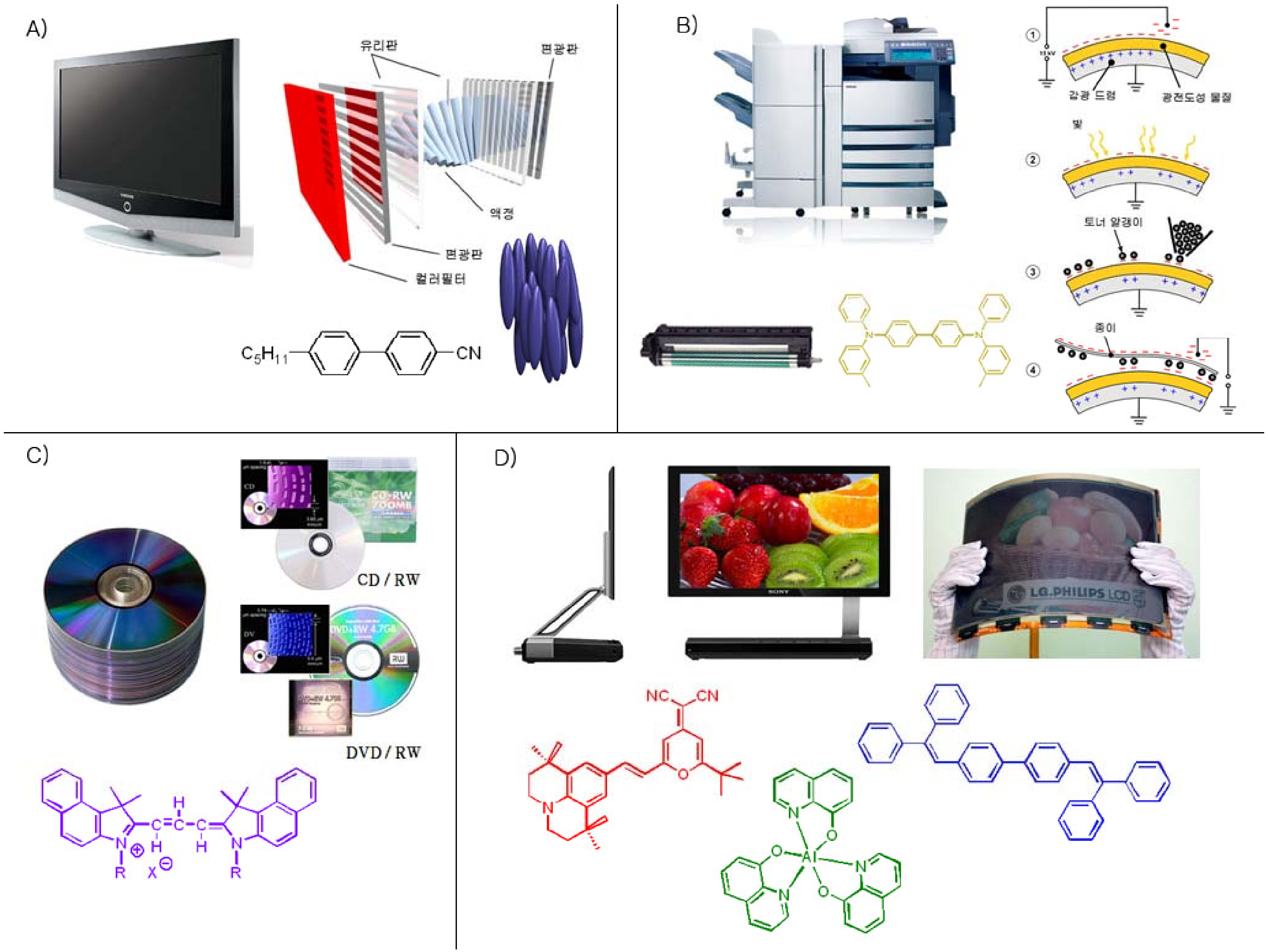
Molecular Electronics 2008

Prof. Soo Young Park

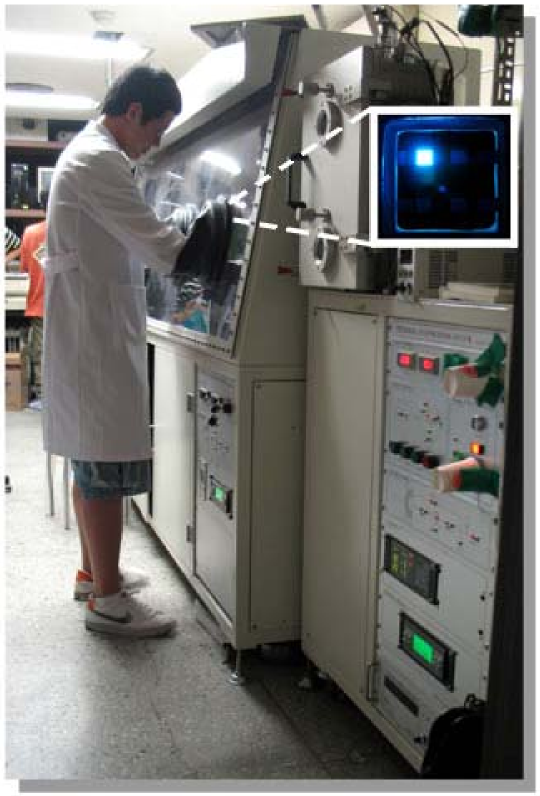
Fall Semester 2008

Molecular Electronics Products



Organic Chemistry to Electronic Engineering

유기전자재료 합성



소자 제작

OLED 제품

Syllabus 2008 Fall

Textbook:
M. C. Petty, "Molecular Electronics: From Principles to Practice", John Wiley & Sons Ltd, 2007.

Lecture Plan
Chapter 1. Scope of Molecular Electronics
Chapter 2. Materials Foundations
Chapter 3. Electrical Conductivity
Chapter 4. Optical Phenomenon
Chapter 5. Electroactive Organic Compounds
Chapter 6. Thin Film Processing and Device Fabrication
Chapter 7. Liquid Crystal Devices
Chapter 8. Plastic Electronics
Chapter 9. Molecular Scale Electronics

Evaluation:
Mid-term exam: 40%
Final exam: 40%
Project Assignment: 20%
Attendance: -2% per each absence

Preface

- Contents of the textbook:

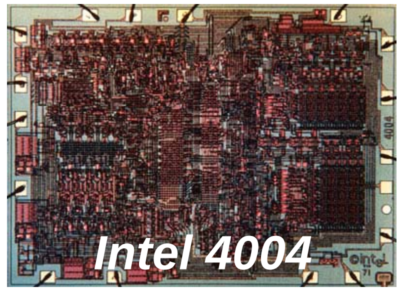
  Insight into the phys and chem of org materials >> Methods of material manipulation and properties measurements >>Present ME Technology >>Future ME Technology
- Molecular Electronics (Plastic Electronics)

- One of the focus is to replace the the silicon and other inorganic semiconductor : the reduced cost and large area capability are the motivation.

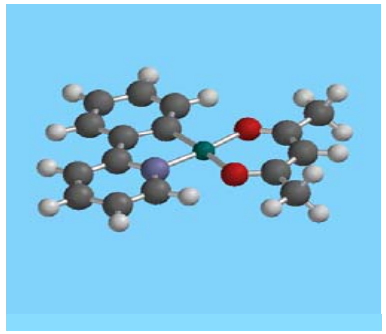
The History of Manufacturing

1. Stone Age

2. Micro-Stone Age



3. Molecular Age



Seoul National Univ
Molecular Photonics Laboratory
분자광전자연구실

- Courtesy: Dr. Paul Burrows (Pacific Northwest National Laboratory)

1. SCOPE OF MOLECULAR ELECTRONICS

1.1 Defining 'Molecular Electronics'

1. **Molecular Materials for Electronics**:

- LCD, OLED, Conducting Polymers, Plastic Electronics Circuitry, Chemical and Biochemical Sensors.

2. **Molecular-scale Electronics**:

- Molecular switching, DNA electronics

⬍ Relevance to Nanotechnology

1 is the 'top-down' and 2 is to the 'bottom-up' issues

1.2 Molecular Materials for Electronics

- Commercialization takes long time: LCD lesson- 19th C first discovery-1922 LC classification scheme by G. Friedel-1960s LCD potential
- Landmarks in conducting polymers: PA in 1958 by Natta- 1967 Shirakawa (serendipity)- 1970s Doping to conducting polymer – 1980s heterocyclic conjugated polymer – 21st C POLED, OTFT
- Long-term stability issue of ME materials?

OPC (organic photoconductor), OLED, LCD

- Piezoelectric, pyroelectric, ferromagnetic applications with ME materials are possible

1.3 Molecular Scale Electronics

- 1950s USA Air Force Idea of ‘Molecular Electronics’: to build a circuit in the solid without reproducing individual component function. The whole was to do more than the sum of the parts.
- Molecular rectifier: 1970s Ari Aviram at IBM– Forrest Carter in Naval Research 1983- Monolayer Film by Hans Kuhn 1989
- Faced strong competition of Si-based Microelectronics so far.

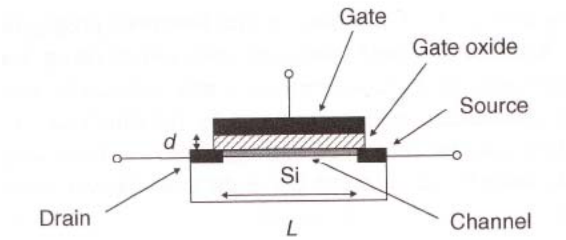
Landmarks in Microelectronics

Table 1.1 Dates of key inventions in microelectronics [9, 10].

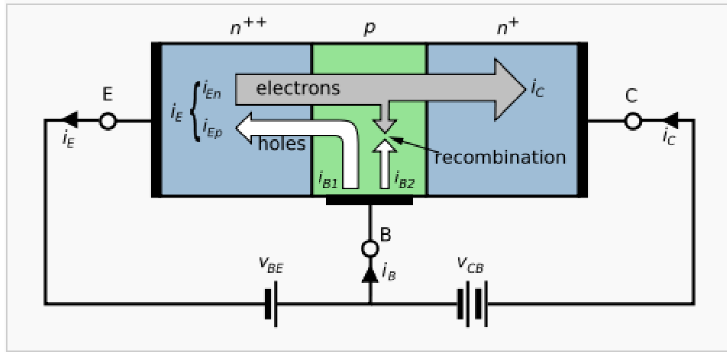
Date	Milestone
1930	MOSFET concept patent (Lilienfield, University of Liepzig, Germany)
1946	Stored-program computer (ENIAC, University of Pennsylvania)
1947	Bipolar transistor (Bardeen, Brattain, Shockley, Ball Laboratories, USA)
1952	IC concept (Dummer, Royal Radar Establishment, UK)
1959	Planar process (Hoerni, Fairchild, USA)
1959	IC patent (Kilby, Texas Instruments, USA)
1960	MOSFET (Kahng and Atalla, Bell, USA)
1962	MOS IC (Hofstein and Heiman, RCA, USA)
1968	CMOS (Westing house, GT&E, RCA, Sylvania, USA)
1969	Internet (ARPAnet, USA)
1971	Microprocessor (Hoff, Intel, USA)
1972	1024 bit DRAM (Intel, USA)
1980	256 k DRAM (NEC-Toshiba, NTT-Musashino, Japan)
1981	MS-DOS (Gates, Microsoft, USA)

MOSFET, Bipolar Transistor, CMOS, IC

- MOSFET (Metal-Oxide-Semiconductor Field Effect Transistor)



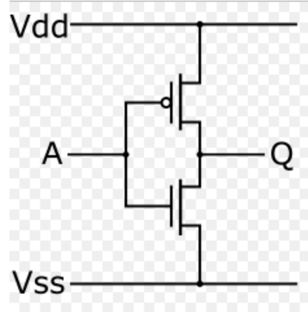
- Bipolar Junction Transistor



NPN BJT with forward-biased E–B junction and reverse-biased B–C junction

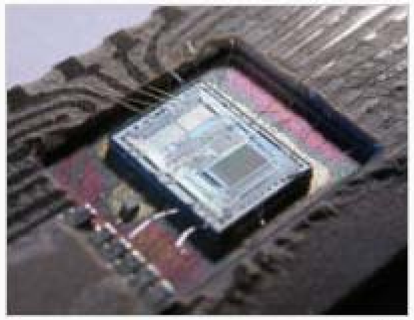
- CMOS (Complementary MOS)

  Two important characteristics of CMOS devices are high noise immunity and low static power consumption.



inverter

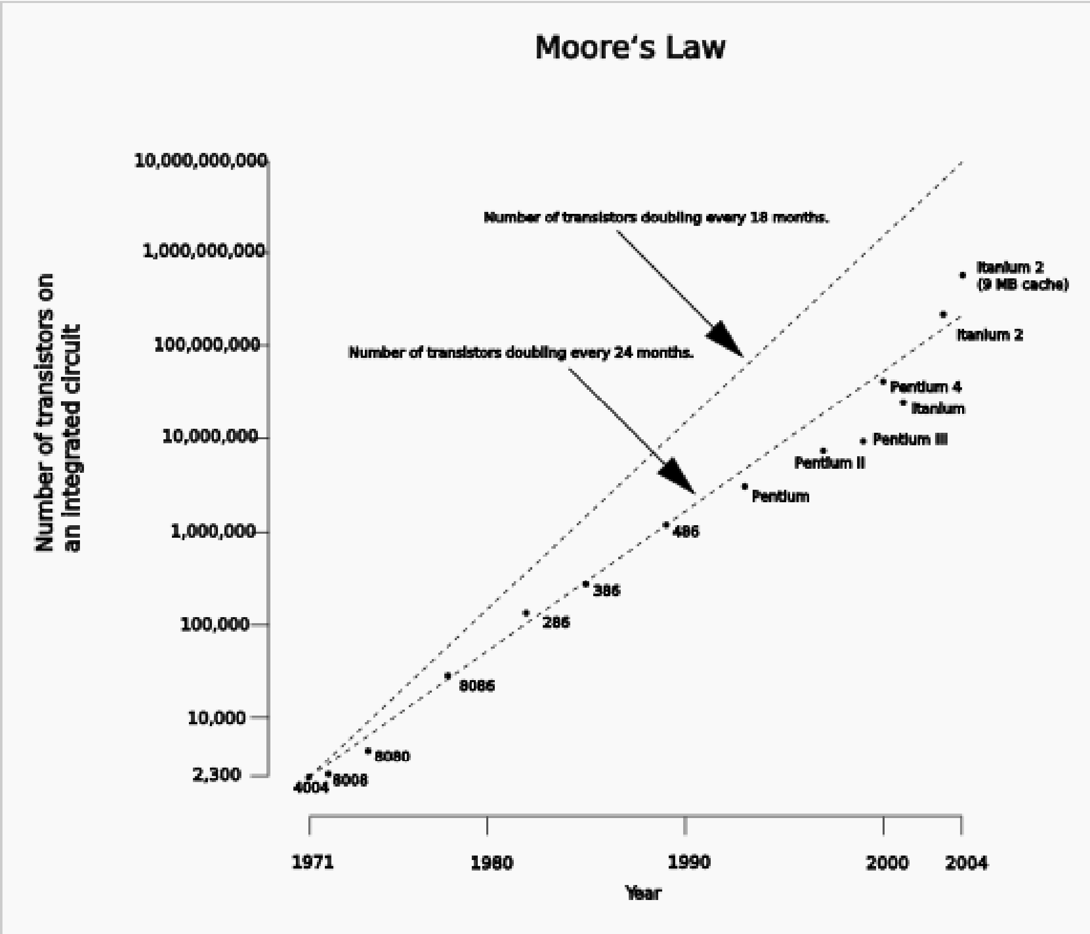
- IC (Integrated Circuit)



The integrated circuit from an Intel 8742, an 8-bit microcontroller that includes a CPU running at 12 MHz, 128 bytes of RAM, 2048 bytes of EPROM, and I/O in the same chip.

Figures from Wikipedia

Moore's Laws



Growth of transistor counts for Intel processors (dots) and Moore's law (logarithmic vertical scale).

-Doubling of integration density per every two year (1st law)

-Doubling of FAB building cost per every chip generation (2nd law)

-Pentium 4 (Feb 2005) chip: 169 million transistors, 90 nm tech, 3.73 GHz clock speed

-ITRS roadmap prediction for y2013: 13 nm feature size for MPU and 40 billion transistors for DRAM

Beyond Moore

- Shrinking device dimension (1/K): K is a scaling factor
- Current density increases (K): limited by 10^{10} Am^{-2} for Al
- Switching energy ($1/K^2$): limited by 3×10^{-21} J (ITRS 2016 MOSFET 4×10^{-18} J)
- Response time (1/K): limited by 5 fs in silicon
- The maximum tolalable power density : 100 Wcm^{-2}
- Fabrication thorough-put problem

Molecular Electronics Challenge

- High Device density:
  10^{13}-10^{14} per cm^2 (cf. 10^8 for Pentium 4)

Table 1.3 Information content of various sources [16]. (1 byte = 8 bits)

Application	Typical information content (bytes)
Colour photograph	10^5
Average book	10^6
Desktop computer	10^8
Genetic code	10^{10}
Human brain	10^{13}
Library of Congress	10^{15}

- Issues
  Switching speed
  Addressing
  Defects
  Reliability

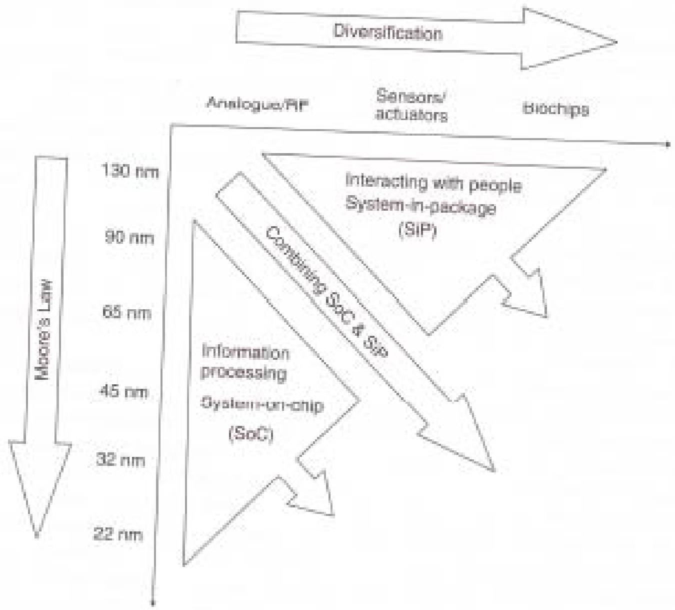
1.4 Biomimetics:Learn from Nature

- Brain vs. MPU (microprocessing unit)
  $10^{11} - 10^{15}$ neuron bit vs. 8 Gbit chip
  (One brain equiv. to 10^5 MPU)
  parallel processing vs. serial processing
  ionic signal vs. electronic signal
- Bacteria vs. Microrobot
  DNA, protein vs. MPU, nanomechanics

1.5 Future Opportunities

- Ambient Intelligence:
  - Ubiquitous computing via implanted small computer chips in everyday objects around us
  - Recognizing the physical and emotional states of a human and react accordingly
- Diversification:

  Lab-on-a-chip



1.6 Molecular Electronics Opportunities

- Currently for niche areas of electronics
  - where silicon or other inorganic semiconductors cannot compete
  - LCD, chemical sensor, OLED, RFID, smart card
- Near Future Opportunity:
  - Bottom-up molecular electronics to overcome the technological barriers of CMOS technology
  - Challenges in ME are fabrication of molecular switches and connection of them