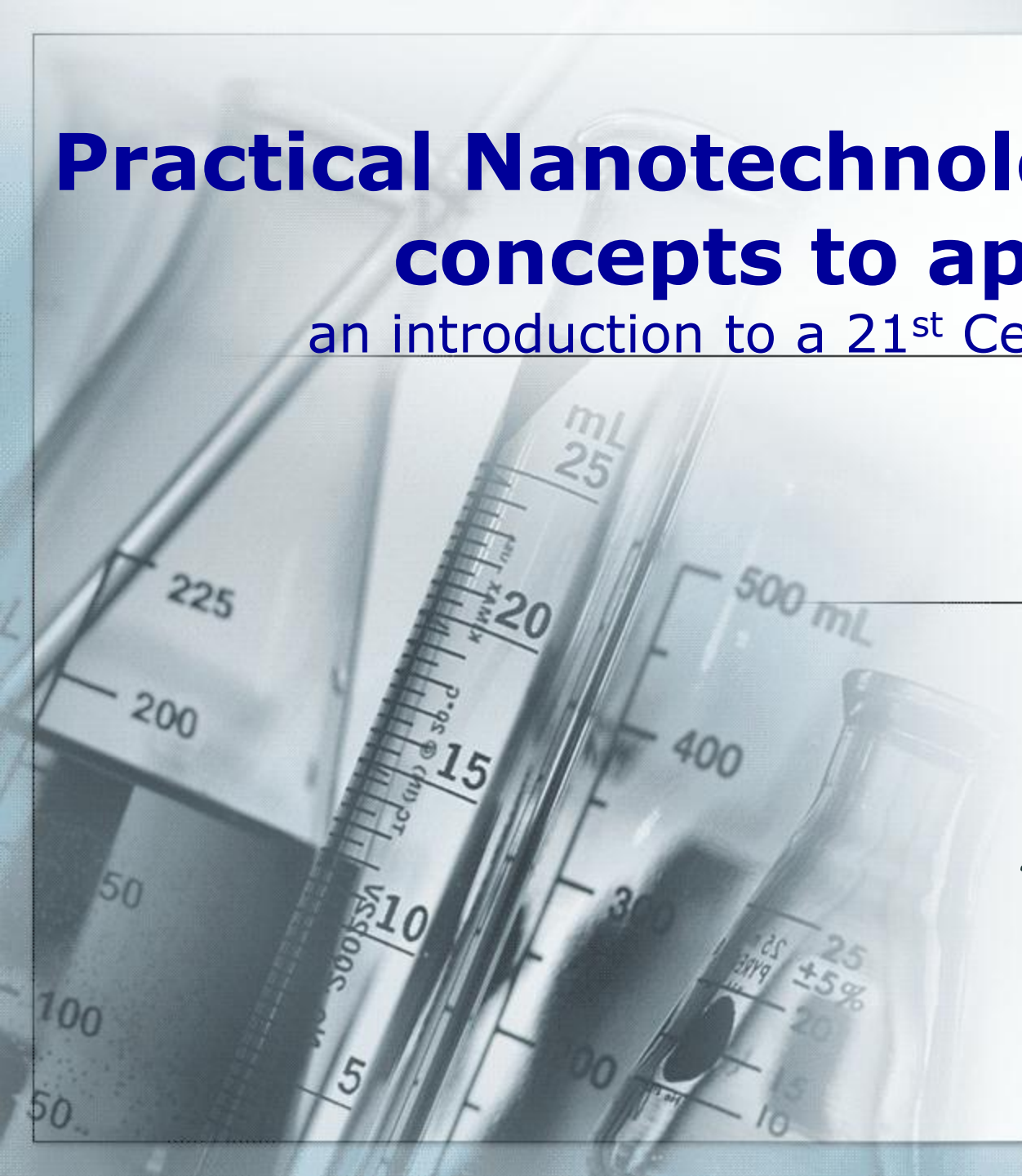
Practical Nanotechnology today- concepts to applications:

an introduction to a 21st Century Technology



Joydeep Dutta

Chair Professor in Nanotechnology

Sultan Qaboos University, Muscat, Oman

Knowledge Development

Rapid changes in the world in Technology and Society*:

1750 and 1900:	technical knowledge doubled
1900 and 1950:	technical knowledge doubled
Today:	Doubles every 5 years
> 2020:	Will double every 72 Days

* Staudt, E., Key note address, 20th ICDE World Conference Dusseldorf, Germany, Plenary Session, 2 April 2001.

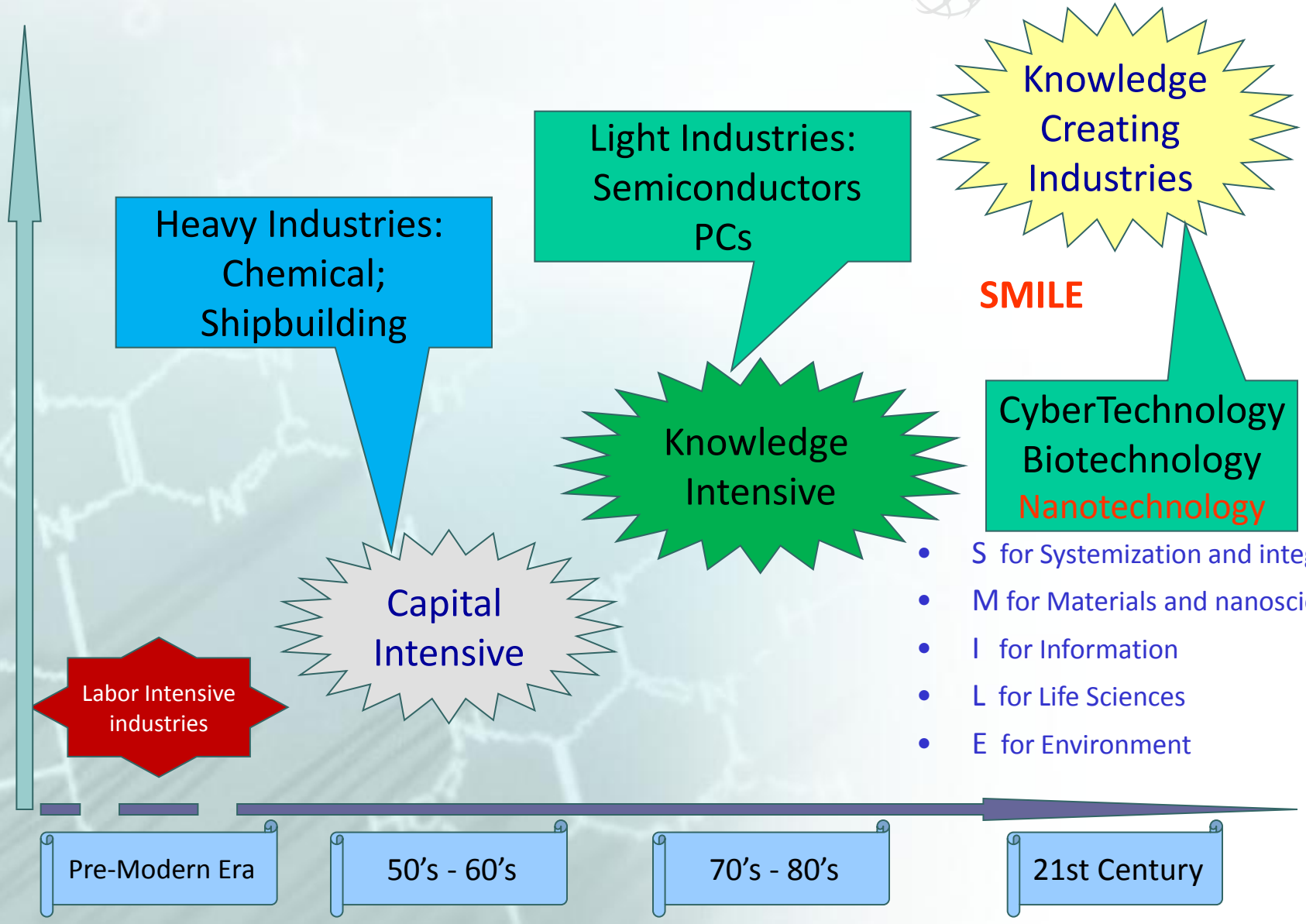
Past

- Stay with what works
- Slow dissemination of ideas
- Minimal media interest
- Few journals in central libraries
- Product controlled practice

Future

- “Innovate or die”
- Globalisation
- Instant adaptation of new techniques
- High media coverage
- Internet access to all
- Customer controlled practice

Driving Forces for Economic Growth



- S for Systemization and integration
- M for Materials and nanosciences
- I for Information
- L for Life Sciences
- E for Environment

Once upon a time… Big was good!

Great Wall stretches approximately 6,700 kilometers from east to west of China.

The Pyramid was originally 146.7 m and measured 230 m along its sides, covering an area of 53, 000 m^2

Nano-Properties & Phenomena?

NANOPHENOMENA are the remarkable "properties and phenomena" ballyhooed by scientists and pundits.

These remarkable properties and phenomena, that you will hear no end of, are due to one thing:

SIZE

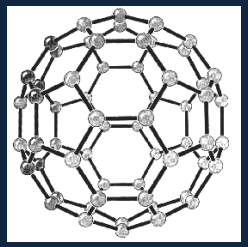
and very small size at that!

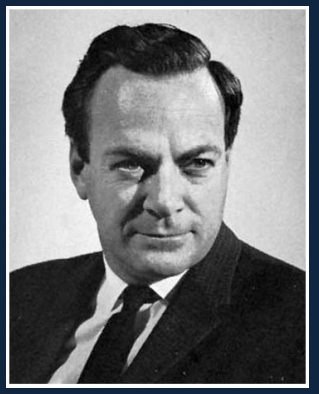
Introduction to NanoScience, (CRC Press), G. Louis Hornyak, Joydeep Dutta, Harry F. Tibbals and Anil K. Rao (2008)

Nanotechnology

AIT TECHNOLOGY EVENT

- **Dimensions below 100 nm**
- **Control of matter, fabrication of devices**





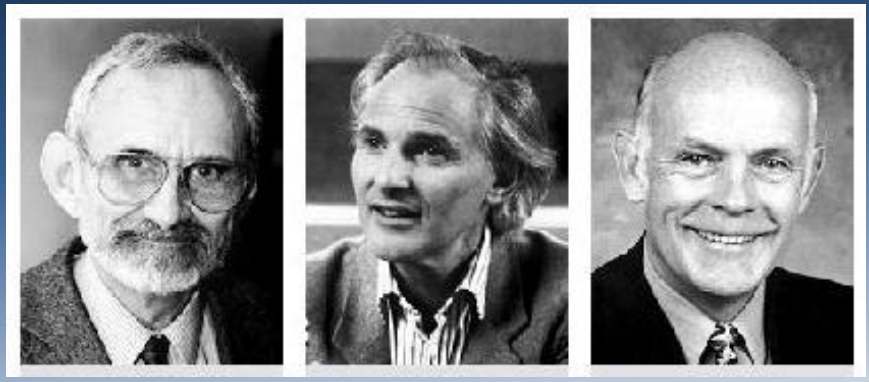
Feynman 1959"There's plenty of room at the bottom" Nobel Prize 1965

Taniguchi 1974"On the basic concept of Nanotechnology"

Binnig & Rohrer 1981STM Nobel Prize 1986

Curl, Krotto& Smalley 1985 Buckyball Nobel Prize 1996

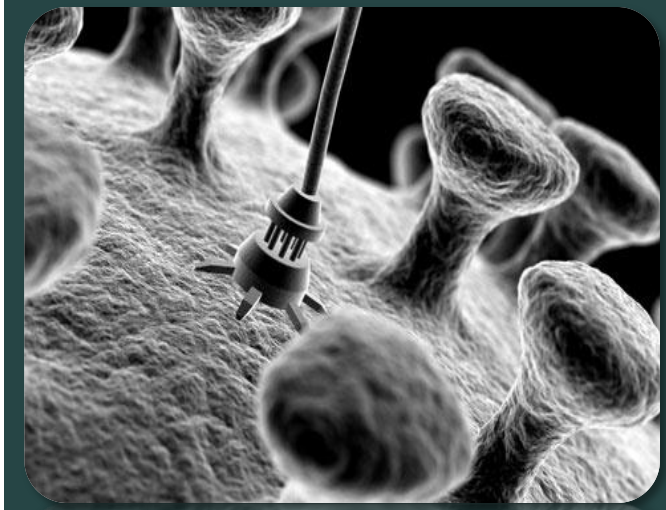
Drexler 1986"Engines of Creation"

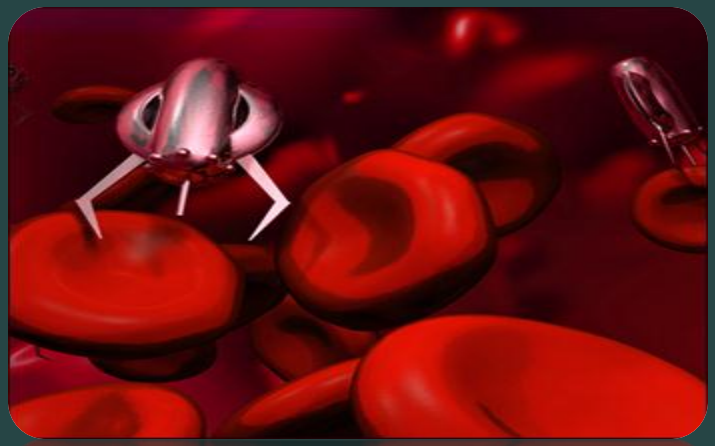


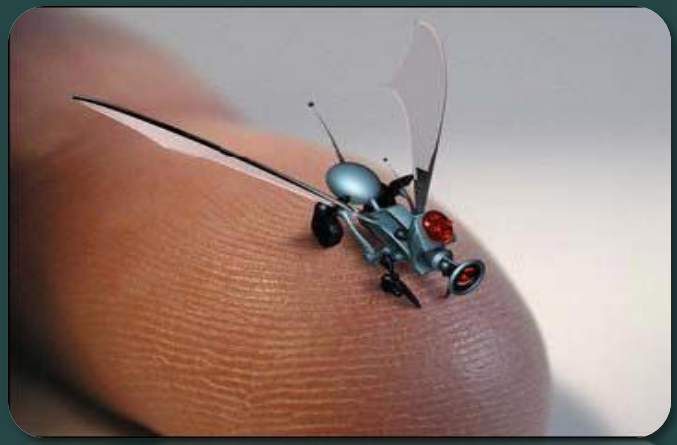
The Nano World

Vision

- To solve critical problems in the fields of ***Energy, Food & water, Electronics, Healthcare*** and many others.
- Fabricate innovative Nano products, devices and components for research and real-world use.
- Offer suitable alternatives to today's technology.

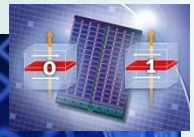
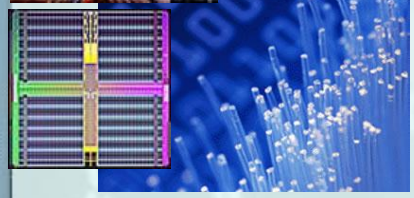






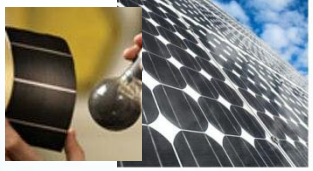
Nanotechnology Applications

Information Technology

- Smaller, faster, more energy efficient and powerful computing and other IT-based systems

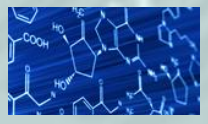
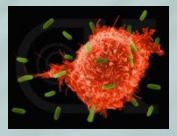
Energy



- More efficient and cost effective technologies for energy production
  - Solar cells
  - Fuel cells
  - Batteries
  - Bio fuels

Medicine

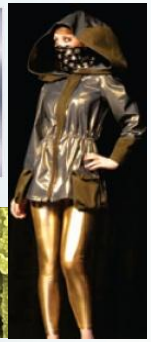
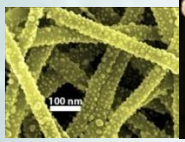


- Cancer treatment
- Bone treatment
- Drug delivery
- Appetite control
- Drug development
- Medical tools
- Diagnostic tests
- Imaging

Consumer Goods



- Foods and beverages
  - Advanced packaging materials, sensors, and lab-on-chips for food quality testing
- Appliances and textiles
  - Stain proof, water proof and wrinkle free textiles
- Household and cosmetics
  - Self-cleaning and scratch free products, paints, and better cosmetics

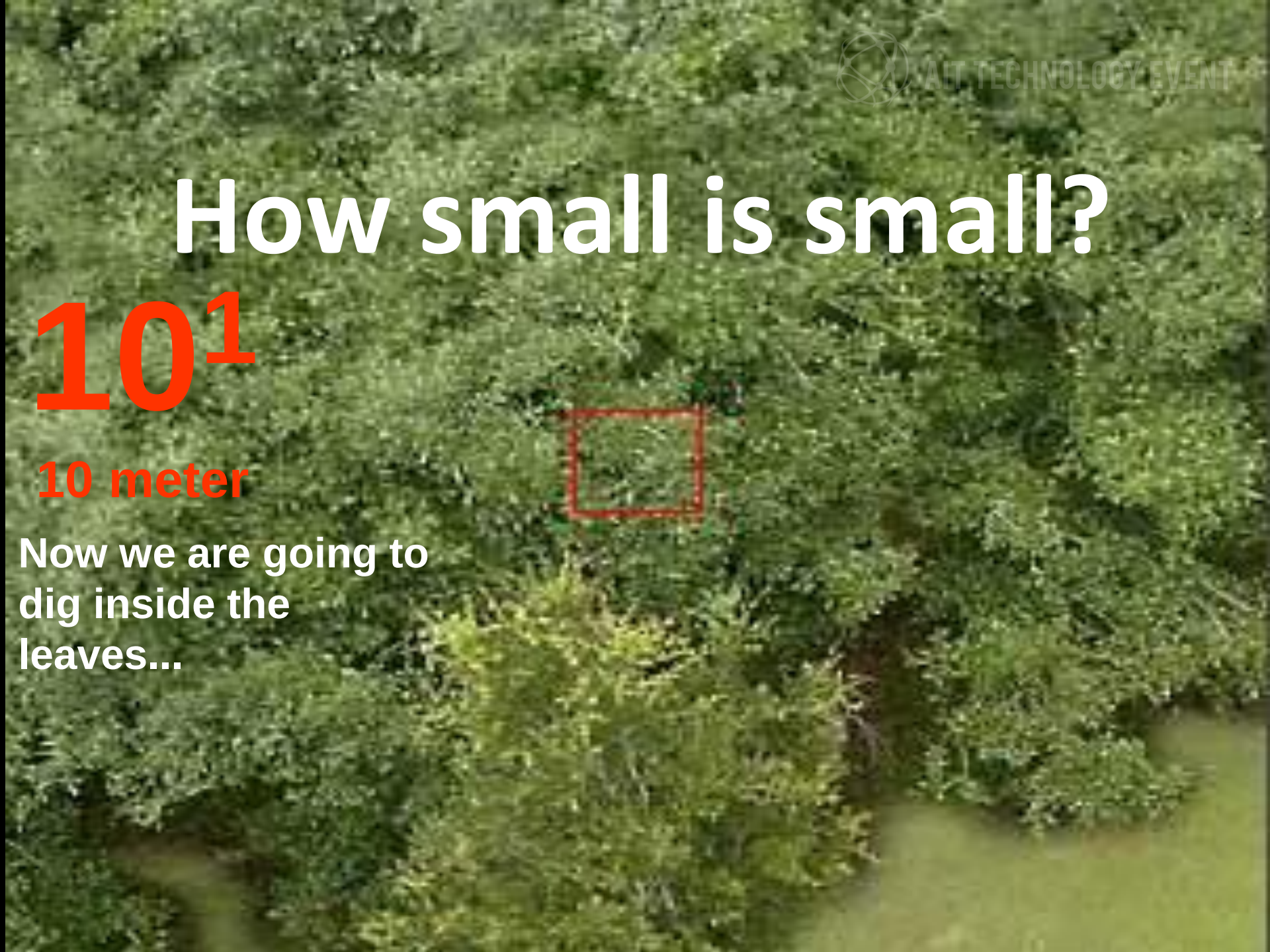
Nanomaterials in Consumer Products: The Future is Now

(Photo by David Hawxhurst-Woodrow Wilson International Center for Scholars.)

AIT TECHNOLOGY EVENT

Nanotechnology

" The manufacturing technology of the 21st century"


How small is small?
10^1
10 meter
Now we are going to dig inside the leaves...

10^{-1}

10 Centímeters

Getting closer at 10 cm ...We can delineate the leaves.

10^{-3}

1 Millímeter

AIT TECHNOLOGY EVENT

The cellular structures start showing...

10^{-4}

100 microns

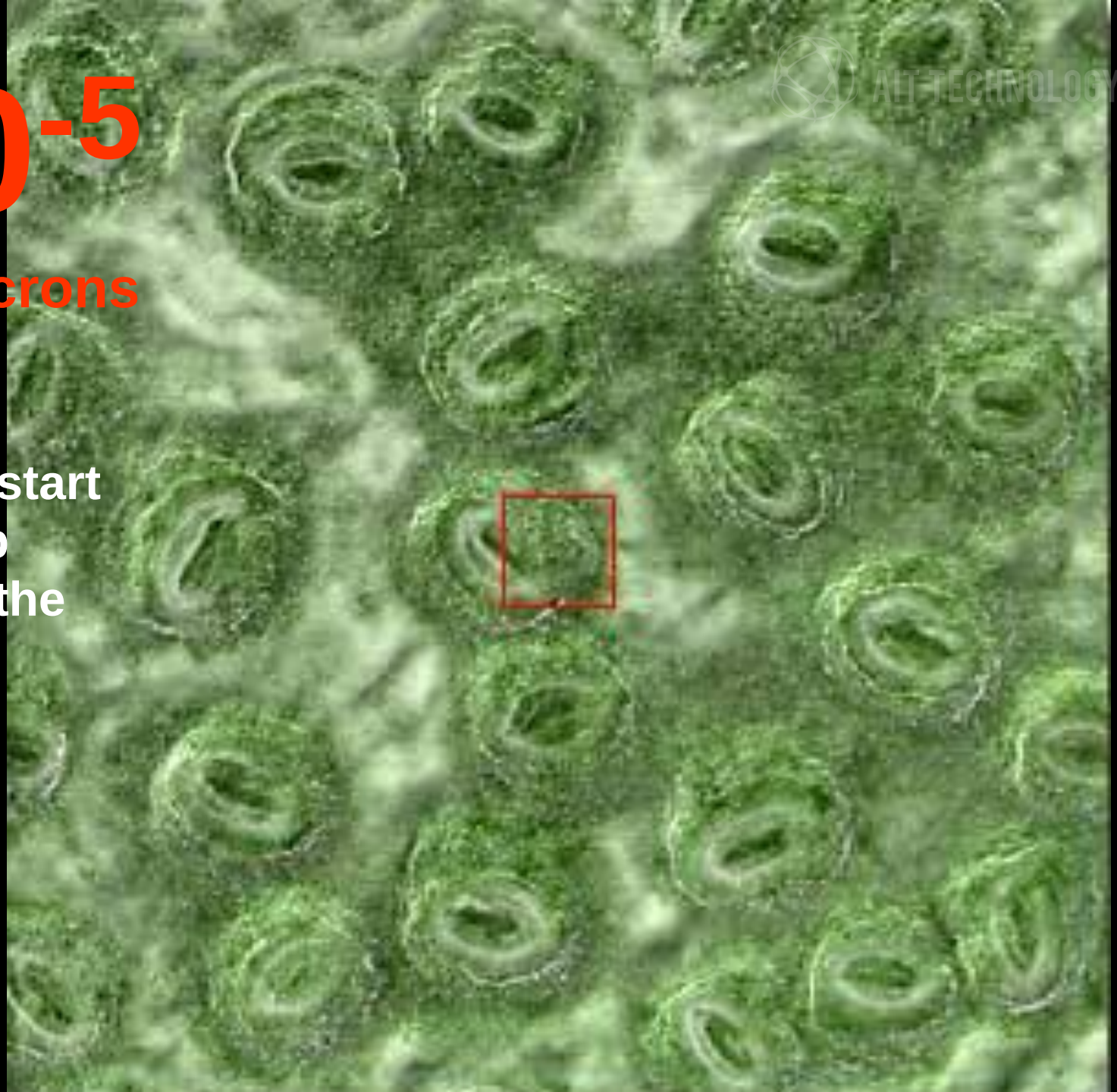
The cells can be defined.

We can see the union between them.

10^{-5}

10 microns

Let us start our trip inside the cell…



10^{-6}

1 micrón

The nucleus of the cell is visible.

10^{-7}

100 nano meter

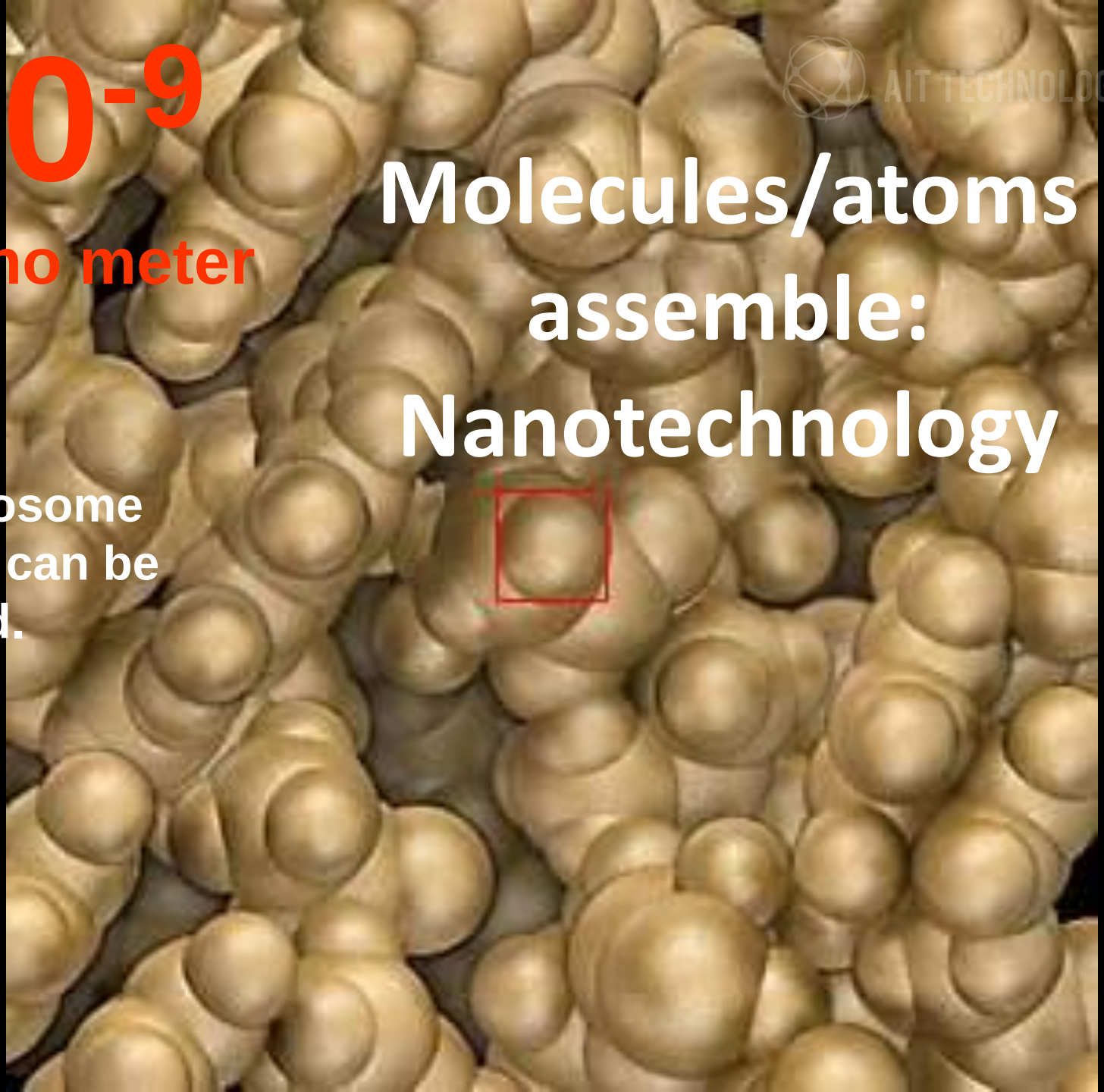
Nanotechnology is all in this scale

Again we changed the messuring unit to adapt to the miniscule size. You could see the chromosomes.

10^{-8}

10 nano meter

In this micro universe the DNA chain is visible.



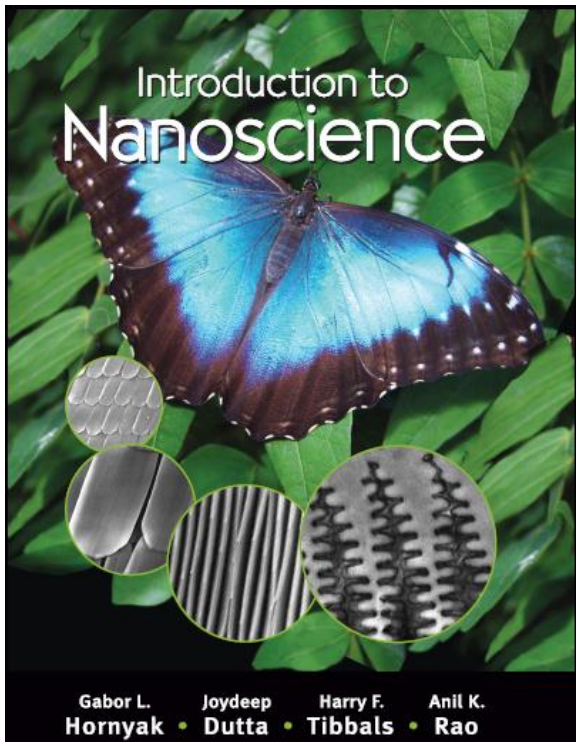
10^{-9}

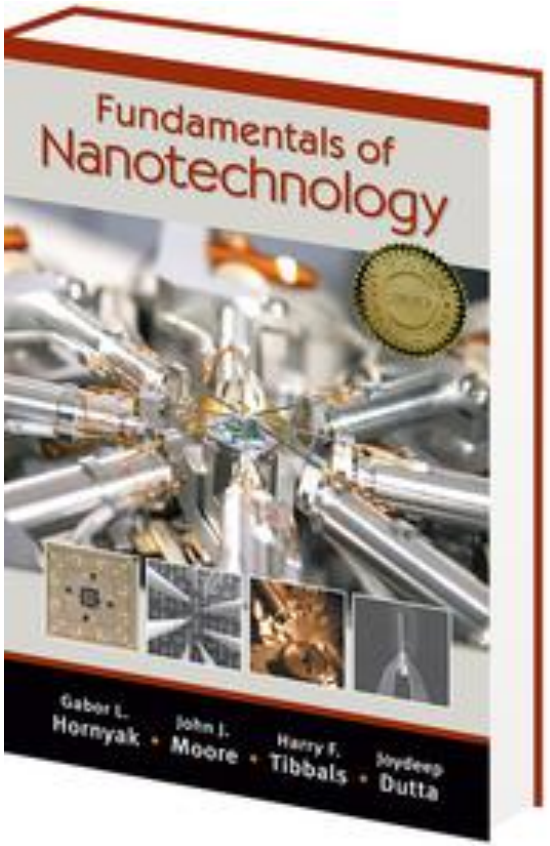
1 nano meter

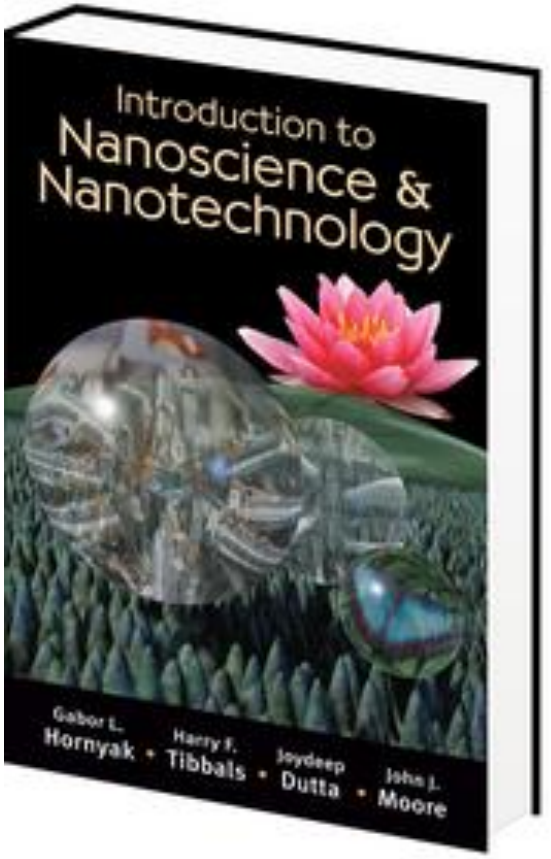
...the chromosome blocks can be studied.

Molecules/atoms assemble: Nanotechnology

Enter the world of Nanotechnology





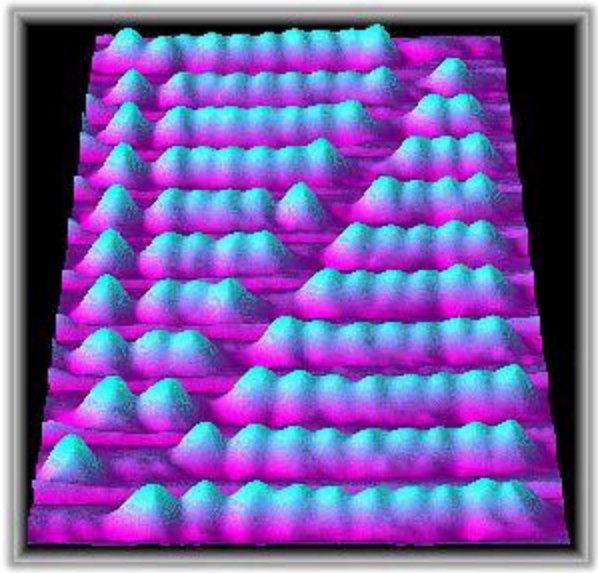


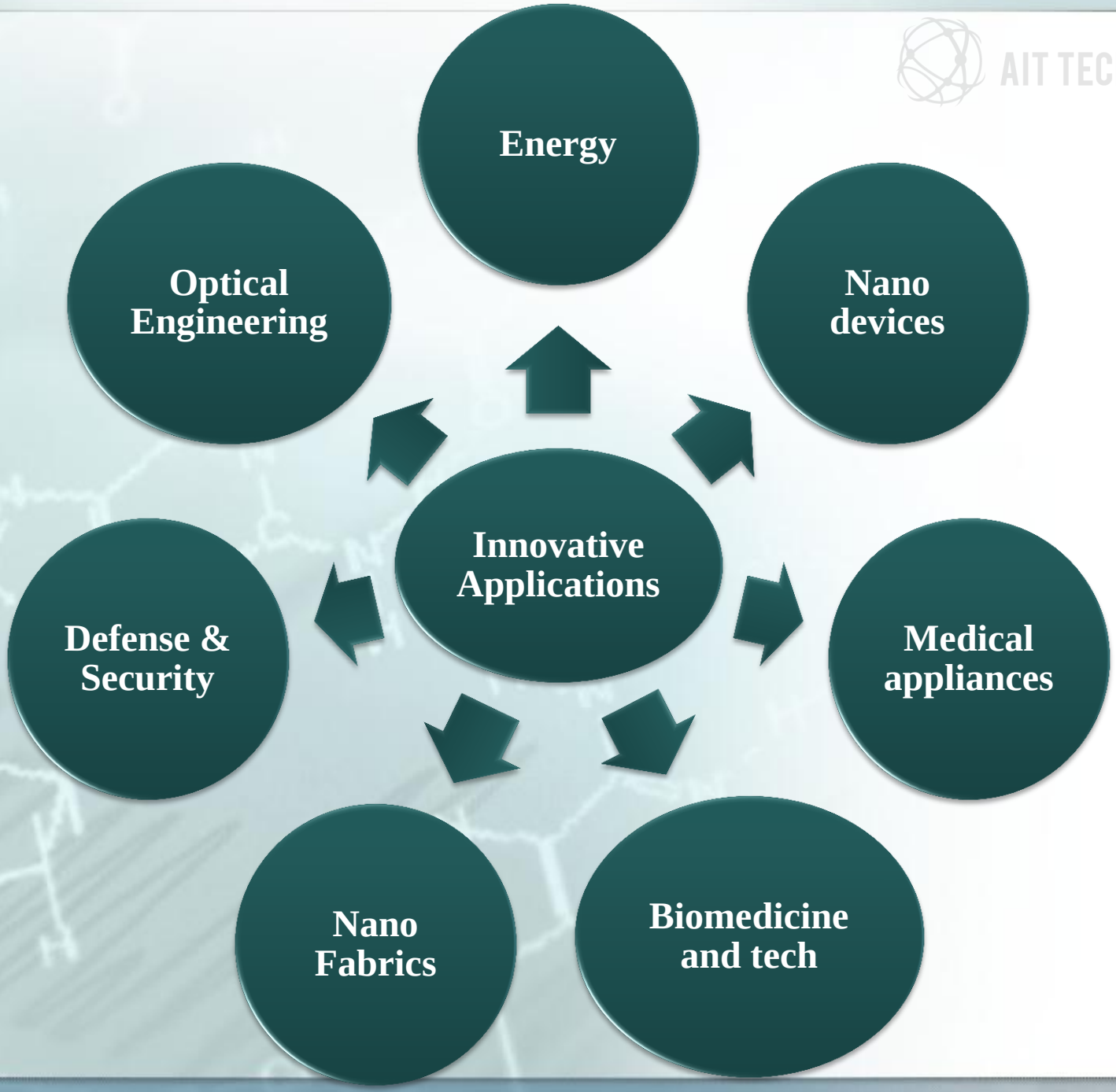
Nanotechnology- Projected Markets

Enormous potential economic impact by 2015

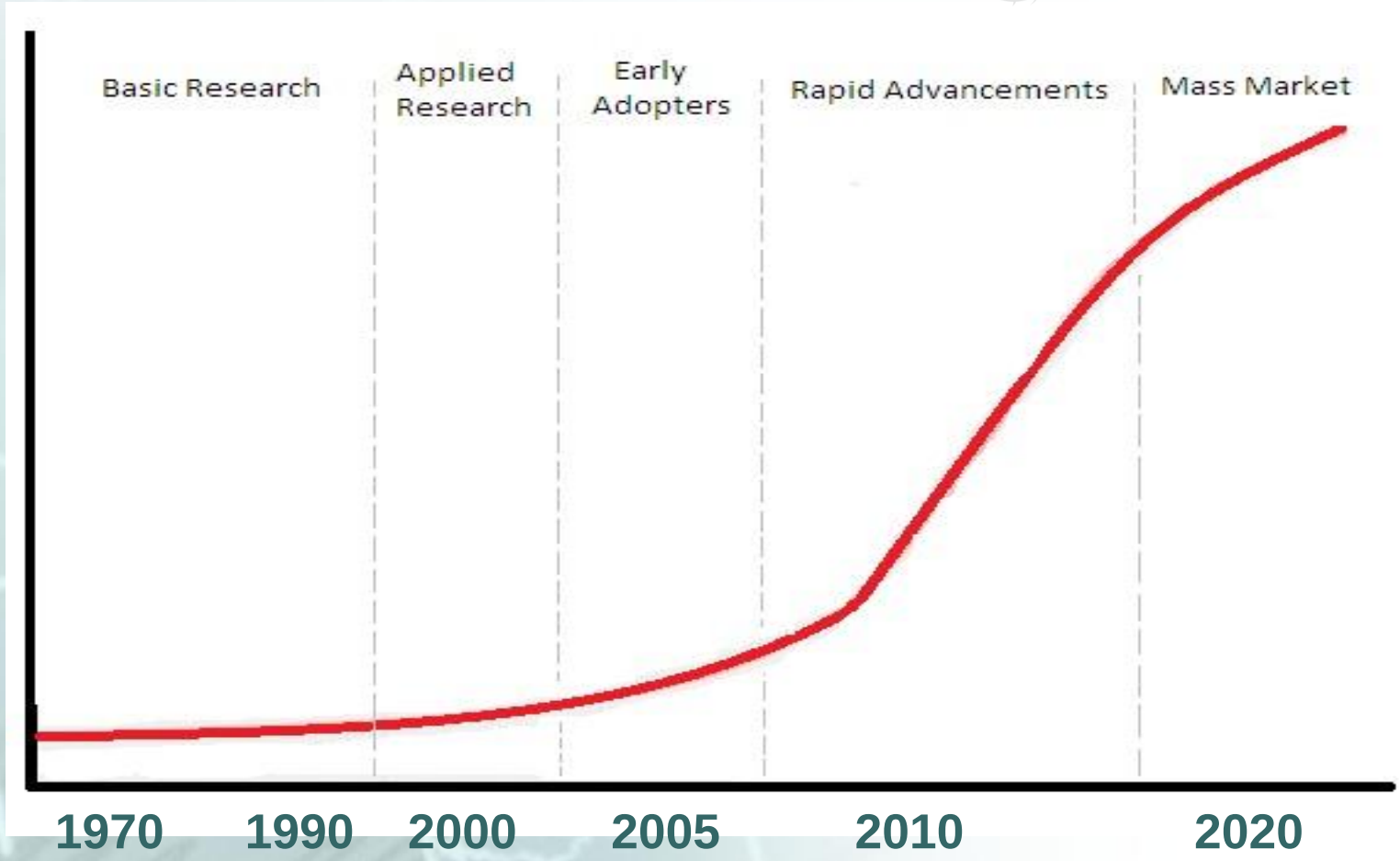
Domain	Value ($US billion/yr)
Materials	340
Electronics	300
Pharmaceuticals	180
Chemicals	100
Aerospace	70
Nanotech Tools	20
Healthcare	30
Sustainability	45
TOTAL	1000

Total = $1 trillion US



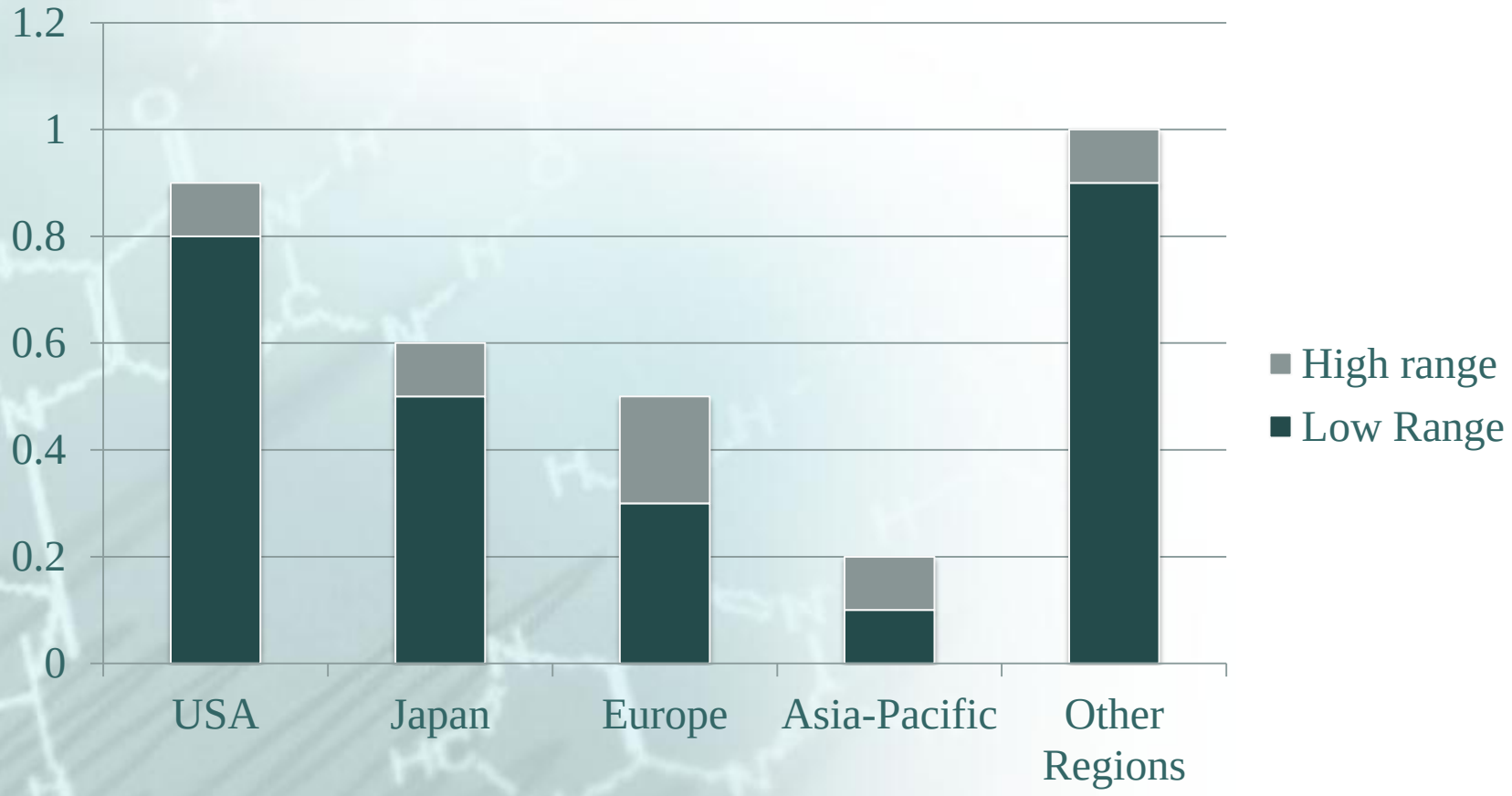

Energy
Optical Engineering
Nano devices
Innovative Applications
Defense & Security
Medical appliances
Nano Fabrics
Biomedicine and tech

Forecast



Nanotechnology R&D has already begun to improve rapidly and its applications are expected to enter the mainstream market by year 2020 and beyond with considerable impact.

Nanotechnology Workforce Requirement (millions)



Year 2010-2015

vision

Technology

Applications

forecast

Humanity's Top Ten Problems for next 50 years

1. ENERGY
2. WATER
3. FOOD
4. ENVIRONMENT
5. POVERTY
6. TERRORISM & WAR
7. DISEASE
8. EDUCATION
9. DEMOCRACY
10. POPULATION

UN Report 2008

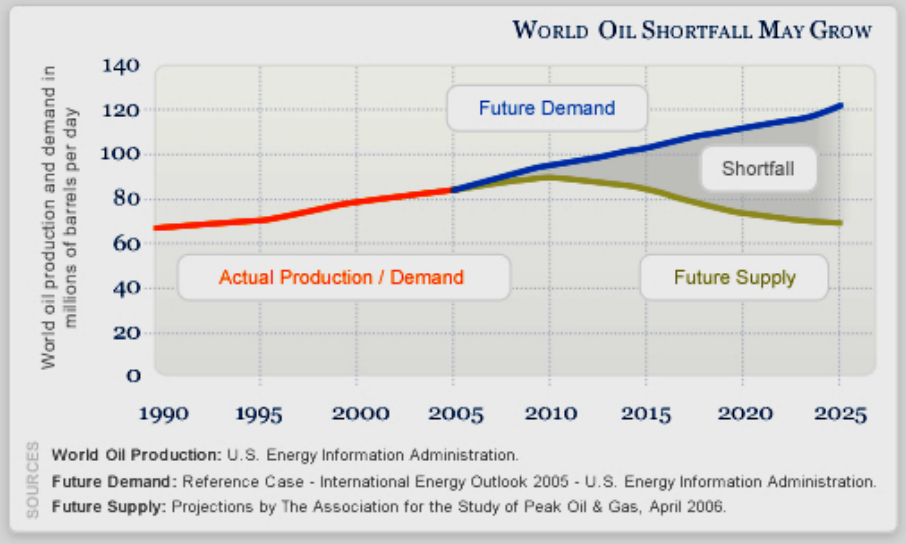
ENERGY

Energy Sources

Energy Sources

Nonrenewable
- Oil
- Coal
- Natural Gas

Renewable
- Wind
- Biomass
- Solar

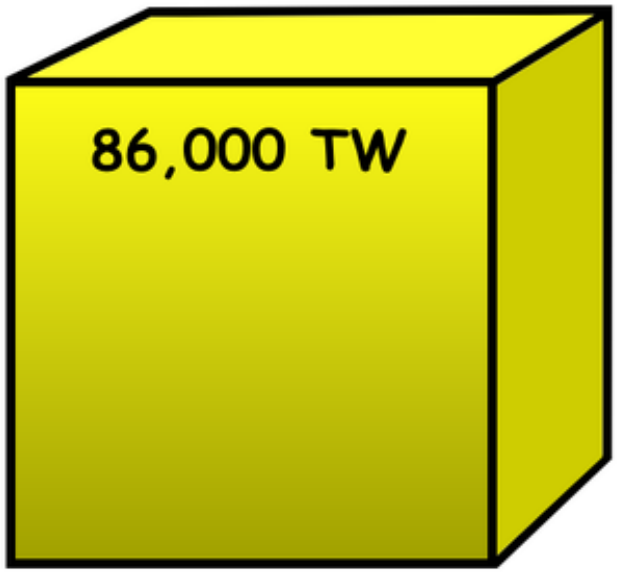


http://ieneurope.com/eng/oil-and-gas-investing.html

Why Solar Energy?

- Abundant
  Available ~ 86,000 TW/y
  World Consumption ~ 15 TW/y
- Never Ending

Energy Available



Solar

7.2 TW

Hydro

870 TW

Wind

32 TW

Geothermal

15 TW

Global Consumption

http://en.wikipedia.org/wiki/File:Available_Energy-4.png

GENERATIONS OF SOLAR CELL

- Photovoltaic Effect – Invented by *Edmund Becquerel* in1839
- 1st Solar Cell was made in 1883 by *Charles Fritts* using Selenium
- In 1954 – Commercial Solar Cell based on Single Silicon Crystal

1st Generation

Single Layer PN Junction

- Monocrystalline Si

2nd Generation

Multi Layer PN Junction

- Polycrystalline Si
- Amorphous Si
- CIGS
- CdTe
- GaAs

3rd Generation

Thin Film Solar Cell

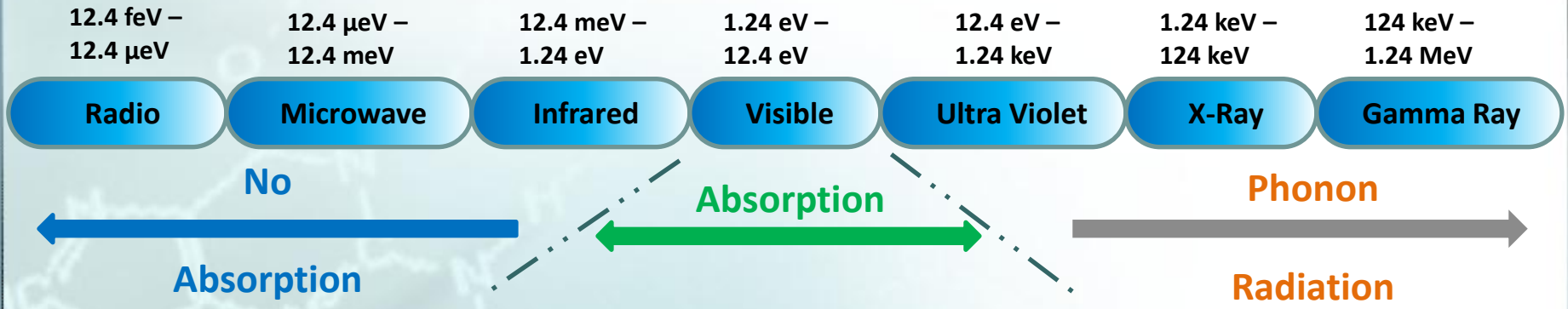
- Dye Sensitized Solar Cell
- Organic Polymer Solar Cell
- Quantum Dot Solar Cell

4th Generation

Polymer & Multi Junction Solar Cell

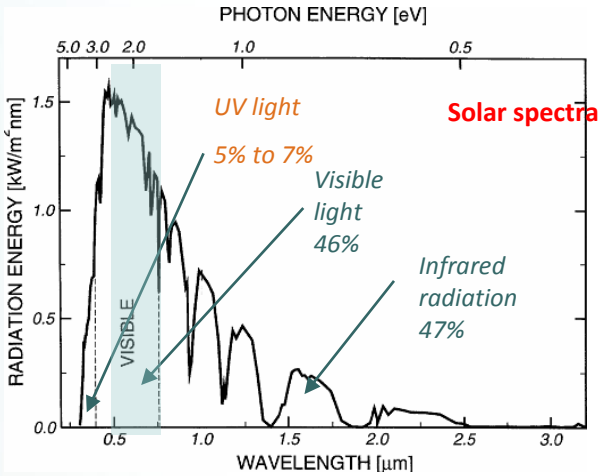
Future Quantum Dot Solar Cells

Shockley-Queisser Limit for P-N junction Si solar cells:



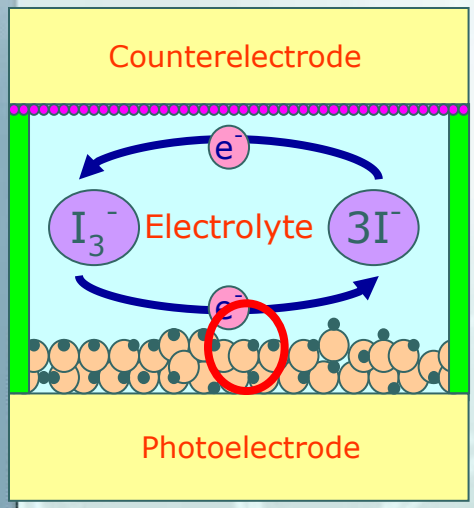
For Si Solar Cell: E_g = 1.1 eV

- $E<E_g$: Transmission (18.50%)
- $E>E_g$: Thermalisation (47.00%)
- Recombination (1.50%)
- Remaining Efficiency = 33.00%

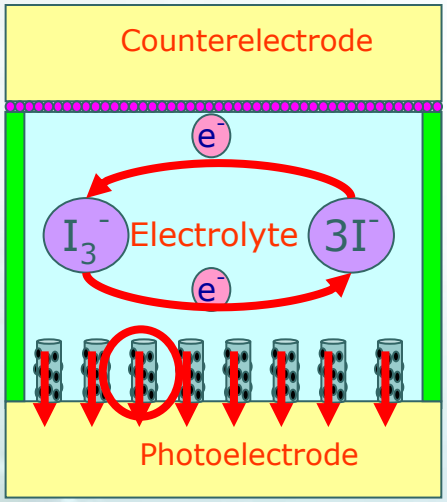


W. Shockley, H. J. Queisser, *J. Appl. Phys.* 1961; 32 (3): 510 – 51

SOLAR CELLS

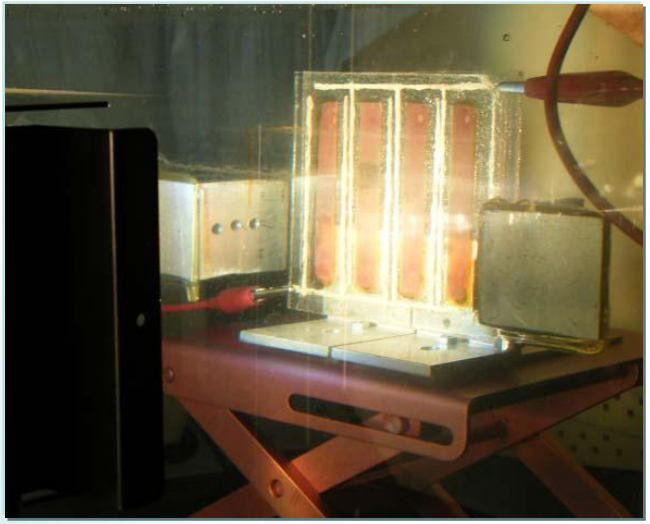


TiO_2-DSSC

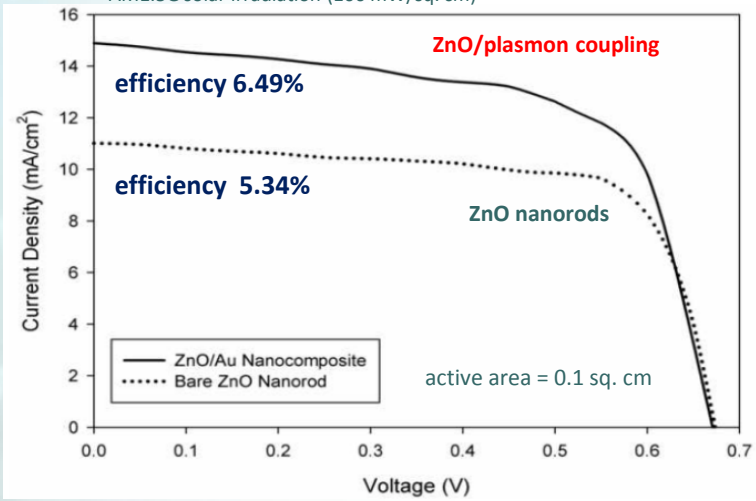


ZnONWs-DSSC

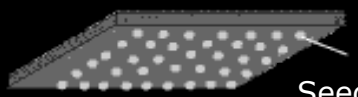
Direct transport of electron in NWs-DSSC



AM1.5G solar irradiation (100 mW/sq. cm)

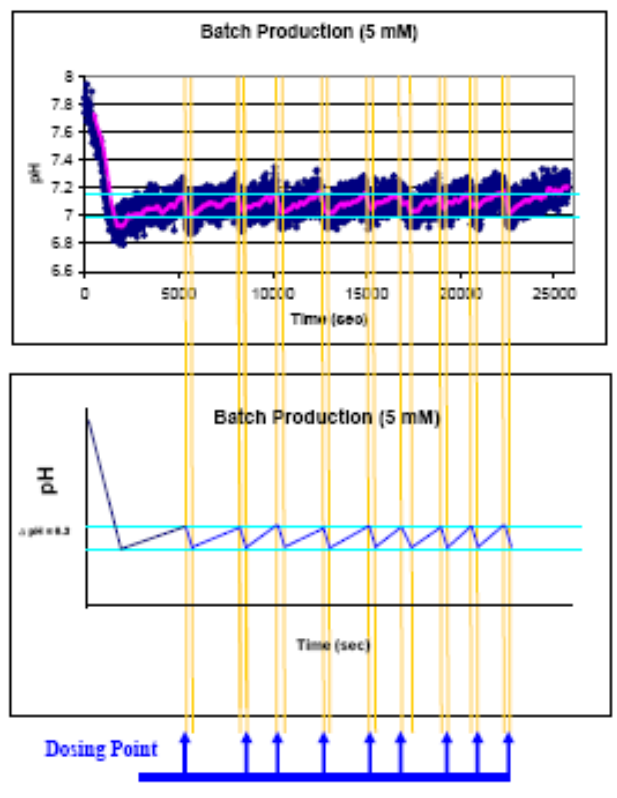


Anisotropic Growth of ZnO Nanorods



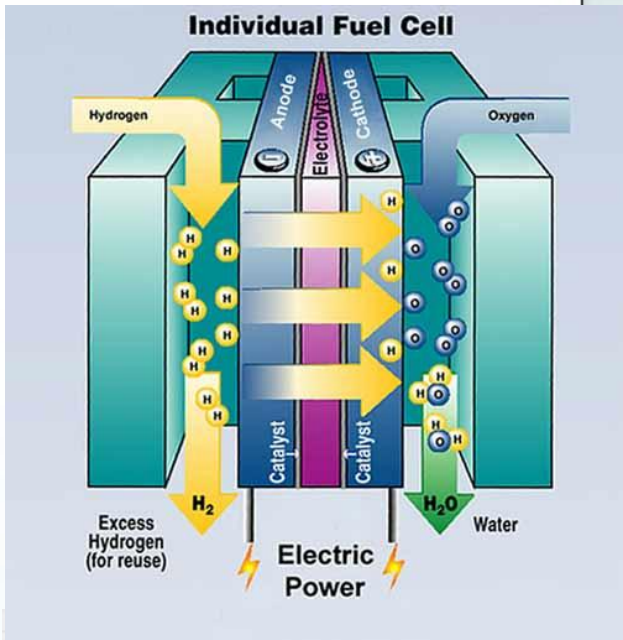
ZINC OXIDE NANOWIRE MACHINE

- Ready to Commercialize
- Process automated
- Optimization complete with Minitab application



Renewable Hydrogen Energy

- Clean energy
- Be obtained from the high abundant compounds on earth such as water and HCs
- High thermal efficiency (35-40%)
- On-broad production

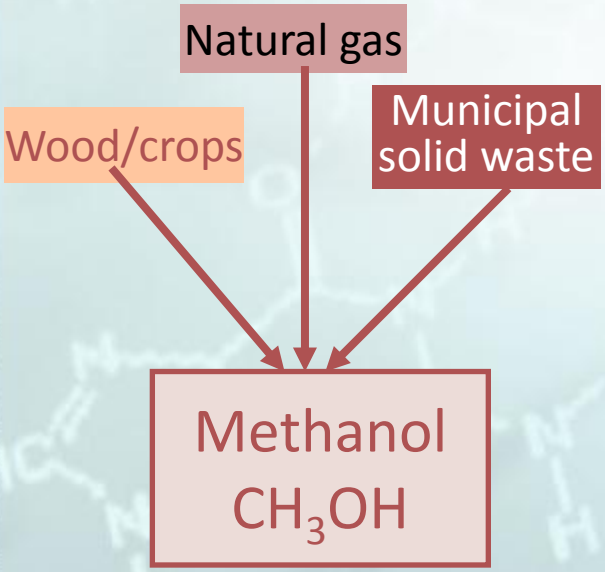


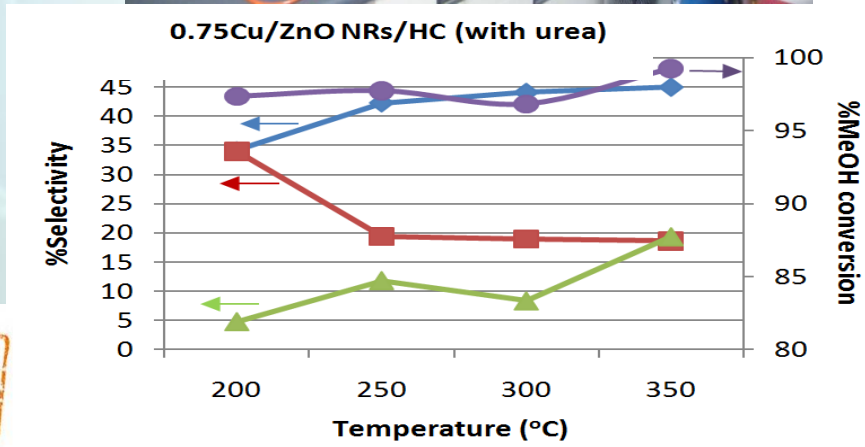
Fuel cell car

http://www.geni.org/globalenergy/library/articles-renewable-energy-transmission/h2-fuel-cell.shtml

http://www.ecoautoninja.com/eco-auto-government-industry-news/gm-may-cut-fuel-cell-development-32250/

HYDROGEN PRODUCTION





Why Methanol?

- Low cost
- Low boiling point (64.7°C)
- No sulfur
- Low reforming temp.
- Easy to store

PATENT PENDING

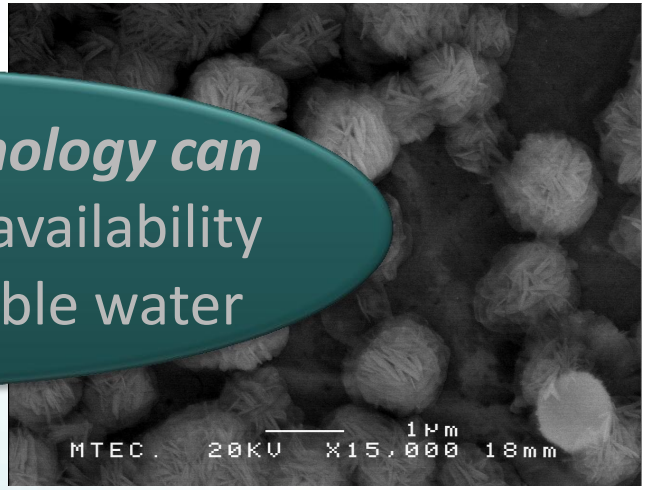
Thai Patent application : 1101001835

SENSING
PURIFICATION
CLEANING

Water & Nanotechnology

AIT TECHNOLOGY EVENT

3 ways nanotechnology can contribute to the availability of abundant potable water



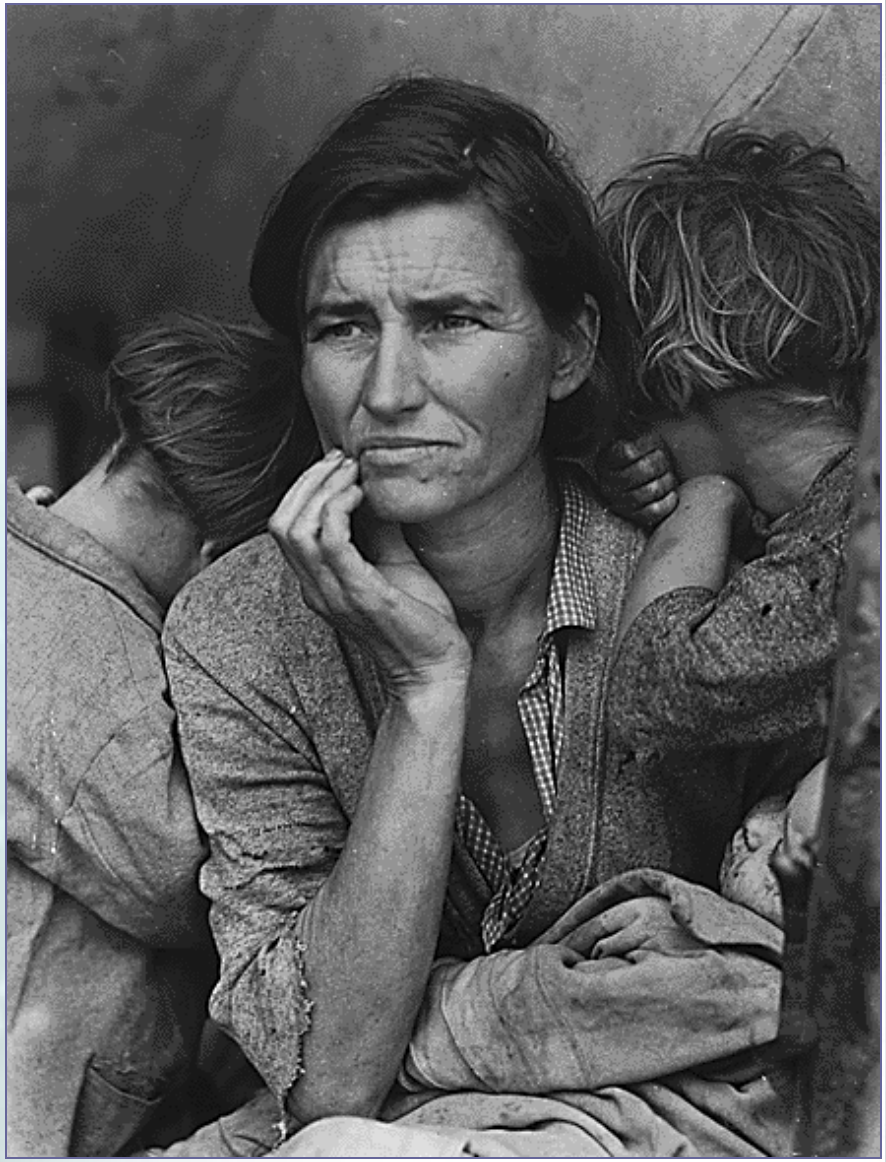
Sterilisation

Decontamination

Water-desalination

Do we need to bother about microbes?

AIT TECHNOLOGY EVENT



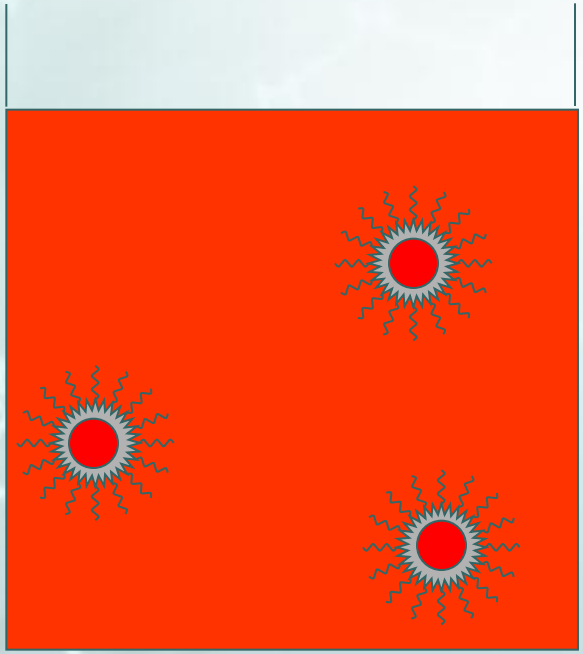
49

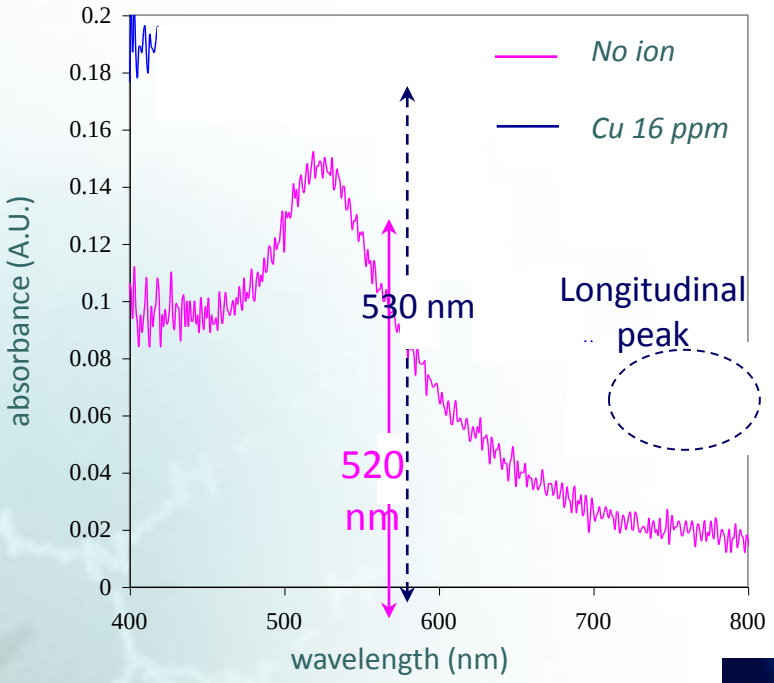
people

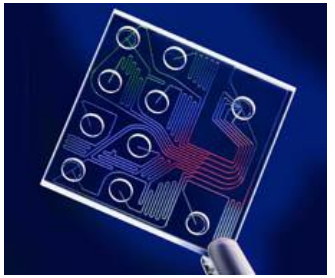
DIE

over **15 min** in the world
due to pathogen–contaminated water

HEAVY METAL ION SENSORS

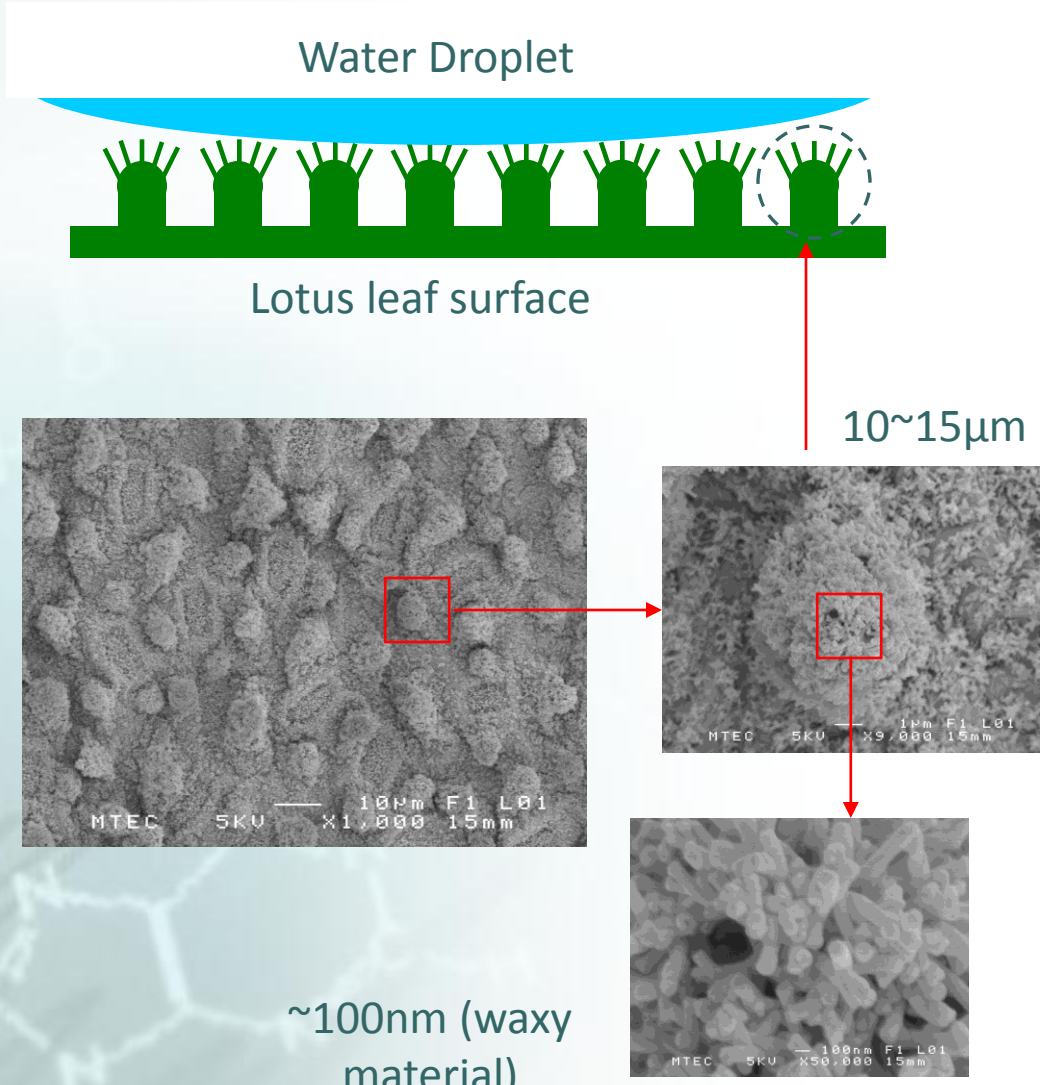






10 nm → 24 nm

Lotus Effect



- Higher contact angle
- Non wetting surface
- Self cleaning properties
- Low surface energy

Physical effect

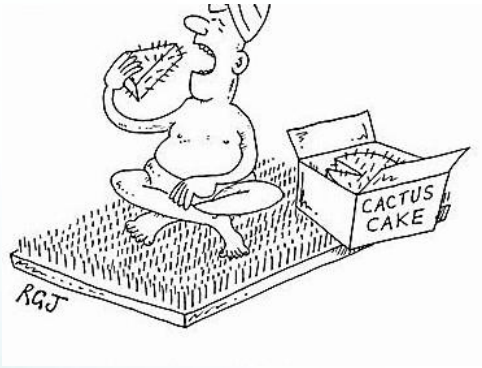
- Micro structure surface
- Nano structure surface

Chemical effect

- Low surface energy material

~100nm (waxy material)

Fakir or Cassie-Baxter Model

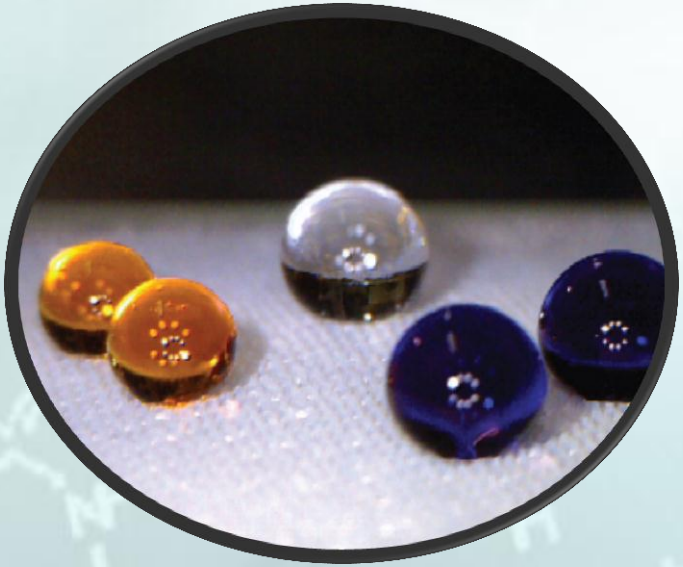


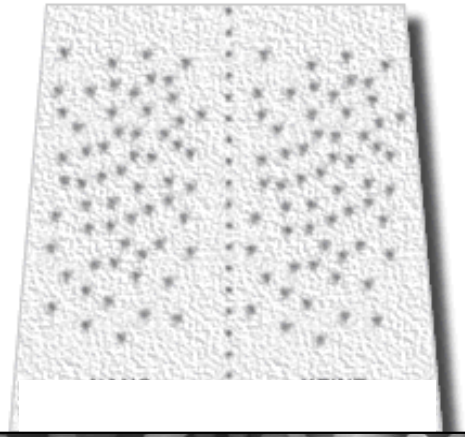
An average human of ***70kg***, when spread out among ca. ***600 nails***, will feel only about ***117g of force per nail*** (Human skin can endure approximately ***900g of force***)

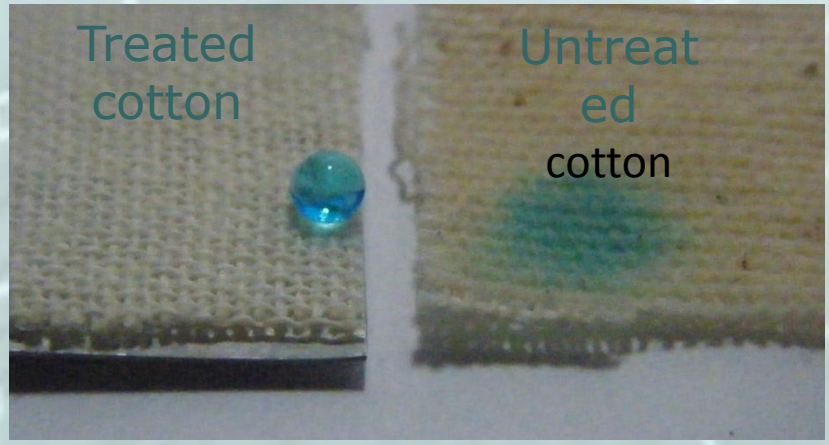
All of the force uniformly distributed on the tip of nails

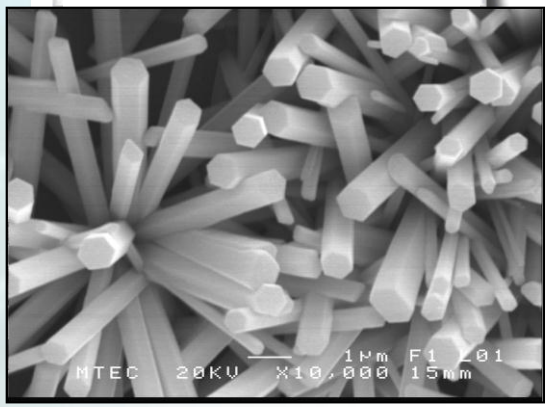
http://en.wikipedia.org/wiki/Fakir

SELF-CLEANING SURFACES





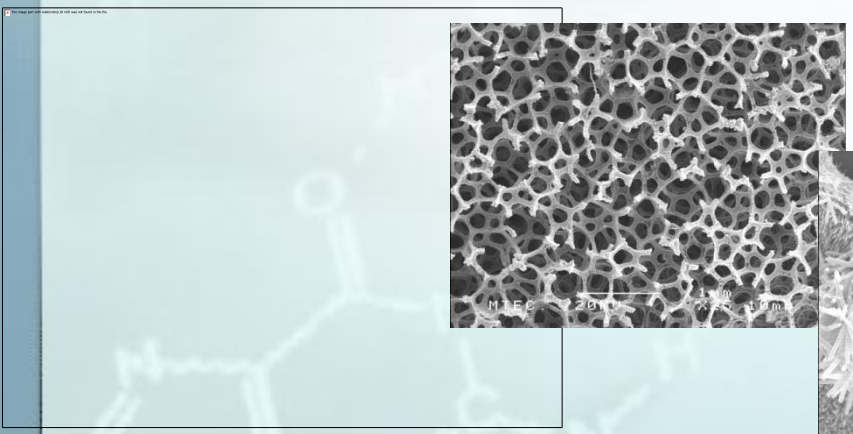


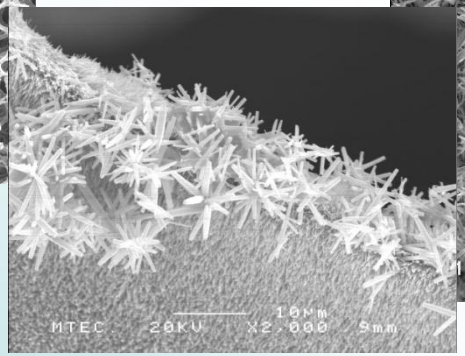


nanoFilters

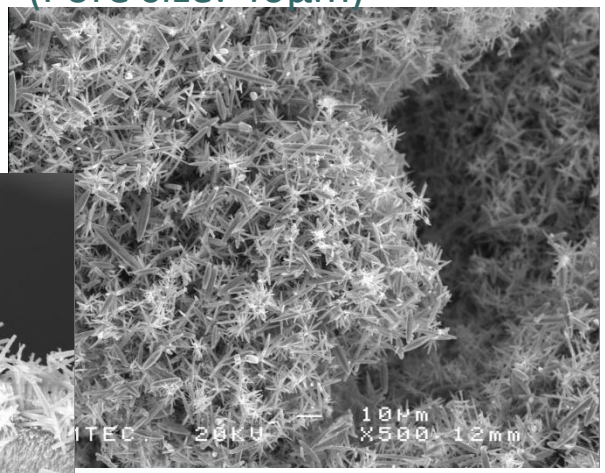
AIT TECHNOLOGY EVENT

Polyurethane Foam (Pore size: 55-65 micron)

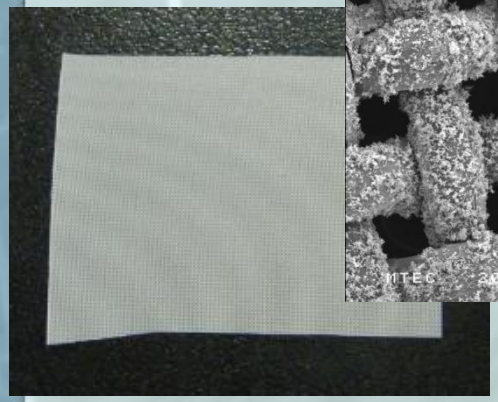


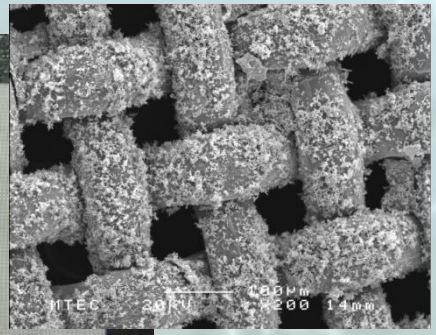


Stainless Steel Porous Metal (Pore size: 40μm)

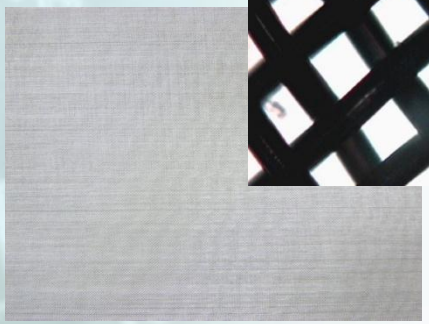


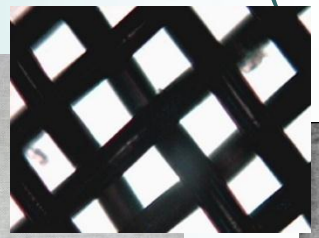
Polyester Scrim-woven

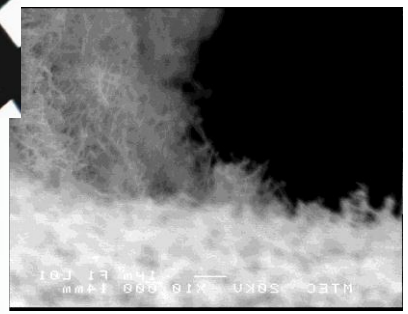




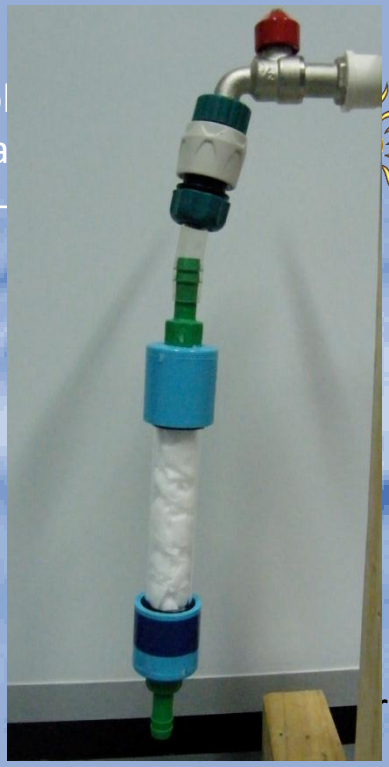
Stainless Steel Screen (Mesh size: 150 x 150 μm)







Water Purification

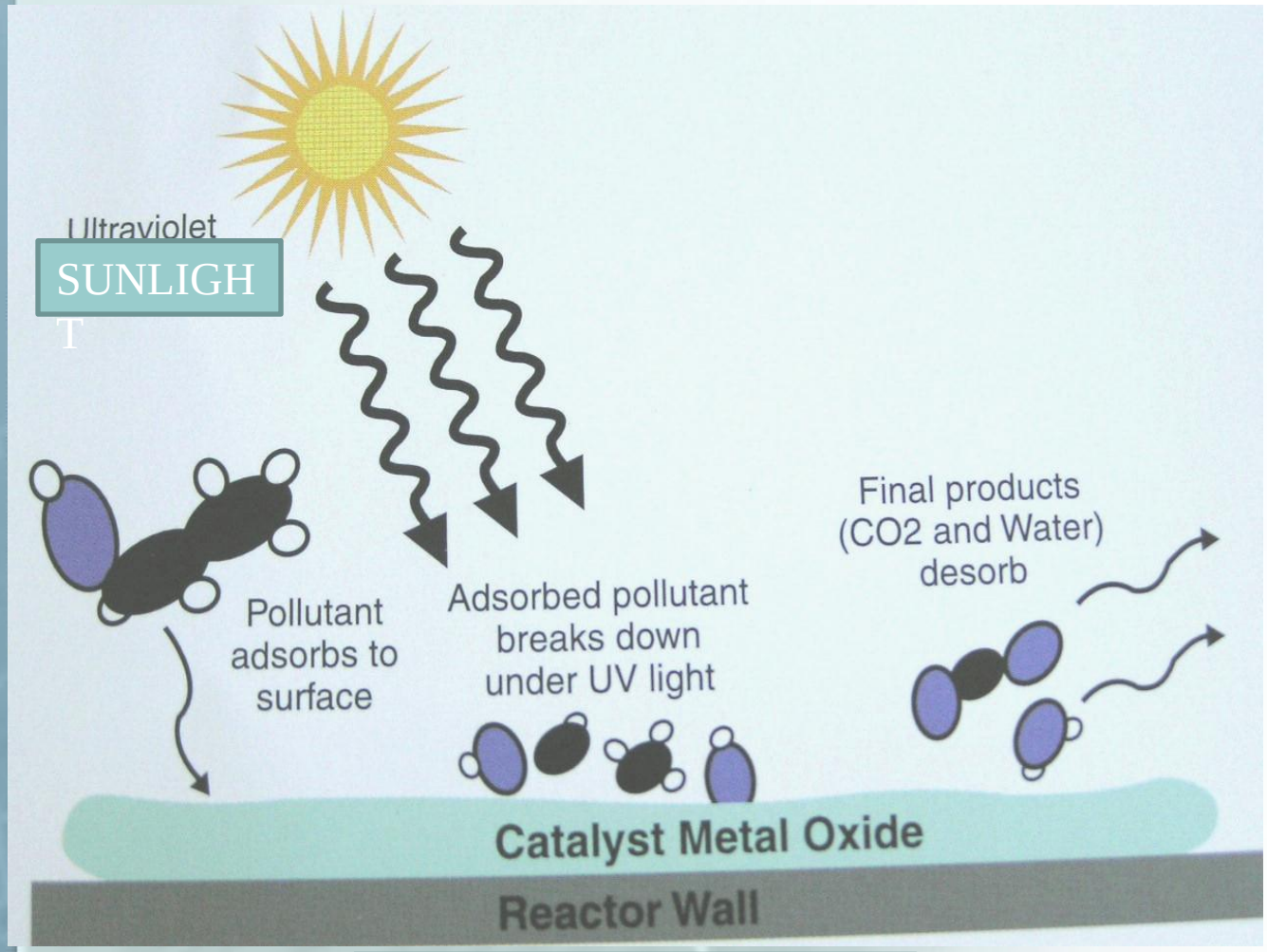


WATER PURIFIER

AIT TECHNOLOGY EVENT

Indian Patent application: 2458/MUM/2011

WATER PURIFIER: Technology behind



Catalyst support membrane

Phototcatalysis

Slow release of Zn^{2+} through dissolution

Amount of microbes present in tap water	≈ 100,000 cfu per liter
Amount of microbes used for testing the filter	≈ 10,000,000,000 (10 billion) cfu per liter

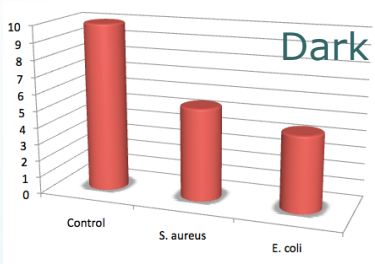
Viable cells (billions)

Amount of microbes removed from water:

In the dark

≈ 5.5 billion cfu per liter (*E. c*

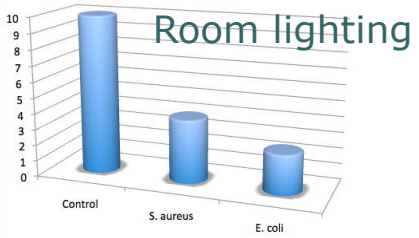
≈ 4.5 billion cfu per liter (*S. a*)



In room lighting

≈ 7.5 billion cfu per liter (*E. c*

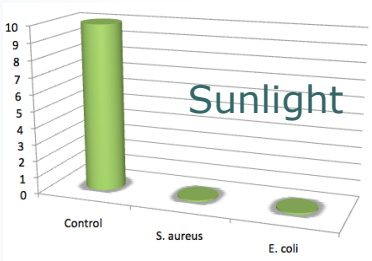
≈ 6.0 billion cfu per liter (*S. aureus*)



In sunlight

≈ 9.9 billion cfu per liter (*E. c*

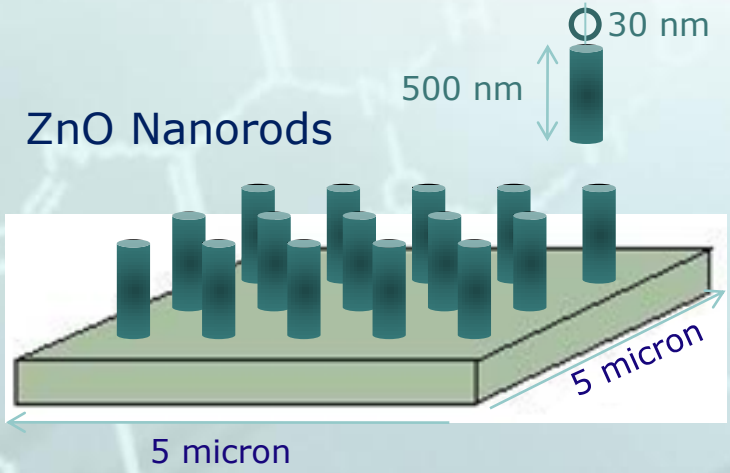
≈ 9.9 billion cfu per liter (*S. aureus*)



100% removal at 100,000 cfu per liter

LPG GAS SENSOR

- Miniature
- High sensitivity
- Fast response
- Simple electronic interface



PATENT PENDING

Thin film: Total sensing area- 2.5×10^{-11} m^2

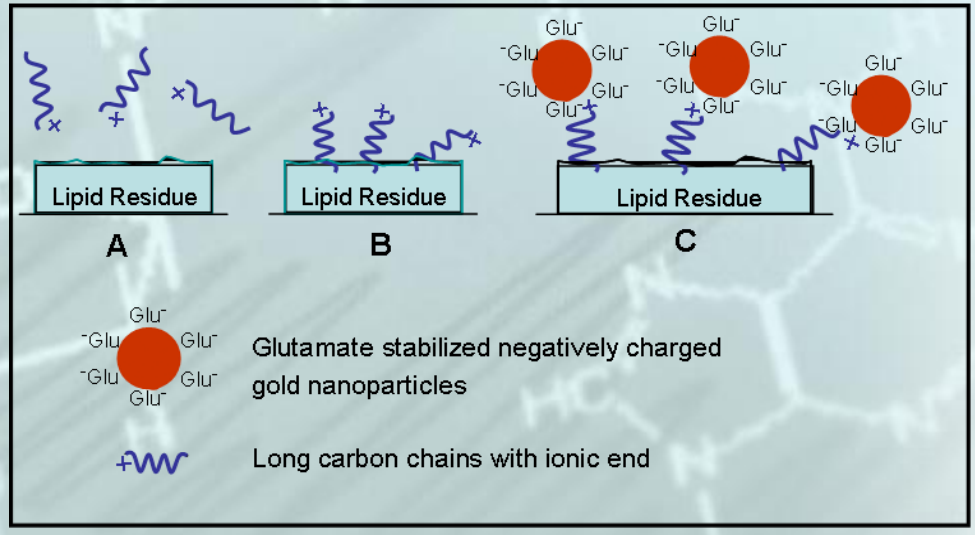
Nanorods: Total sensing area- 1.202×10^{-8} m^2

Area increased ~ 500 times

Thai Patent application: 1101000530

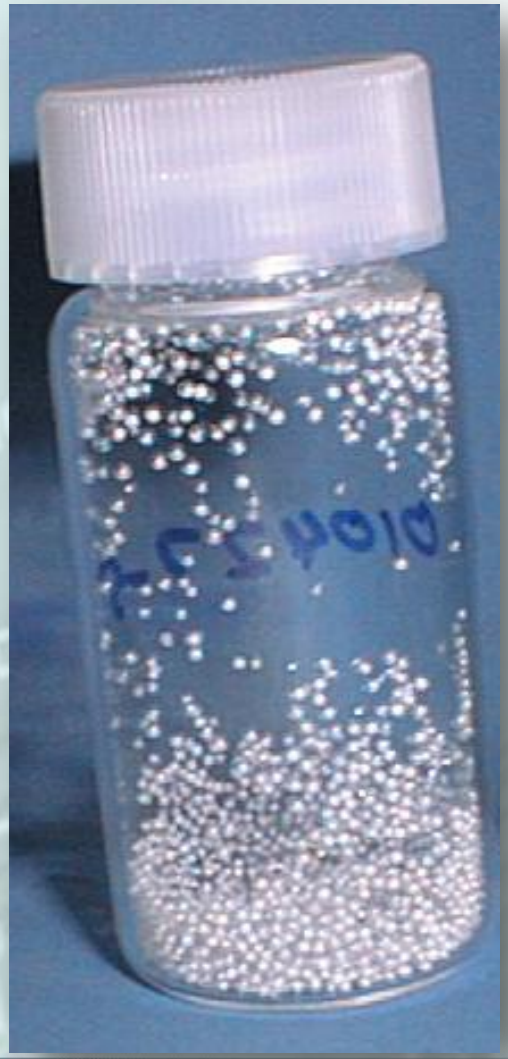
FINGERPRINT IDENTIFICATION

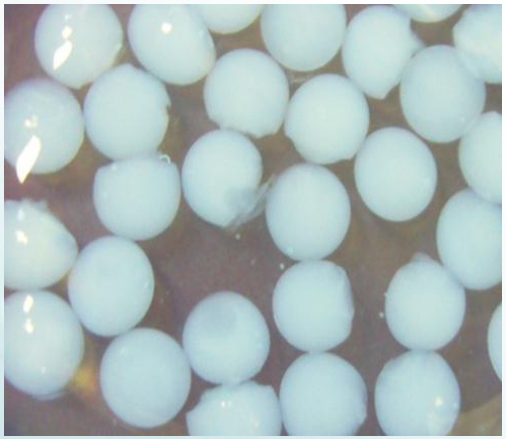
- Simple technique
- Can be applied to wet surfaces (not possible for *dusting*)
- Short development time
- Cost Effective



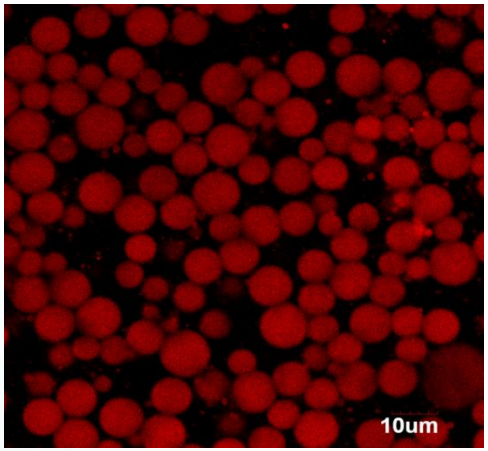
BIOTECHNOLOGY

CONTROLLED RELEASE AGROCHEMICALS

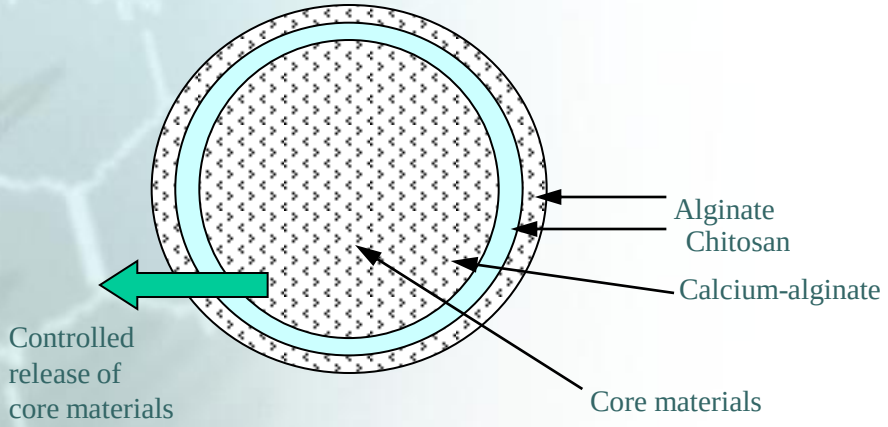




Chitosan-Alginate Beads

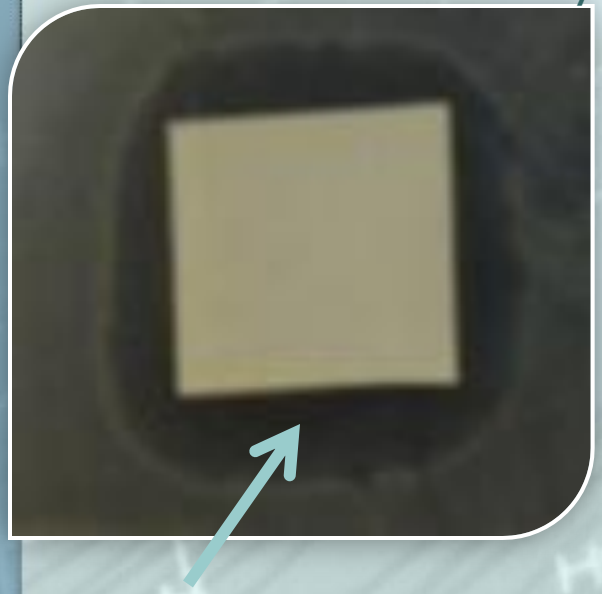


Chitosan-Alginate Microspheres



PHOTOCATALYTIC PAPER

- Reusable with nominal decrease in efficiency
- Low cost and environmentally-friendly
- Lower ink absorbency

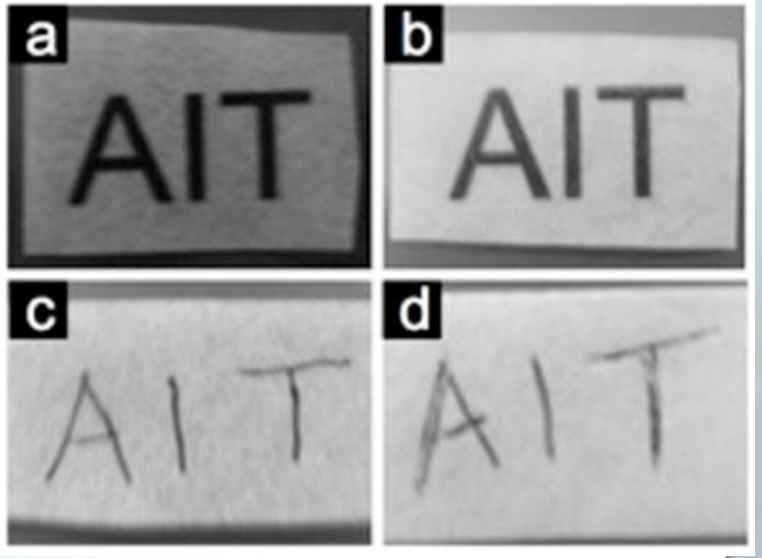


No Bacterial Growth

PATENT PENDING

Potential Applications in:

- chromatography
- Hospital environments
- filtration
- Ink Jet printing

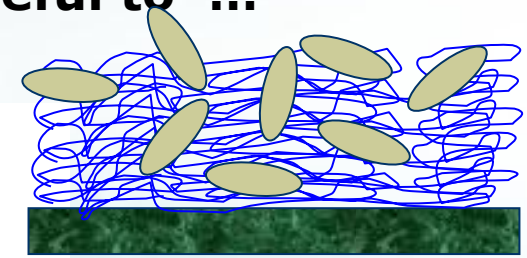


Thai Patent application: 1101001830

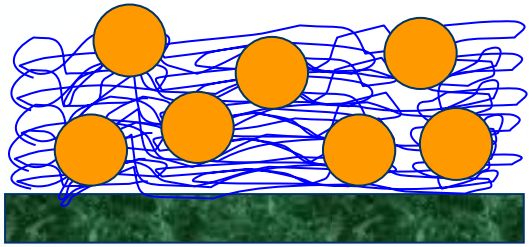
FUZZY DIP COATER

Layer by layer method useful to ...

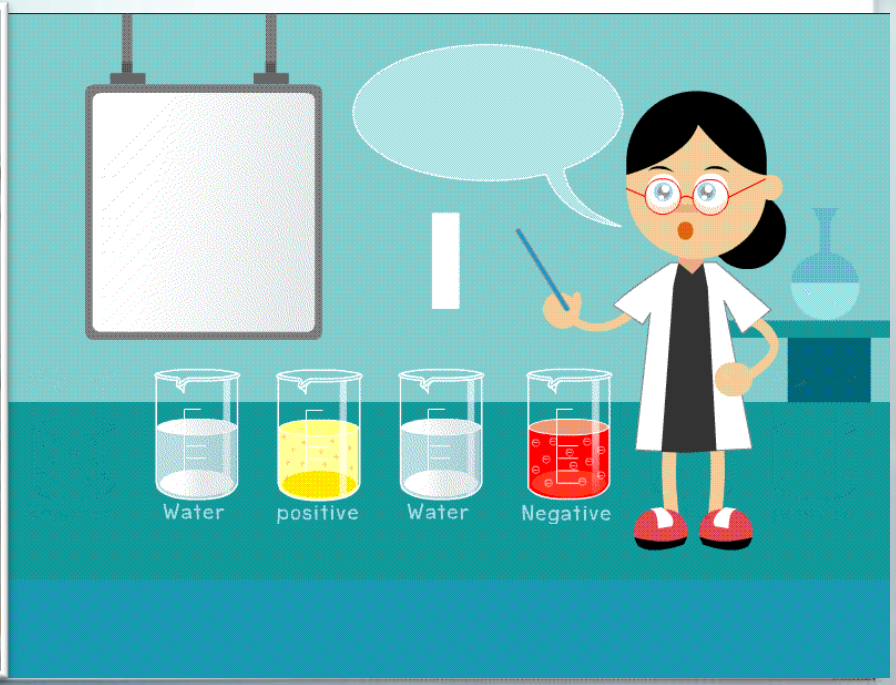
alter surface properties



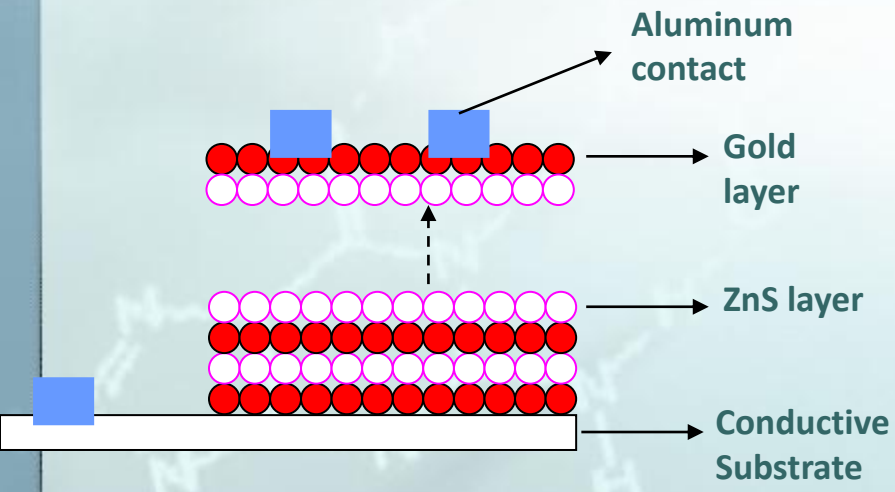
immobilize biomolecules

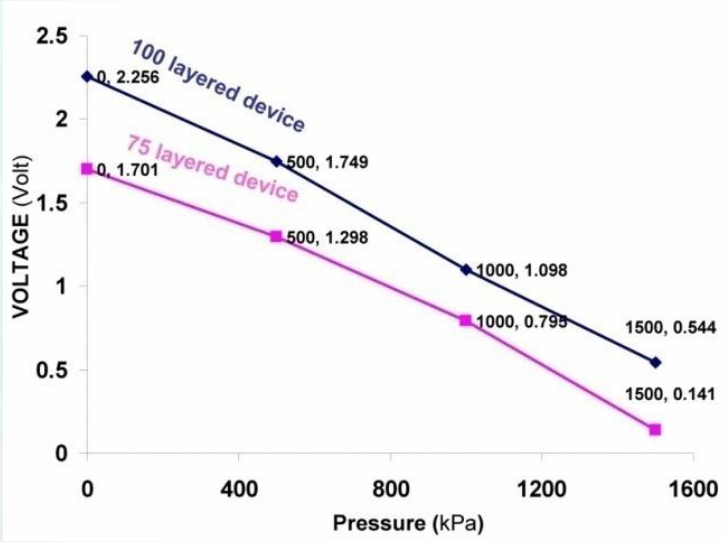


immobilize nanoparticles



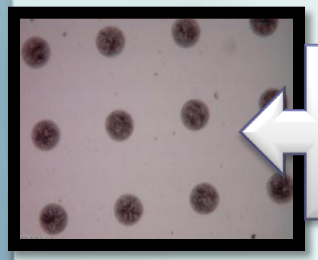
PRESSURE SENSOR



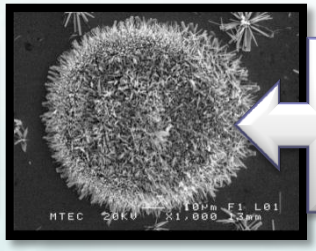


- Novel fabrication method of electronic devices
- Simple, Low-cost and flexible fabrication
- All ranges of Pressure can be measured
- Repeatable characteristics

Inkjet printed RFID

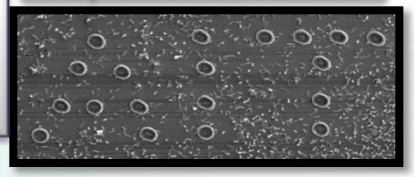


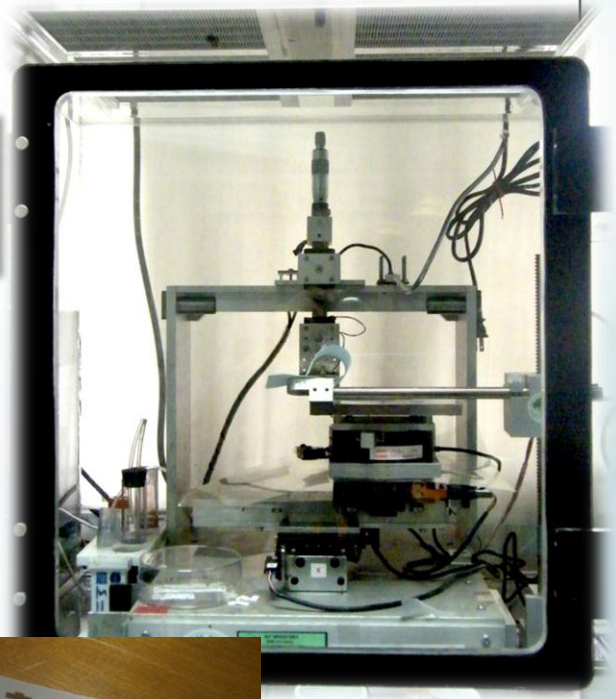
Array of ZnO dots

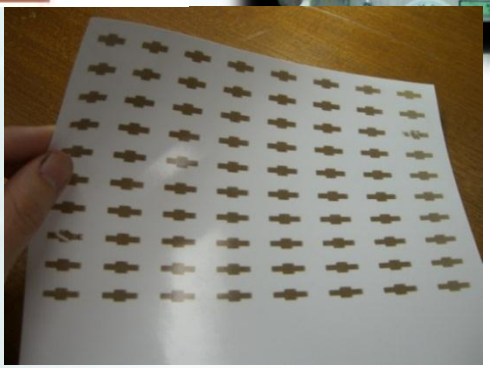


The zoom-in of a ZnO-nanorod dot

Implemented Pattern



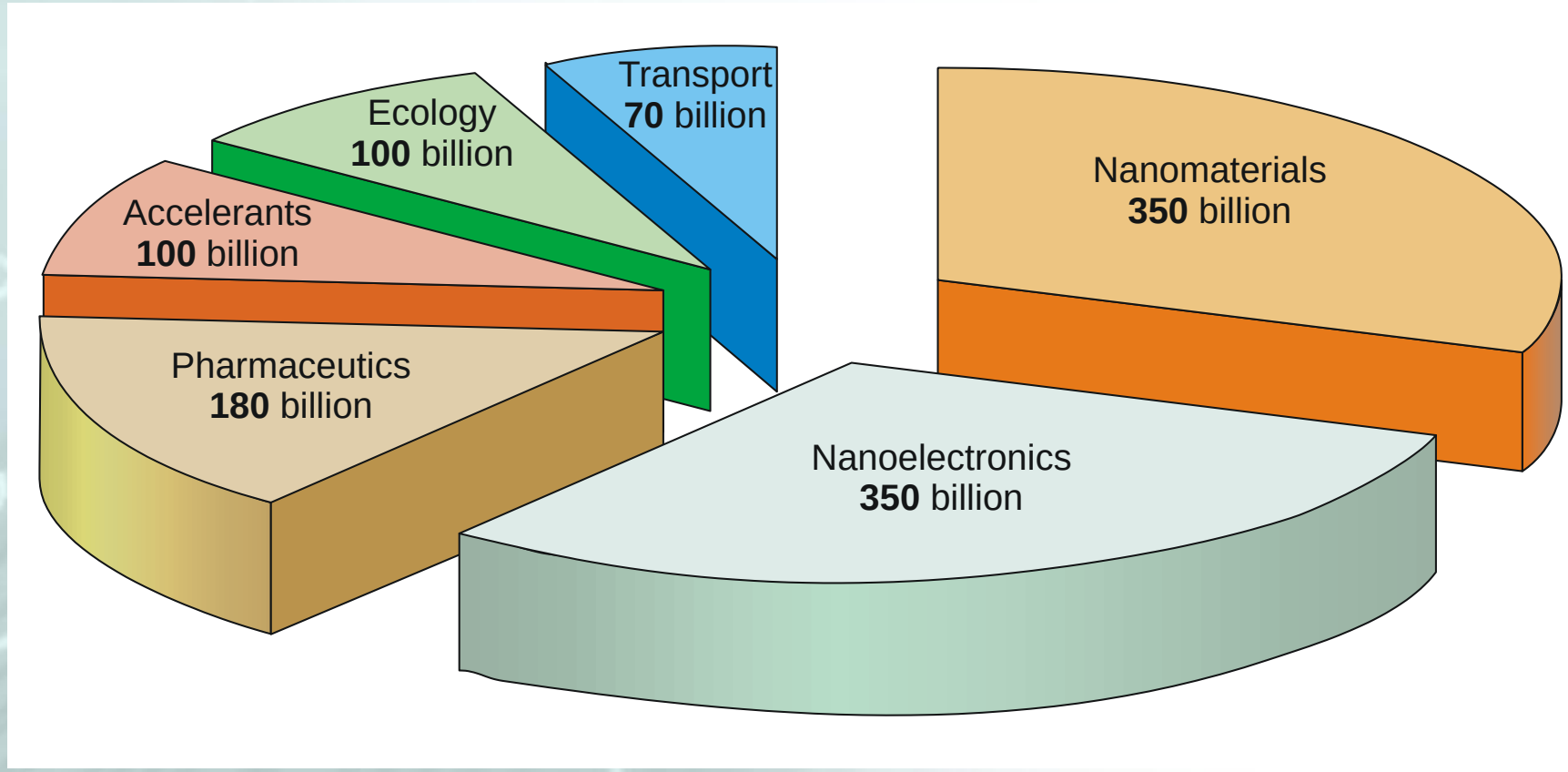




- Direct writing by ink-jet printer
- Low-cost electronic fabrication
- Direct growth from nanocrystals
- Low temperature non-polluting process

Be a part of the business

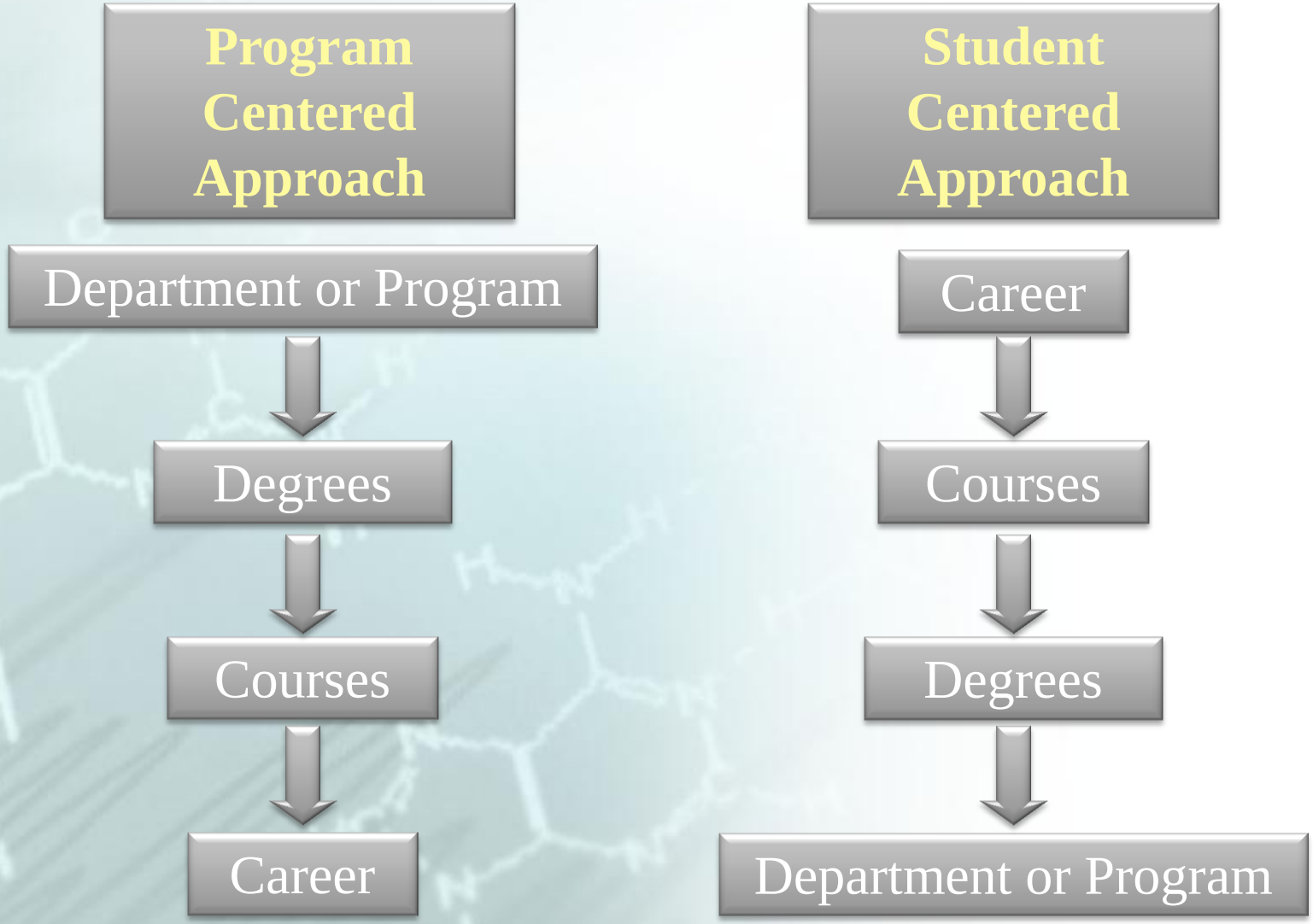
More than 1 trillion USD annually by 2015



"We are entering a new age, an age of knowledge, in which the key strategic resource necessary for prosperity has become knowledge itself – educated people, their ideas and innovation, and their entrepreneurial spirit."

- (Bloch, 1988)

AIT in the 21st Century



"It is not necessary to change. Survival is not mandatory."

-*W. Edwards Deming*

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nano

THE MAGAZINE FOR SMALL SCIENCE

Nanomaterials for the Future

- clean, green and profitable

PLUS: NANOIMPRINT LITHOGRAPHY - FROM EMERGING TO ESTABLISHED TECHNOLOGY

Innovation


Thank you for your attention
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is the Future
Be a part of the
revolution
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