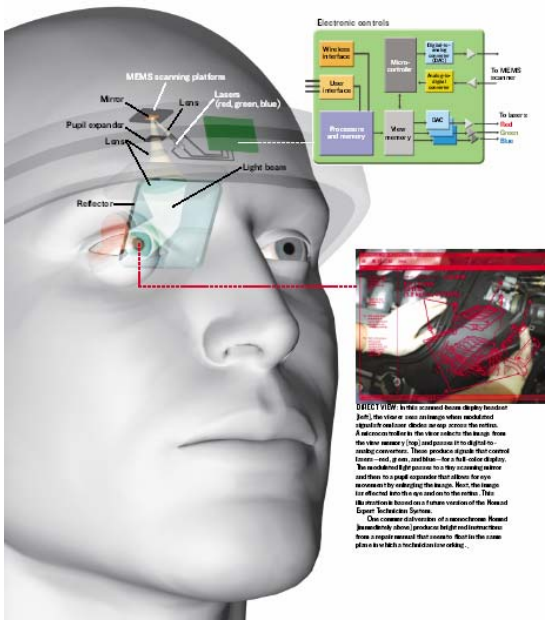
PERSPECTIVES IN NANO TECHNOLOGY EDUCATION IN TERMS OF ENGINEERING POINT OF VIEW

Chang K. Kim
Hanyang University

Nanotechnology Working Definition

Nanotechnology refers to
any application of science
that deals with
elements between
100 nanometers (IT industry in Korea)
and a tenth of a nanometer in size,
in which size is critical
to the application's ultimate purpose.

New Growth Engines : $10 Billion Investment For the Next 5 Years

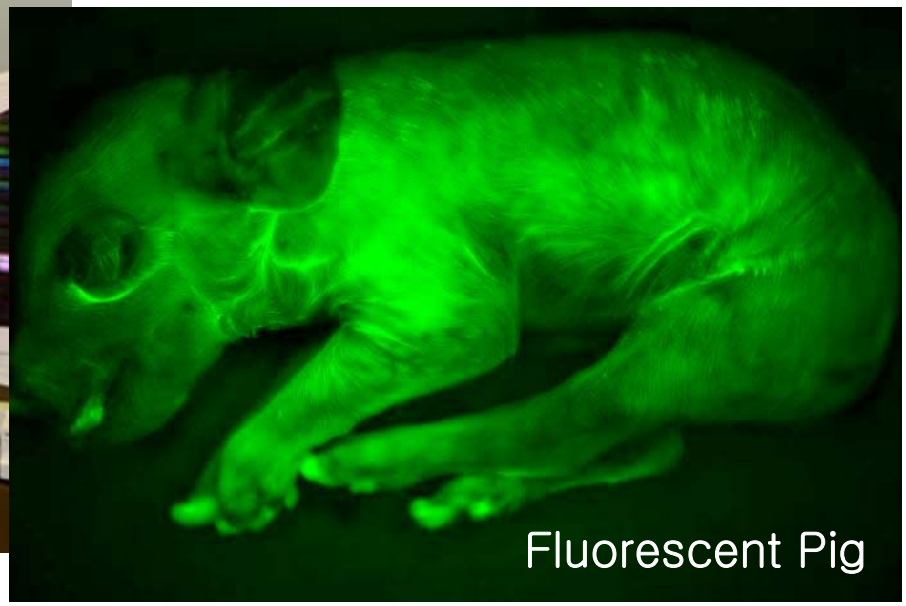


10 Industries	Total 38 Items
Digital TV/B Broadcasting	Broadcasting System, DTV, DMB, Set top box, Fusion Mobile Device
Display	LCD, LED, PDP, OLED, 3D, Electronic Paper,
Intelligent Robot	Domestic Robot, IT Based Service Robot, Extreme Robot, Medical Robot
Next Generation Vehicle	Intelligent Car, Environment Friendly Car
Next Generation Semiconductor	Memory, SoC, Nano Electronics, Nano Devices Nano Materials
Next Generation Mobile Communication	4G Mobile Phone & System, Telematics
Intelligent Home Network	Home Server/Home Gateway, Home Networking, Intelligent Home Appliances, Ubiquitous Computing
Digital Contents/SW Solution	Digital Contents, Intelligent Logistics System, Embedded SW,
Next Generation Cell/Battery	Secondary Battery, Fuel Cell, Materials
Bio New Drugs/ Changeable Organs	New Drug, Bio organs, Bio Chip

Ambitious Plan :
Korea Nano Technology Initiative

2 Billion $ Investment During 2001~2010
Goal : World Top 5 Nano Technology Capability

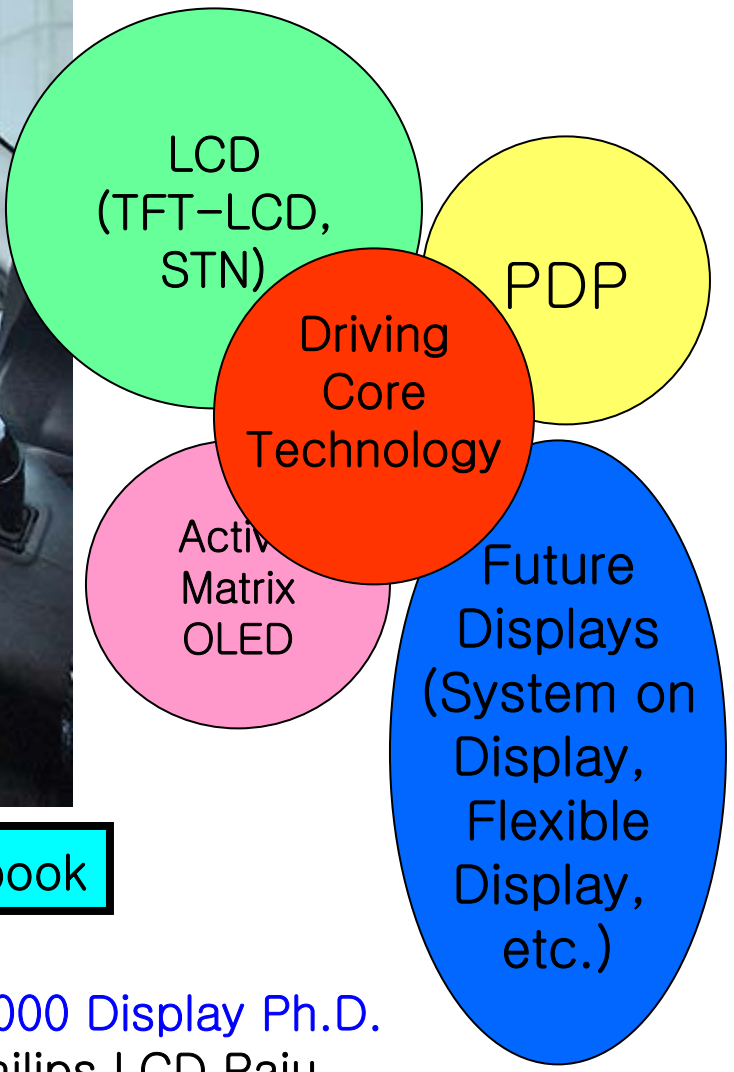
8 Giga Nand Flash Memory


Fluorescent Pig

Demands from IT Industry I.

- Korea enjoys the largest market share in DRAM, TFT-LCD, PDP and Nand Flash Memory.
- Design rule in semiconductor industry is already in the Nano regime.

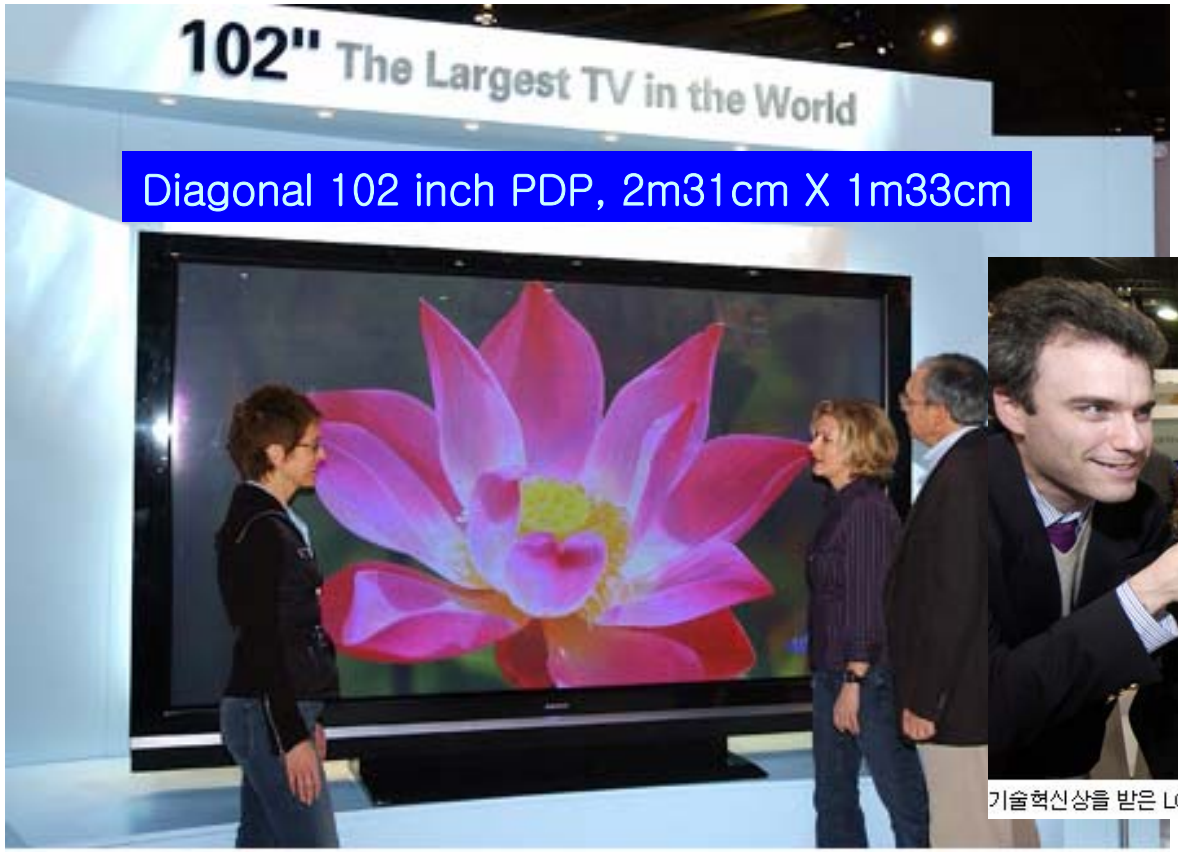
World 1st Digital Multimedia Broadcasting Notebook



At the year 2005 alone, We need 3,000 Display Ph.D. Level Engineers at newly built LG Philips LCD Paju Factory, Samsung Electronics CheonAn Factory and at newly extended LG Electronics and Samsung SDI PDP lines.

CES 2005

****Mass Customization Nano Engineer
****Process Nano Engineer



Diagonal 102 inch PDP, 2m31cm X 1m33cm

삼성전자가선보인 102인치 PDP TV

기술혁신상을 받은 LG전자의 LCD 모니터

Samsung 102 inch PDP and LG Electronics 17 inch LCD Monitor(L1730S)
: Best of Innovations Award with Best Functions and Design

****Nanoscale Design Engineers For Fusion Devices

삼성전자는 폴더를 자유롭게 움직일 수 있는 휴

Samsung Video Streaming Phone

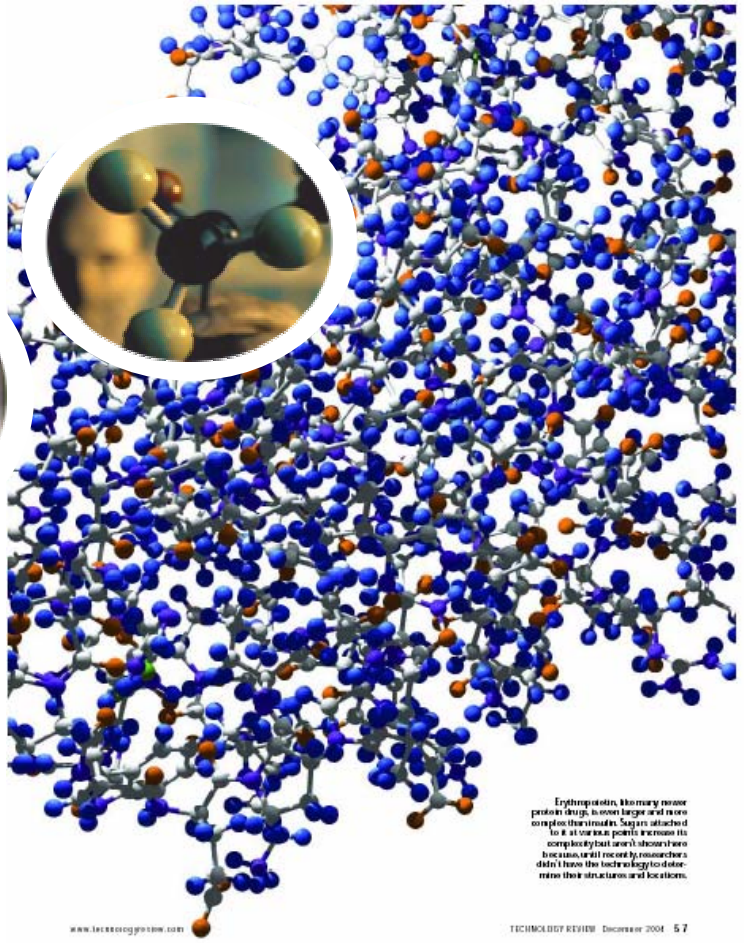
삼성전자가 내놓은 미주 최초의 비디오 스트리밍폰

Bill Gates with
Made in Korea ReignCom. MP3 Player

빌게이츠 회장이 레인콤의 MP3플레이어를 들고 시연하고 있다

Demands from Pharmaceutical & Bio Industry II.

- Structural Genomics
- Protein X-ray crystallography



Laying an golden egg industry

Crystal Genomics : Korea Bio Venture Shows Viagra Working Mechanism. Nature Cover Page

High Throughput Screening NMR
Viagra is locked at the active site
Of PDE 5 which prevents cGMP
From being attached to PDE 5.

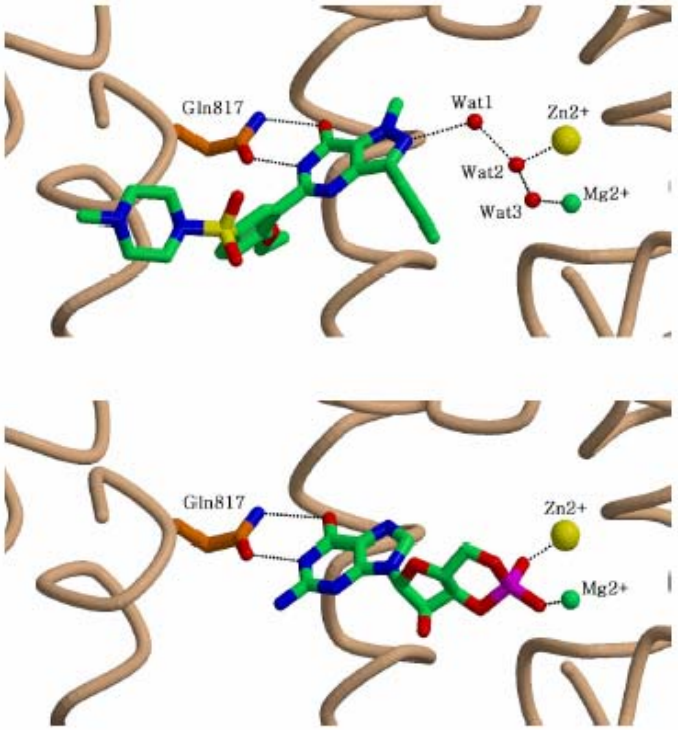


그림 3 상: PDE5 단백질의 활성부위에 비아그라가 결합된 모습.
하: PDE5 단백질의 활성부위에 기질인 cGMP가 결합된 모습

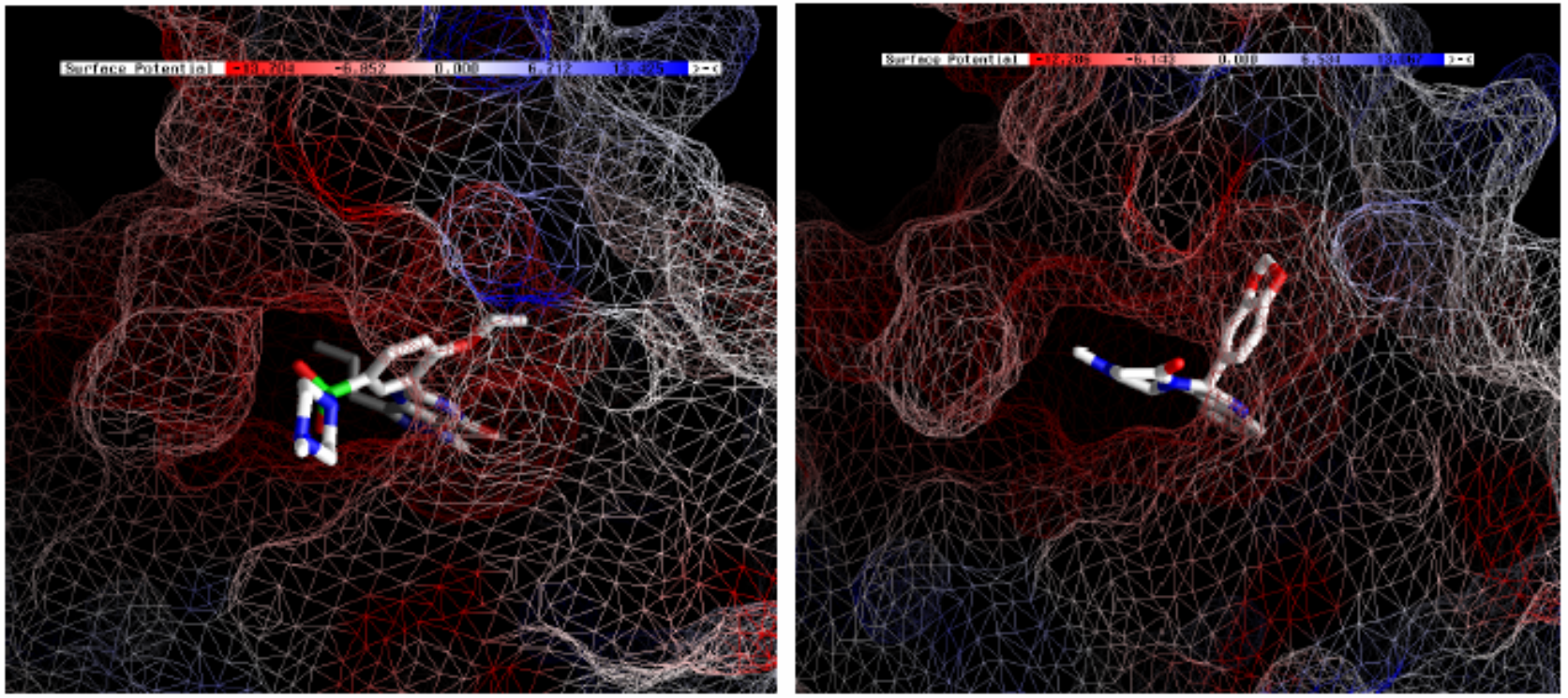
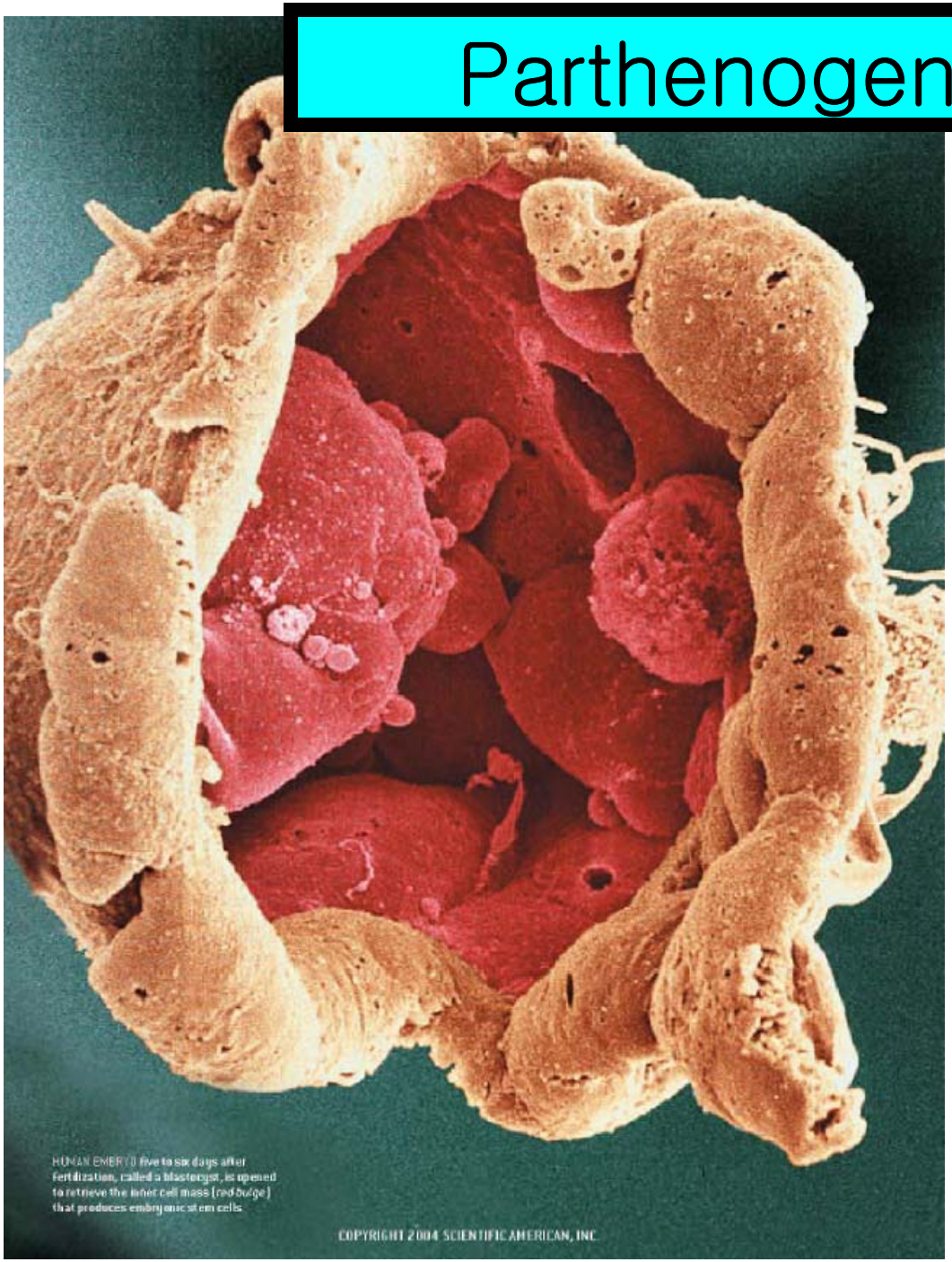
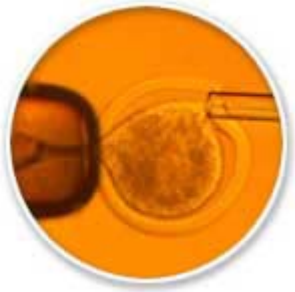


그림. 비아그라(좌)와 시알리스(우)의 결합 모양

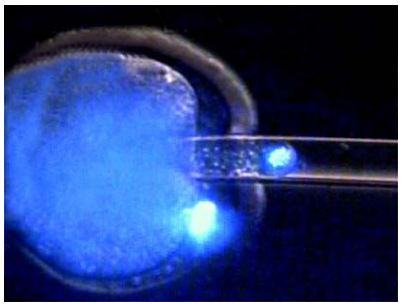
Viagra (left) and Cialis (right) lock in PDE5 Protein.

Parthenogenesis





Cloned Embryo Stem Cell



- Researchers in South Korea succeeded in extracting stem cells from a cloned human embryo -- a breakthrough that brings researchers closer to developing individualized disease treatments.

Korean Life Science:
Professor Hwang Woo-seok

CLONING COLLEGE

BY B. J. LEE

HE THERMOSTAT ON THE

South Korea's biomedical

personal life. But I do this research because it can help cure incurable diseases."

A big pile of grant money and a swank lab come in handy when you want to make major medical breakthroughs. But the 40 researchers at Seoul National University's College of Veterinary Medicine have shown that grit and determination—and the absence of government interference—can be just as important. Two weeks ago, Hwang Woo Suk and Moon Shin Young, who direct the work at the cloning lab in Building 85, published a paper in the prestigious journal Science that shocked biomedical researchers and put South Korea at the center of one of the hottest and most controversial research fields: stem-cell therapy.

Researchers have for years thought that

ow into any type of

may one day pro-

uch as Parkinson's

't know for sure,

menting with stem

human embryos,

ated by cloning.

While the most well-endowed labs in the United States, Britain, France and elsewhere are hamstrung by a political backlash against cloning research, South Korea has quietly filled the vacuum.

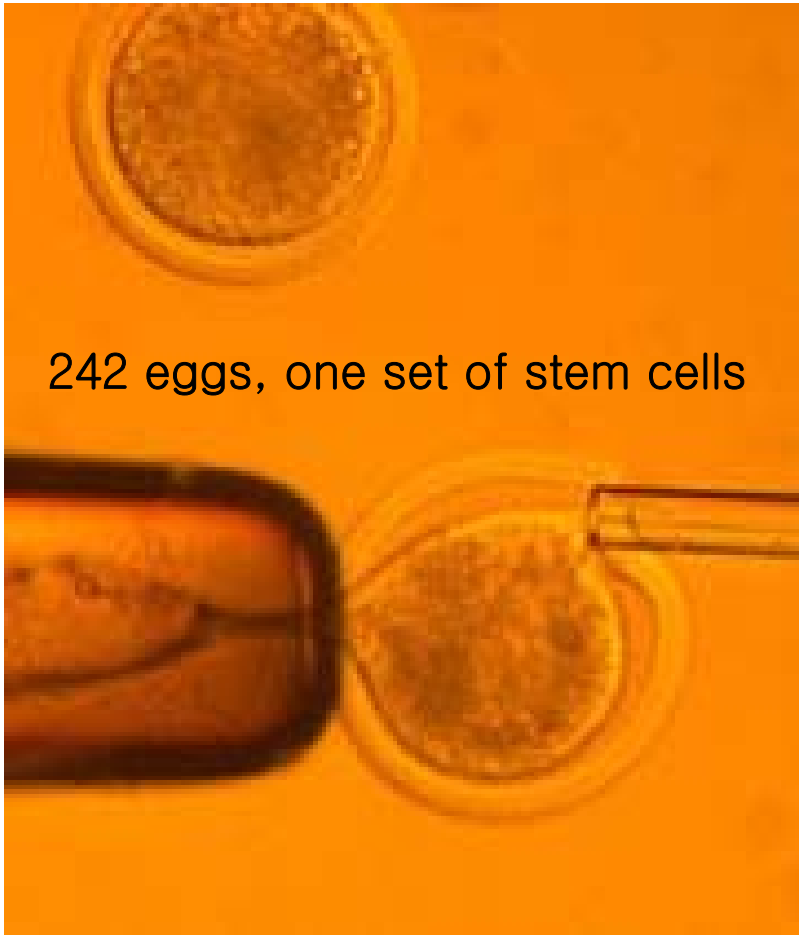
come back with grisly remains, from which they extract ovaries. Kim, whose husband also works at the lab, typically puts in 14-hour days, seven days a week, and the

meticulous, skillfully puncturing the membrane of an ovary with a tube too thin to see with the naked eye—is tedious and intricate. "I sacrifice a lot," she says. "For the past five years, there has hardly been any

44

Human Cloning Research at U.N. Address, 2004 Oct. 13
"Opening the Door to Discovery of Cures for Degenerative Diseases."

Cloned human embryos yield stem cells.



The embryos divided for 5 to 6 days and were then terminated.

Genetic material was injected into eggs that had their own DNA removed.

National Facilities I.
1250 keV Ultra High VoltageElectron Microscope

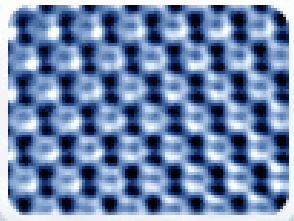
Korea Basic Science Institute

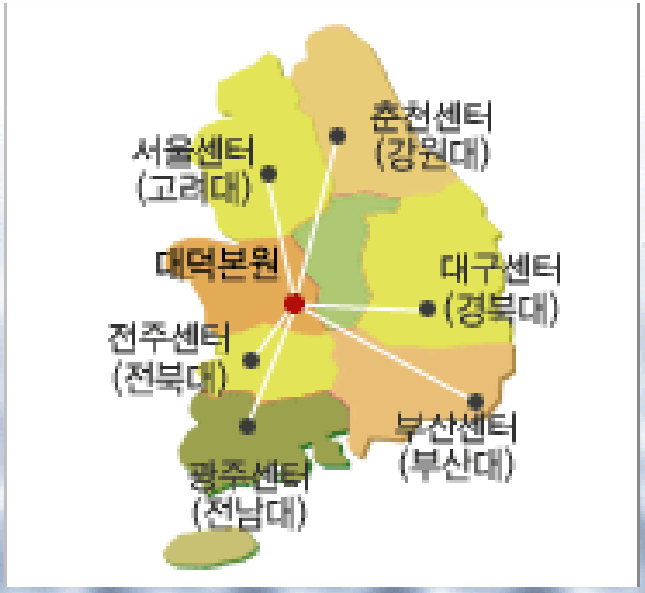
Remote Accessibility from Nationwide Universities

한국기초과학지원연구원

초고전압 투과전자현미경

세계최고의 삼차원 분해능을 추구하는 테크놀로지

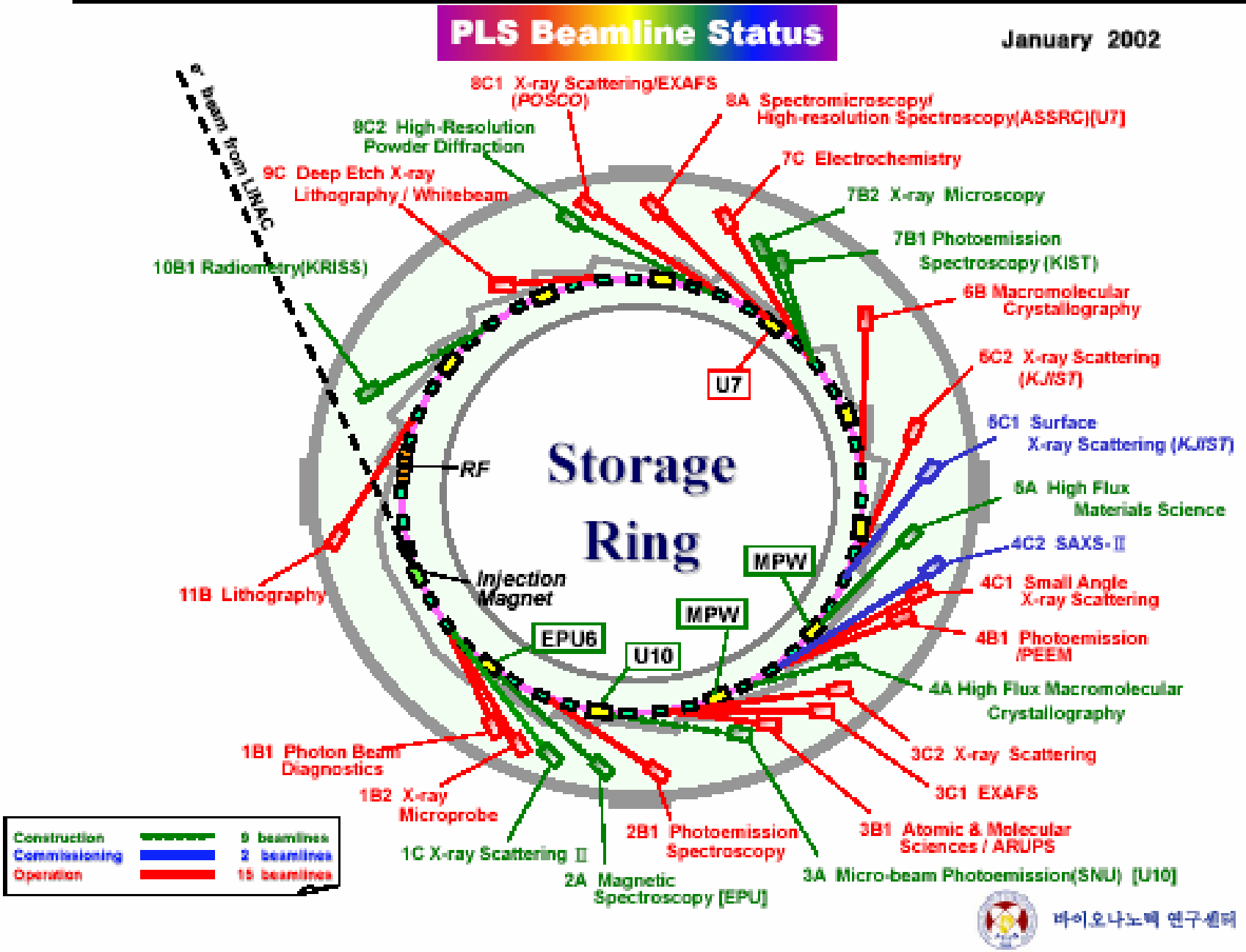




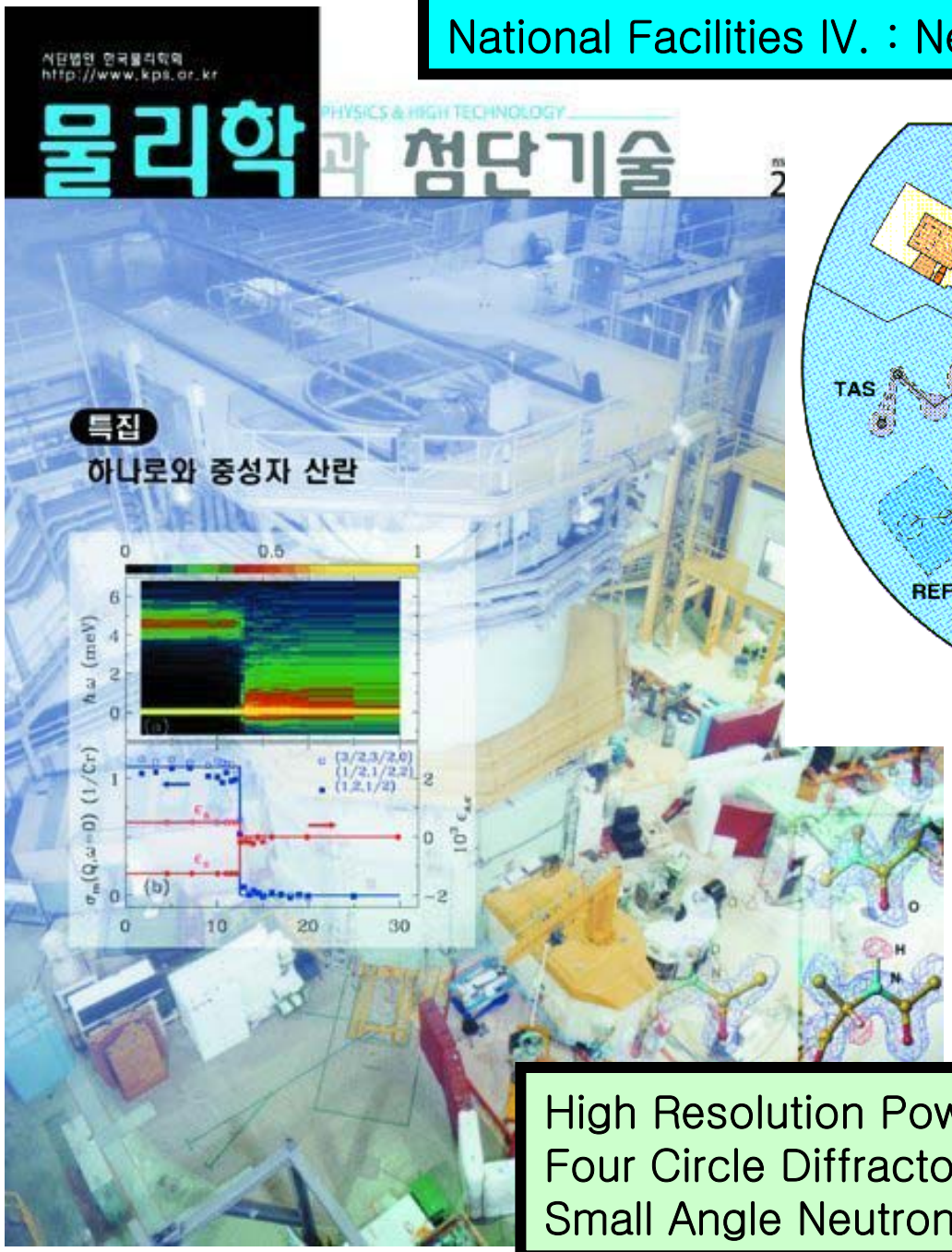
High Voltage
Electron Microscope

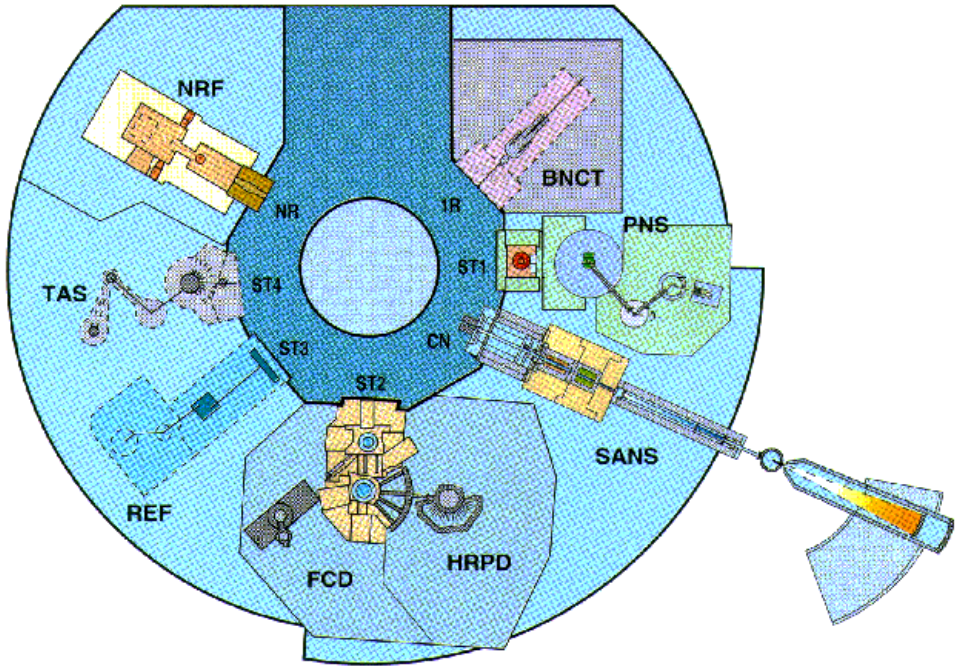
National Facilities II. 600 MHz NMR

National Facilities III. High-flux Synchrotron Radiation Source



National Facilities IV. : Neutron Diffraction Facility





Proteomics,
Nano Scale
Structure Determination

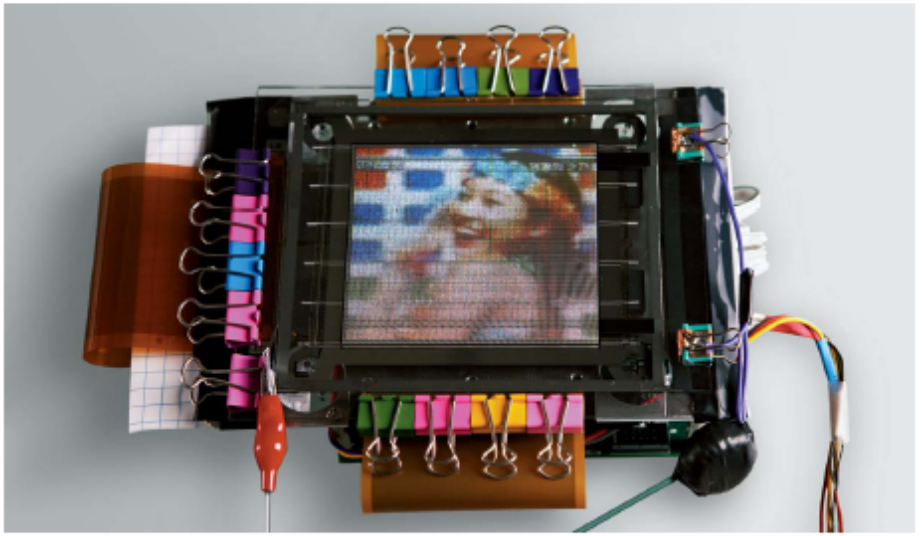
High Resolution Powder Diffractometer, HRPD,
Four Circle Diffractometer, (FCD),
Small Angle Neutron Spectrometer, (SANS)

National Facilities V. : Nano Fab (Budget $0.4 Billion)

	Instrumentation
Lithography	E-Beam, i-Line Stepper, Mask Aligner, Imprinter, Microscope
Etch	Oxide / Poly Etcher, Metal Etcher, PR Stripper, Deep Si Etcher
Diffusion	LPCVD, RTP, Wet Station, Part Cleaner, Furnace
Thin Film	Sputter, CVD, ALD, Ion Implanter, MBE, MOCVD, CMP
Biochemical & New Material	Bond Aligner, Chip Aligner, Laser Micro Machine, Fusion Bonder, Femto second Laser, Nano Cluster Generator, Chemical Vapor Condensation, Nano Indentor XP
Metrology	TEM, SEM, FIB, AFM

NANOTECH

The first commercial
Product that brings
Nanoscale electronics
Into the middle class
Home.



ON DISPLAY

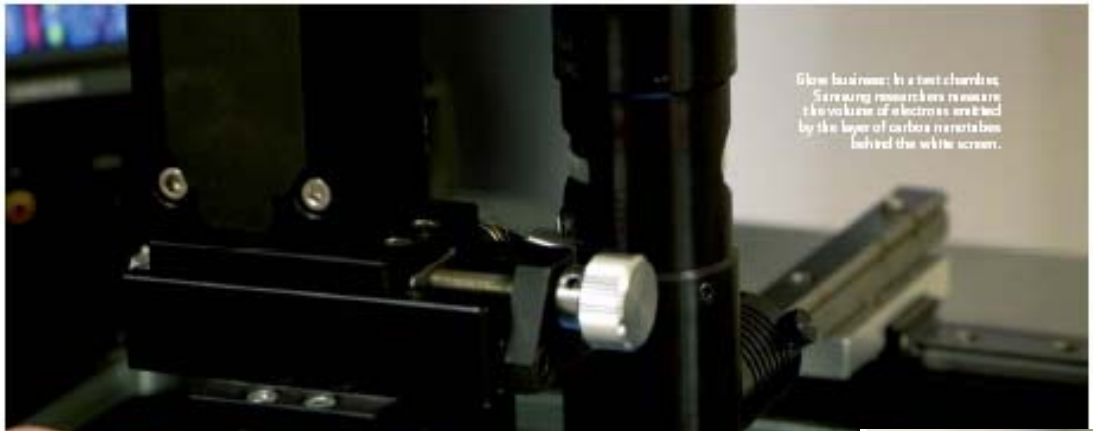
SAMSUNG'S CARBON-NANOTUBE TELEVISION COULD MAKE THE COMPANY'S OWN LUCRATIVE LIQUID-CRYSTAL AND PLASMA DISPLAYS OBSOLETE. THAT'S NOT STOPPING IT.

BY CHARLES C. MANN PHOTOGRAPHS BY VIRGILE SIMON BERTRAND

60 TECHNOLOGY REVIEW November 2004 www.technologyreview.com

www.technologyreview.com TECHNOLOGY REVIEW November 2004 61

Samsung Advanced Institute of Technology

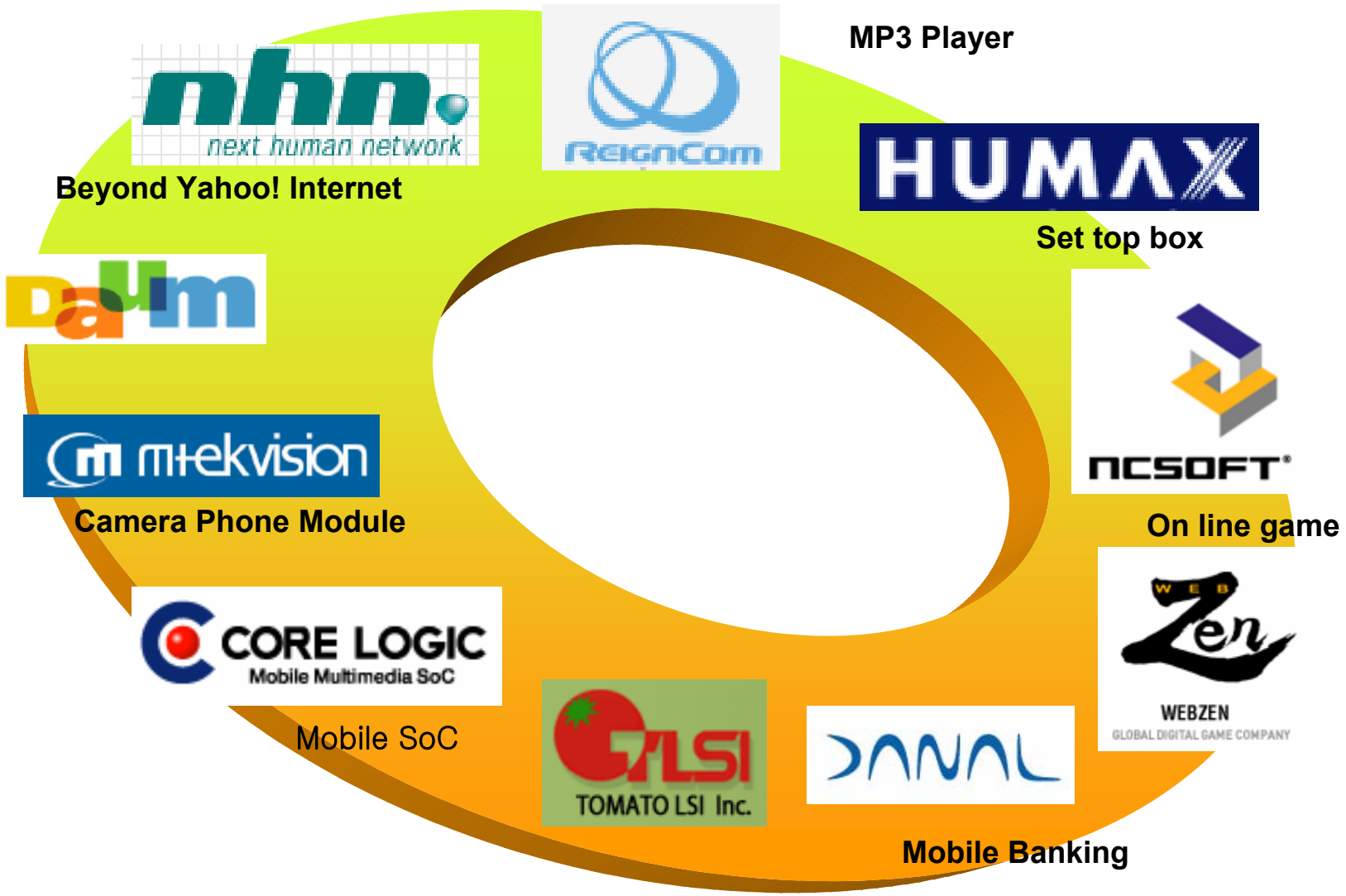


Glow business: In a test chamber, Samsung researchers measure the volume of electrons emitted by the layer of carbon nanotubes behind the white screen.

Real Challenge in
Bringing nanotechnology

Making the product affordable

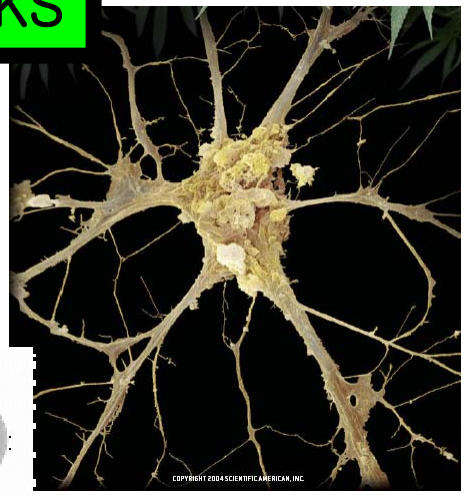
Venture Again in 2005 !!!

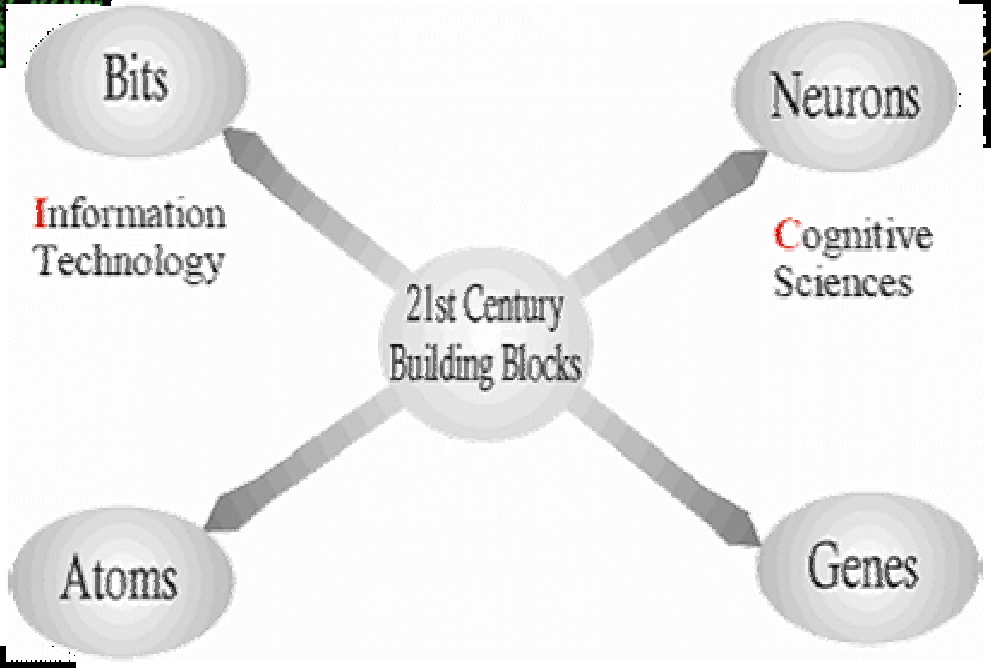


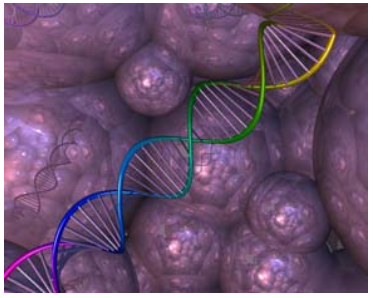
Goal for Nano Tech. Education in Korea

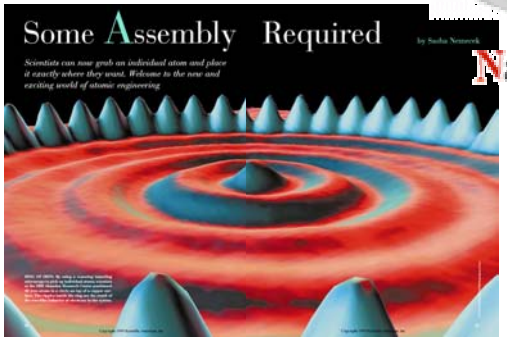
- Provide the best and brightest Nano-Scientists Nano Technologists to the Industry as well as National Labs and Universities.

21 Century Building Blocks

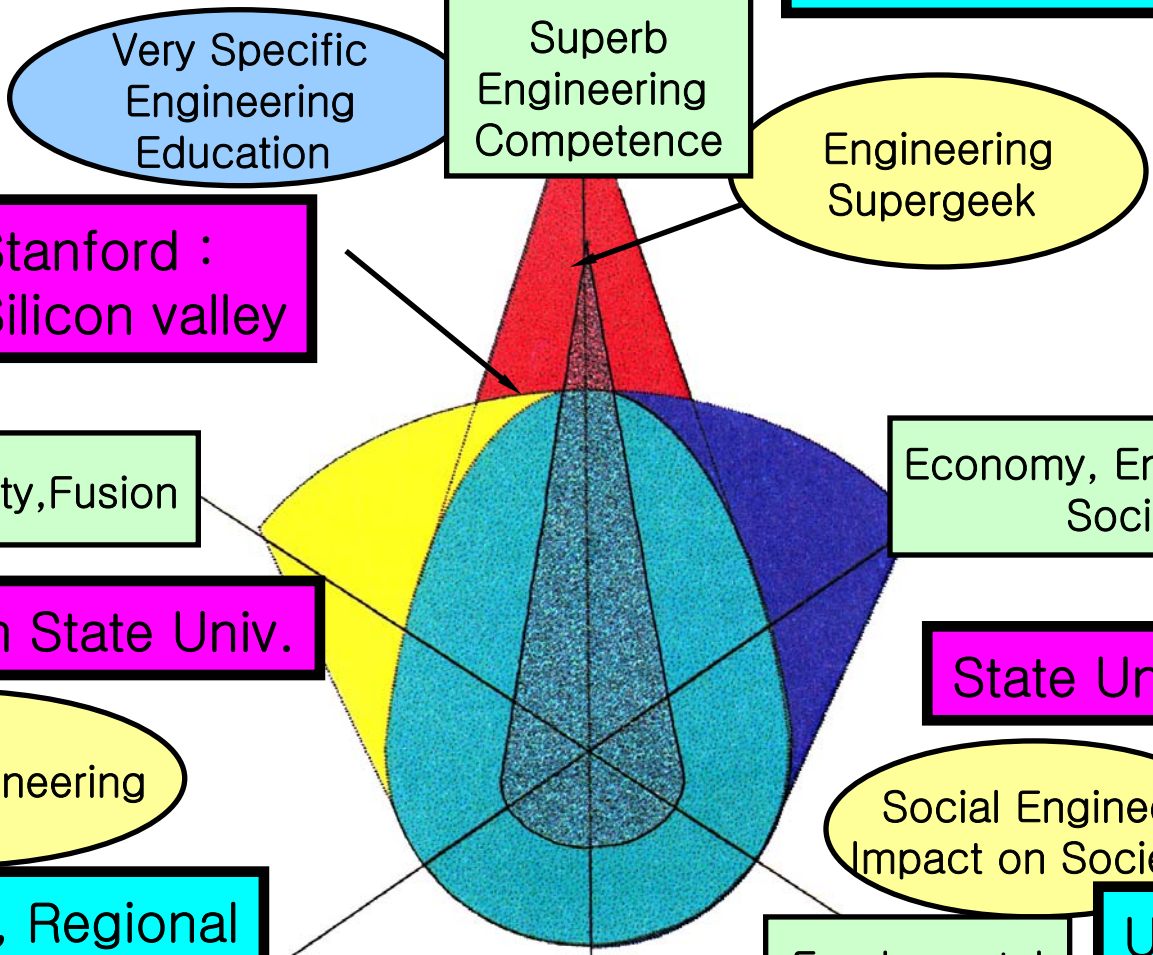




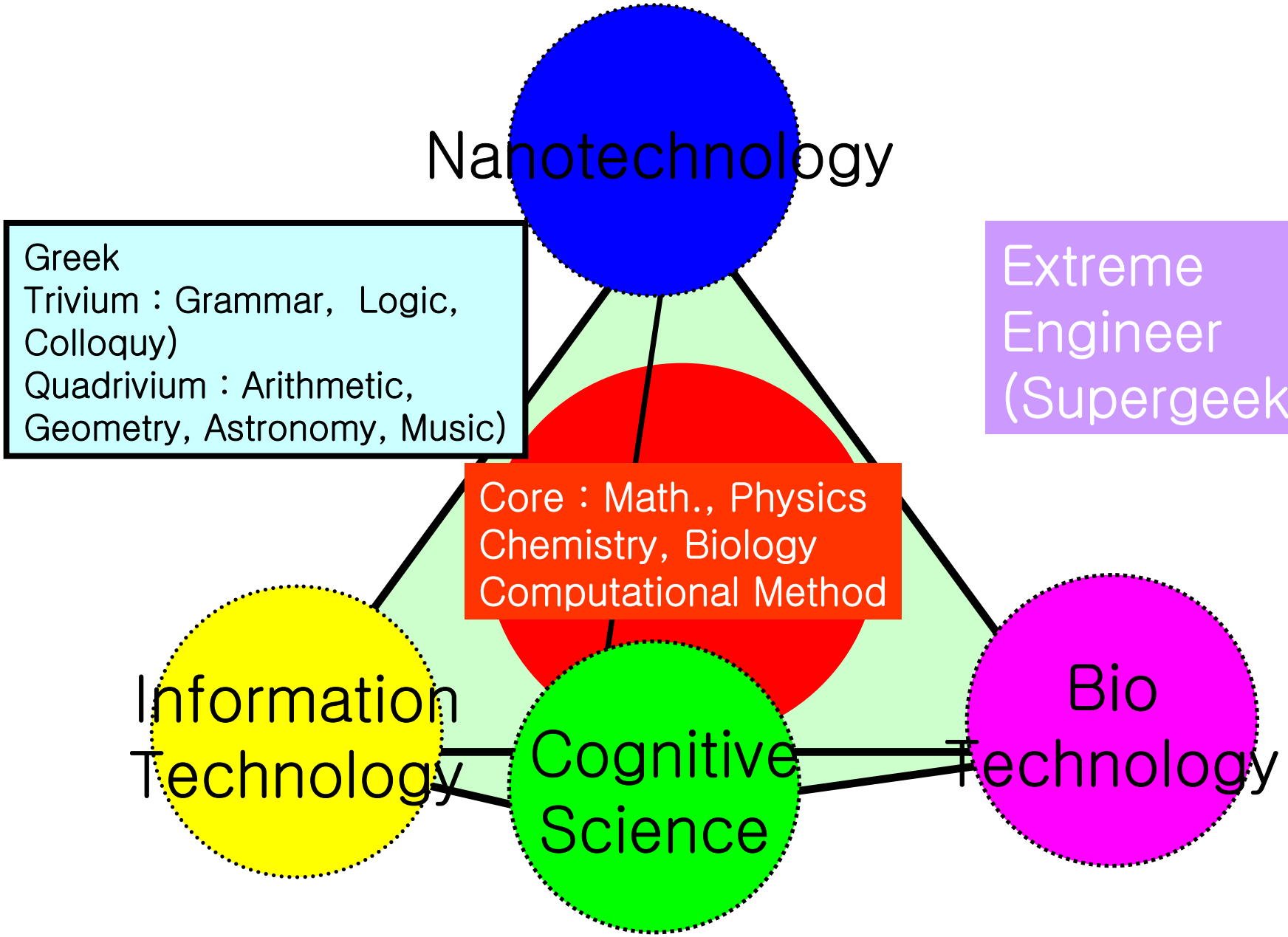




π Type Education



-Type, T Type, ㅠ Type, Triumvirate , Diamond Type



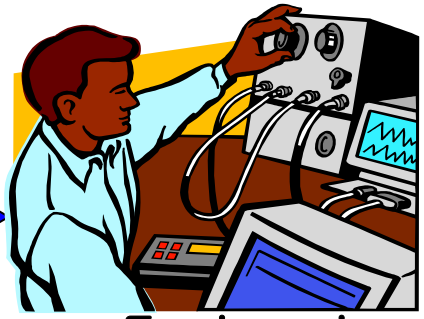
Career Path after Engineering Schools

Graudation(100%)

Find Jobs

Engineer
74%

80%



Engineering
Professionals
Master of
Engineers

Graduate
School

Master
/Ph.D.
15%

Researcher/
Faculty

Educational Integration : Double Core Education System

Double Educational Track System

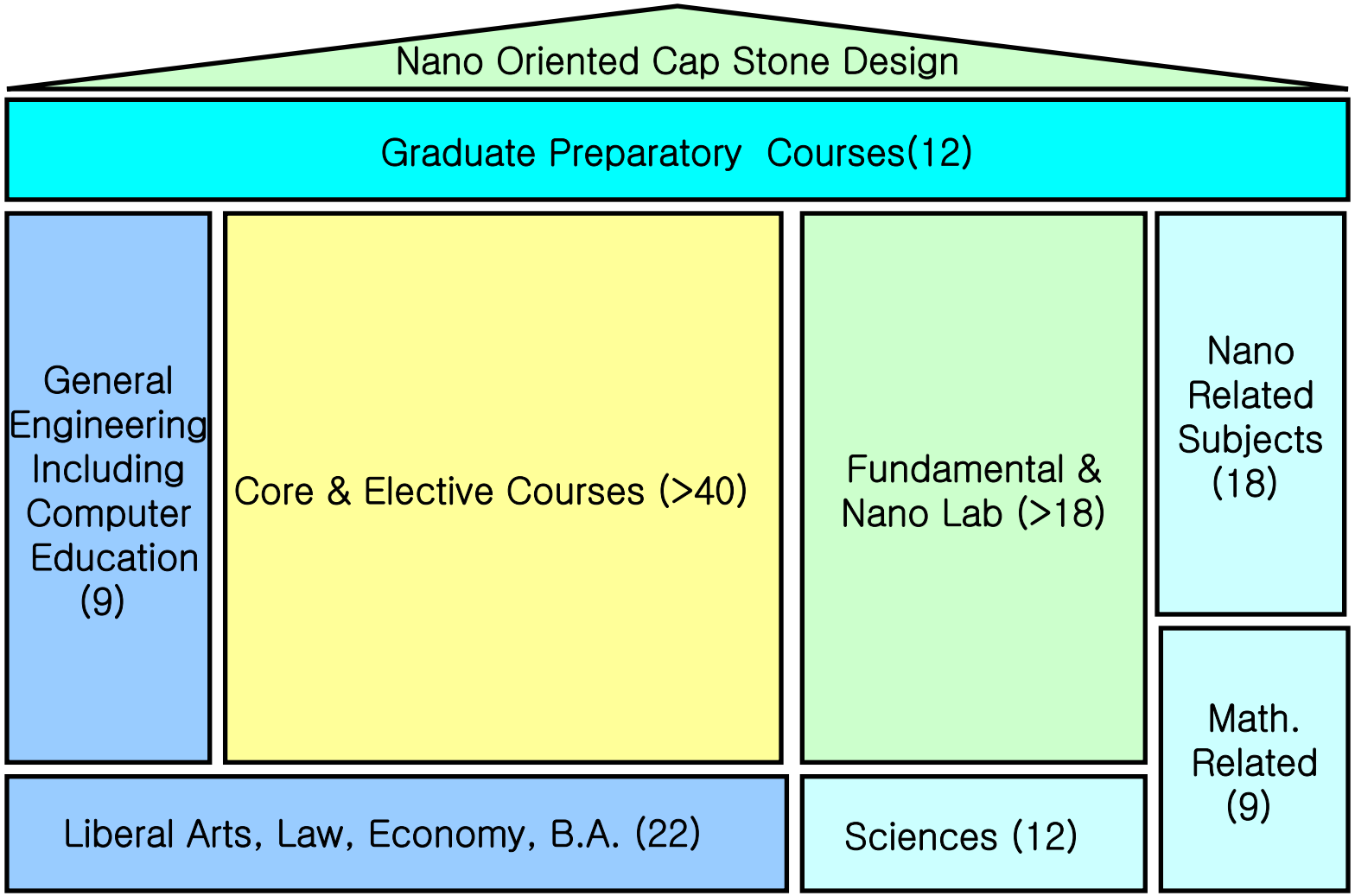
Freshman (2 Semes-ters)	Engineering Fundamentals (36) Physics I, II Chemistry I, II Computer Programming Calculus I, II, Foreign Languages, Communication Skills Philosophical Understanding of Sci. and Tech. Biology I, II	Basic Science Sciences , Math., Language , Computer Skills
Sophomore ~ Senior (6 Semes-Ters)	Double Major(110) For Job Search 1st Major Core & Electives : 45 2nd Major Core & Electives : 45 Economy, Law : 6 Free Choice : 6	Graduate Preparatory Courses Pro. & Stat. Math.: 9 Graduate Related:15 Core & Electives : 54~60 (Lab : 18) are enforced. Economy, Law : 6 Free Choices : 12~18
Total Credit	138~145 Credit	

Deepened Eng.

1.Courses for Job Search
2.Courses for Higher Grade
-Business Mind
-Innovative Venture

Student Initiate Course Planning

Course Structures (Total 140 Credits)



eXtreme Engineer Education (E^3) Nano Manpower (eXtreme Engineering Epicenter) Initiative Project

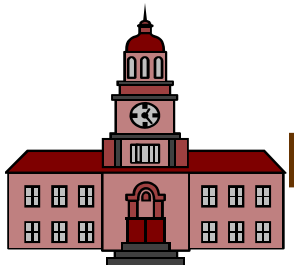
E Cube Project

Government

University-Industry
Joint Curriculum
Steering Committee

Suggest Curriculum

Nano Soft Network



College
Education

Nano Extreme Engineer
(Extreme Engineering
Epicenter)

Nano Lab of Excellency

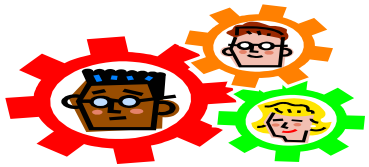
Industry Feed
back to Uni.

Industry

Customer-Needs

Based Nano
Engineer

Curriculum suitable
for New Growth
Engine

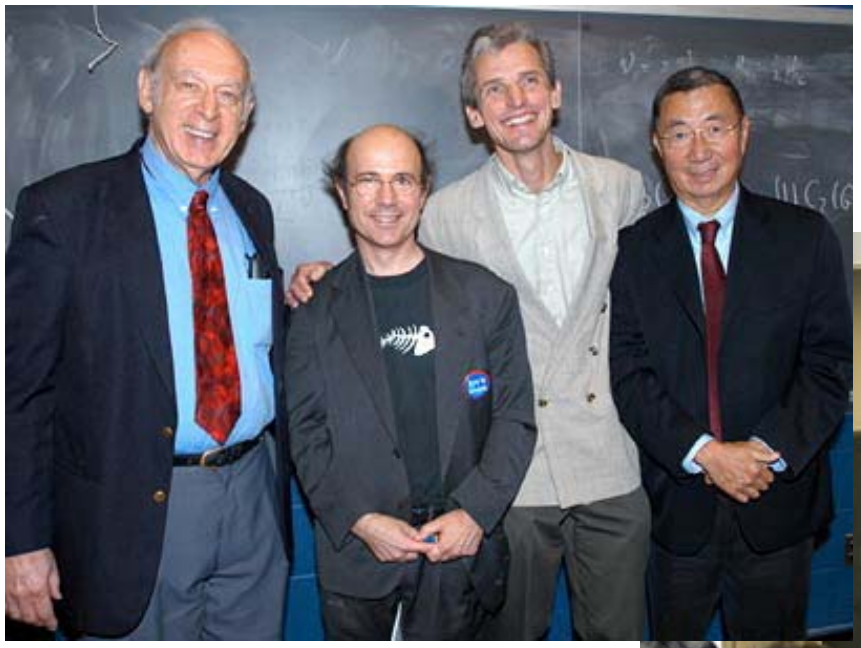


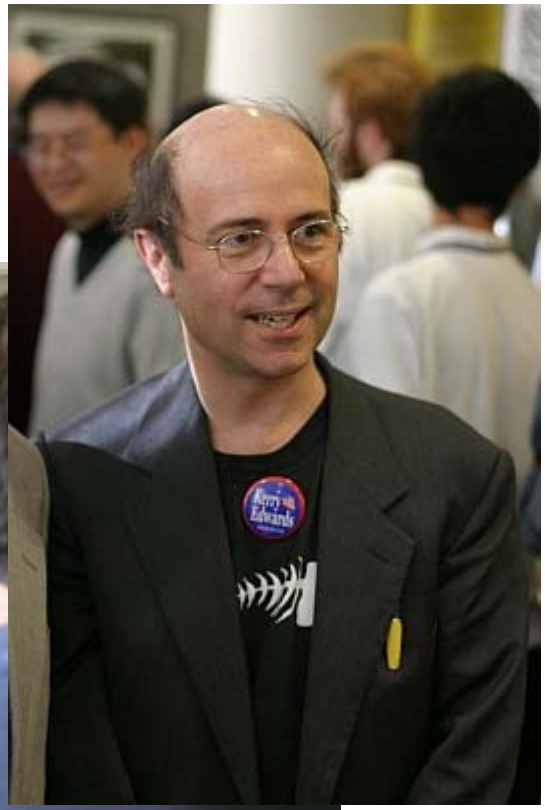
Nano Extreme
Engineer

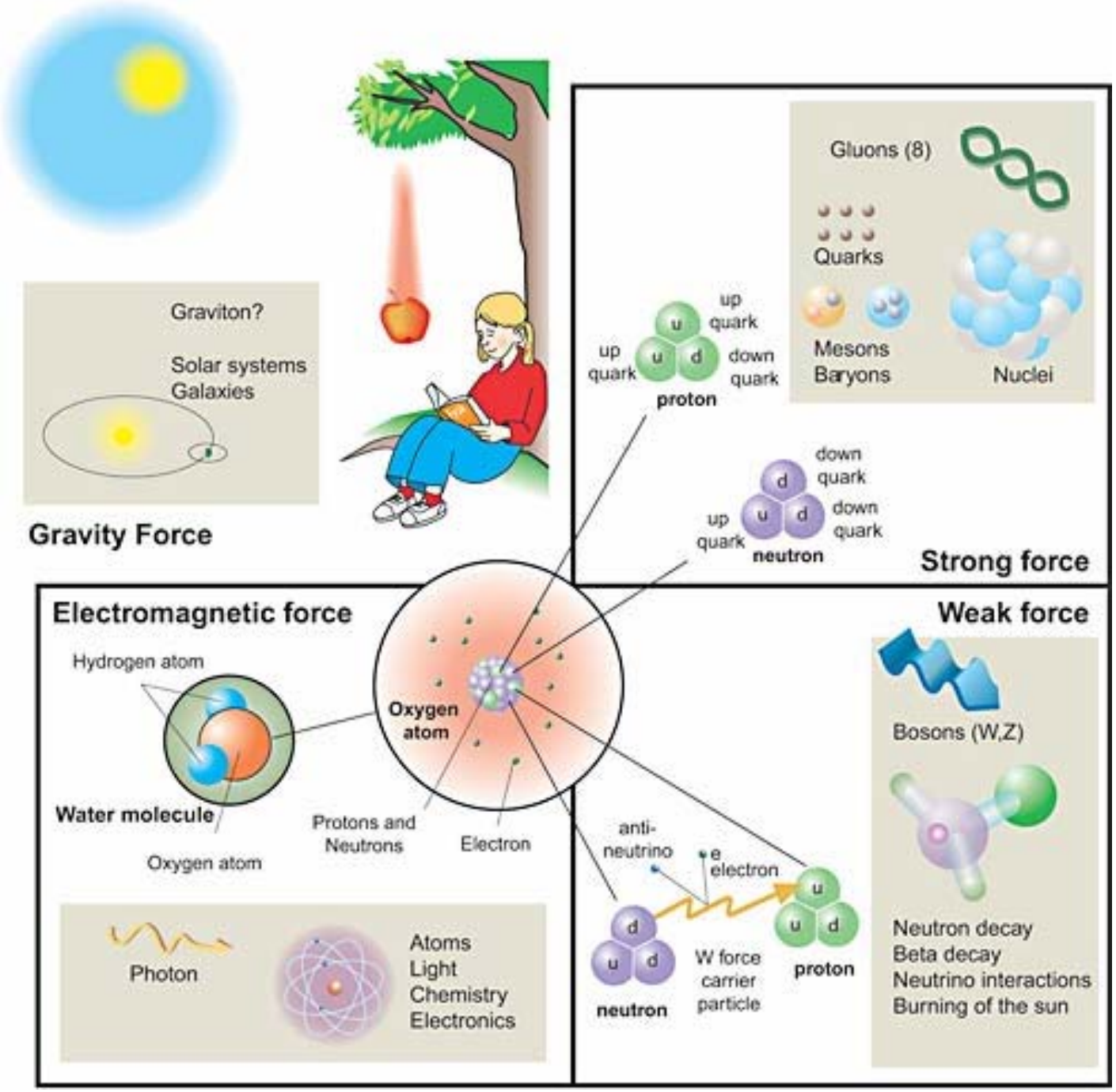
Nano related
Community College
Education

Nobel Prize in Physics in 2004 : Wiczek at MIT

1. Ultraviolet Behavior of Non-Abelian Gauge Theories (with D. Gross), *Phys. Rev. Lett.* **30**, 1343 (1973).
2. Asymptotically Free Gauge Theories, I (with D. Gross), *Phys. Rev.* **D8**, 3633 (1973).
3. Asymptotically Free Gauge Theories, II (with D. Gross), *Phys. Rev.* **D9**, 980 (1974).
4. Gauge Dependence of Renormalization Group Parameters (with W. Caswell), *Phys. Lett.* **B49**, 291 (1974).






Graviton?
Solar systems
Galaxies
Gravity Force
Gluons (8)
Quarks
Mesons
Baryons
Nuclei
up quark
up quark
down quark
proton
down quark
up quark
down quark
neutron
Strong force
Electromagnetic force
Hydrogen atom
Oxygen atom
Water molecule
Oxygen atom
Protons and Neutrons
Electron
Photon
Atoms
Light
Chemistry
Electronics
Weak force
Bosons (W,Z)
anti-neutrino
e electron
W force carrier particle
neutron
proton
Neutron decay
Beta decay
Neutrino interactions
Burning of the sun

- We now know it was incorrect because in June 1973 this year's Laureates entered the arena. In two publications back-to-back in the journal Physical Review Letters, one by Gross and Wilczek and one by Politzer, the amazing discovery was announced that the beta function can be negative.

•When their discovery was made, these physicists were quite young
Wilczek and Politzer were still graduate students, in fact.

H. David Politzer

**California Institute of Technology,
High Energy Physics
452-48
Pasadena, CA 91106-3368
USA**

American citizen. Born 1949 (55 years). Doctor's degree in physics in 1974 (25) at Harvard University. Professor at the Department of Physics, California Institute of Technology (Caltech), Pasadena CA, USA.

Frank A. Wilczek

**Massachusetts Institute of Technology
Center for Theoretical Physics
77 Massachusetts Ave.
6-305 Cambridge, MA 02139
USA**

American citizen. Born 1951 (53 years) in Queens, NY, USA. Doctor's degree in physics in 1974 (23) at Princeton University. Professor at the Department of Physics at MIT, Cambridge MA, USA

Core and Elective Courses in Nanoscale Science and Engineering (45 Courses)

1. Solid State Electronics
2. Solid State Photonics
3. Solid State Spintronics
4. Solid State Ionics
5. Device Physics
6. Logic & Architecture of Electronic Devices
7. Materials Science for Information Technology
8. Materials Science for Flat Panel Display
9. Materials Science for Data Storage
10. Optics
11. Diffraction Physics

12. Materials for Extreme Engineering
13. Materials Science for Ferroelectric Materials
14. Milimeter Wave Materials
15. Mesoscopic Materials Science
16. Mechanical Properties of Solids
17. Electrochemistry of Solids
18. Basic Principles of Microprocessors
19. Physics of Non-volatile Memories
20. Materials Science for Artificial Bio Materials
21. Engineering for Microscopic Machines/MEMS/Actuators

22. Intelligent Materials
23. Superconducting Devices and Circuits
24. Materials Science for Energy
    (Solar Materials, Nuclear Materials)
25. Materials Design for Environment
26. Structure and Properties of Crystalline & Non Crystalline Solids
27. Perspectives in Materials Science
28. Transport Phenomena
29. Thermodynamics and Kinetics of Materials
30. Defects and Defect Chemistry
31. Physical Chemistry of Steel making/Chemical metallurgy
32. Innovative Data Handling Techniques
33. Networking
34. Physical Metallurgy
35. Introduction to Bioinformatics, Proteomics and Pharmaco genomics
36. Software Tools : Atomistix Virtual Nanolab, Chemistry 4-D draw, 3mol, BioModel

Math Enforced Curriculum

41. Mathematical Methods for Physicists
42. Advanced Engineering Mathematics I, II
43. Advanced Partial Differential Equations and Applications to Molecules and Atoms
44. Solution of Ordinary and Non linear Schrodinger's Equations
45. Solve Partial Differential Equations in MathCAD

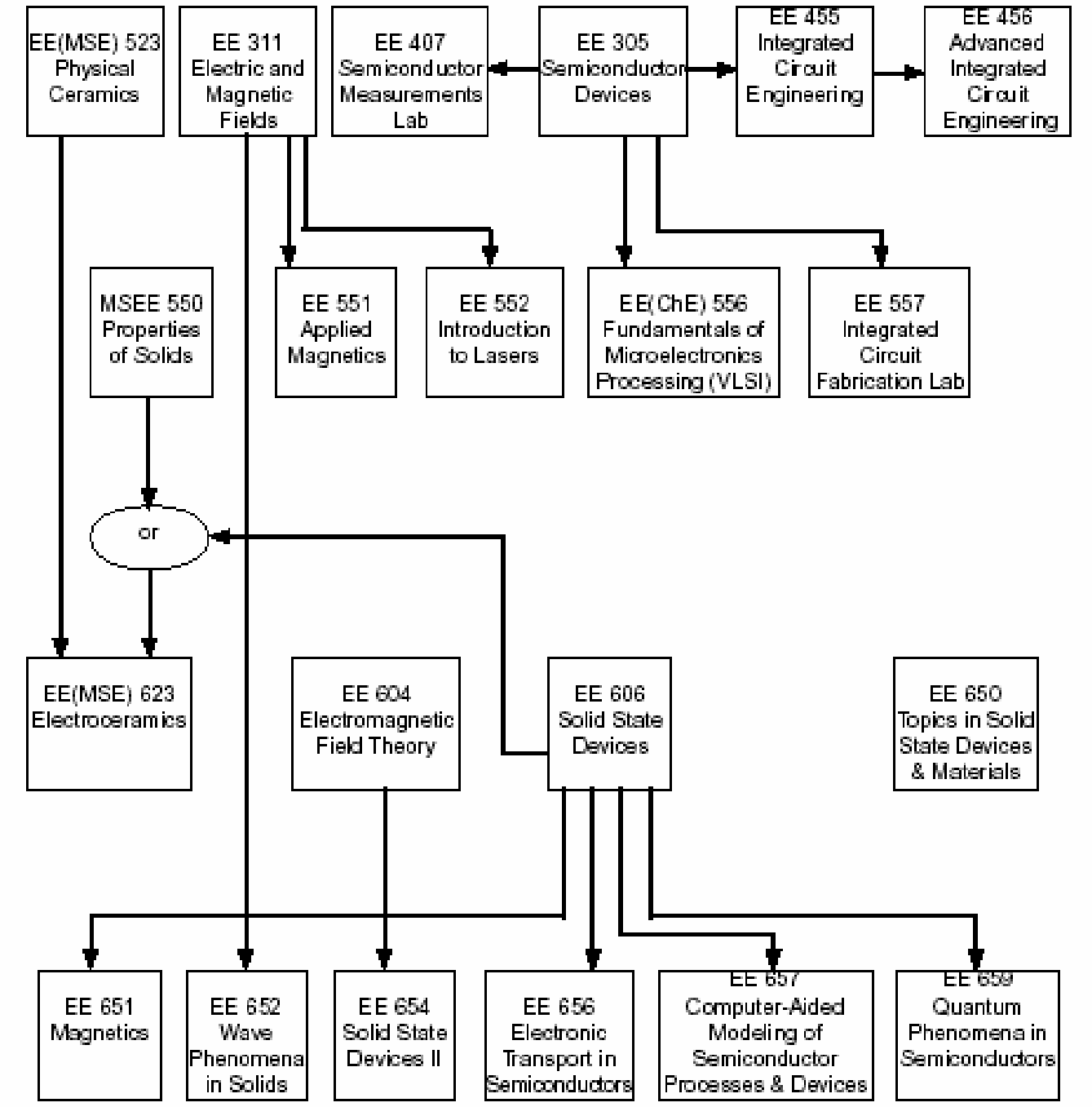
Elective Courses for Fusion Nano-Field (15 Courses)

1. Nano/Molecular Electronics
2. Supramolecular Chemistry / Self-assembly Material
3. Nano systems / Mesoscopic Systems
4. Quantum Nano Devices and Electronics
5. Nanostructured Materials
6. Colloid Chemical Sciences
7. Synthesis, Assembly and Processing of Nano Structures
8. Chemistry and Physics of Nanomaterials
9. Nano-Bio Materials / Hybrid Materials
10. Scanning Probes and Nanoscale Materials Characterization
11. Next Generation Lithography / Bottom-up process

Nano Simulation and Nano Design

12. Modeling of Nanostructures and Nanodevices
13. Simulation of Nanostructures and Nanodevices
14. Optimization of Nanosystems
15. Design and Product Development of Nanosystems

Electrical Engineering & Nanotechnology Curriculum



Nanotechnology I: Fundamentals of Nanoscience	
Course Content	**Corresponding Science and/or Engineering Course**
The macroscopic and microscopic world	Freshman Engineering
Molecular manufacturing	Freshman Engineering
Self assemble	Freshman Engineering
Impact on the society	Freshman Engineering
Building blocks of living organisms	Biology
The cell	Biology
DNA, RNA and genes	Biology
Protein synthesis and protein engineering	Biology
Biosensors	Biology

Integration of Nano Technology I within Introductory Freshman and Sophomore Courses

Recombinant techniques	Biology
Genetic engineering	Biology
Introduction to molecular chemistry	Chemistry
Introduction to solidstate physics	Physics and Materials Science
Introduction to quantum mechanics and statistical mechanics	Physics
Chemical, electrical, mechanical, magnetic, optical and thermal properties of nanomaterials	Materials Science
Structure-property-application relationship of nanomaterials	Chemistry and Materials Science

Nanotechnology II: Synthesis, Processing and Manufacturing of Nanocomponents and Nanosystems	
Course Content	**Corresponding Science and/or Engineering Course**
Molecular manufacturing and mechanosynthesis	Molecular Biology, Physical Chemistry, Organic Chemistry and Mechanics of Materials
Nanomechanics	Physical Chemistry, Dynamics, Mechanics of Materials and Mechanics of Continuous Media
Nanosystem components MEMS, Self-assembly	Electronics, Thermodynamics, Quantum Mechanics, Bioengineering
Synthesis and processing of nanostructures	Engineering Materials, Microelectronic Processing
Molecular manufacturing	Microelectronics, Semiconductor Manufacturing
Nanofabrication	Microelectronic Processing

Integration of Nano Technology II within Junior and Senior Courses

Nanotechnology III: Design, Analysis and Simulation of Nanostructures and Nanodevices	
Course Content	**Corresponding Science and/or Engineering Course**
Modeling of nanostructures and nanodevices	Modeling and Simulation, Engineering Design
Simulation of nanostructures and nanodevices	Modeling and Simulation, Engineering Design
Sensors, intrumentation and microcontrol techniques	Instrumentation and Controls
Optimization of nanosystems	Optimization and Engineering Design
Design and product development	Microchip Design, Engineering Design

Integration of Nano Technology III within Senior and Graduate Level Courses

Undergraduate Nanotechnology Laboratory Courses : Example (Chemical Engineering)

Challenges:

- Drawing students into new discipline
- Incorporating nano into curriculum at many levels
- Ensuring continuing enrollments in Nano graduate programs

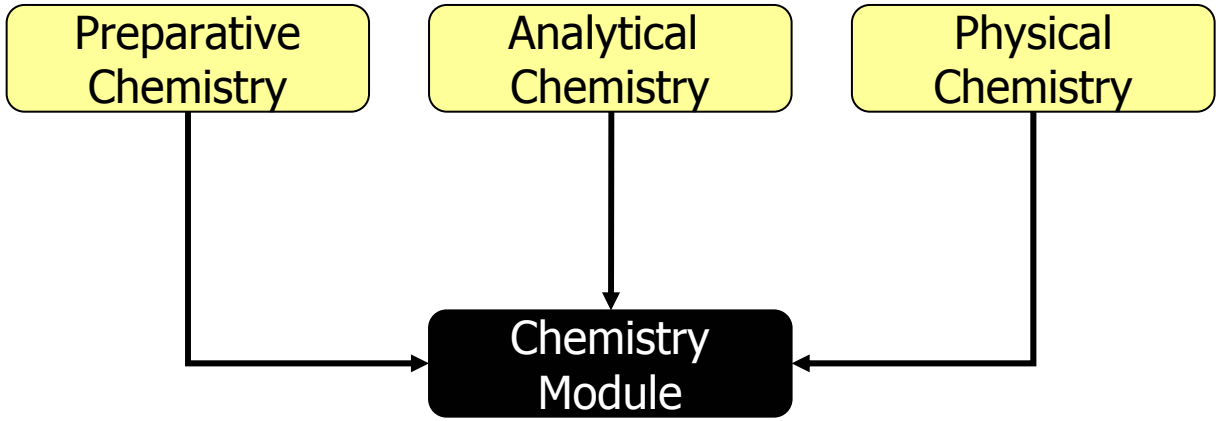
Guiding Principles:

- Interdisciplinary approach to curriculum required

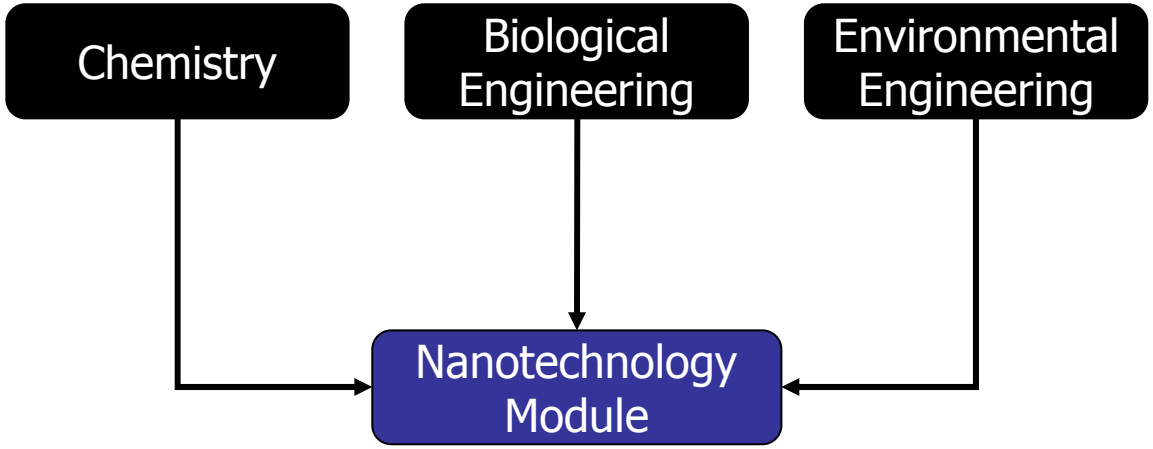
- Intersubdisciplinary Approach
  - Breaks down artificial boundaries between synthetic, analytical and physical aspects
- Hands-on Experience
  - Allows students to gain experience in new lab techniques
- Project-oriented (Capstone Design)
  - Provides an organizing principle and more closely resembles research project
- 4 Unit for a semester
  - Focuses on selected topic in reasonable depth

From Intra disciplinary to Interdisciplinary

Intradisciplines→ Chemistry Module

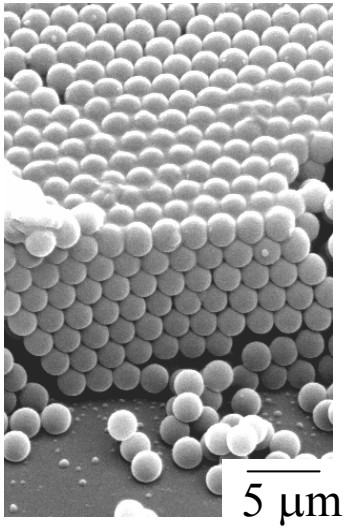


Interdisciplinary Disciplines → Nanotechnology Module



Unit I: Colloidal Chemistry

- Basic colloidal properties and chemistry (lecture)
- Scanning electron microscopy (lecture)
- Synthesis of monodisperse silica (lab week 1)
- Analysis of silica colloids (lab week 2)



SEM of SiO_2 colloidal crystal

JEOL6300 F SEM

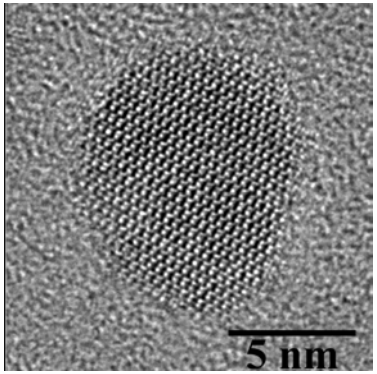
- Large flat panels permit easy viewing
- Students can 'touch' instrument
- Data collected digitally for analysis

Unit II: Metal colloids/nanocrystals

- Properties of metal colloids, historical uses (lecture)
- Chemistry and capping of gold nanocrystals (lecture)
- Transmission electron microscopy (lecture)
- Synthesis of gold nanocrystals–citrate method (lab week 2)
- Phase transfer method for gold nanocrystals and capping (lab week 3)
- Transmission electron microscopy of gold nanocrystals (lab week 4)

JEOL 2010 TEM

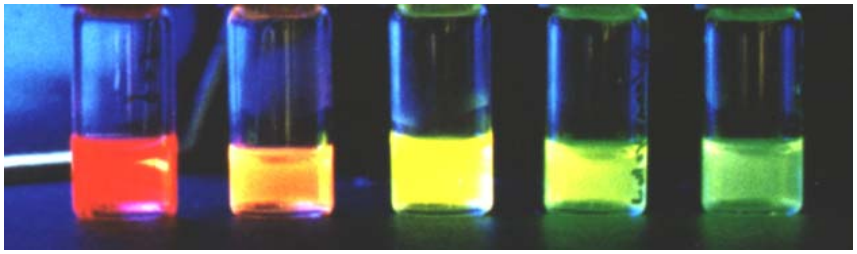
- Room for two to watch process
- High resolution imaging is possible/digital images



High resolution EM of TiO_2 nanocrystal

Unit III: Semiconductor Nanocrystals

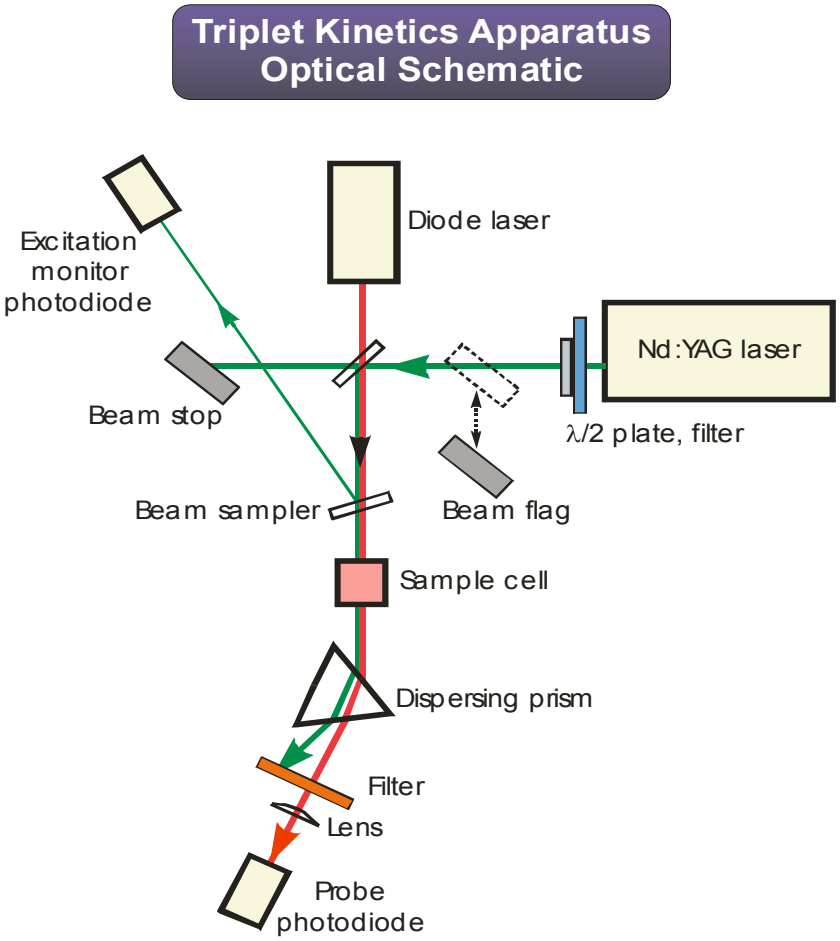
- Quantum dots and confinement (lecture)
- Synthesis of semiconductor nanocrystals—Inverse micelle method (week 5)
- TOPO synthesis with $CdAc_2$ for CdSe (rods and dots) (week 6)
- Transmission electron microscopy of gold nanocrystals (week7)



Visible fluorescence from semiconductor nanocrystals*

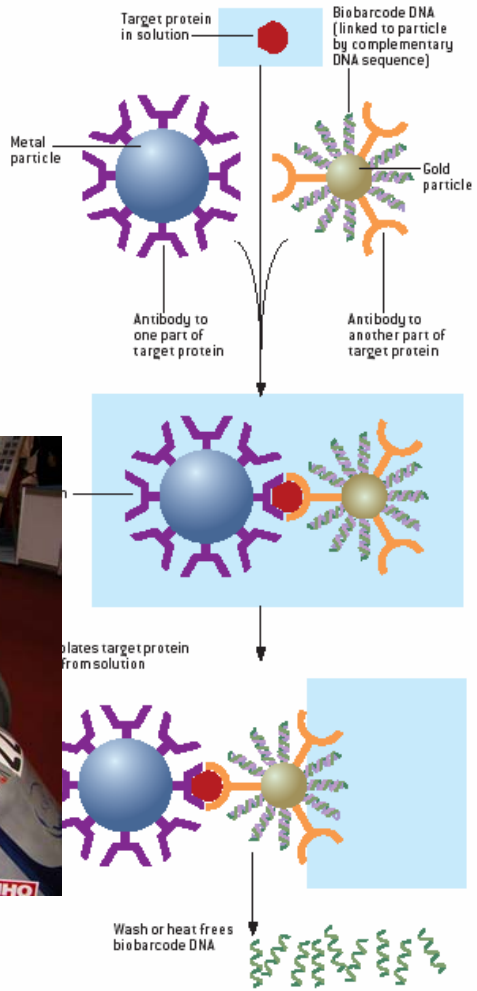
Unit IV : Fullerene Chemistry

- Isolation, Purification and Characterization
  - Soxhlet extraction of fullerenes from soot
  - HPLC separation of C_{60} and C_{70}
  - UV–vis spectrophotometry
  - Mass Spectrometry
  - ^{13}C NMR Spectrometry
- Electrochemistry
  - Cyclic Voltammetry and Differential Pulse Voltammetry
- Photophysics
  - Triplet decay Kinetics via Flash Photolysis



Nano Capstone Design Project :
For one semester, 5~7 team workers design and build Nano principle embedded final products.

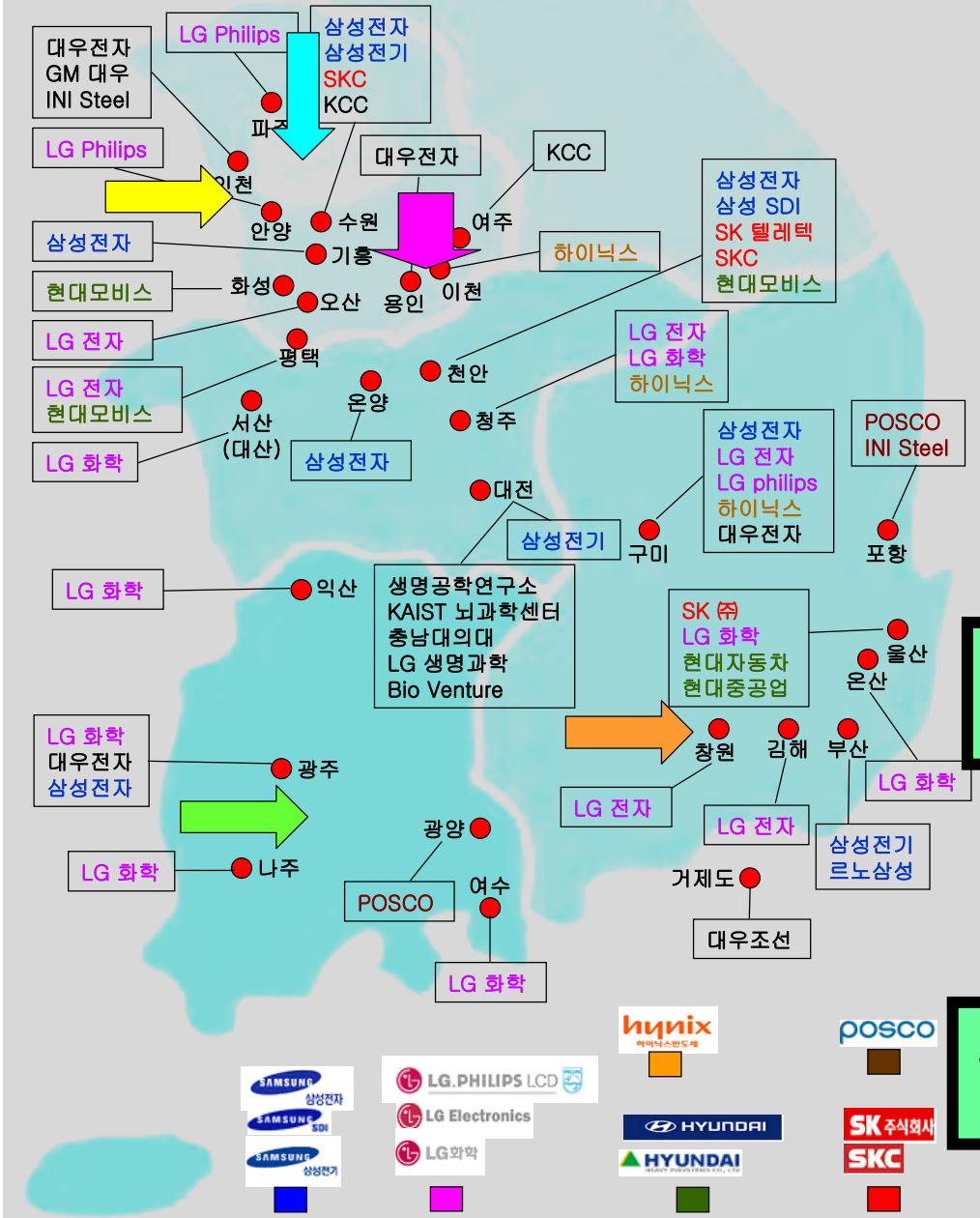
Micro Fluidic Chip



Collegiate Nano Inventors Competition

Nano Bio Barcode

나노 거점 Cluster를 위한 연구실 구축

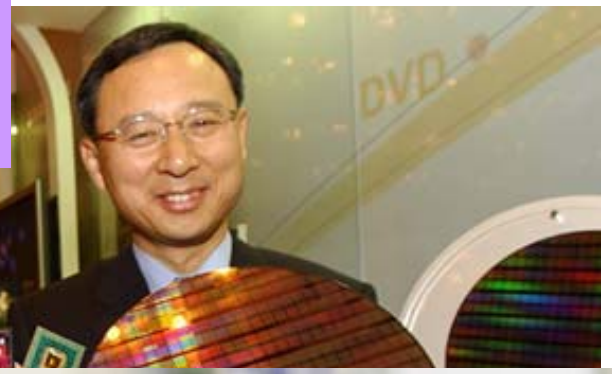


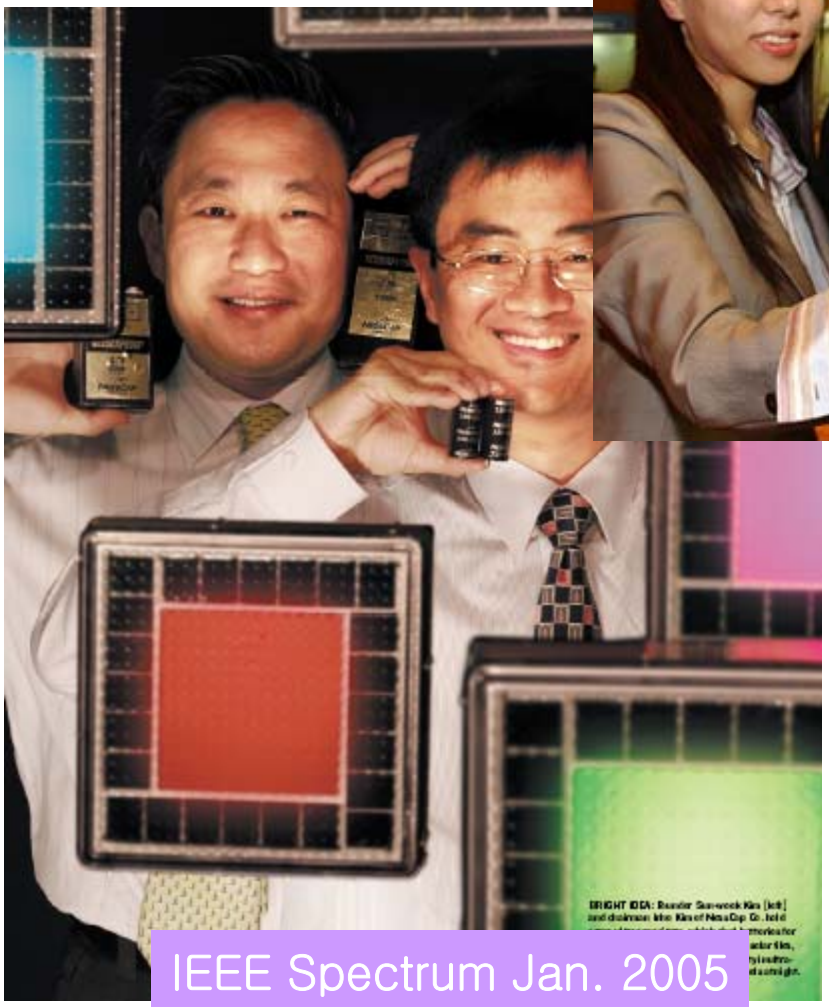
Nano Strongpoint Cluster

Nanoscopia Center of Excellency

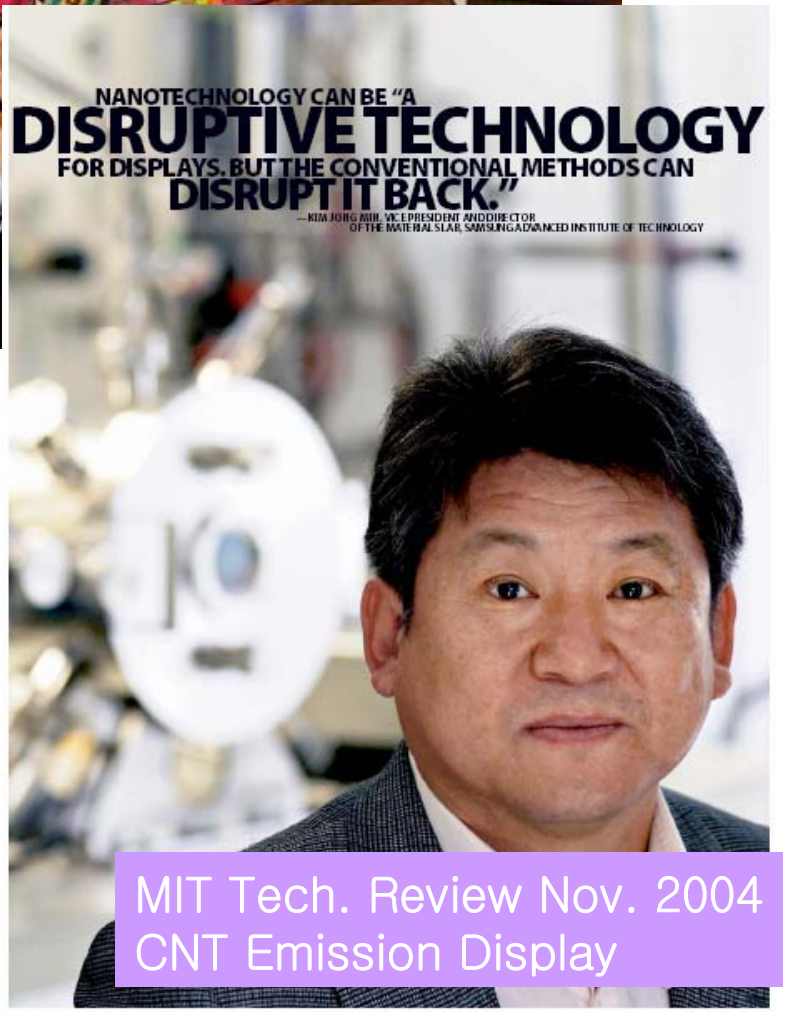
1. NT-IT Mesoscopic Lab.
2. Nano Quantum Fusion Characteristics Lab.
3. Nano Quantum Physical Transfer Phenomenon Lab.
4. NT-BT Mesoscopic Lab.
5. Nano Information Transfer Pathway Lab.

Hwang's Law
The memory density in Flash memory
Doubles every year. (Samsung Electronics CEO)

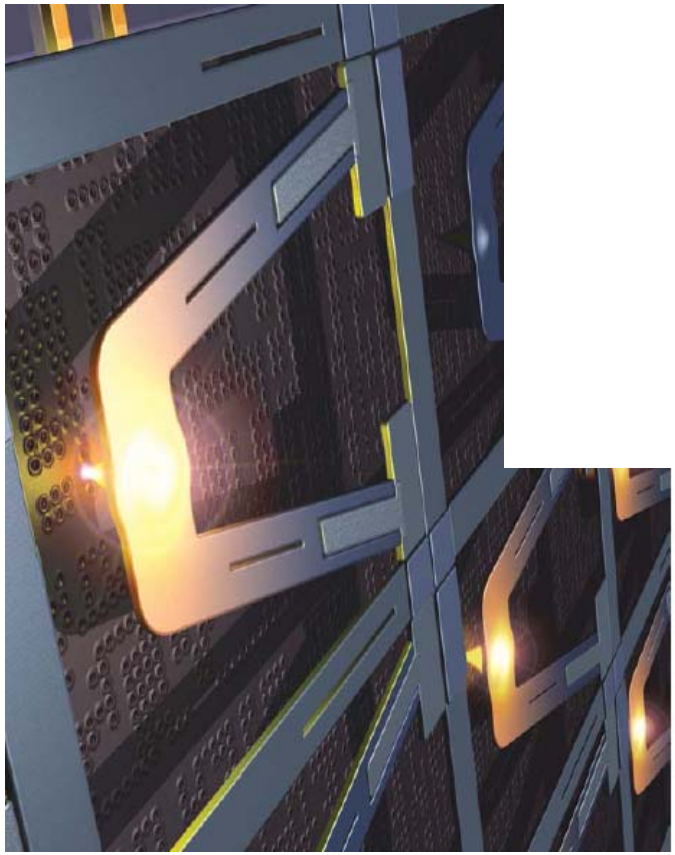


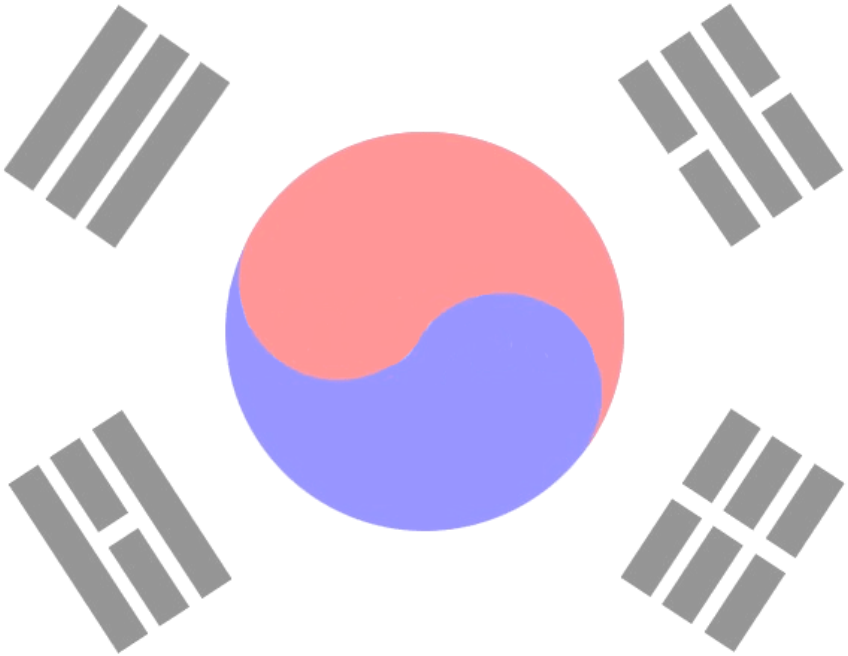


IEEE Spectrum Jan. 2005
Super Capacitor



MIT Tech. Review Nov. 2004
CNT Emission Display





Thank you very much!!