Course: Engineering Physics
PHY 1701

10-01-2020

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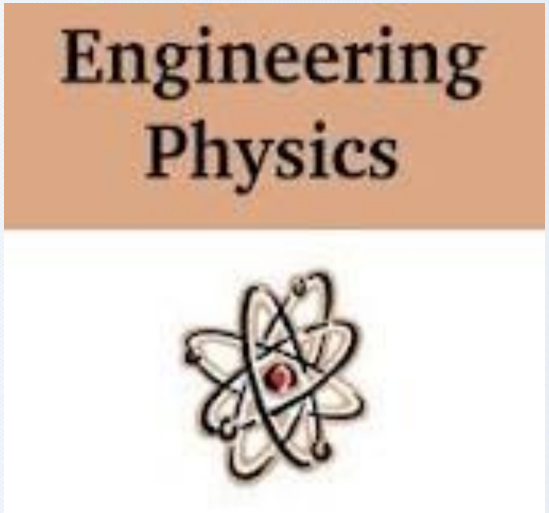
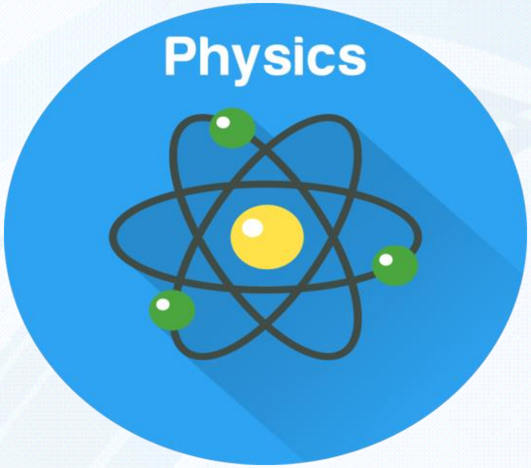
Outline

- Introduction to Nanotechnology
- Nanomaterials
- Moore’s Law
- Applications of Nanomaterials





Nanotechnology: Introduction

"The development and use of devices that have a size of only a few nanometres."

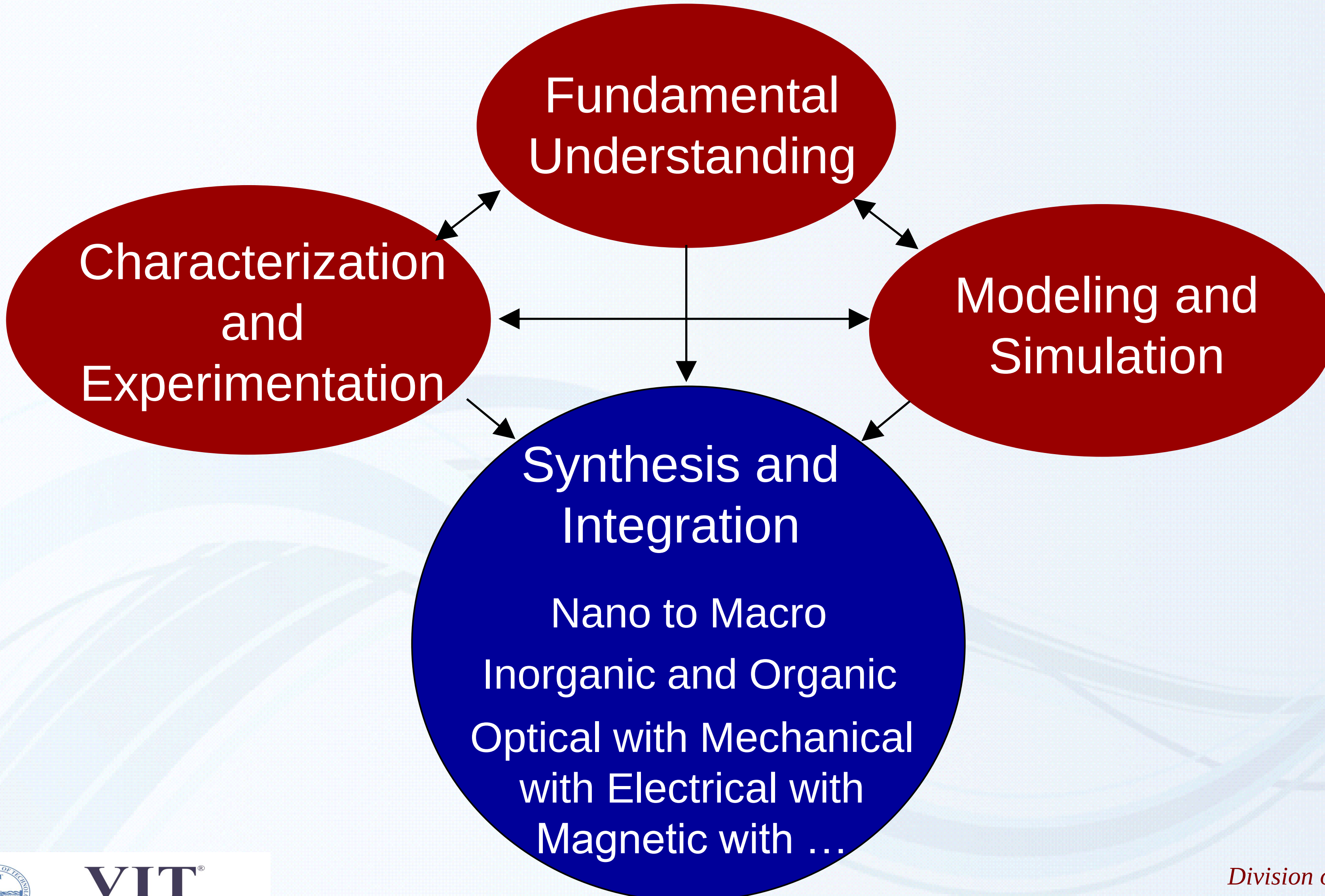
"Research and technology development at the atomic, molecular or macromolecular level in the length scale of approximately 1 - 100 nm range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices and systems that have novel properties and functions because of their small and/or intermediate size."

"Branch of engineering that deals with things smaller than 100 nm (especially with the manipulation of individual molecules)."

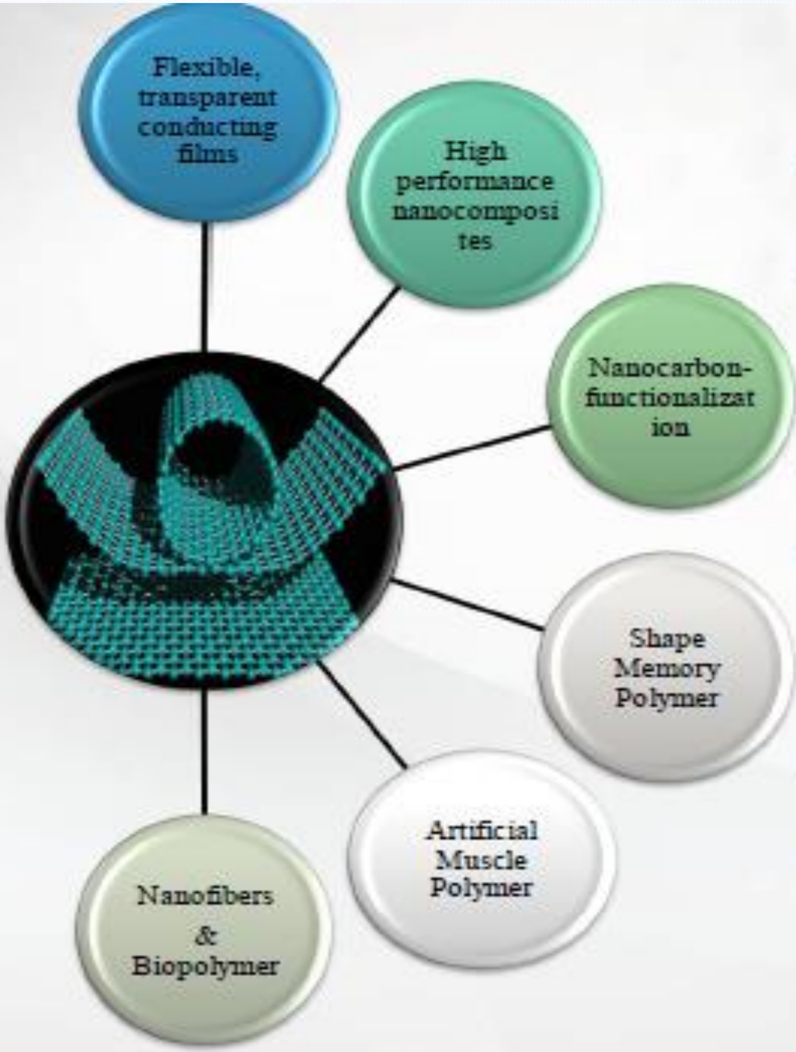
"Nanotechnology, or, as it is sometimes called, *molecular manufacturing*, is a branch of engineering that deals with the design and manufacture of extremely small electronic circuits and mechanical devices built at the molecular level of matter."

"The art of manipulating materials on an atomic or molecular scale especially to build microscopic devices."

Development of Nanotechnology



Nanomaterials



- Graphene, CNT based Transparent Conducting Films (TCFs)
- Functionalization of CNT and Their Nanocomposites
- Shape Memory Polymers: Actuator, Orthodontics, Textiles
- Artificial Muscle Type Polymer Actuator
- Organic-Inorganic Hybrids Including POSS Molecules
- Synthesis of Nanosilvers and Ag-Nanofibers by Electrospinning
- Biomimetic Organic-Inorganic Hybrids: Biomineralization
- Energy Harvesting Through Electroactive Polymers

Nano Fabrication

Nanofabrication can generally be divided into two categories based on the approach:

"Top-Down": Fabrication of device structures via monolithic processing on the nanoscale.

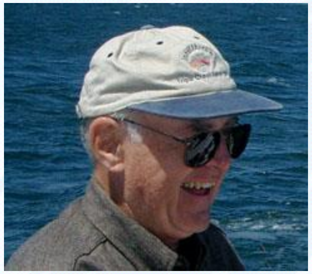
"Bottom-Up": Fabrication of device structures via systematic assembly of atoms, molecules or other basic units of matter.

Moore’s Law

- **Gordon Moore: a co-founder of Intel**

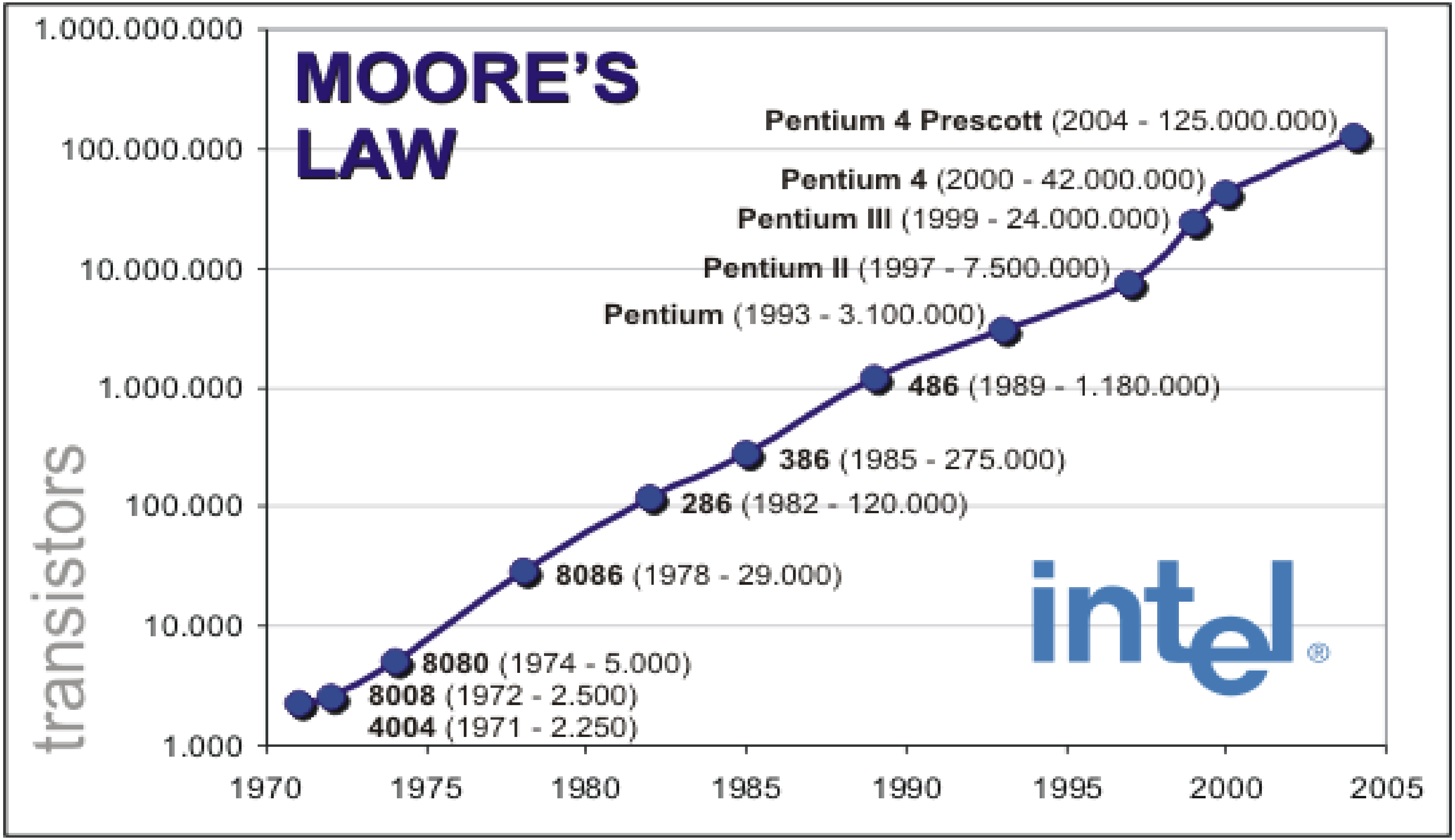
“Component counts per unit area doubles every two years .”

- **Feature size reduction enables the increase of complexity.**



	# of devices
SSI (Small scale IC)	1 ~ 100
MSI (Medium scale IC)	10^2 ~ 10^3
LSI (Large scale IC)	10^3 ~ 10^5
VLSI (Very Large scale IC)	10^5 ~ 10^6
ULSI (Ultra Large scale IC)	10^6 ~ 10^9
GSI (Giga scale integration)	10^9 ~
RLSI (Ridiculously Large scale IC) ?	Next to GSI

Moore's Law


MOORE'S LAW
Pentium 4 Prescott (2004 - 125.000.000)
Pentium 4 (2000 - 42.000.000)
Pentium III (1999 - 24.000.000)
Pentium II (1997 - 7.500.000)
Pentium (1993 - 3.100.000)
486 (1989 - 1.180.000)
386 (1985 - 275.000)
286 (1982 - 120.000)
8086 (1978 - 29.000)
8080 (1974 - 5.000)
8008 (1972 - 2.500)
4004 (1971 - 2.250)
transistors
1.000.000.000
100.000.000
10.000.000
1.000.000
100.000
10.000
1.000
1970
1975
1980
1985
1990
1995
2000
2005
intel

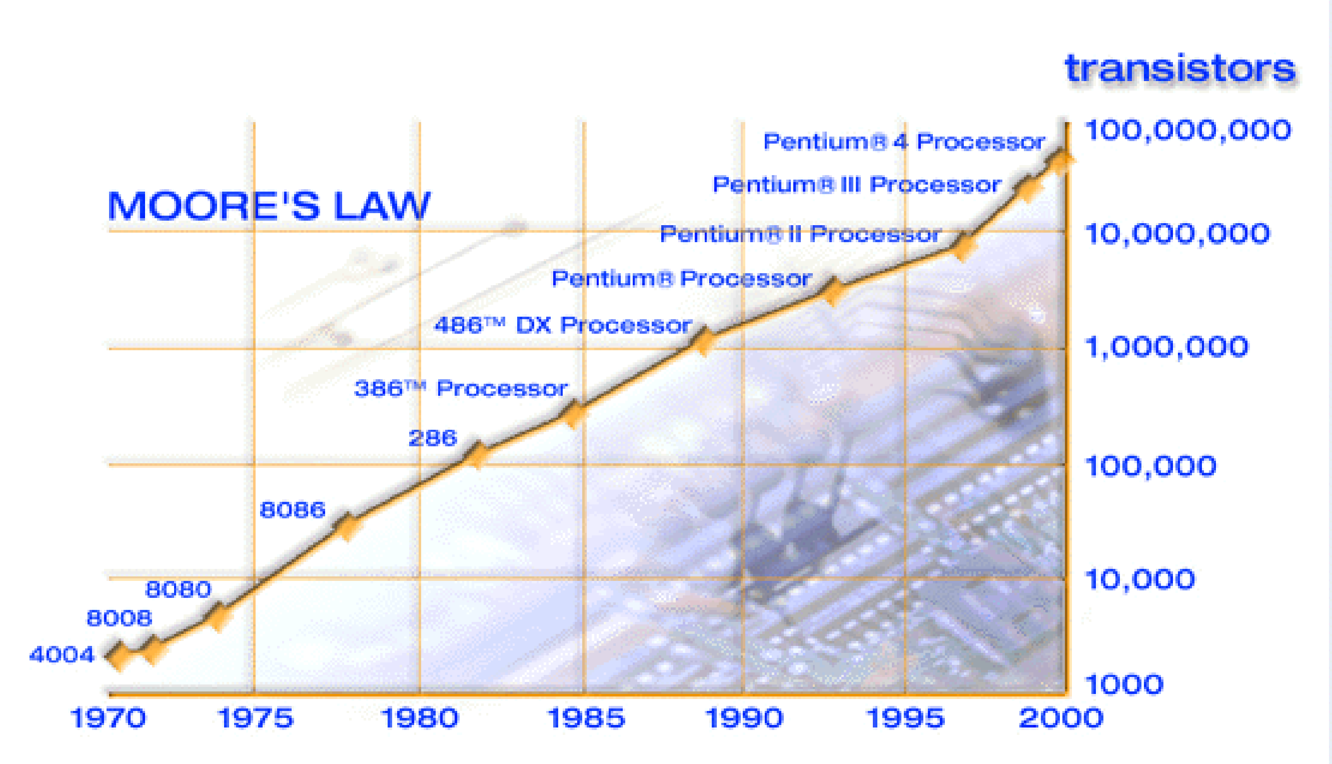
History of IC: Increase of Complexity

Intel Pentium 4 processors
3.2 GHz

↓

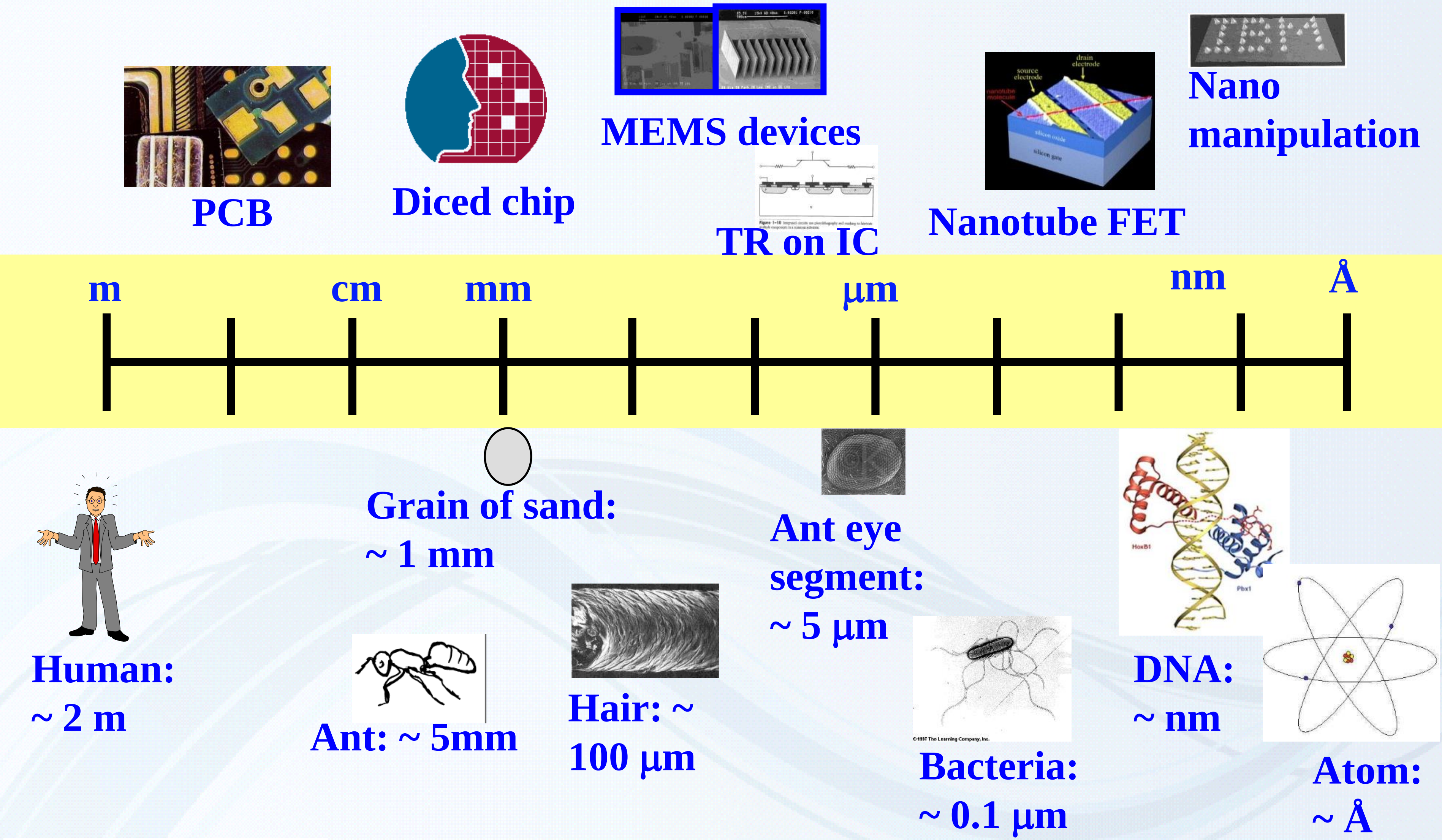
0.13 μm technology

Transistor counts: over 54 million transistors



IBM announced in June, 2001 that it has created the world's fastest silicon-based transistor, and that it expects the new technology to drive communications chips to the astonishing speed of 100 gigahertz within two years. IBM said its approach uses a combination of silicon and germanium to make ultra-thin transistors that can speed along information far faster, while using far less power, than current technology. Company researchers said it can reach speeds of 210 GHz while using just one milliamp of electrical current.

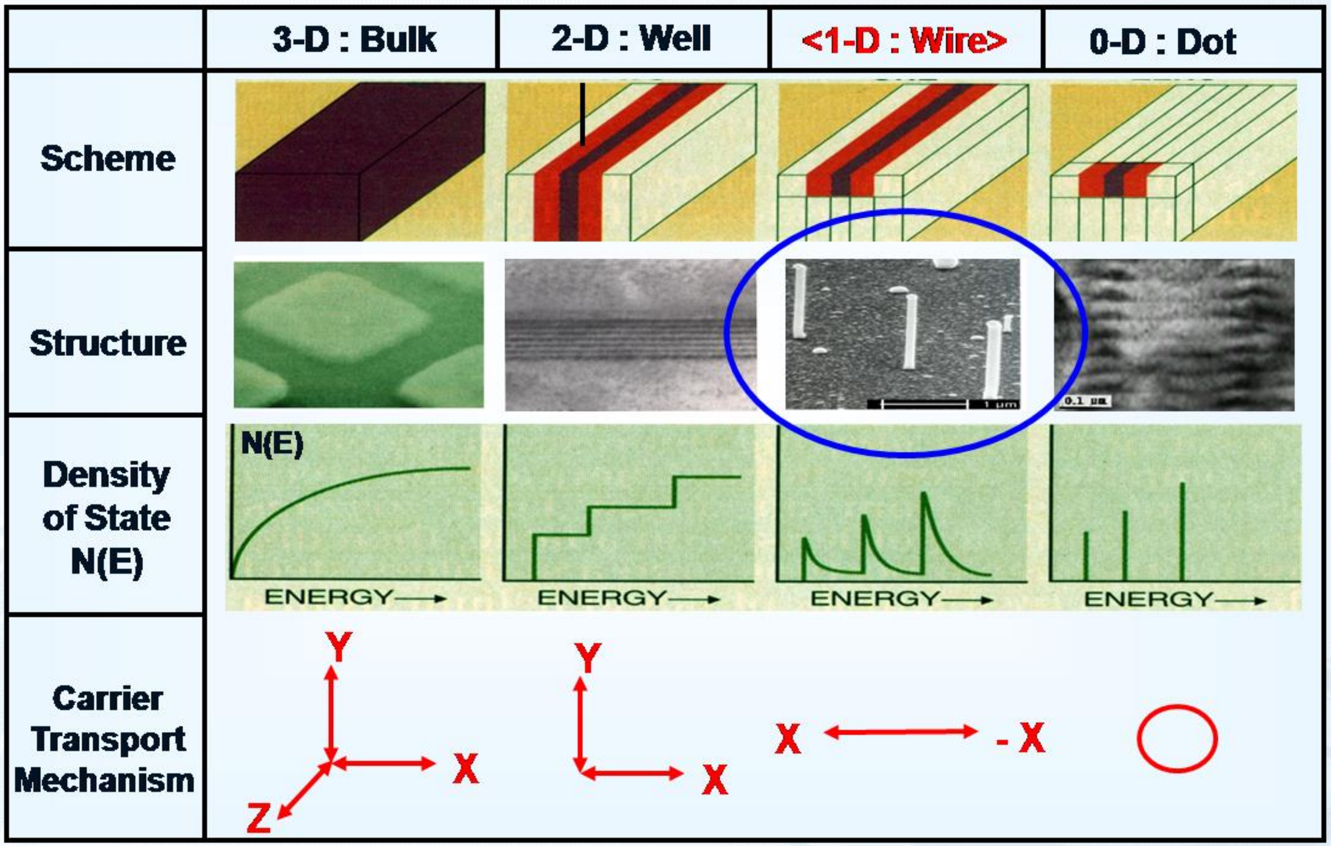
Electronics and Nature



Nanomaterials: Properties

Advantages of 1-D NW (Nanowire)

- Most simple structure for carrier transport(electron and hole) in Semiconductor
- Block for the fabrication of 1-D nano-device and system
- Very low defect density



< Comparison of 3-D(Bulk), 2-D(Well), 1-D(Wire) and 0-D(Dot) >

Nanomaterials: Applications

Field effect transistors

Thermoelectric materials

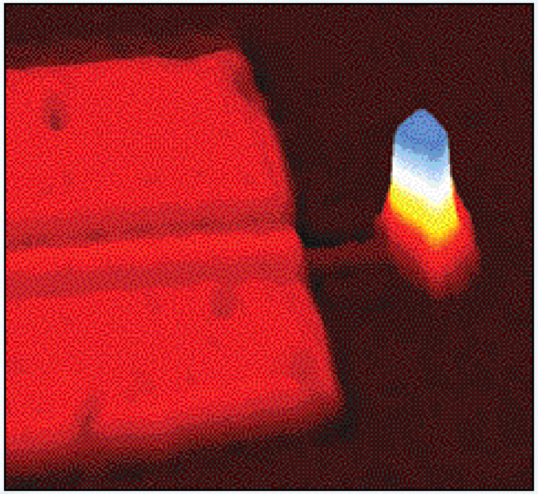
Light emitting diodes

Detectors

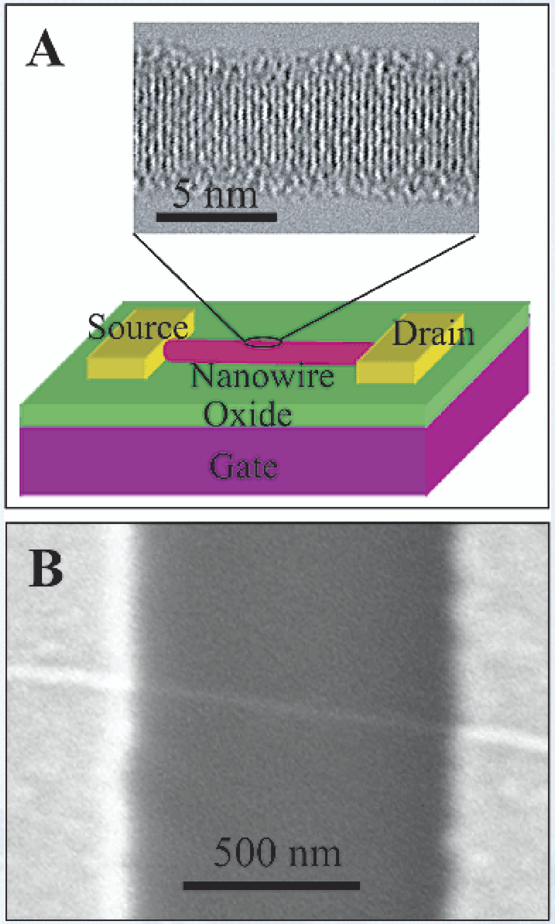
Sensors

Nanolasers

Superlattice nanowires in applications requiring superlattices



Nanolaser from 100 nm CdSe nanowire



5 nm Si nanowire FET