

ELEC 315:

Electronic Materials and Devices

Winter 2025-26, Term 1

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Course Info

- Text books:
 - Kasap, Principles of Electronic Materials and Devices
 - Pulfrey and Tarr, Introduction to Microelectronic Devices
 - Optional: Solymar and Walsh, Electronic Properties of Materials
 - Optional: Streetman, Solid State Electronic Devices
 - Optional: Kittel, Introduction to Solid State Physics
 - Optional: Jiles, Introduction to the Electronic Properties of Materials
- Evaluation (approximate): final (45%) + midterm (25%) + assignments, participation and small project(s) (30%).
- Office hours: Please check Connect for schedule or get an appointment with TAs for other times.
- TAs: TBD
- All course contents, lecture notes, and discussions about the course is posted and updated on the website. Check it often.

What Is ELEC 315 About?

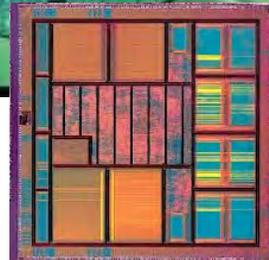
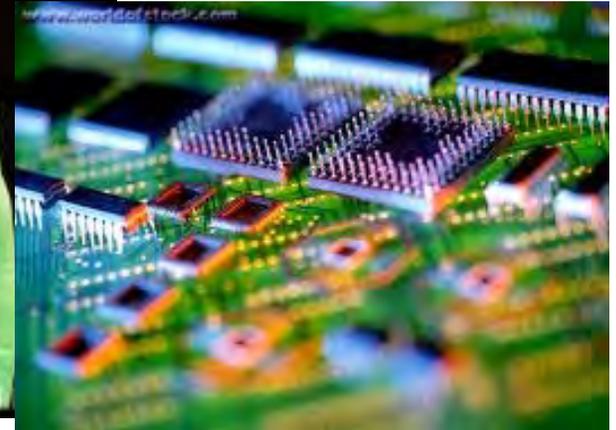
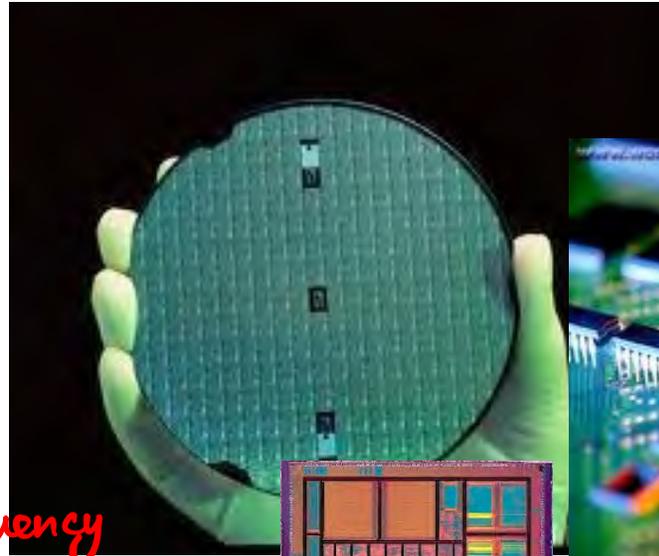
- Electronic materials and devices

GaAs

- Integrated circuits (ICs)

silicon (Si), Ge

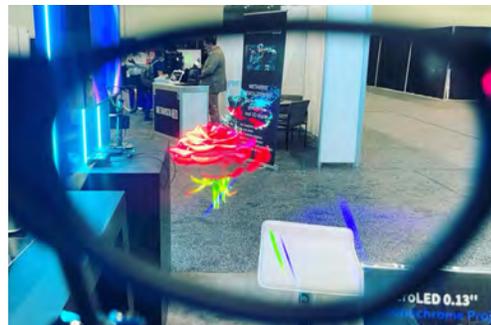
- Transistors, VLSI
- Digital and analog circuits, RF *radio frequency* devices, Microprocessors



Integrated circuits (ICs)

- Large area electronics

- Displays
- Solar cells
- Cameras



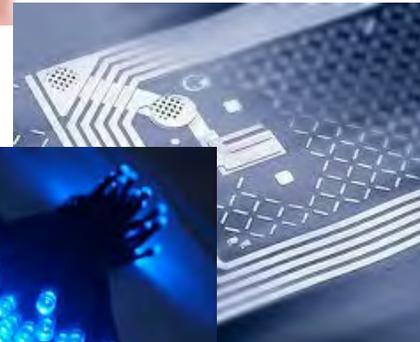
Flat panel displays (FPDs)



Solar cells

What Is ELEC 315 About? Cont.

- Memory and storage
 - Hard disks → magnetic materials
 - RAMs → Si
 - Communications
 - Mobiles
 - Radio Frequency Identification (RFID) tags
 - Biomedical engineering
 - DNA assay analysis, digital X-ray imaging, MRI, medical devices
 - Photonics
 - Optical fibers
 - Lasers, semiconductor lasers, lighting devices
 - Power Devices
 - IGBTs, HEMTs
- Si, SiC, GaN

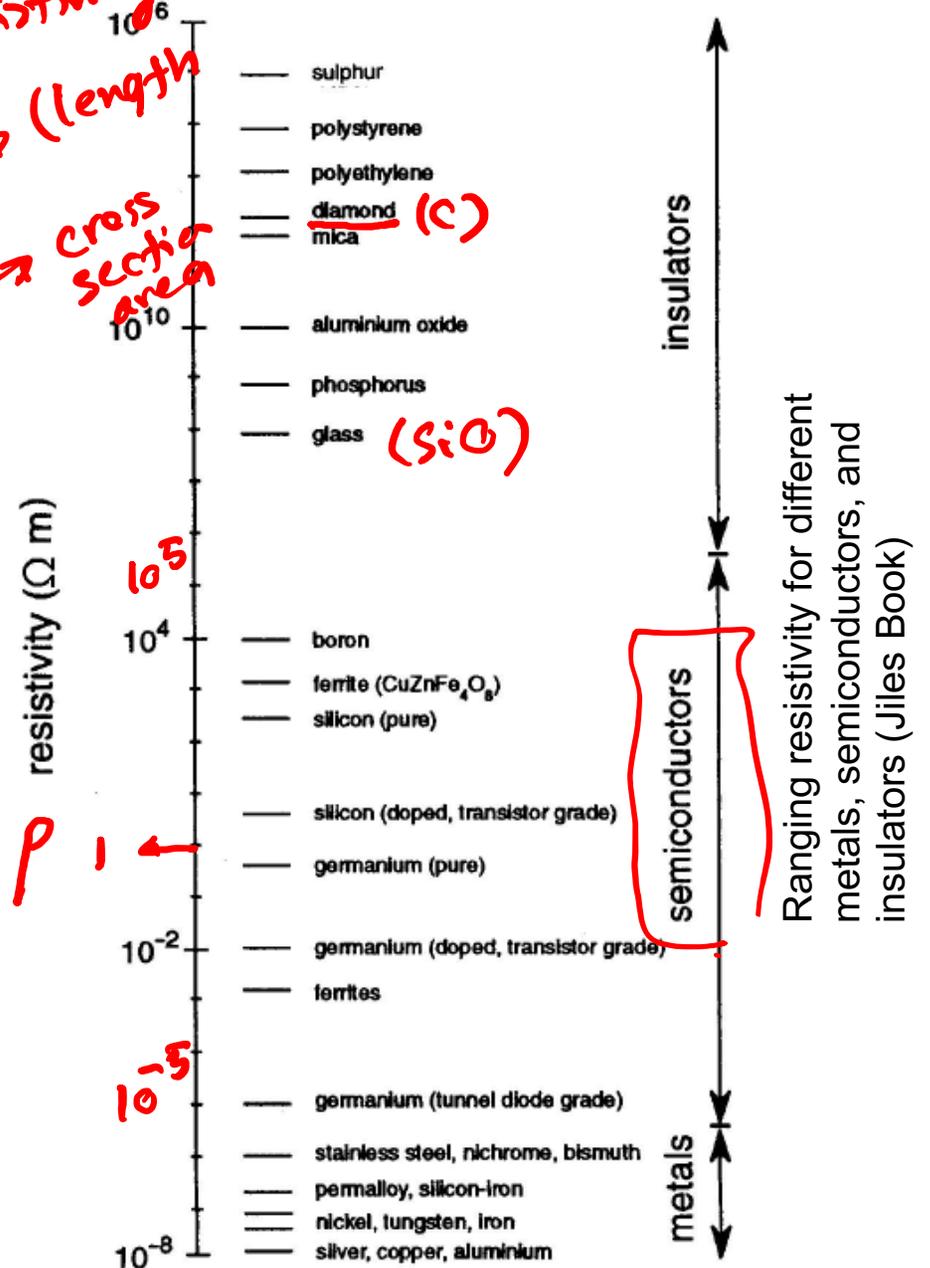


Different Electronic Materials

- Dielectrics
- Semiconductors
- Metals
- Optical materials
- Magnetic materials
- Electrochemical materials
-

conductivity $\sigma \leftarrow \frac{1}{\rho} \Rightarrow \rho = R \frac{A}{L}$

resistance \uparrow
 resistivity \uparrow
 $R = \rho \frac{L}{A}$
 (length) $\rightarrow L$
 cross section area $\rightarrow A$



Course Outline

- Semiconductors and Metal, Devices (weeks 1-8)
 - Basic properties; Growth; Structure of crystalline and non-crystalline materials
 - Quantum mechanics; Electrons and holes; Density of States; Fermi energy; Band structures
 - Continuity equations; PN junctions; Diodes; Devices and applications
- Dielectrics (weeks 9-11)
 - Dielectric properties; Polarization; Devices and applications
- Magnetic materials (weeks 12-13)
 - Magnetic dipoles, Hysteresis



diamond (C)

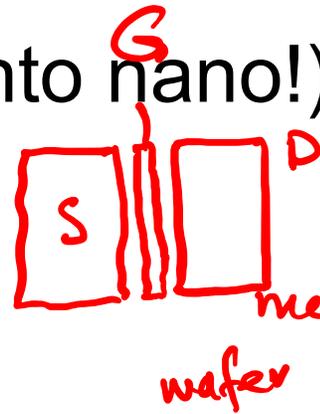
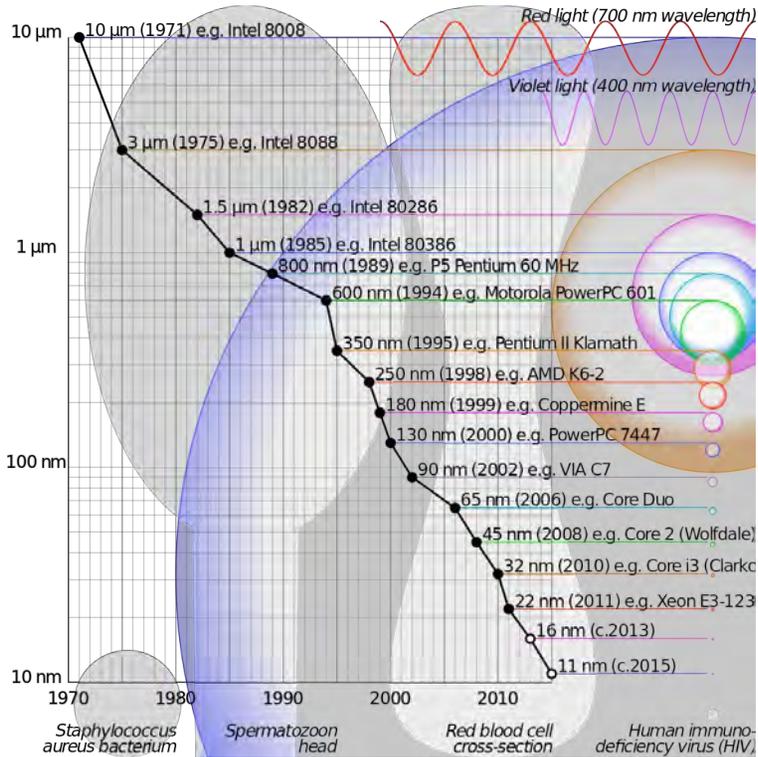
Questions

copper, gold, Al, Na, graphite (C)

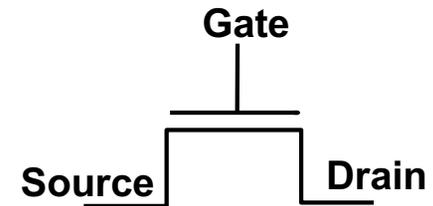
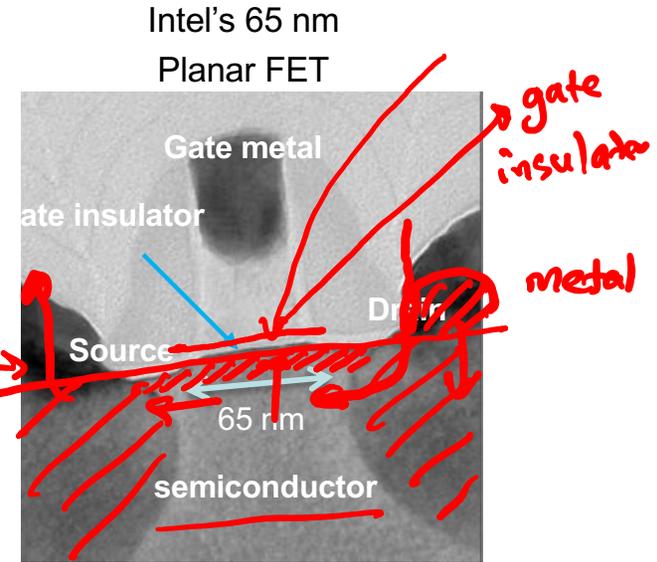
- Give examples for some widely used conductors, dielectrics, and semiconductors.
- What makes some materials good conductors? *free (mobile) electrons*
- Why other materials are semiconductors or insulators? *not having free electrons (core + valence electrons)*
- What are the example properties of semiconductors? *modifying resistivity with doping*
- Why are some materials transparent to light and others are not? *metals with free e^- are not transparent*
exception: transparent conductor (indium tin oxide)
- Provide examples of some electronic devices? *transistors (BJTs, MOSFETs), diodes (LEDs), sensors, transducers*
- How light-emitting diodes (LEDs) work? *E_2 \rightarrow E_1 $h\nu$ (photon)*
- How does a solar cell work?
- What are ferroelectricity and piezoelectricity?
- What makes a material magnetic?

Scale Down and Feature Size

- Smaller and smaller (into nano!)

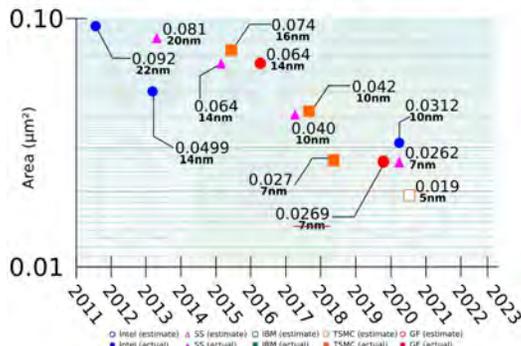


Field effect transistor (FET)

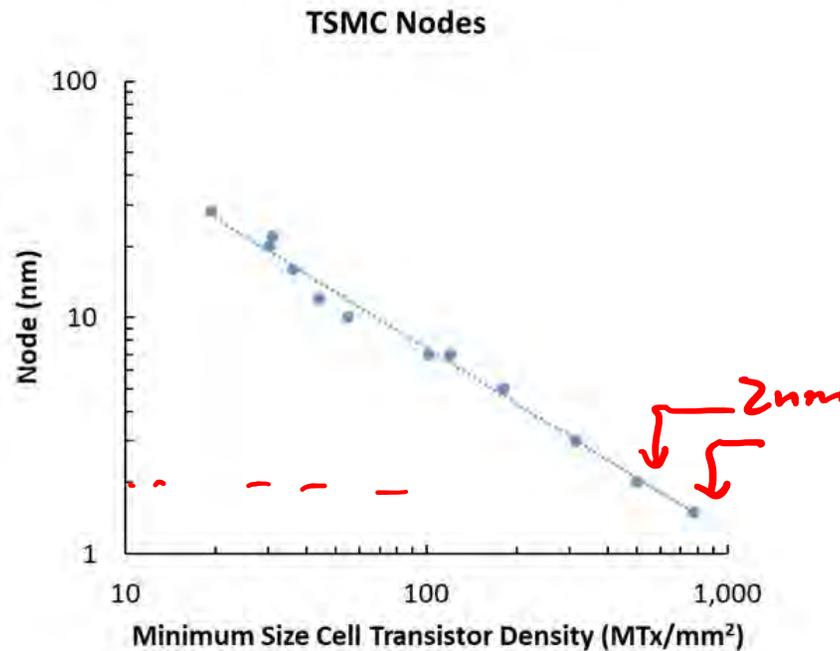
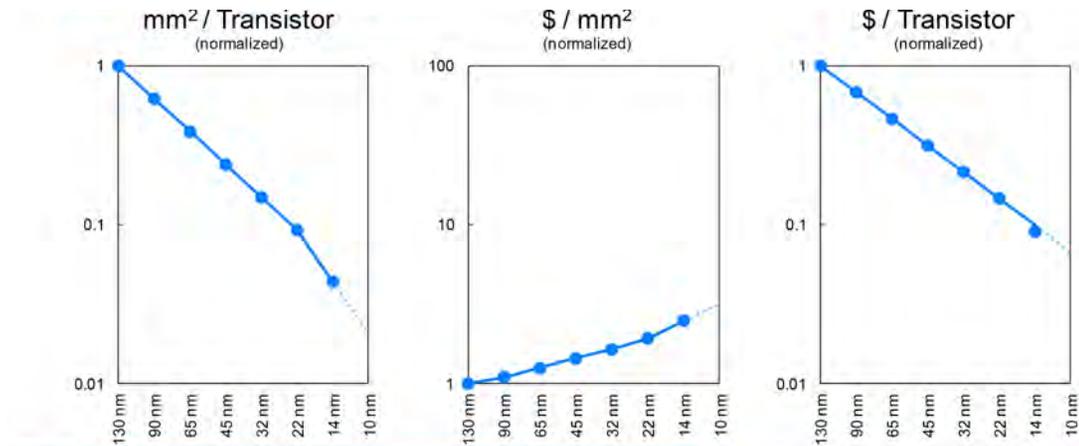


14 nm 2nd Generation Tri-gate Transistor

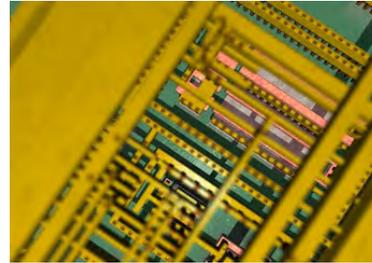
Leading-Edge Foundry HD SRAM



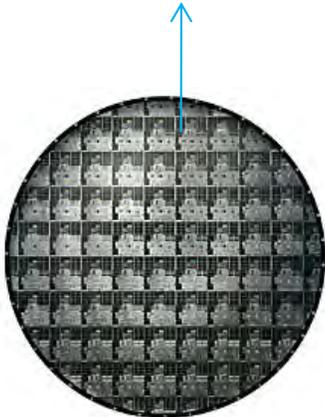
Cost per Transistor



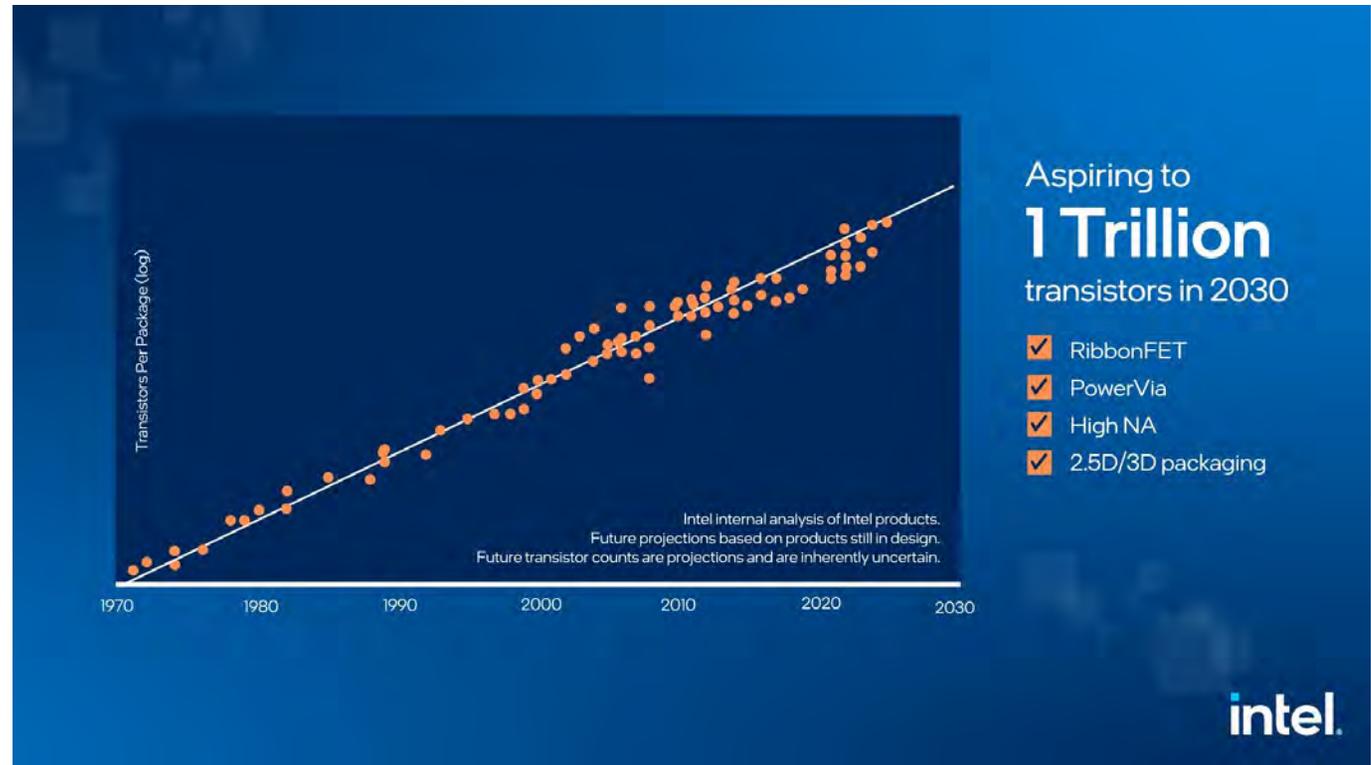
Moore's Law



Itanium® 2 Processor
Introduced: **2002**
Initial clock speed: 1 GHz
Number of transistors: 220 million
Circuit line width: 0.18 micron

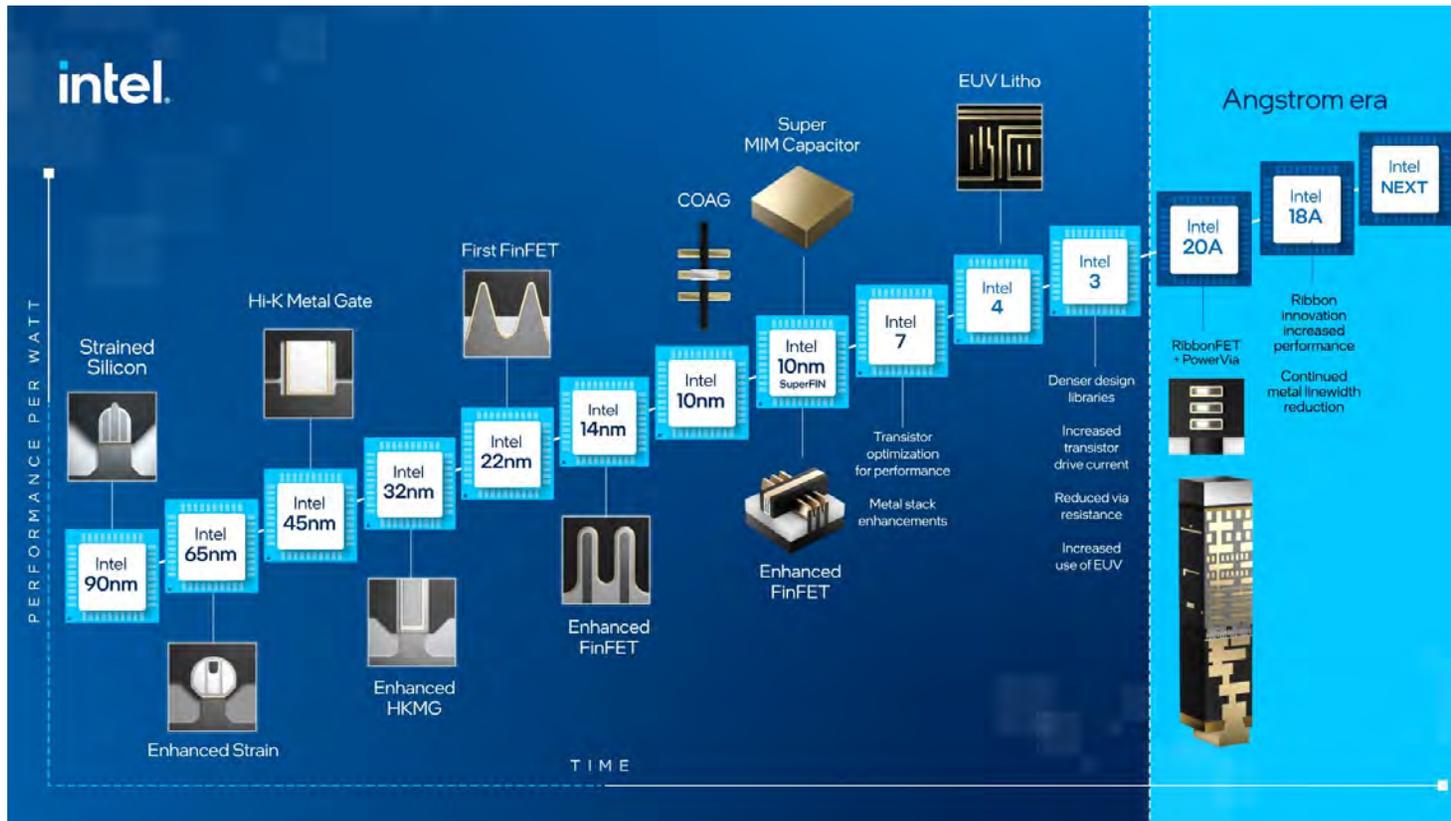


Wafer of Intel
Itanium
processor

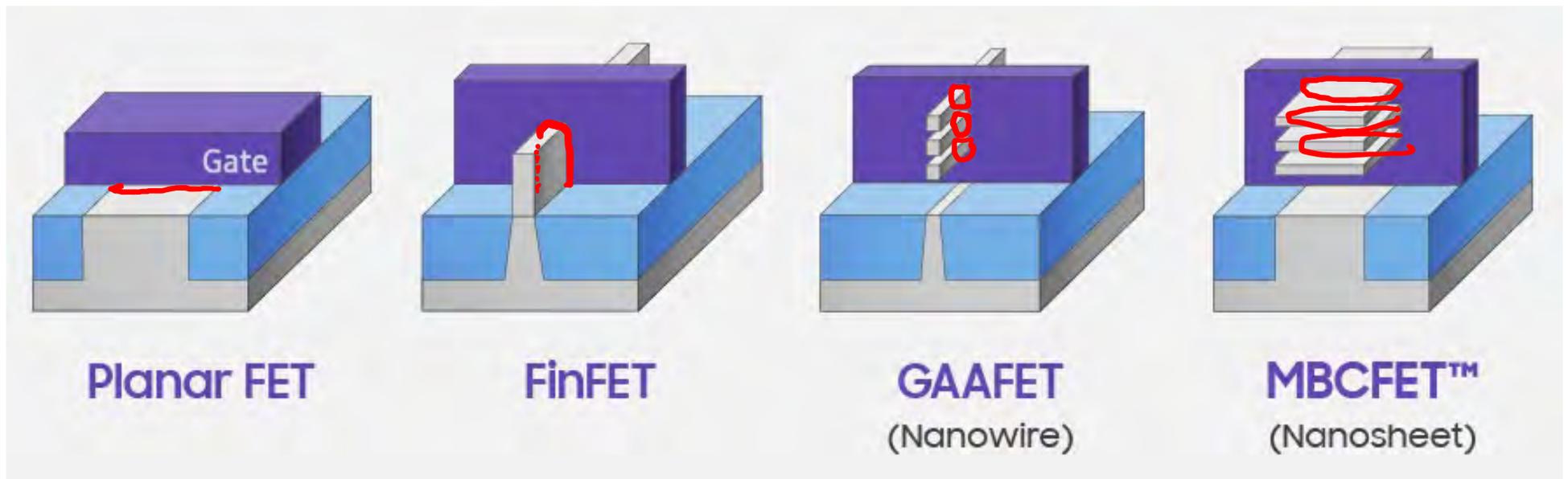


Making Smaller Transistors

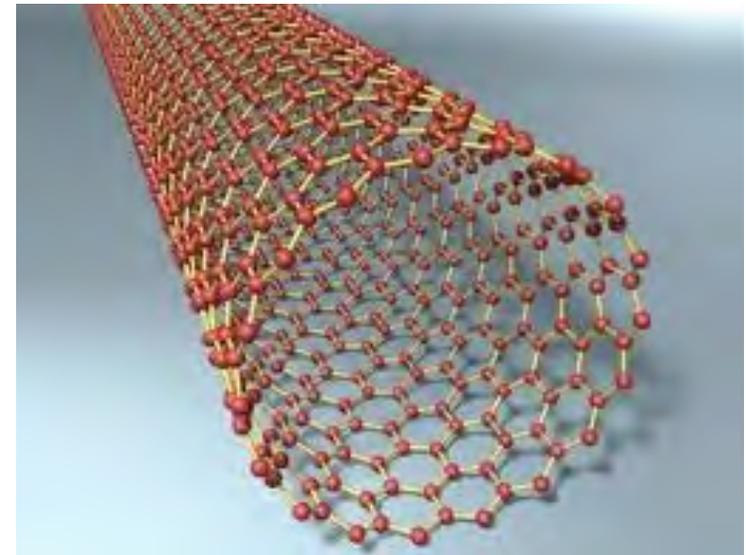
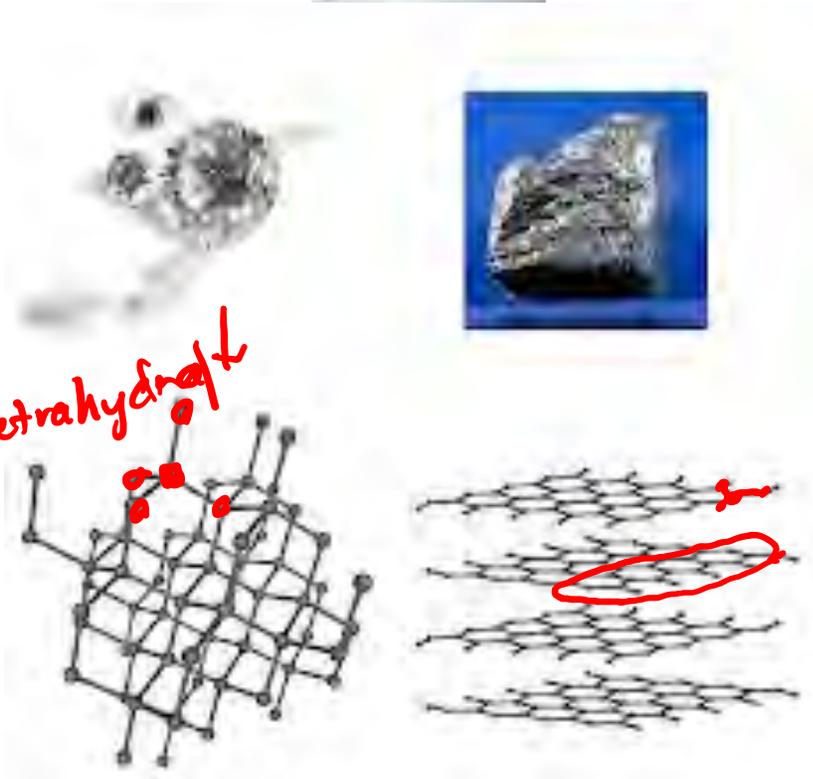
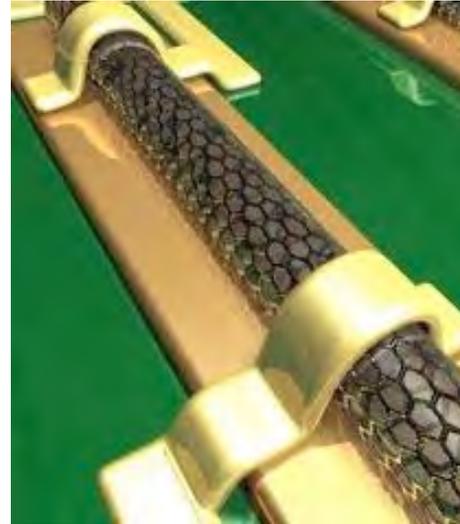
- 2 nm node will start being used in 2025-26.



New Transistor Structures

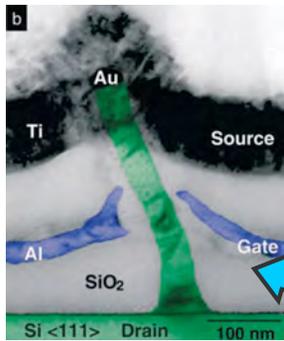


Carbon Nanotubes



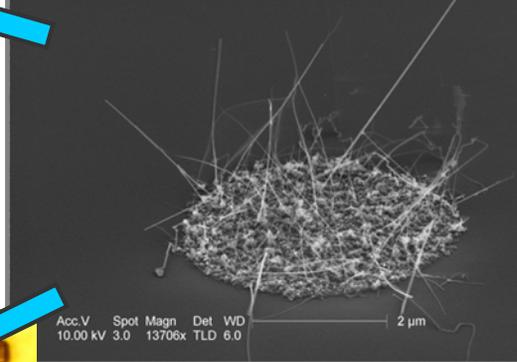
Nanowires (NWs)

Transistors



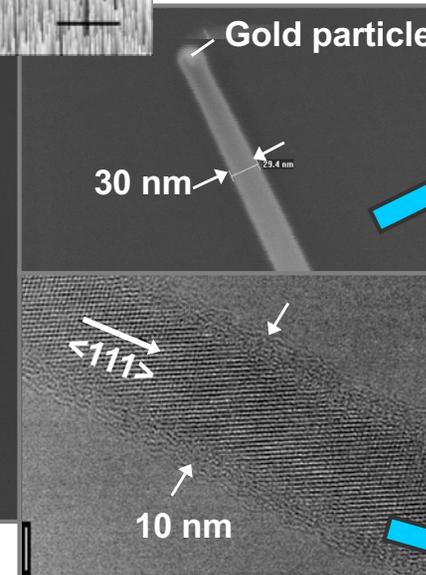
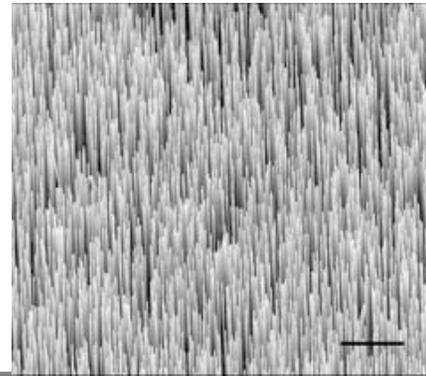
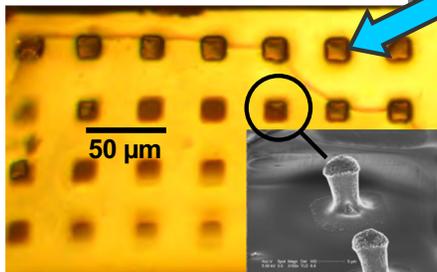
Gosele, Small, Jan. 2006

Si NWs grown on a 5 μm disc.

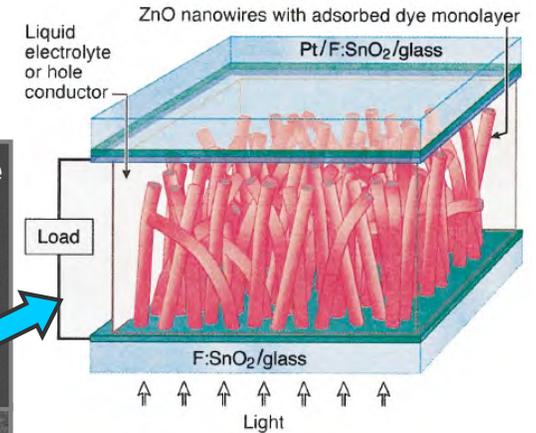


P. Servati et al. Physica E 2006.

Biosensors



Solar Cells



Yang et al. Nature Materials, June 2005

Flexible Displays

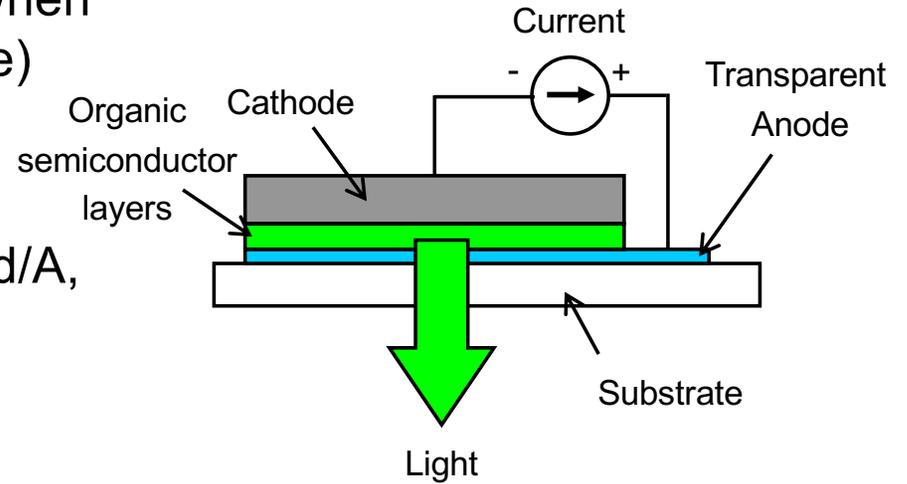


Organic Light-Emitting Diodes

- The organic semiconductor emits light when electrically excited (current driven device)
- Different emission colours by modifying organic molecule
- High conversion efficiency: (green: 50 cd/A, red: 10 cd/A, blue: 5 cd/A)

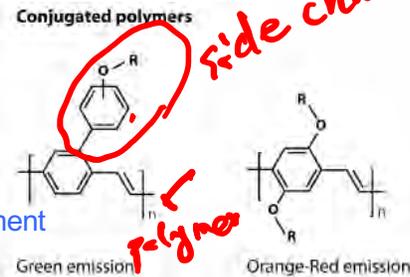
→ *Low power displays*
Lighting applications

- Low cost processing: spin-coating, ink-jet printing



Alan Heeger, A. G. MacDiarmid, and H. Shirakawa, Chemistry Nobel Prize 2000

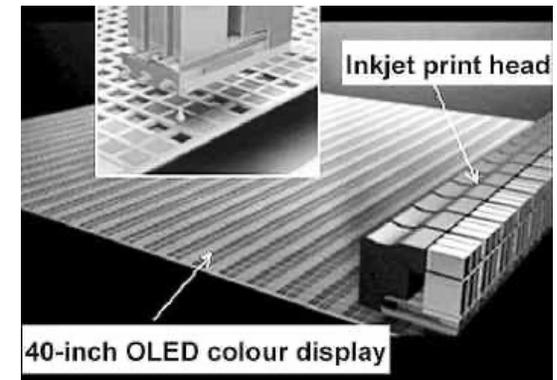
Discovery and development of conductive polymers



By varying the molecular structure, light of different colours can be obtained.



GE lighting panel organic light emitting panel

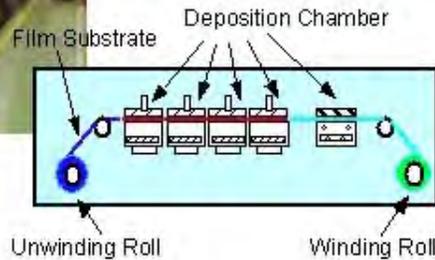


Flexible Electronics

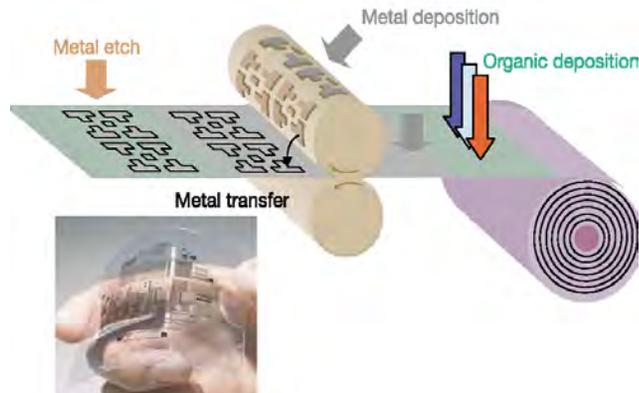
- Low cost roll-to-roll manufacturing
- Flexible roll-up displays



SKIFF



United Solar, solar panel roll-to-roll manufacturing system



ideo.com : Businessweek, March 2000



Forrest, Nature 428 (2004) 911

More info: Flexible Electronics and Energy Lab (FEEL) <http://feel.ece.ubc.ca>