fibers conduct electricity

# Carbon Nanotubes

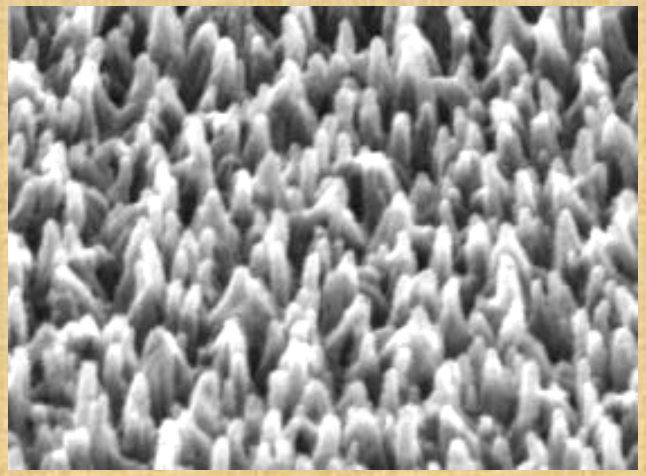
- Carbon nanotube (CNT) is a new form of carbon, equivalent to two dimensional graphene sheet rolled into a tube
- Two main types of nanotubes are,
  - Single-Walled Nanotubes (SWNTs) and
  - Multi-Walled Nanotubes (MWNTs).
- Tensile strength ~ 200 Giga Pascal, ideal for reinforced composites and nano-electromechanical systems (NEMS)
- Metallic or semiconducting and offers amazing possibilities to create future nanoelectronics devices, circuits, and computers
- Nanotubes are based on carbon or other elements. These systems consist of graphitic layers seamlessly wrapped into cylinders.

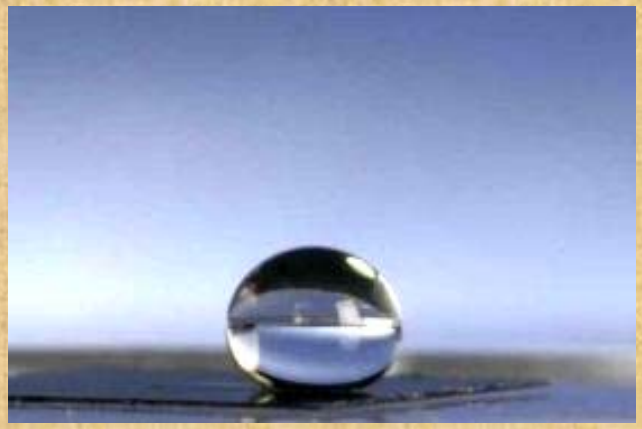




# New, invisible nano-fibers conduct electricity, repel dirt

- A SEM image of plastic fibers grown on a sheet of transparent film. A **surface carpeted with tiny plastic fibers** can be made to attract or repel water and oil.
- Tiny plastic fibers could be the key to some diverse technologies in the future -- including self-cleaning surfaces, transparent electronics, and biomedical tools that manipulate strands of DNA.
- A drop of water balances perfectly on a plastic surface covered with microscopic fibers and can be made to attract or repel water. It is water repellant, so the drop can not spread out along the surface; instead, it retains its spherical shape.





**Source:** Ohio State University, Published: 15:58 EST, June 28, 2007

# Nanotech clay armour creates fire resistant hard wearing latex emulsion paints

To-date latex emulsion paints have relied on the addition of soaps or similar materials to overcome the polymer parts of the paint's aversion to water, stabilize the paint and make it work. Individually coated polymer particles used in such paints with a series of nanosized Laponite clay discs effectively create an armoured layer on the individual polymer latex particles in the paint. The clay discs are 1 nanometre thick by 25 nanometres in diameter. The Lapointe clay discs can be applied using current industrial paint manufacture equipment. They not only provides an alternative to soap but can also be used to make the paint much more hard wearing and fire resistant.

**Source:** University of Warwick , The ACS Journal of Surfaces and Colloids Vol. 23, Issue 31st July, 2007

# Nanotechnology and Catalysis

# Nanotechnology in Catalysis

- Fabrication of model platinum nanoparticle catalysts by electron beam lithography
- Nanostructure processing of advanced catalysts
- New catalytic materials for clean technology
- Design of open metal sites in porous metal-organic crystals
- Nanofunctionalization of catalysts for methanol-to-olefin chemistry
- Synthesis of nanocrystalline perovskites for catalytic combustion of Methane
- Nanocrystalline LaCoO3 based perovskites as catalysts for VOC oxidation
- Mixed-metal clusters as precursors for nanoparticle bimetallic catalysts embedded in mesoporous silica MCM-41
- Catalysis by metallic nanoparticles, the good and the bad
- Nanoporous carbon membranes for catalysis and separation

# Nanotechnology in Catalysis (Continued)

- Performance of nano-nickel particles containing catalyst in the hydrogenation of toluene
- Characterization and catalytic activity of gold nanoparticles
- Catalytic Properties of Mixed Nanoparticles
- Preparation and Characterization of Sulfated Zirconia/Silica Super Acid Nano-catalyst
- Highly selective dehydration of 4-methyl-2-pentanol to terminal olefin catalyzed by (hydrous) zirconia solid catalysts
- Synthesis of Ti-MWW as a catalyst for selective epoxidation of alkenes
- Construction of multisite chiral catalysts: Dendrimer-fixation of C2-symmetrical
- Preparation and characterization of catalyst applied for synthesis of carbon nanotubes via CCVD method

# Nanotechnology Optimizes Catalyst System

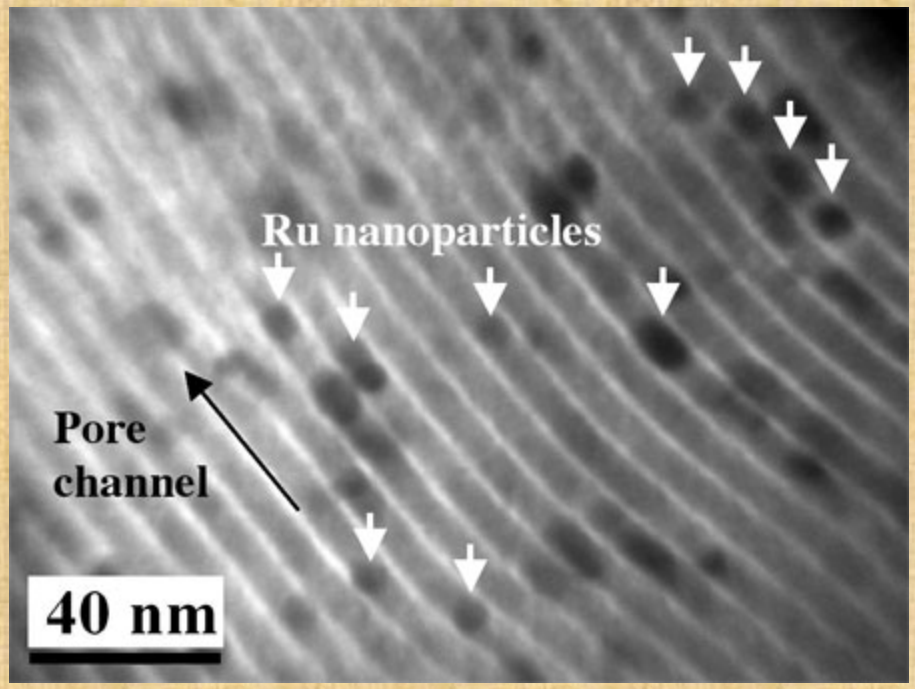
- 90% of chemical based products use catalysis.
- The most effective catalysts; transition metals or transition metal complexes e.g. Platinum, manganese
- Compare to normal Catalysts, nanoparticles with extremely large surface to volume ratio provide very acitve and effective catalysts

# Ruthanium (Ru) Nanoparticles

- Nanostructured catalyst designed with ruthenium nanoparticles sandwiched in the pore walls of carbon Dr. Xiu Song Zhao
- Current Applications: Chemical, petrochemical, food, and pharmaceutical industries, and in energy-conversion technologies.

# Ruthanium Nanoparticles

Preparation: First, catalyst nanoparticles dispersed on the pore surface of a hard template (e.g., zeolite Y and mesoporous SBA-15) are prepared. Then, the pores of the template are filled with a carbon precursor followed by carbonization. Finally, the template was removed by using a HF solution to yield a porous carbon with the catalyst nanoparticles incorporated in the carbon matrix.

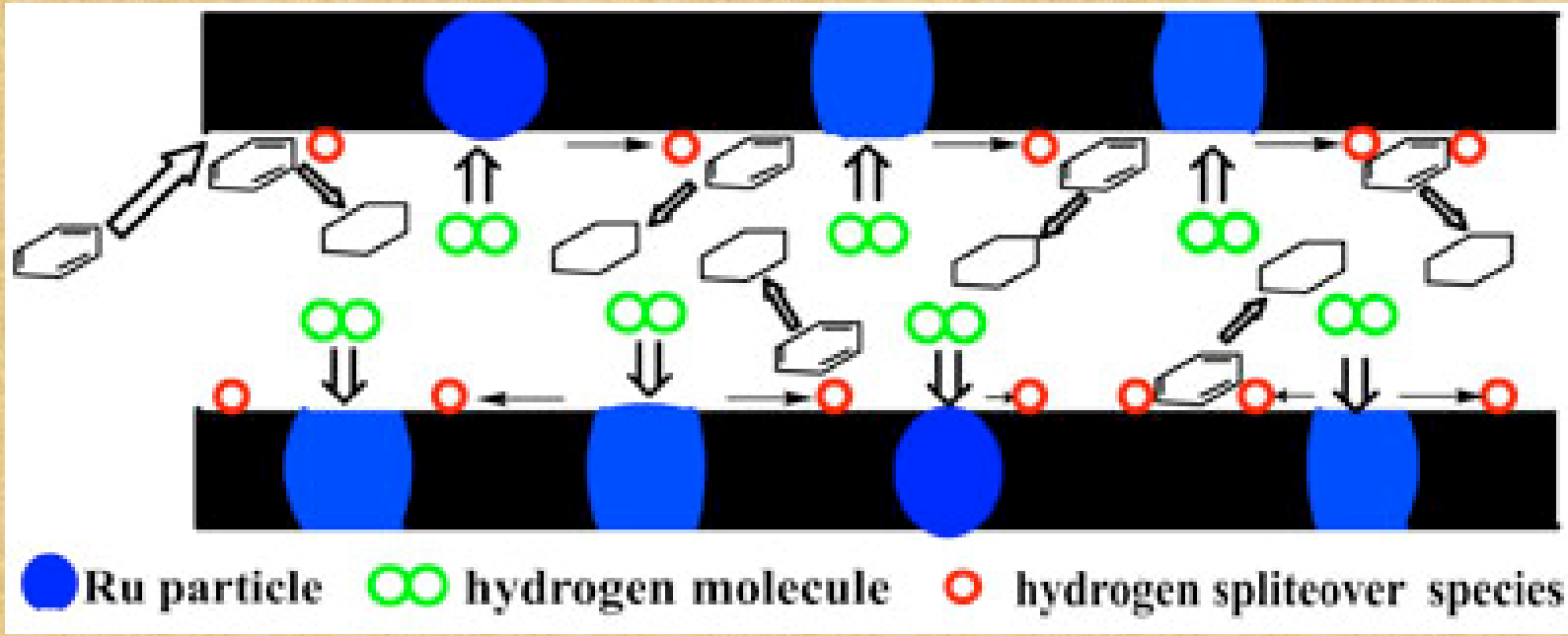



*The TEM image clearly shows sandwiched ruthenium nanoparticles in porous carbon. (Image: Dr. Zhao, National University of Singapore)*

# Advantages of Ruthanium Nanoparticles

- Firm fixation in the carbon matrix
- No aggregation
- No pore blocking
- Extremely intimate contact between the metal and support
- Controllable ruthenium nanoparticle size
- Tailorable pore size of the support.

# Catalytic Hydrogenation of Benzene



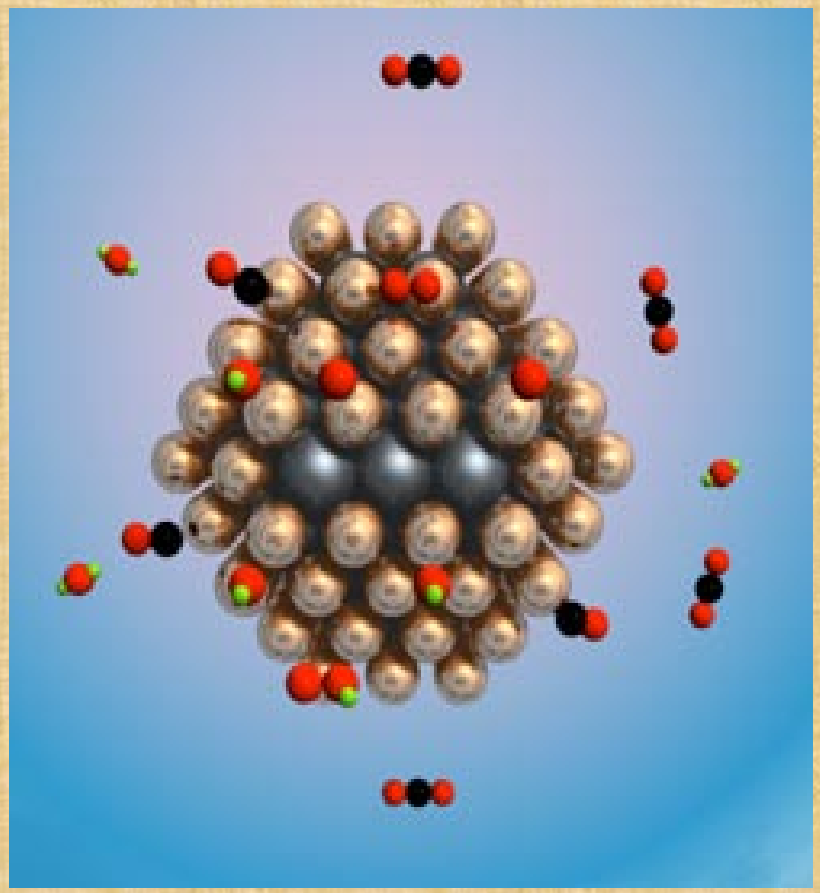

*This scheme illustrates catalytic hydrogenation of benzene enhanced by hydrogen spillover promoted by the ruthenium-carbon nanostructured catalyst (Image: Dr. Zhao, National University of Singapore)*

# Applications of Ru Nanoparticles Fixed in C-layers

- Selective hydrogenation
- Hydrogen storage
- Methanol electro-oxidation for Fuel Cell Technology

# Ru Surrounded by 1-2 Layers of Pt Atoms

- Nanotechnology-driven chemical catalyst paves the way for more efficient hydrogen fuel-cell vehicles
- Catalyst created by surrounding a nanoparticle of ruthanium (Ru) with one to two layers of platinum (Pt) atoms, produces robust room temperature catalyst that dramatically improves hydrogen purification reaction and leaves more hydrogen available to make energy in the fuel cell



Credit: University of Wisconsin-Madison

# v. Computer / Information Technology

# Computer / Information Technology

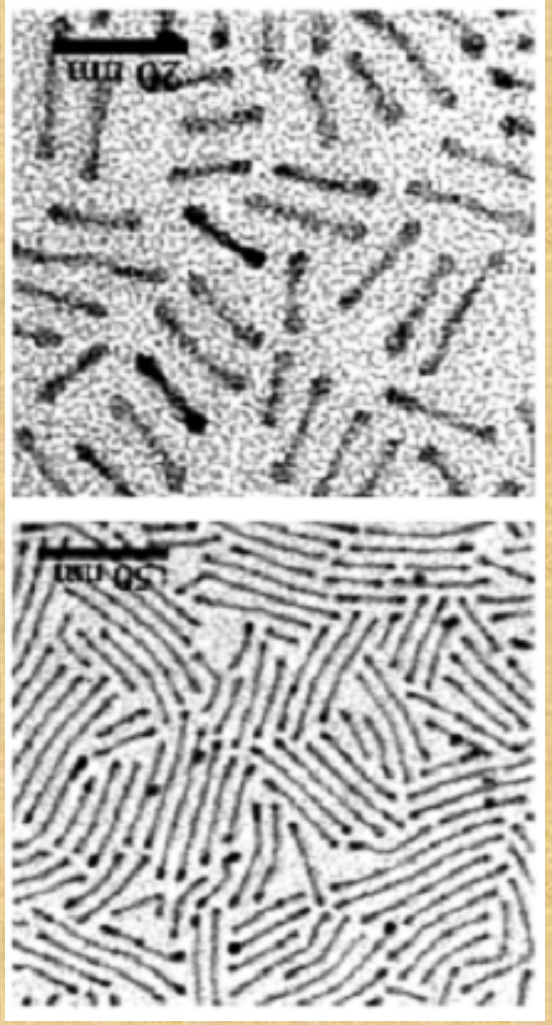
- Nanoelectronics: Biomolecules
- IT: Large density information 1012
- Next generation computer chips
- Large electro-chromic devices
- Nano-computers with molecular machines will allow almost anything to be designed and made from inexpensive raw materials, such as, air, sunlight or even dirt.
- Specific magnetic properties for magnetic recording
- High erosion resistance

# Nanorods and nanowires could increase memory

**Nanoparticles** can be used to increase the **magnetic-based data storage** on future generations of computer hard drives.

Recently, **iron-platinum nanorods and nanowires** were synthesized with increased control of composition and shape of particles by varying the concentrations of surfactant, which affects surface tension and solvent in the solution. Using more surfactant lowers the surface tension and longer wire can be produced. Rods and wires with lengths, **20 to 200 nanometers** with iron concentrations, 45 to 55 percent were produced. It is hoped that particles shaped less like wires and more like bricks may be fabricated making it easier to use.

Some experts believe that **conventional magnetic storage** techniques will reach their **limit by about 2010**.



**Source:** http://www.nanotechnology.com Friday, July 06, 2007

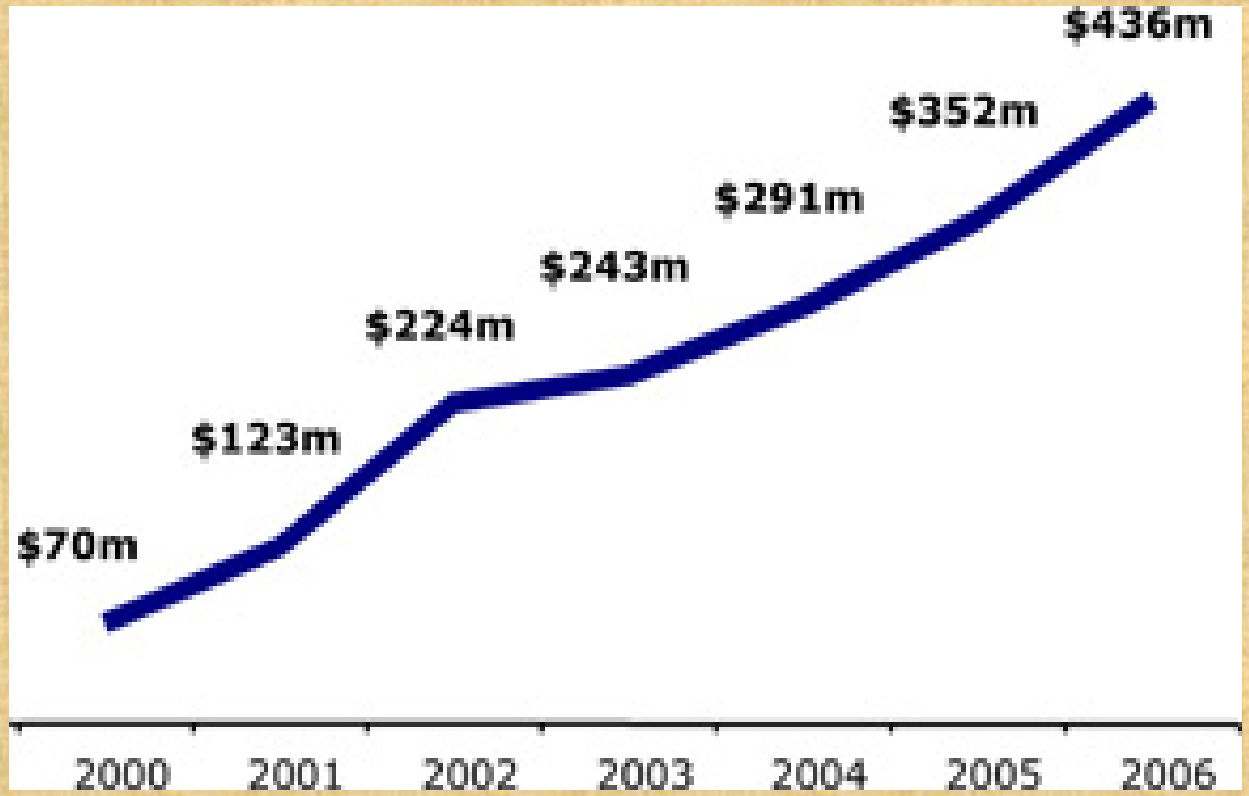
# vi. Defence

# Nanotechnology in Defence

- Lightweight and strong material for defence
- Better and future weapons platforms (for missile launching): Replacement of depleted uranium missile launching platforms
- Kinetic Energy (KE) penetrators with enhanced lethality (replacement of depleted uranium penetrators).
- Nano paint could boost antiterrorism, rescue efforts
- Killing machines prepare to do warfare's dirty work
- Specially prepared clouds of nanotechnology particles to disrupt electronic surveillance systems
- New forms of sensors, information technology will enable small unmanned systems and autonomous weapons to reach their target with the ability to adapt to unexpected changes in weather, detect and counter threats directed at them
- Wide range of military equipment including clothing, armour, weapons, personal communications equipment with optimized characteristics, operation and performance enhanced to meet changing conditions automatically

# Annual DoD Investment in Nanotechnology; 2006 estimated.

DoD, USA "Defence Nanotechnology Research and Development Programs", May 8, 2006



# Defence and Security

- Changing military requirements brings need for new technologies: to negate camouflage, & allow for passive, undetectable surveillance and target ranging
- DSTO CTD contract – three years & up to $ 2.7 million. Developing QPI to enable imaging over greater distances
- International interest from other key military organizations
- Large markets but long development lead times

# Processed Image Shape

- Defence Science Technology Organization (DSTO) $ 2.7million research contract commenced

Conventional Image

Iatia Processed Shape Image

# vii. Cosmetics

# Nanotech Skin Creams

- Anti-Wrinkle Nanotech Skin Cream: As compared to conventional skin creams that sit on top of the skin, nanotechnology-enhanced cosmetic treatments penetrate deep beneath the surface and affects the base molecular layer.
- Nanocrystalline Sunscreen: Zinc oxide provides broad-spectrum protection against UVA and UVB rays. Z-COTE by BASF: Nano-dispersed zinc oxide is the basis of Z-COTE.
- **4nm Spheres for Cosmetics:** Used in orthopaedic and dental surgeries to facilitate the bone rebuilding, hydroxyapatite is gaining ground in cosmetic skincare for women over 60.
- **Nano Gold Anti-aging:** In one-time use, about 1 billion nano- gold powder grains work on the skin to prevent aging by moisturizing (lasts for 72 hours in one time use) with whitening and anti-wrinkle effects.

# Nanotech Skin Creams (Continued)

- Eternalis Anti-aging: Anti-aging formulations based on the latest advances in nanotechnology for nourished, radiant, firmer and younger looking skin.
- Nanolotion: The nanolotion melts into skin thanks to its ultra fine moisturizing texture (nanotechnology)...
- NanoCream Filters: NanoCeram® pleated filter cartridges provide unusually high flow rates, yet provide extremely efficient filtration solutions, low pressure-drop associated with a 25-35 filter, yet achieving a removal efficiency of 99.9% for 0.25 particles.

**Source:** various

# viii. Agriculture

# Ten Big Problems for Humanity in the Next 50 Years

**AGRICULTURE**

1. Energy
2. Water
3. Food
4. Environment
5. Poverty
6. Education
7. Democracy
8. Population
9. Disease
10. Terrorism and War

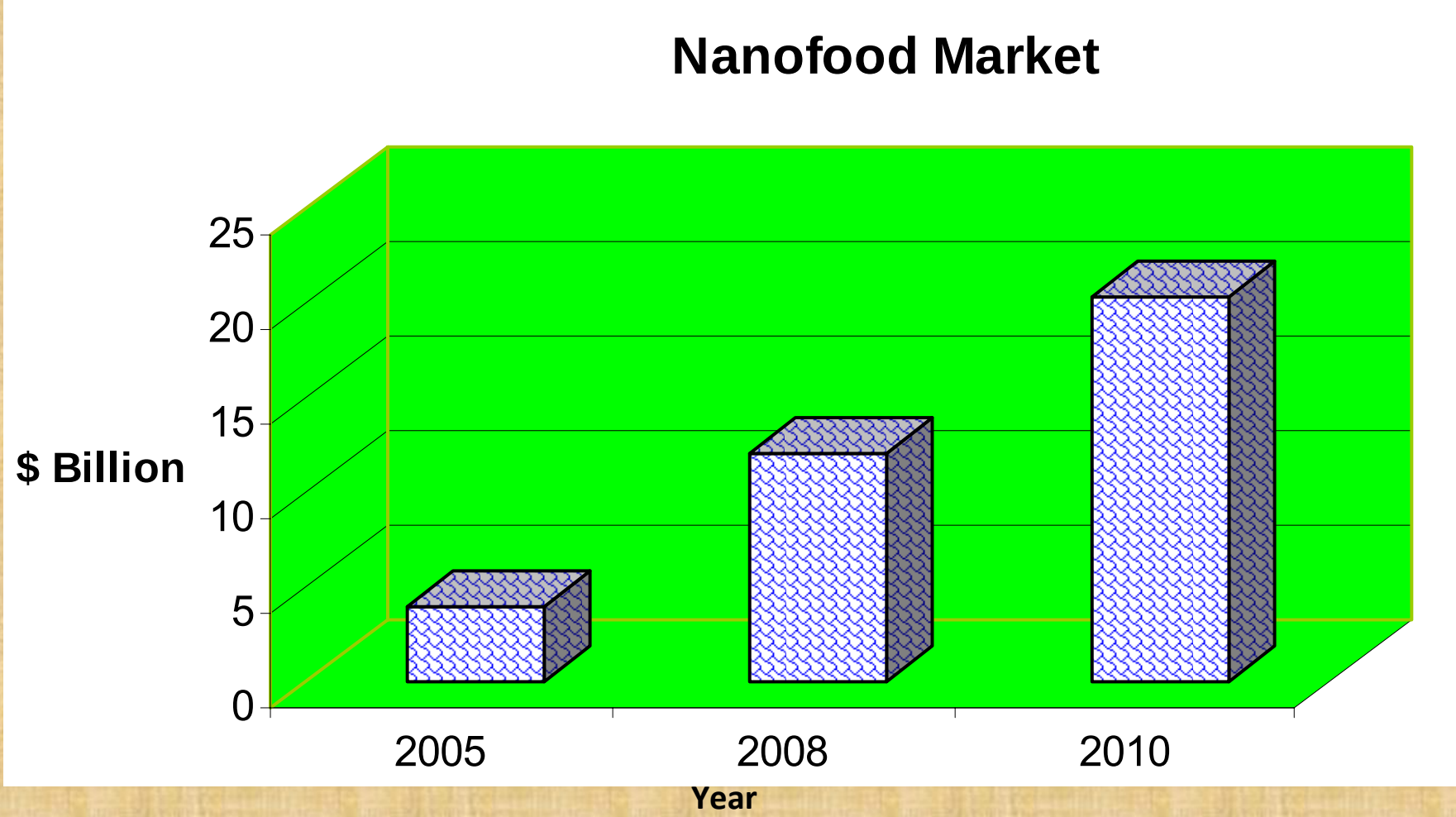
**Source:** Alan MacDiarmid, em São Carlos, SP, abril de 2005

# Fluorescent nanoparticles shed light on plant proteins

- Researchers have employed fluorescent semiconducting nanoparticles - or quantum dots - to label plant proteins. This is the first use of quantum dots for live imaging in plant systems; previously they have been applied to live mammalian cell cultures

The University of California, Riverside, USA

# Why Nanotechnology is Important?




**Source:** Helmut Kaiser Consultancy, Germany

# Nanotechnology in Food & Agriculture

**Food industry is facing some pretty dominant issues to its business:**

| | |
|---|---|
| Productivity | Technology Development |
| Cost Effectiveness | Product Innovation |
| Fast and Easy-To-Use Solutions | Health Benefits |
| Food Safety | Disease Prevention |
| Quality Assurance | Consumer Perception |

## Nanotechnologies can provide the following solutions

1. Nanoscale biosensors for pathogen detection and diagnosis.
2. Delivering bioactive ingredients in foodstuffs through improved knowledge of food materials at the nanoscale.
3. Nanocale filtration systems for improved texture modification.

**Source:** http://www.nanofood.info

# Nano Food: Examples

- Nanocapsules and nano-objects for "on demand" preservatives, enriched food, flavour, smell, taste and colours
- Interactive food: attractive surface treatment, glaziers and colours,
- Improvement of food safety and quality, Extension of products shelf-life
- Nanotechnology for food processing
- Nanocontrol of healthy digestion tube and micro-flora, digestion more compatible food
- Improved cooking, control of food ingredients
- Alternative feeding : transmucosal, skin etc..
- Special foods for: Hospitals, Space, Hot and Cold areas
- Controlled extraction and release of nanoparticles
- Nanocarriers for food and delivery of nutrients

**Source:** http://www.hkc22.com/nanofood2040.html

# Food Packaging: Examples

- Magnetic nanocomposite for tag sensors
- Nano-particle filled polymers
- Enhancement of durability and usability of plastic packaging
- Nanoprinted, intelligent packaging, controlled release, nano-additives, nanocoding of plastics and paper materials for authentication & identification purposes
- Radio Frequency Identification (RFID), monitoring tagging, trade mark & fraud protection, improved supply chain efficiency, nanobarcodes
- In situ sensors, food quality monitoring (e.g colour), control and nutraceuticals delivery, paper and plastics with sensing ability, portable DNA / protein chips for food quality tests
- Extreme condition packaging (for hot, cold, aerospace areas)

**Source:** http://www.hkc22.com/nanofood2040.html

# Nano Composites

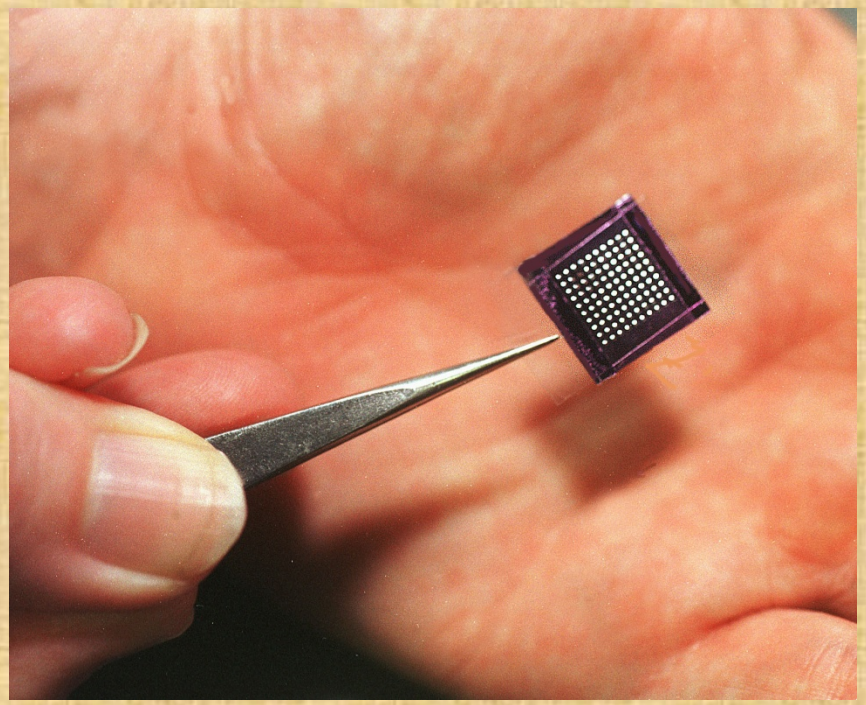
Nano food-packaging film
(Bayer Polymer Inc)

Lighter and stronger

Minimizes loss of $CO_2$ from beer

Nanoclay particle based beer bottle
(Nanocor Inc)

# Nano-Electronic Tongue



Nano-Electronic Tongue

Quality control for beverages by electronic tongue

**Source:** Kraft Foods

# Nano Feed for Chicken

- Nano Selenium may stop bird flu
- Nano Chicken Feed – polystyrene nanoparticles bind with bacteria in chickens as alternative to chemical antibiotics

**Source:** Biofactors Journal, 2001 Altair Nanotechnologies Ltd

# ix. Environment

# Nanotechnology and Environment

- Airborne nanorobots could be programmed to rebuild the thinning ozone layer.
- Contaminants could be automatically removed from water sources and oil spills could be cleaned up instantly.
- Many resources could be constructed by nanomachines: Cutting down trees, mining coal or drilling for oil may no longer be necessary. Resources could simply be constructed by nanomachines.
- Manufacturing materials using the bottom-up method of nanotechnology also creates less pollution than conventional manufacturing processes. Our dependence on non-renewable resources would diminish with nanotechnology.

# Water Purification by Nanotechnology

- Water purification is among the most challenging health, social and technological issues facing the world
- Development of nanoscale sensors that can be applied to membrane surfaces, enabling optimized maintenance of water purification membranes and significant extension of their lifetimes

# Nanomaterial Filters Water at Low Cost

New nano-material could reduce the cost of filtering and recycling water in a few years' time because it works better than conventional cleaning filters or membranes. It eliminates unwanted matter like dissolved salts and chemical compounds in water by using ultraviolet and visible light. The material then clears its surface to collect more unwanted material.

**Source:** http://www.nanotechnology.com, 4th June, 2007

# x. Textiles

# Nano-Tech Clothing

- Nano-Tech Ski Jacket : Nanotechnology makes the two-layer laminate windproof, waterproof, breathable and grime resistant, uses Nano-Tex enhancements.
- Wrinkle-Resistant, Stain-Repellent Nanotech Clothes: California-based Nano-Tex forms a barrier that causes liquids and stains to bead up on the surface and prevent absorption. It is wrinkle-proof but repels stains from perennial offenders like soda, coffee, wine, mayonnaise and syrup.

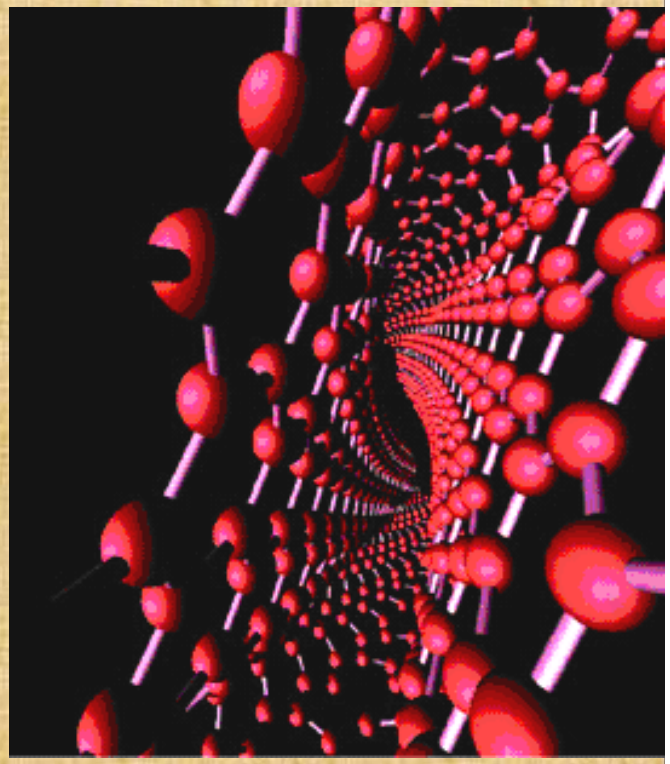
# xi. Sports

# Nano-tech Products

- Nano-tech Sunglasses: Ohio-based Nanofilm uses nanotechnology to produce protective and antireflective ultrathin polymer coatings for eyewear. It not only seals and repels grime and skin oils but also makes the lenses more responsive.
- Nano-Tech Tennis Rackets: Lightweight, oversized-head models are made out of high modulus graphite with carbon nanotubes supplied by France's Nanoledge. One hundred times stronger than steel, yet one-sixth the weight and five times more rigid.
- Nano-Tech Tennis Balls: Remain playable for four weeks. double the life of normal balls by coating the ball's inner core with 20 microns thick layered sheets of clay polymer nano-composites - each 1 nanometer thin (InMat).

# The Nano Revolution in Materials

- This new science of the small has brought to market self-cleaning windows, smog-eating concrete and toxin-sniffing nanosensors.
- Three hundred nanoengineered products are now commercially available; $32 billion worth of them were sold last year, with sales expected to top $1 trillion by 2015.
- Nanoscientists are creating revolutionary materials like single atom thick coatings, carbon nanotubes up to 50 times stronger than steel (yet 10 times lighter), and quantum dots that could enable us to change the color of almost any object instantaneously.



**Source:** ARCHITECT Magazine, May 1, 2007

# xii. Aerospace

# Nanotechnology in Aerospace

(A decrease in payload/onboard instrumentation of a missile leads to about nine times reduction in the booster weight)

- Lightweight and strong materials
- Nano-sensors, e.g. gyro
- Nanoelctronics and computers with high density memories
- Lightweight, wrinkle-free, stain-free and responsive clothing
- Personalized communication equipment
- Nanocapsules and nano-objects for "on demand" preservatives, enriched food, flavour, smell, taste and colours
- Solar cells: high efficiency and lightweight
- High energy density batteries

# xiii. Oil and Gas

# Nanotechnology in Oil and Gas Exploration

Nanotechnology has been used in almost in any kind of Industry for increased production due to nanomaterials, nanodevices and nano techniques.

In particular for Oil and Gas industry several important applications of Nanotechnology are tried:

1. To develop geothermal resources by increasing thermal conductivity.
2. Development of non-corrosive materials.
3. Use of nano scale metals to separate deposits for geothermal exploration.
4. Developing nano catalysts and nano scale membranes for GTL (Gas To Liquid) production.
5. Improved oil and gas production to separate oil from gas in the reservoir through improved studies of the process at molecular (nano scale) level.
6. More effective separation of oil and water through nanotechnology.

# Nanotechnology in Oil and Gas Exploration

(Continued)

7. To improve the drilling speed by mixing nanosized particles with fluids.
8. Reduced pollution through filters and particles at nano-scale which allows the removal of volatile organic compounds from oil vapour and mercury from soil and water.
9. Using new nanotech sensors for improving exploration and which last longer than the present sensors.
10. Use of improved catalysts for on-site field upgrading combined with hydrogen methane production.
11. Lightweight and rugged materials to reduce weight requirements on off-shore platforms and more-reliable and energy-efficient transportation vessels.
12. New imaging techniques of computation for improved discovery, sizing and characterization of reservoirs.
13. Small drill-hole evaluation instruments to reduce drilling costs.
14. Use of Nano Sensors to provide data on reservoir characterization, fluid flow monitoring and fluid type recognition.
15. Nano-based high performance temperature and pressure sensors

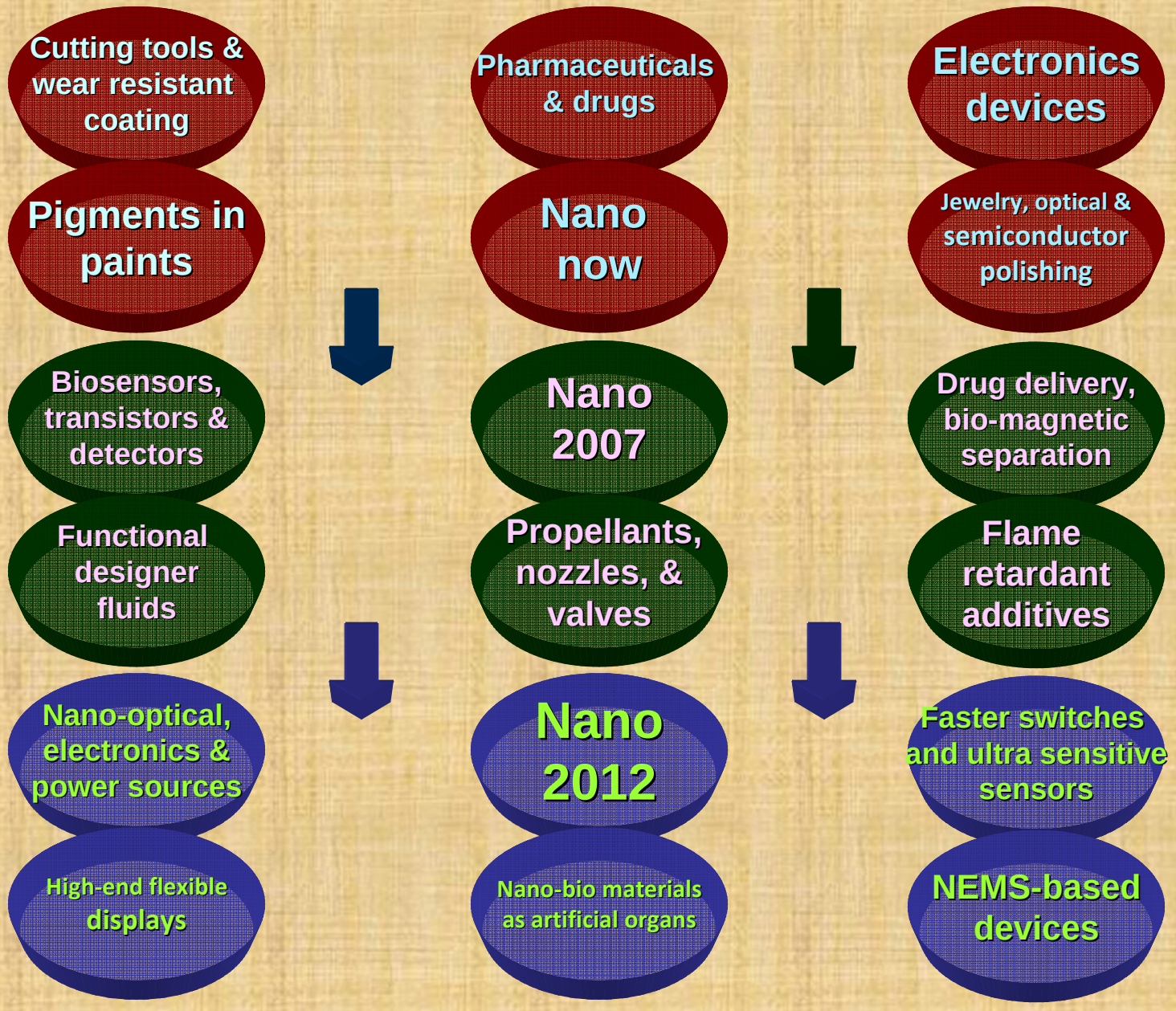
# 8. Nano Present and future

# Development of Nanotechnology

## Current and future applications

| Current | Short Term | Long Term |
|---|---|---|
| Nano Filters | Paints | Nanotube Composites |
| Cosmetics | Remediation | Lubricants |
| Composites | Fuel Cells | Magnetic Materials |
| Clays | Displays | Medical Implants |
| Coatings | Batteries | Machinealble Ceramics |
| Tougher Tools | Fuel Additives | Water Purification |
| | Catalysis | Battle Suits |

# Nano Future


Cutting tools & wear resistant coating
Pigments in paints
Biosensors, transistors & detectors
Functional designer fluids
Nano-optical, electronics & power sources
High-end flexible displays
Pharmaceuticals & drugs
Nano now
Nano 2007
Propellants, nozzles, & valves
Nano 2012
Nano-bio materials as artificial organs
Electronics devices
Jewelry, optical & semiconductor polishing
Drug delivery, bio-magnetic separation
Flame retardant additives
Faster switches and ultra sensitive sensors
NEMS-based devices

# 9. Nanotechnology for Developing Countries

# Nanotechnology for Developing Countries

- Agriculture
- Energy
- Water Treatment
- Healthcare
- Substitution of Precious Materials

# Agriculture

- Enhanced productivity through control of nutrients and pesticides (smart pesticides)
- Control of microbial and chemical contamination
- Nano chicken feed, nano-selenium to stop bird flu

# Energy

- Solar energy: Nanotechnology hike hydrogen production, Solar Cells
- Energy saving: more efficient and long life solid state lighting
- Energy saving through the use of advanced materials
- Automobiles with greater fuel efficiency

# Water Treatment

- Low cost filters for potable water
- Removal of contaminants from water sources
- Removal of oil spills

**Healthcare / Nanomedicine**

- Diagnostic sensors (Easy detection of diseases)
- Anti-cancer drugs
- AIDS prevention

# Substitution of Precious Materials

- Nanostrctured ceramics to substitute special alloys, tungsten etc
- Catalysis research to substitute platinum in petrol industry
- Low cost flat panel displays
- Nano catalysts and nano scale membranes for GTL (Gas To Liquid) production
- More effective separation of oil and water through nanotechnology
- Small drill-hole evaluation instruments to reduce drilling costs

# 10. Nanotechnology Activities in Developing Countries

# Nanotechnology in Pakistan

# Constitution of the National Commission on Nano- Science & Technology (NCNST)

Realizing the importance of Nanotechnology the Government of Pakistan setup a National Commission on Nano-Science and Technology (NCNST) in October, 2003.

The main objective of the NCNST was to popularize R&D and its applications for the socio-economic benefits of the people of Pakistan.

NCNST developed two prong strategies:

a) To recommend the Government to support Nano-Science & Technology Projects of universities and R&D centers which are already involved in precision science and technology at micro level so that they can conveniently switch over to nano-scale precisions. Some of the precision methods involve Solid State Science, Biological Science, Molecular Chemistry and Atomic and Nuclear Sciences.

b) To suggest the Government to set a central facility in Nano-Science and Technology on priority areas according to the needs of Pakistan.

Over these years some institutions have already started R&D in Nano-Science and Technology, which will be briefly described

# National Commission on Nano-Science and Technology

**(1st tenure: October 2003 - October 2006, 2nd tenure: October 2006 - 0ctober 2008)**

**[Gazette No. 5(54)/2003-ASA (P&C)] Government of Pakistan**

**Ministry of Science and Technology : October 31st, 2003 and July 24th, 2007**

**New Composition**

1. **Dr. N.M.Butt** — Chairman
   Chairman,
   Pakistan Science Foundation, Islamabad.
2. **Dr. Abdullah Sadiq** — Member
   Rector, GIK Institute of Engineering and Technology,
   Topi, Swabi.
3. **Dr. Anjum Tauqir** — Member
   DG, Metallurgy Department, KRL, Kahuta, Rawalpindi.
4. **Prof. Dr. Fazal Ahmad Khalid** — Member
   Dean Faculty of Metallurgy and Materials Engineering,
   GIK Institute of Sciences & Technology, Topi, Swabi.
5. **Dr. Hameed A. Khan, H.I., S.I.** — Member
   Executive Director, COMSATS Secretariat, Islamabad.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6. **Prof. Ikram-ul-Haq** — Member
   National Centre of Excellence in Physical Chemistry,
   University of Peshawar, Peshawar.
7. **Dr. Khalid Javed Chaudhry** — Member
   Chairman/(CEO), Medi Pak Private (LTD.),
   132 Industrial Estate, Kot Lakhpat, Lahore.
8. **Dr. Khalil A. Qureshi H.I., S.I.** — Member
   Member (CAC)
   Pakistan Atomic Energy Commission, Islamabad.
9. **Prof. M.A.K. Malghani**, — Member
   Balochistan University of Management
   Sciences and Information Technology, Quetta.
10. **Prof. M. Iqbal Chaudhry** — Member
    Acting Director, HEJ Research institute of chemistry,
    University of Karachi, Karachi.
11. **Prof. Mohammad Mujahid** — Member/Secretary
    Institute of Space Technology, Islamabad


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| | | |
|---|---|---|
| **12.** | **Prof. Mohammad Naseem**<br>Principal, Dawood Engineering College, Karachi | Member |
| **13.** | Representative of NESCOM | Member |
| **14.** | **Dr. Shahzad Alam**<br>Principal Engineer, Pakistan Council of Scientific and Industrial Research, Lahore. | Member |
| **15.** | **Prof. shahzad Naseem**<br>Microelectronics Research Centre Punjab University, Lahore. | Member |
| **16.** | **Dr. Shaukat Hameed Khan**<br>Member (S&T), Planning and Development Commission, Islamabad. | Member |
| **17.** | Representative of M/o Science and Technology (Deputy Scientific Adviser (P&C)) | Member |


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# Nanotechnology Activities

a. Lectures on Nanotechnology
b. Conferences Organized & Co-sponsored
c. Research Projects
d. International Interaction


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# a. Lectures on Nanotechnology

A series of lectures on New Materials and Nanotechnology were delivered by Dr. N.M. Butt over the years.

## 1995– 2005

- PINSTECH, **(New Materials)**, **Islamabad,** 1994-1997
- Conference on Nanotechnology, COMSATS Institute of Information Technology (CIIT), **Islamabad,** 2001
- **Nanotechnology: An Overview:** The Twelfth Conference of the Islamic Academy of Sciences, **Islamabad,** October 14-17, 2002
- **Nanotechnology: The Key Technology:** Pakistan Academy of Sciences, **Islamabad,** July 31, 2003
- NUST (Material Science), **Rawalpindi,** February2004
- **Review Paper,** International Conference, PCSIR **Lahore,** September 2004
- PCSIR (Advanced Materials), **Lahore,** 2005
- **Nano-technology:** NUST, EME, **Rawalpindi,** 2005
- **Nano Science and Technology in Pakistan:** International Congress on Nano-technology (ICNT 2005), **San Francisco, California, USA**, October 30 – November 4, 2005
- **Nanotechnology,** 18$^{th}$ FAOBMB Symposium on "Genomics and Proteomics in Health and Agriculture", Punjab University, Lahore, November 23, 2005



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# Lectures – 2006

1. “Review of Nanotechnology and its applications”, Riphah International University, Islamabad, “Nanochemitry Conference”, Karachi
2. Pakistan Institute of Physics (PIP) Conference: (UET) Lahore.
3. University of Faisalabad / Faisalabad Chamber
4. Sialkot Chamber of Commerce
5. CIIT [NIIT], Islamabad
6. Live-Stock Conference, Lahore
7. Pakistan Engineering Council, Islamabad
8. International Conference on Technology based Development: Strategies & Options for Pakistan, Islamabad (Organized by COMSATS)


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# Lectures – 2006 (Continued)

9. ***"Introduction to Nanotechnology"***, Computer Society of Pakistan, Rawalpindi / Islamabad Chapter
10. ***"Comparative study of Bulk and Nanoparticles Ferrites using the Mossbauer Spectroscopy"***, 3rd International Congress of Nanotechnology (ICNT 2006), San Francisco, California, USA. 30th Oct. - 2nd Nov. 2006
11. ***"Comparative study of Bulk and Nanoparticles Ferrites using the Mossbauer Spectroscopy",*** Advanced Light Source, Lawrence Berkeley National Laboratory, University of California at Berkeley, California, U.S.A. 3rd Nov. 2006
12. ***"Comparative studies of Mossbauer Parameters of Bulk and Nanoparticles Ferrites using the Mossbauer Spectroscopy"***, Department of Materials Engineering, University of Dayton, 300 College Park Dayton, Ohio, U.S.A., Oct. 28, 2006
13. ***"Comparative studies of Bulk and Nanoparticles Ferrites using the Mossbauer Spectroscopy"***, Department of Physics, National Nanotechnology Research Centre, Bilkent University, Bilkent, Ankara, Turkey.
14. ***"Comparative studies of Nano Size and Bulk Size Ferrites using the Mossbauer Spectroscopy",*** Department of Physics, KOC University, Istanbul, Turkey.

- **Media:** Radio, TV and Print media has been utilized for creating awareness of the importance of Nanotechnology for National benefits.


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# Lectures – 2007

1. **The Era of Nanotechnology,** PAF Academy, Risalpur, January 12, 2007
2. **Recent Trends in Nanotechnology,** International Conference on the Role of Chemistry and Biochemistry for National Development, University of Balochistan, **Quetta,** April 16-18, 2007
3. **Nanotechnology & Health Care,** Army Medical College, **Rawalpindi,** 19th May, 2007
4. **Nanotechnology as a Multidisciplinary Subject,** CIIT, Islamabad Campus, **Islamabad,** 28th May, 2007
5. **Nanotechnology and its Wonders,** Quaid-i-Azam University (QAU), **Islamabad,** 20th July, 2007
6. **Nanotechnology and its Current Status,** Pakistan Academy of Sciences (PAS), **Islamabad,** 31st July, 2007
7. **Nanotechnology and Diffraction from Materials**, National Workshop on Crystal Structure Determination using Powder X-Ray Methods, Center of Solid State Physics, Punjab University, **Lahore,** 15-17 August 2007
8. **Nanotechnology and Microbiology,** Department of Microbiology, University of Karachi, **Karachi,** September 1, 2007
9. **Overview of Nanotechnology in Pakistan,** Seminar on the Role of Nanomaterials in Biotechnology and Medicine, NIBGE, **Faisalabad,** September 10, 2007
10. **Nanotechnology and Physics,** Physics Department, CIIT, Chak Shehzad Campus, Park Road, **Islamabad,** November 29, 2007



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# 8. Lectures 2008

1. **Nanotechnology and its Current Status,** Regional Workshop on Nanotechnology, Sultan Qaboos University, Muscat, Oman, January 13-14, 2008
2. **Nanotechnology and its Applications in the Labour Market,** Regional Experts Meeting in the Field of University Scientific Research and the Labour Market, Islamabad, February 25-27, 2008
3. **Overview of Nanotechnology,** International Workshop on Nanomedicine, COMSTECH, Islamabad, March 13-20, 2008
4. **Nanotechnology for Quality Consumer Goods,** National Conference on Consumer Protection in Pakistan, "Science and Technology for Promoting Quality and Standards", Karachi, March 15, 2008
5. **Application of Nanotechnology in Agriculture,** National Conference on "Recent Advances in Agriculture Biotechnology", Islamabad, March 18, 2008



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# b. Conferences on Nano-Science and Technology Organized / Co-Sponsored by NCNST

i. Nano-Science and Technology in Pakistan, COMSATS Headquarters, Islamabad, June 13-14, 2005

ii. Nano-Science and its Applications, Nanotech Week, 30th International Nathiagali Summer College, Nathiagali, July 4-9, 2005

iii. 9th International Symposium on Advanced Materials, ISAM-2005, Islamabad, September 19-22, 2005

iv. Nanochemistry, HEJ, Karachi, January 9, 2006

v. International School on Surfaces, Thin films, Nanostructures & Application, CIIT, Lahore, October 26 - 31, 2006

vi. International Meeting on Emerging Technologies and Developing Countries, COMSATS Headquarters, Islamabad, November 28-29, 2006

vii. 2nd International Conference on Frontiers of Advanced Engineering Materials (FAEM-06), Pakistan Institute of Technology for Minerals and Advanced Engineering Materials (PITMAEM), PCSIR Laboratories Complex, Lahore, December 4-6, 2006

# c. Research Projects

Following research projects in Pakistan are being carried out in various organizations/institutions, evaluated and recommended by NCNST

| No. | Project | Institution | Rs million | Funded by |
|---|---|---|---|---|
| i. | Synthesis and Characterization | PIEAS | 60 | HEC |
| ii. | Nano-magnetism | QAU | 137 | HEC |
| iii. | Micro/Nano electronic devices | CIIT | 189 | HEC |
| iv. | Nano-Composites | GIK | 195 | HEC |
| v. | Nano-biotechnology | NIBGE | 155 | MoST |
| vi. | Nano-devices, L.E.D. etc | PINSTECH | 196 | MoST |
| | **Total (US$ 15 million):** | | **932** | |

# Nanotechnology R & D in Pakistan

1. Nanocomposites: Copper-Carbon Composites using Multi-Wall Carbon Tubes (MWCT)
   Prof. Fazal A. Khalid, M. Bashir, GIK, Topi
2. Nanotechnology Products of Various Oxides: Rare earth nano oxides
   Prof. Ikram-ul-Haq, University of Peshawar
3. (a). Synthesis of Biocompatible Gold Particles
   (b). Development of Nanobiotechnological Research at NIBGE: Functionalization Nanoparticles
   Dr. Irshad Hussain, NIBGE
4. Nanochemistry of Iron Oxide by Mossbauer Spectroscopy
   Prof. M. Mazar, Quaid-e-Azam University, Islamabad
5. Nano Research at Microelectronics Research Centre : Non-volatile memory devices, Magnetic Tunnel Junction Device
   Prof. Shahzad Naseem, Punjab University, Lahore
6. Nanoscience at Department of Physics CIIT, Islamabad: Quantum dot and thin films
   Dr. Arshad Saleem Bhatti, CIIT, Islamabad
7. Influence of Rate of Deposition on the Dewetting: Characterization of Nano-clusters
   Shaista Babar and A. S. Bhatti, University of Illinois at Urbana-Champaign
8. Nanotechnology Research at PIEAS: Mesoporous alumina
   Dr. Mazhar Mehmood, PIEAS, Nilore, Islamabad

# d. International Interaction

Some contacts are in progress for interaction with Nanotech laboratories in

- UK
- Germany
- USA
- China
- Korea
- Hong Kong

# Pakistan's Perspective

1. National Commission on Nano- Science and Technology (NCNST)
2. Funding of R&D projects on nanotechnology by HEC and MoST (~ Rs one billion)
3. Several R&D organizations working on nanotechnology: COMSATS, KRL, PIEAS, PINSTECH, PCSIR, Universities …
4. Establishment of nanotechnology lab at PCSIR, Lahore (Rs 15 million)
5. PC-1 for the Establishment of National Institute of Nano-Science and Technology

# India: Growth Opportunity through Nanotech

- Technology can help GDP touch $2 trillion
- Harnessing of technologies will help India achieve a Gross Domestic Product (GDP) of USD 2-3 trillion in the next 15 years, from the current USD 650 billion, according to [Reliance Industries Ltd Chairman and Managing Director, Mukesh D. Ambani]
- During the fiscal year (2006-07), Rs 1.8 billion were budgeted to set up seven to eight nano-science and technology centers in the country.

# Iranian Nanotechnology Initiative (INI)

- The Special Office of Nanotechnology Development established in the Islamic Republic of Iran Presidency in 2003
- Ten year strategy of nanotechnology development (2005-2014)
- ECO-NAN, ECO Nanotechnology Network- Proposed by Iran (2007)

# China

- National R&D Centres: National Centre for NanoScience and Technology, National Engineering Centre for Nano Technology and its Applications
- About 3000 S&T workers in 50 universities, 20 CAS institutes and 300 enterprises are working on nano-science and technology
- Market for nanotechnology products in 2006 was US$ 5.4 bn which will increase to US$ 155 bn in 2015

# Taiwan

- Six year nanoscience and nanotechnology programme with US$ 700 million launched in January 2004
- National nanotechnology programme is centred at the Industrial Technology Institute
- Taichung Science Park completed: A science-based industrial complex focusing on nanotechnology – 60 high-tech firms to invest US$ 5.78 billion, creation of 40-50 thousand jobs is expected

# 11. Conclusion


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# Matter of Concern

Looking on the current literature through the Internet and the initiatives on national level by various countries it is obvious that there is lot of race going on because of commercial and defense potential of Nanotechnology. Advanced countries would not invest without obvious gains of controlling the world economically and strategically.

*The more we go into the study, the more concern we feel the way the advanced countries, even India, are laying hands on Nano-Technology*.

This lecture is only an awareness attempt for Nanotechnology in the area of Multidisciplinary subjects. It is now upto the Scientists/Engineering's /Enterprogrammers to tap the unbound treasures of Nanotechnology for the benefit of our dear homeland.

**God Bless Us All, Ameen!**


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# 12. Video Clips

- Microplane-Shanghai Nanotech Inst-Helicopter Demonstration.MPG
- Micropump-Shanghai Nanotech Inst-Demonstration.MPG
- Microreducer- Shanghai Nanotech Inst-Demonstration.MPG
- Nanotechnology in Cancer.mpeg
- Soldier Nanotechnology.mpeg
- Nanobot vir caution.wmv


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# Thank You