EECE 480
Semiconductor Devices:
Physics, Design and Analysis

LECTURE 1

- Contact and website details
- Audience
- Introduction
- Towards an understanding of energy band structure
  - primitive unit cell
  - periodic potential

EECE 480
Semiconductor Devices
transistors,
solar cells, LEDs, memory

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http://courses.ece.ubc.ca/480/

Audience

1. Would-be hardware engineers (IC, digital, HF, mixed signal, photovoltaics, optoelectronics) who want to know how they can fully utilize device and material properties to improve their designs.
2. Would-be technical managers, and company presidents, who want to anticipate trends in semiconductor-device improvement, thereby ensuring the continued success of their company.
3. Would-be entrepreneurs who want to know whether they should continue to invest in silicon devices, or whether they should switch to III-V compound semiconductors, or even carbon nanotubes.
4. Would-be semiconductor research engineers and applied scientists who want to work at the frontiers of electronics.
5. All EECE graduates who want answers to:

   - how are computers/cell phones/entertainment widgets/etc getting smaller and faster?

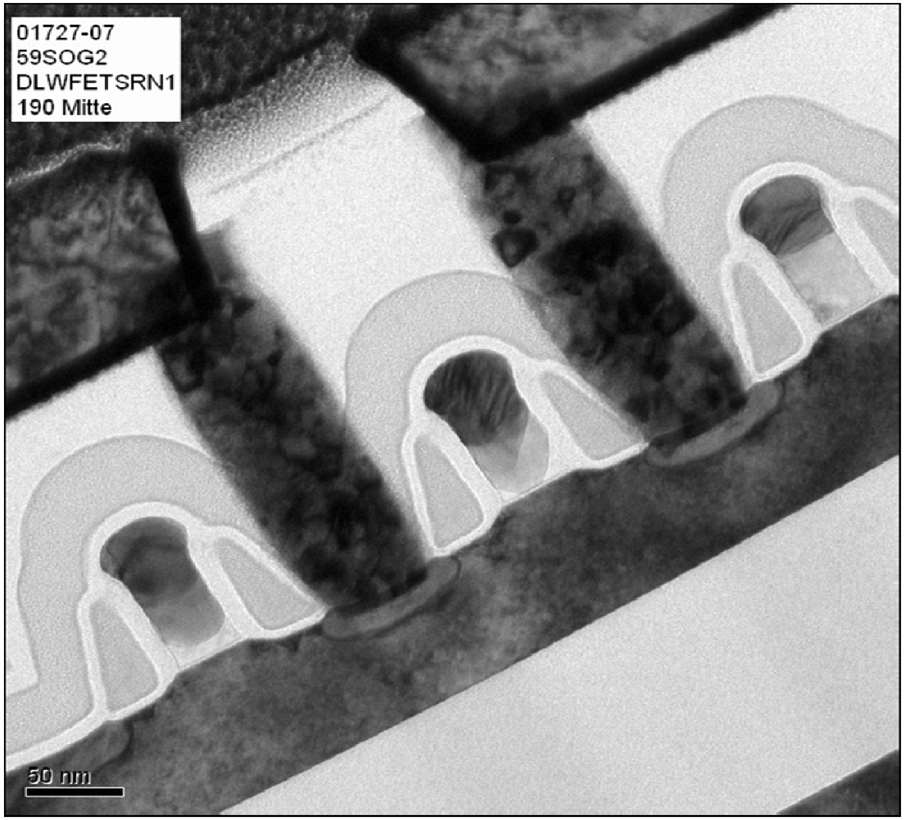
   - how fast/small/ powerful can these things become?

   - what is the limit to Si technology?

   - can solar cells ensure the continued supply of electricity?

   - will LEDS provide general lighting at greater electrical efficiency?

Transistors: then and now



- world's 1st transistor

-Bell Labs, 1947

- gold foil, wedge, weight

- Nobel 1956

- Shockley, Si valley

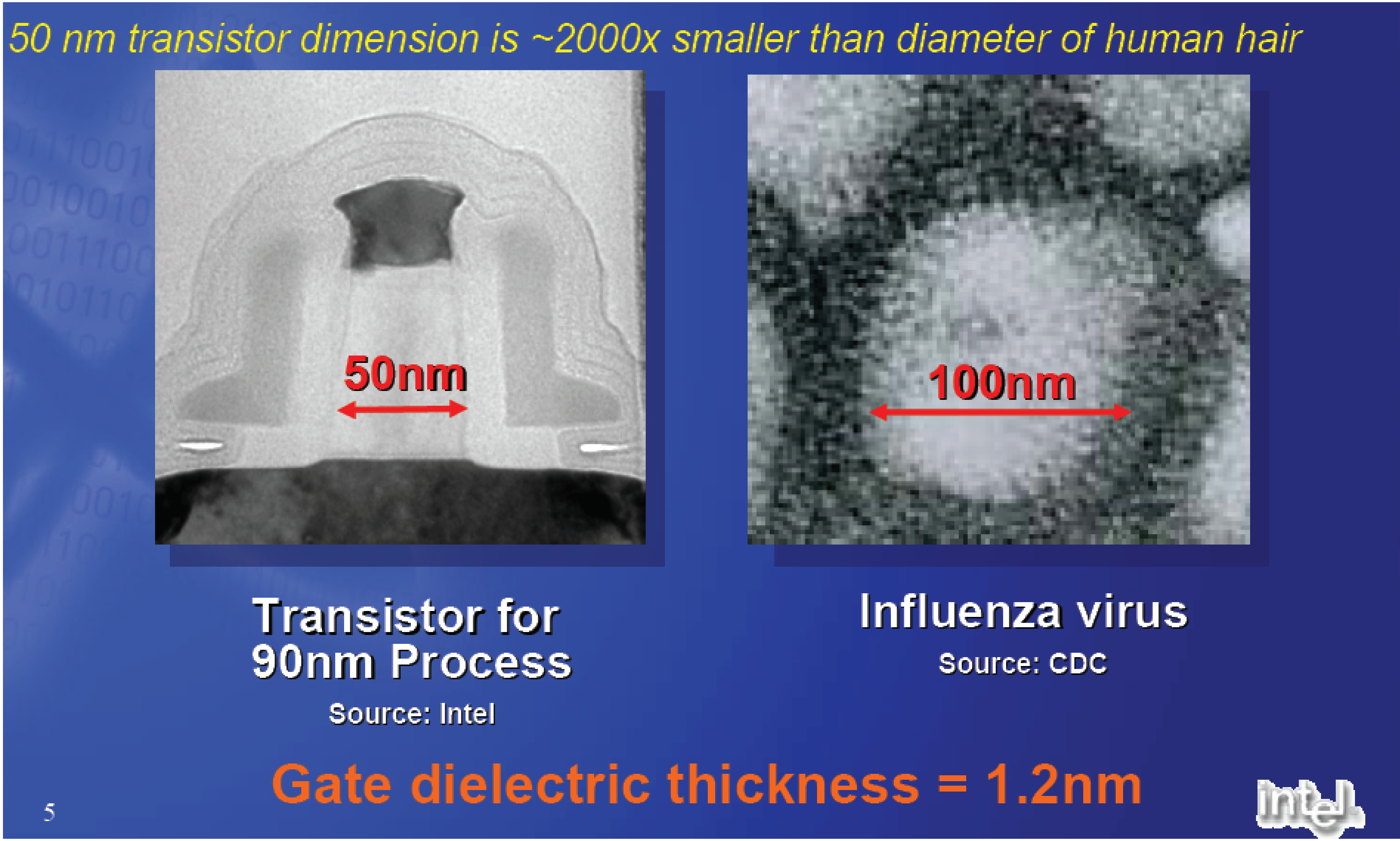
- modern 45-nm Si MOSFETs

- AMD, 2009

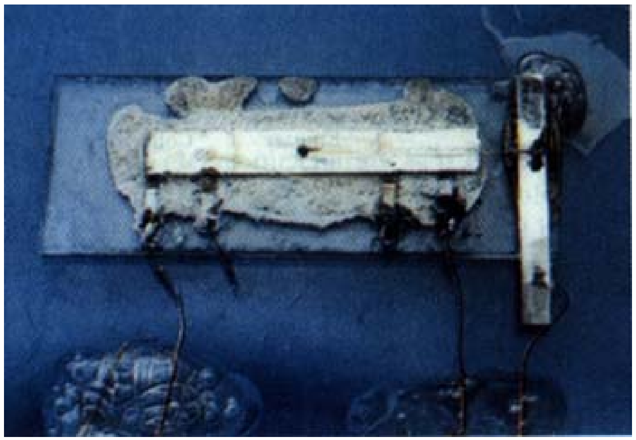
- SOI

- 36 nm gate

Appreciating the smallness



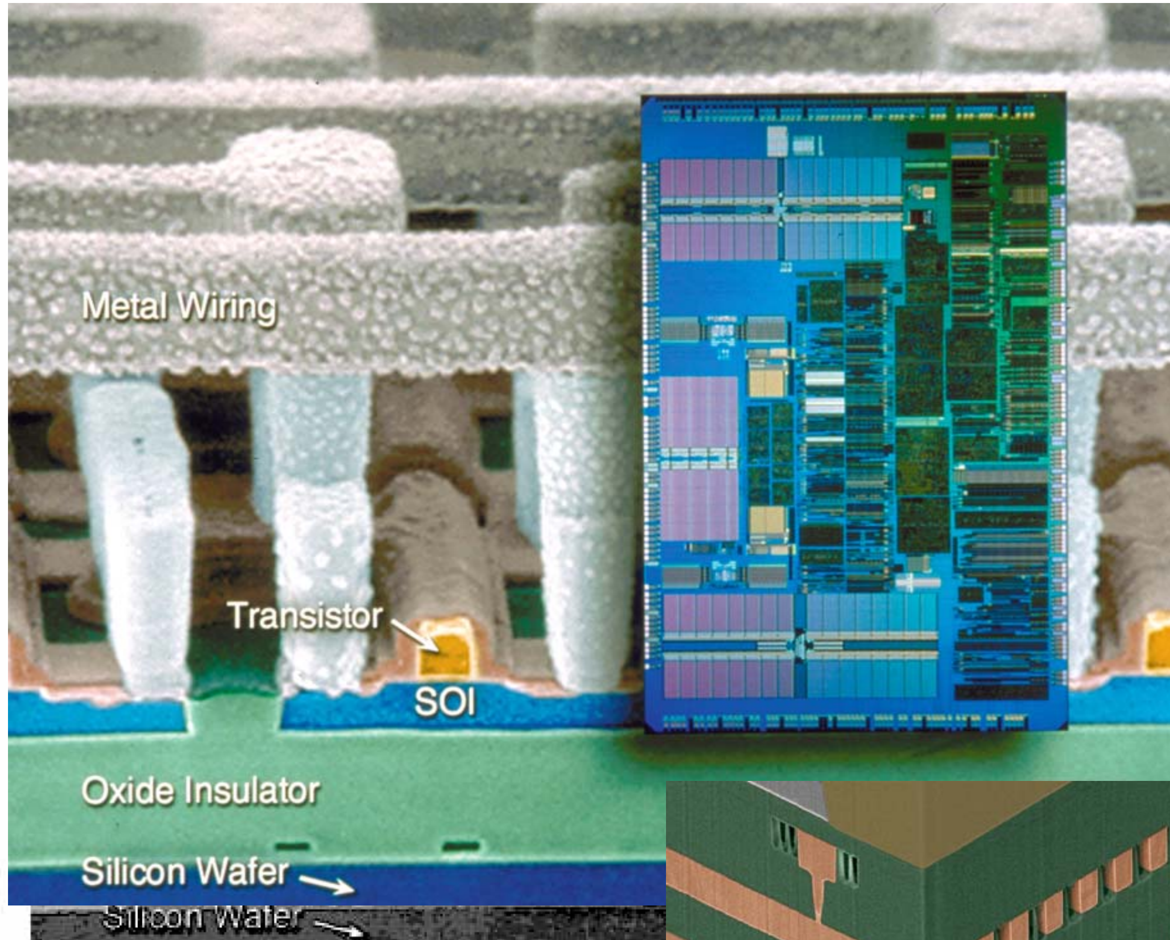
ICs: then and now

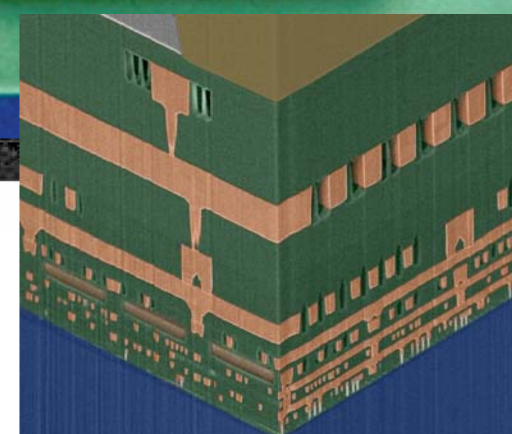


(a)

- world's 1st IC
- Kilby, TI, 1958
- Nobel 2000
- Ge, 5 components
- phase-shift oscillator

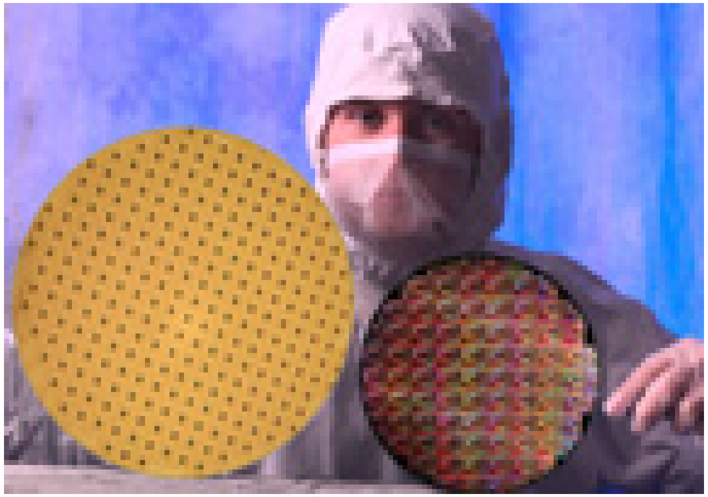
(b)



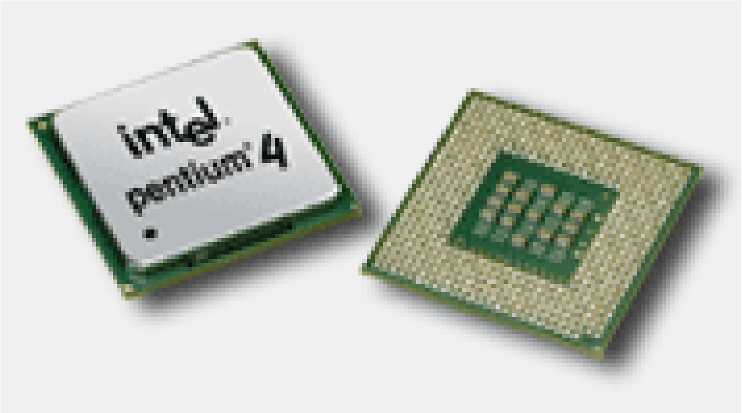


- modern Si IC
- IBM, 2005
- 64-bit power PC microprocessor
- FET only a tiny part of chip

Bigger wafers, smaller chips



(a)



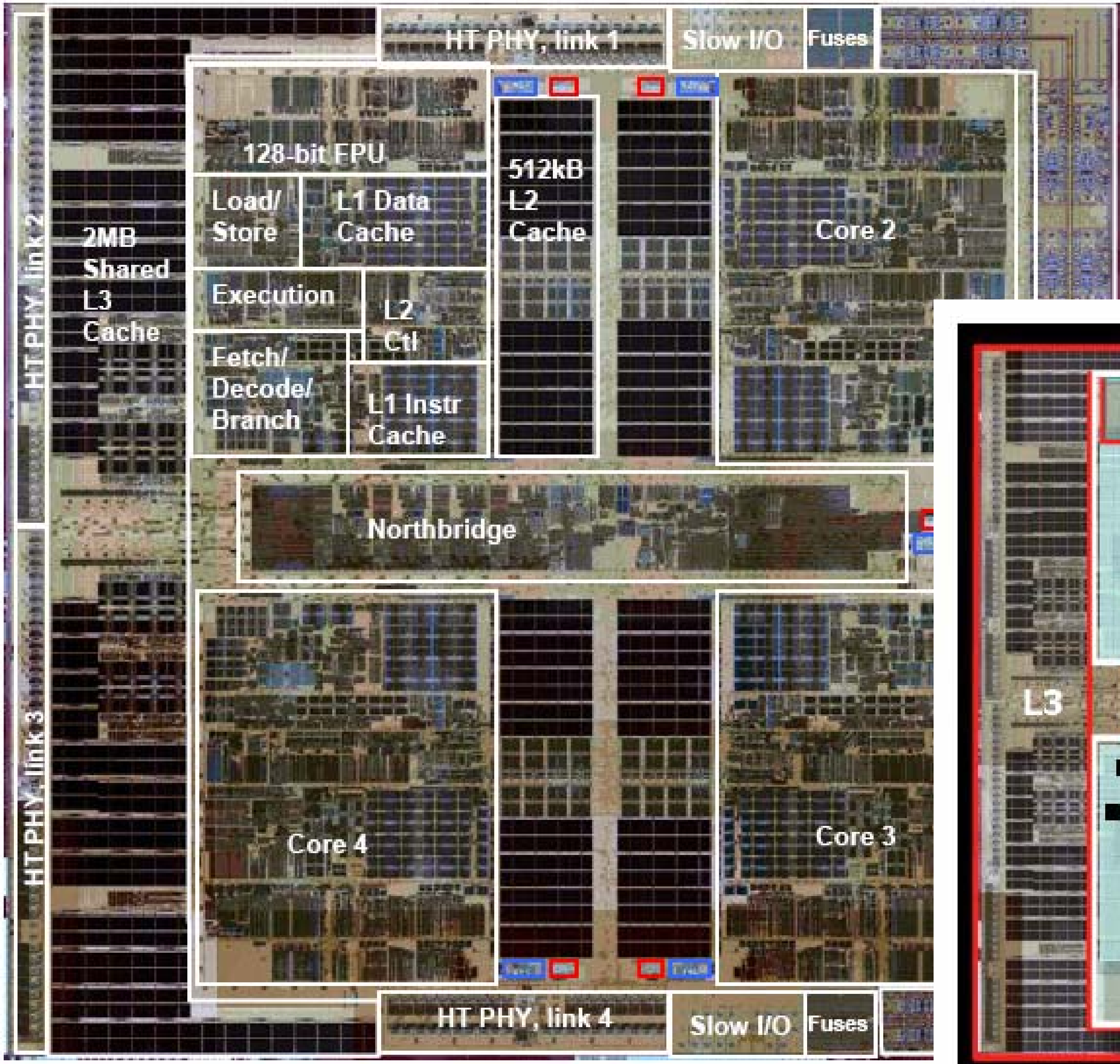
(b)

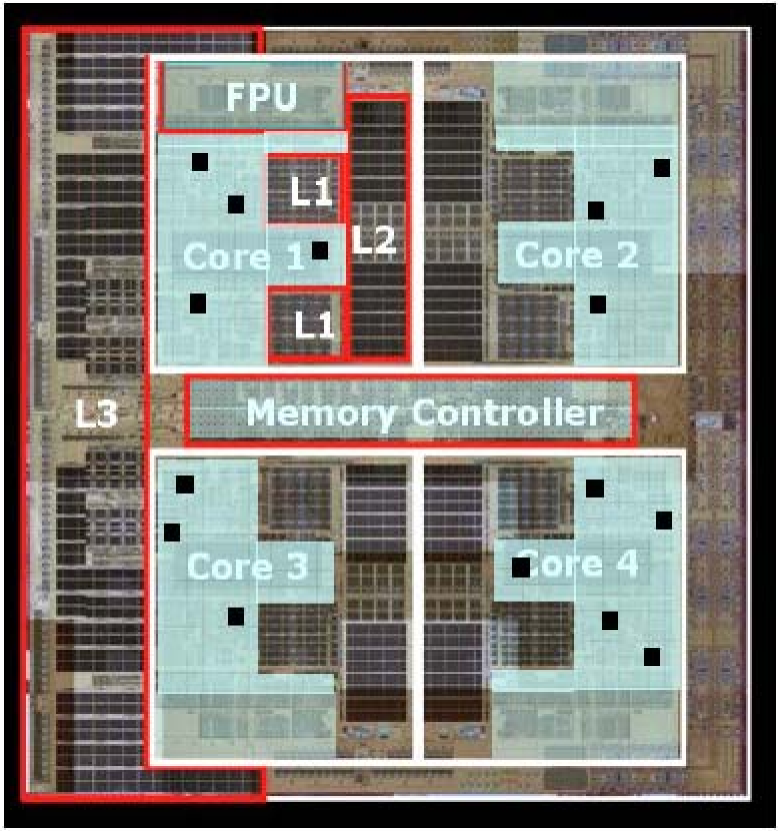
- 300 and 200 mm Si wafers
- lots of die

- one of the die
- 100M transistors per sq. cm
- " most abundant object made by mankind"

AMD Opteron

- 463 Million Transistors
- $283mm^2$



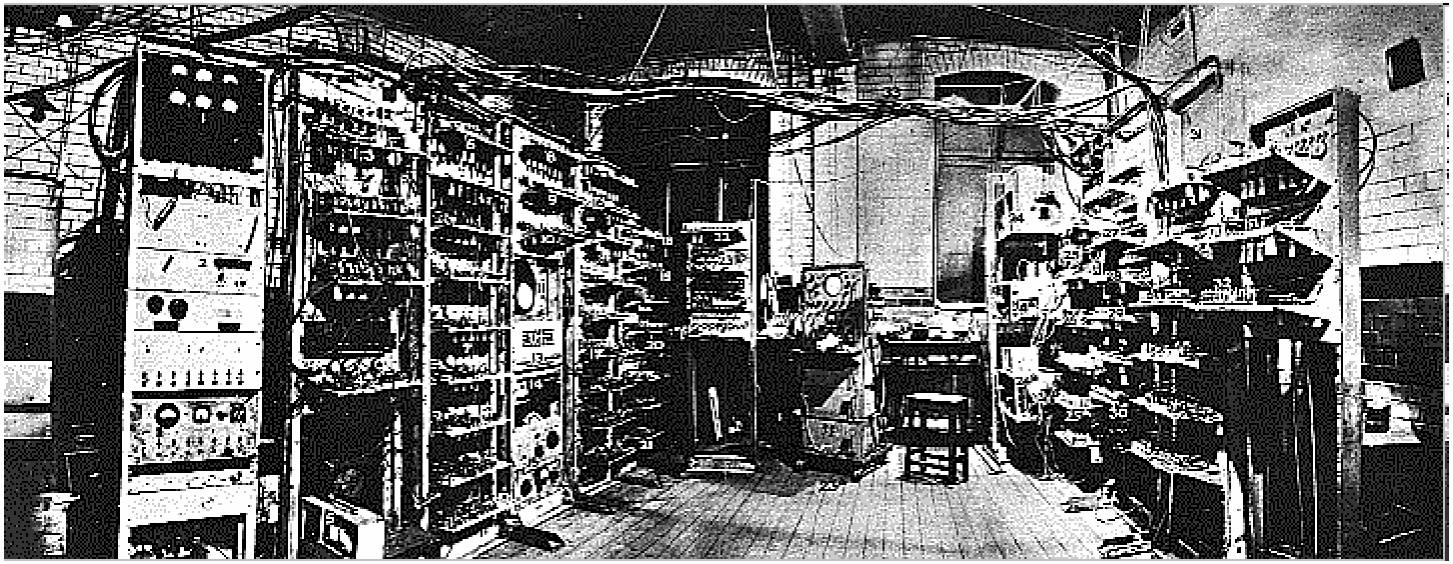


What do YOU have in common with these guys?

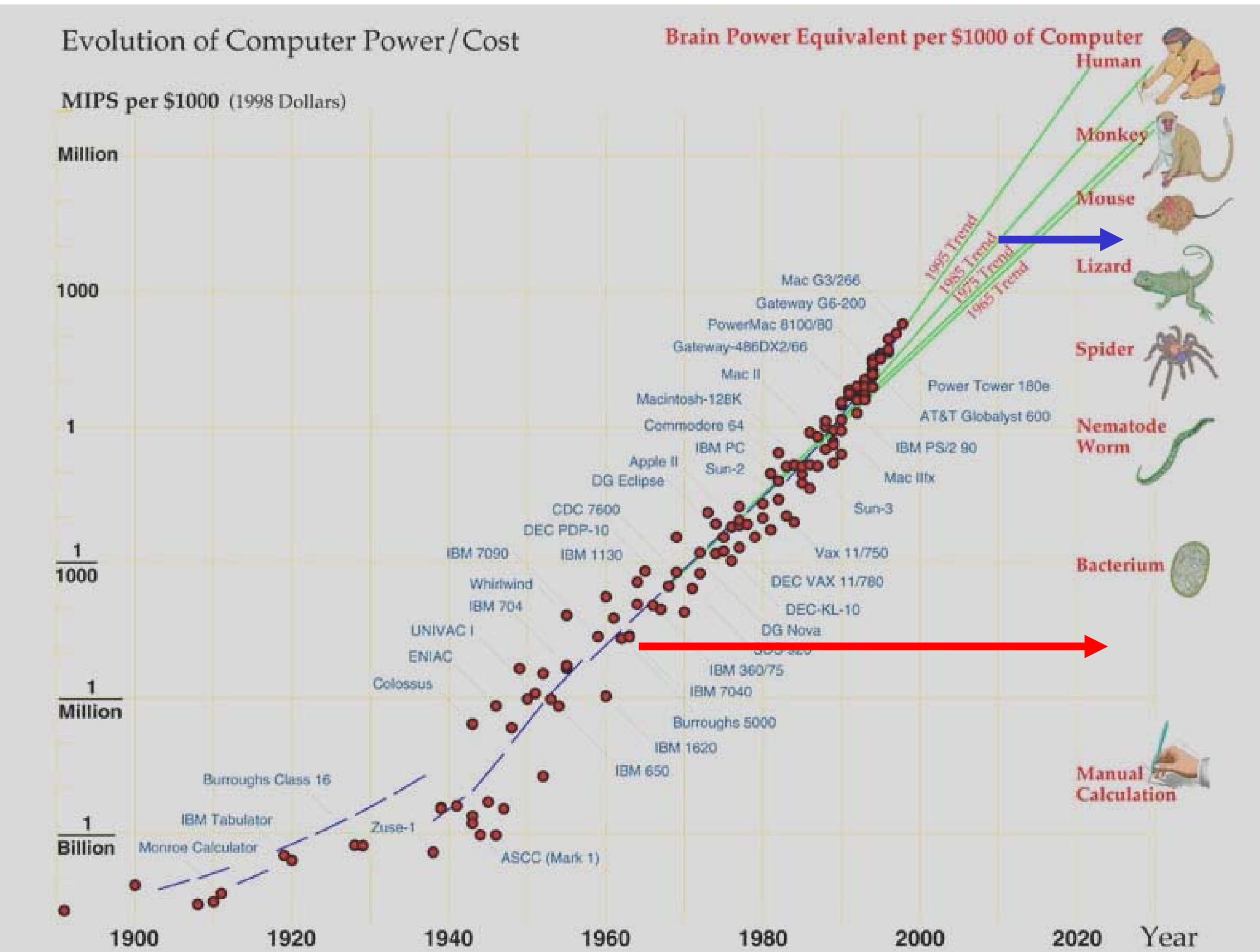
Chap. 1

Transistors enable

Laptop vs. Manchester Mark 1
Which has the greater computational power?



Computing power development



Hans Moravec, Carnegie Mellon

Moore's Law

G.E. Moore,
Electronics Magazine, vol. 38, pp. 114-117, 1965

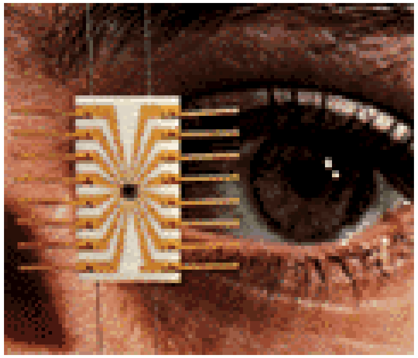
" The complexity for minimum component costs has increased at a rate of roughly a factor of two per year ".

This was taken to mean that the number of transistors per square inch on ICs was doubling every year.

Now, it is used for any transistor-related function that shows an approximate doubling, or halving, per year.

Transistors enable

PDA

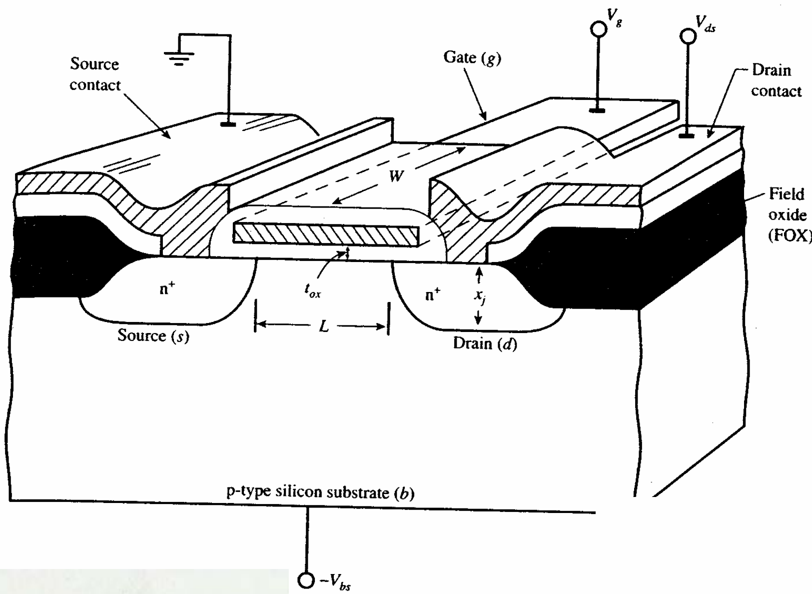


Artificial retina

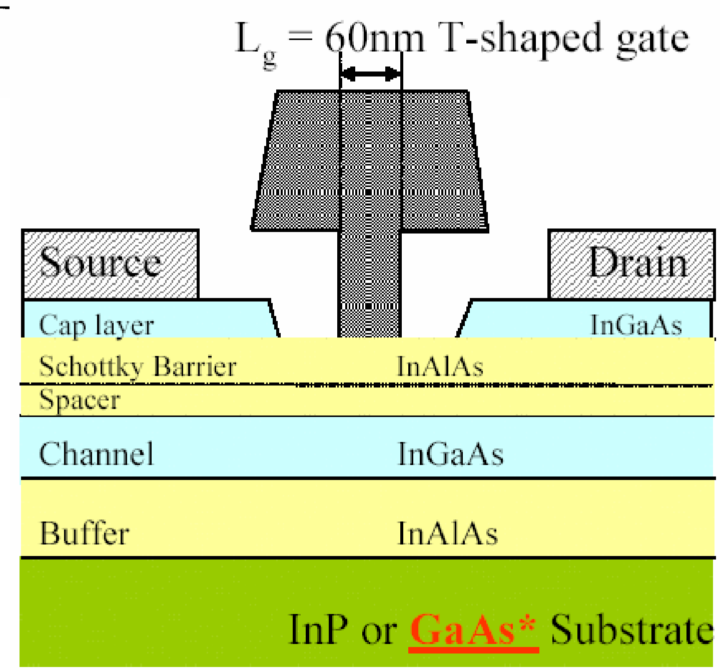
Chap. 1

There's more to transistors than Si MOSFETs

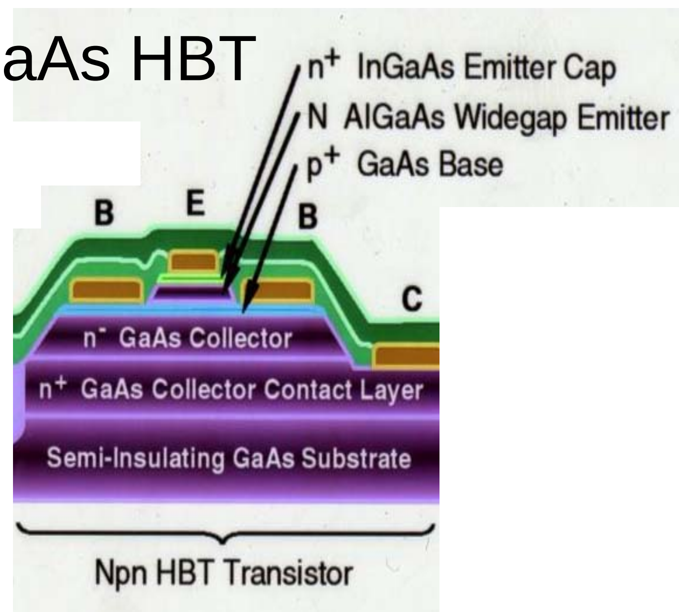
Si MOSFET



InP HEMT



GaAs HBT



Chap. 1

Can the planet tolerate more of this?

PV: large and small

12 MW Arnstein, Germany

5kW Boston Massachusetts
http://256.com/solar/

Residential usage of electricity

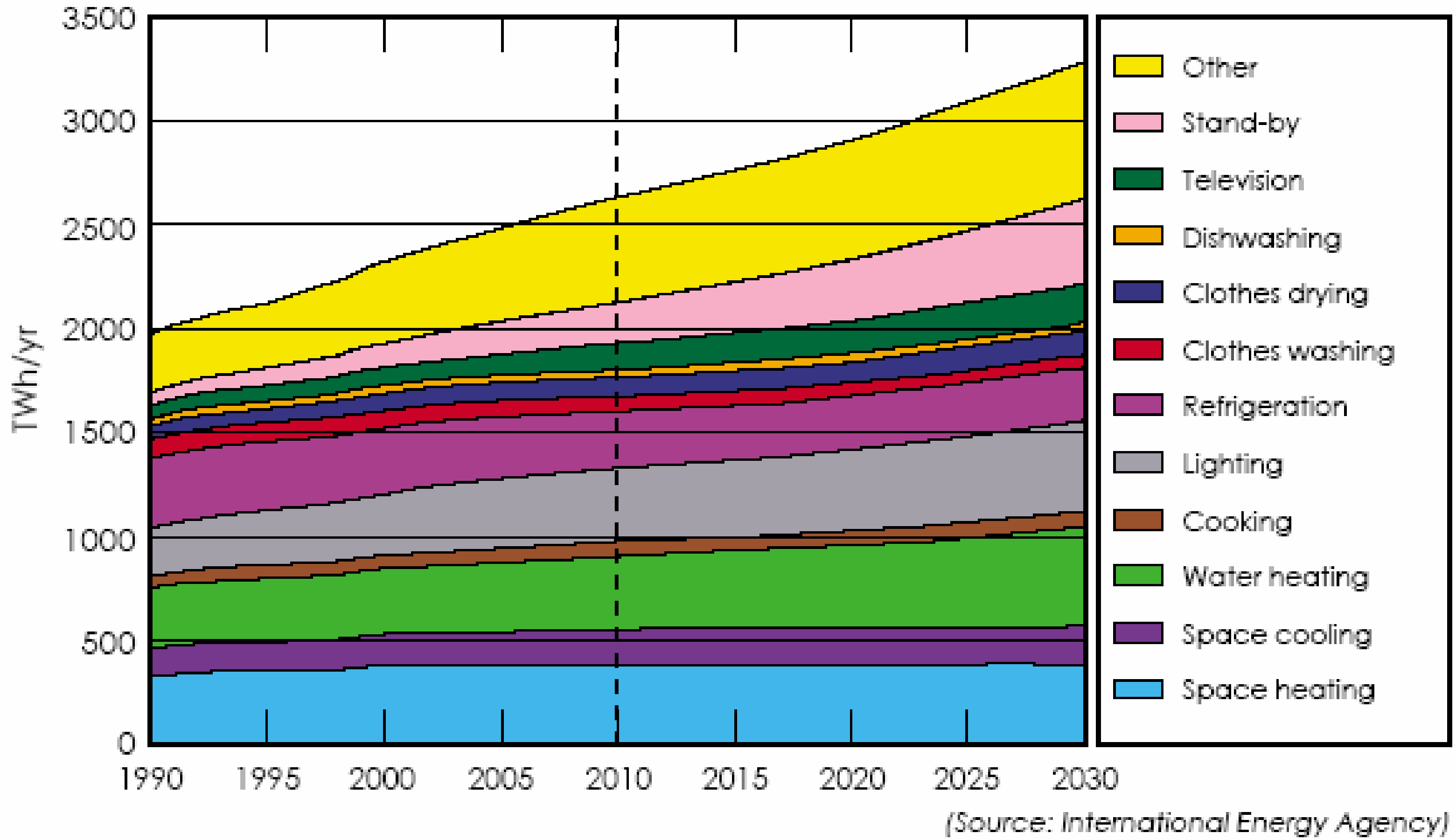


Figure III-21. Real and Projected Appliance Electricity Demand (Source: Policy Strategies for Energy Efficient Homes, IEA, April 2003).

Light bulb comparison

	W	lumens	khours	CRI	$US
Incandescent (long life)	75	(1200)	10	(95)	1.75
W-halogen (PAR38)	75	940	5	(95)	5.95
Fluorescent (T10 tube)	40	3550	20	84	6.95
Fluorescent (compact)	20	1295	12	82	4.95
LED (PAR20, warm)	9	400	40	77	58.95

Data: 12 April, 2010: BuyLighting.com

Semiconductor Basics

1. Transistors are getting smaller.
2. Feature sizes are of the order of the wavelength of an electron.
3. Solar cells and LEDs are optoelectronic devices.
4. They depend on the interaction of electrons, holes, and photons.
5. We need an understanding of semiconductors at the quantum mechanical level.
6. Get your pencil ready to answer some questions related to the next 3 slides

Sec. 2.1

Semiconductor crystal structure

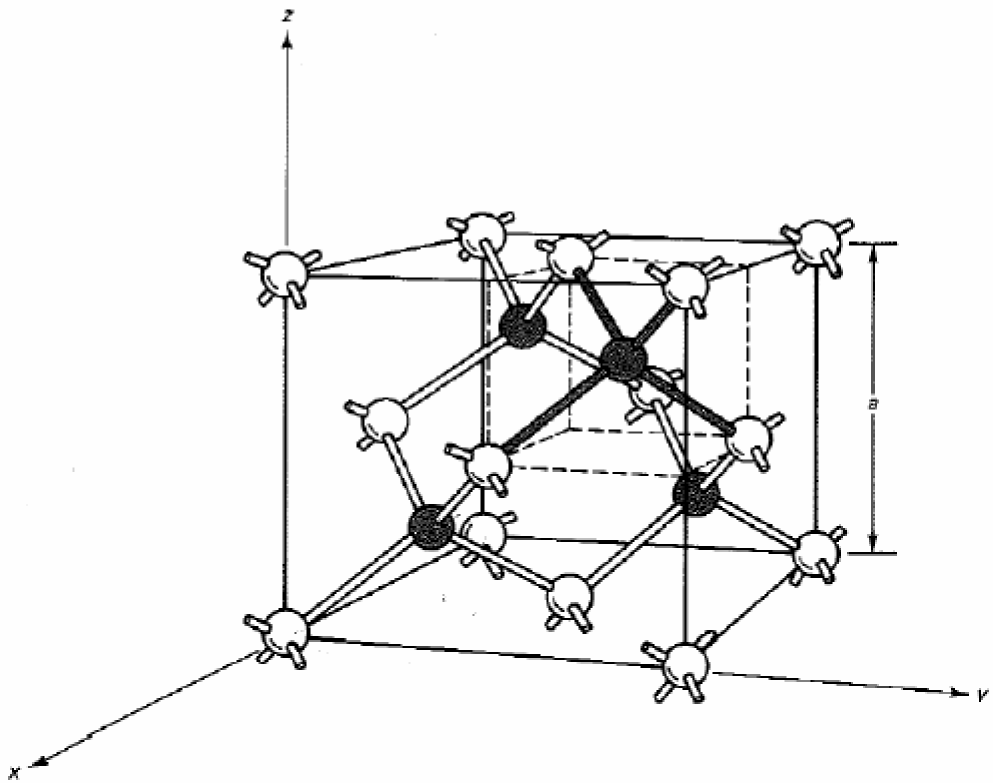


Figure 2.1: A unit cell of the diamond and sphalerite crystal structure. There are two, interpenetrating, face-centred cubic lattices, one comprising the shaded atoms and the other comprising the unshaded atoms. The corresponding points in each FCC lattice are displaced by $\frac{a}{4}(\hat{x}+\hat{y}+\hat{z})$, where a, the **lattice constant**, is the length of the side of the cube.

What is a primitive unit cell?

Why do we need to consider such a cell?

Wigner-Seitz primitive unit cell

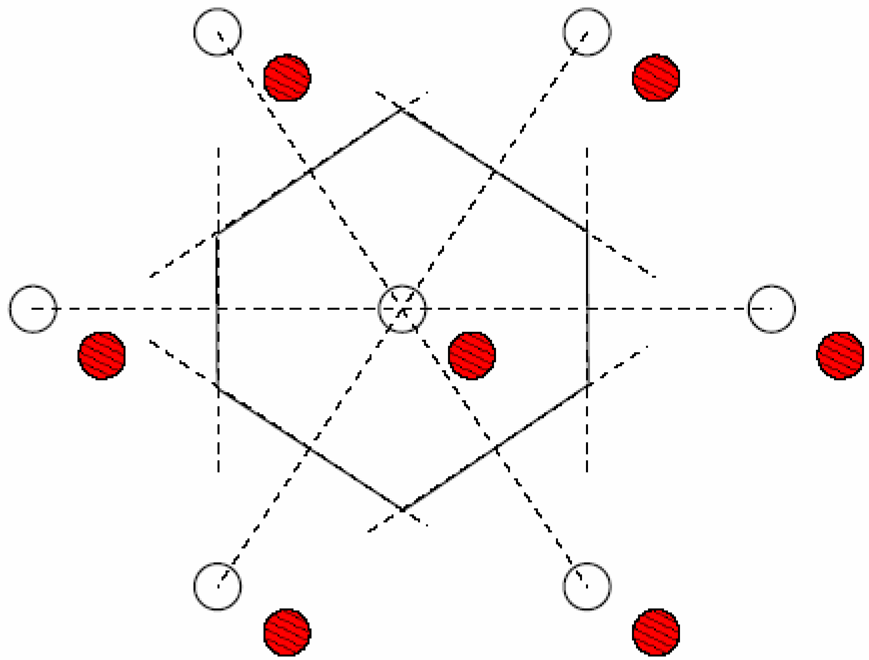


Figure 2.2 Example of a 2-D crystal comprising simple face-centred rectangular arrays of unshaded and shaded atoms. The Wigner-Seitz primitive unit cell is shown by the solid lines.

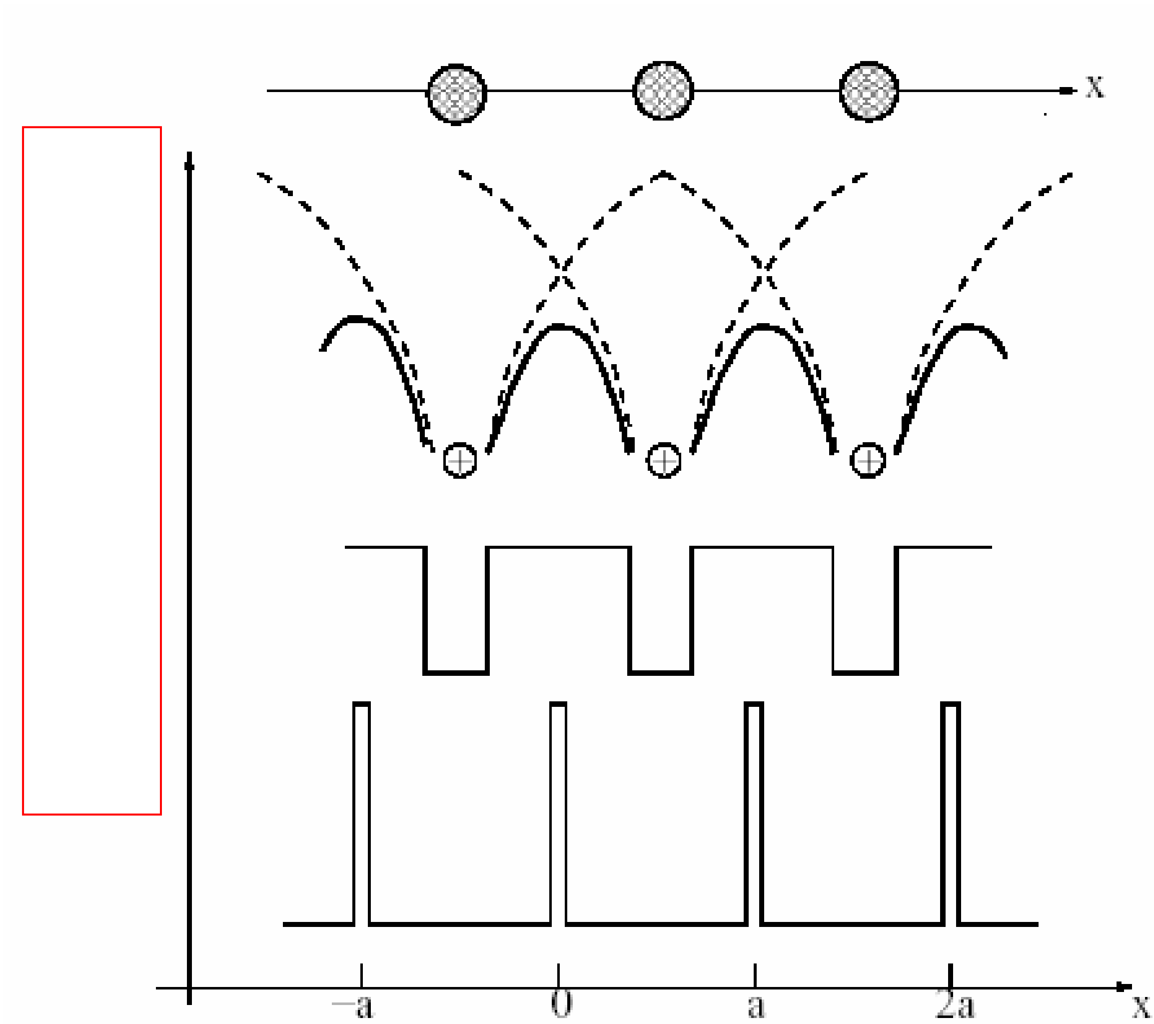
What is the Bravais lattice?

How is this primitive unit cell constructed?

How many atoms per primitive unit cell?

What is the basis?

Periodic potential



1-D periodic array of primitive cells, each containing 1 monovalent atom.

1-D Coulombic potential for an array of primitive cells

Square-well representation

Delta-function representation

Any periodic potential will do for our purpose of revealing and