Course Objective

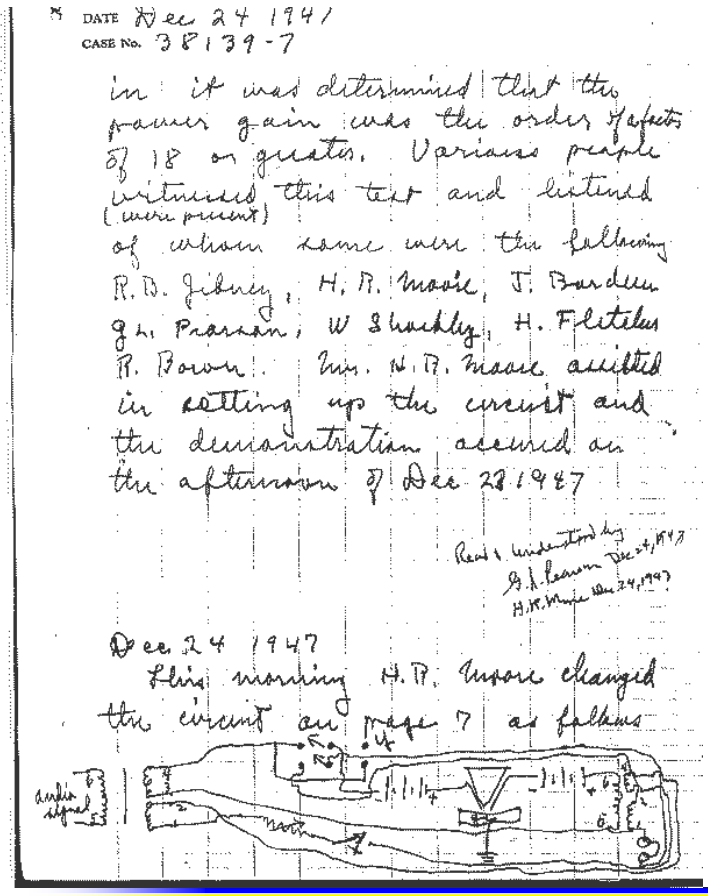
- Review and practice fundamental chemical engineering concepts (mass, energy, and momentum transport coupled with heterogeneous and homogeneous reactions and thermodynamics).
- Apply these concepts to problems in unit operations for fabrication of integrated circuits and electronic and optoelectronic devices.
- Learn about the field of microelectronics processing, its history, and its future.

Transistor and Integrated Circuits: History

- 1906: Lee DeForest developed the triode in vacuum tube that could amplify signals.
  - "Killer Application" = transcontinental telephone service.
  - It worked but was unreliable, used and produced too much power.
- 1915: Coast-to-coast telephone system.
- 1920-30: Quantum mechanics
- 1930s: Mervin Kelly, Bell Labs Director of Research envisioned something made of semiconductors to replace the vacuum tube.
- 1940: Russel Ohl discovered p-n junction.
- 1945: Bill Shockley assembles solid state research team at Bell Labs
- 1946: ENIAC, the 1st digital computer, uses 18,000 vacuum tubes

Transistor and Integrated Circuits: History

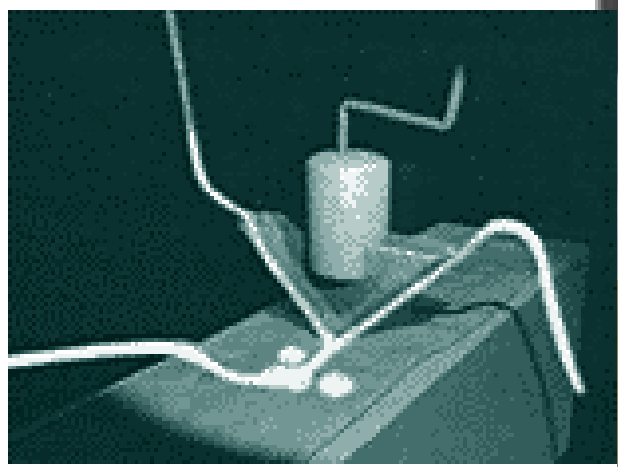
- 1947: Christmas Eve; Bill Shockley, John Bardeen & Walter Brattain invented the point contact transistor


DATE Dec 24 1947
CASE No. 38139-7

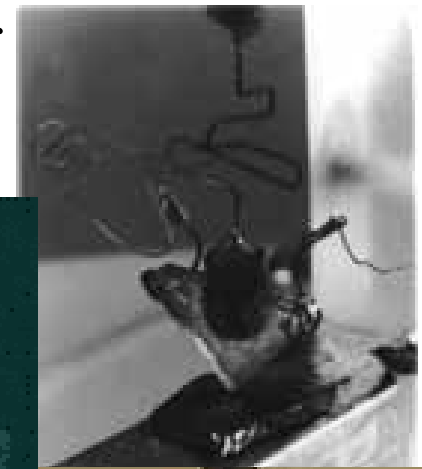
in it was determined that the power gain was the order of 18 or greater. Various people witnessed this test and listened (were present) of whom some were the following R.B. Gibney, H.R. Moore, J. Bardeen G.L. Pearson, W Shockley, H. Fletcher R. Bown. Mr. H.R. Moore assisted in setting up the circuit and the demonstration occurred on the afternoon of Dec 24 1947

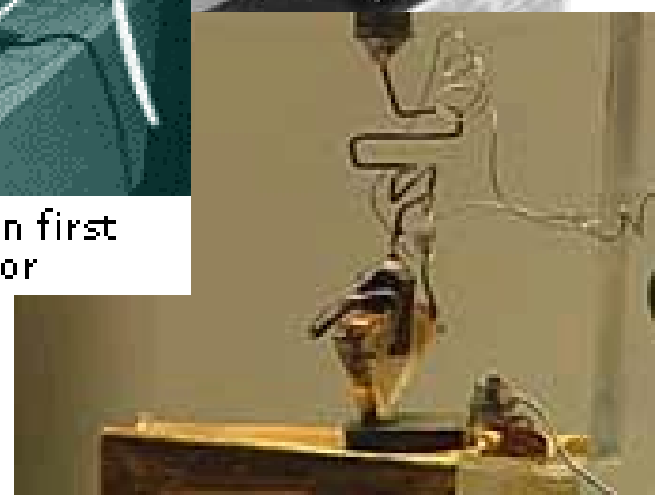
Read & understood by G.L. Pearson Dec 24, 1947 H.R. Moore Dec 24, 1947

Dec 24 1947
This morning H.R. Moore changed the circuit on page 7 as follows



Path of current flow in first point contact transistor





http://www.pbs.org/transistor/science/index.html

Transistor and Integrated Circuits: History

- 1948: Shockley invents the junction transistor
- 1952: Dummer suggested that “electronic equipment can be manufactured in solid block without connecting wires”
- 1953: First commercial application of transistors: hearing aids
- 1950s: Czochralski growth and Bridgman growth techniques invented
- 1954: First transistor radio; first fully transistorized computer
- 1954: Texas instruments makes first Si transistor
- 1956: Nobel Prize in Physics to Bill Shockley, John Bardeen & Walter Brattain for inventing the transistor
- 1957: Shockley leaves Bell labs and establishes Shockley semiconductor in Palo Alto, CA
- 1958: “Traitorous Eight” leave Shockley Semiconductor to form Fairchild Semiconductor and Intel (Robert Noyce and Gordon Moore)
- 1958: Bill Pfan invented purification by zone melting

The First Integrated Circuit

- 1958: Jack Kilby at Texas Instruments and Robert Noyce at Fairchild invent the integrated circuit.

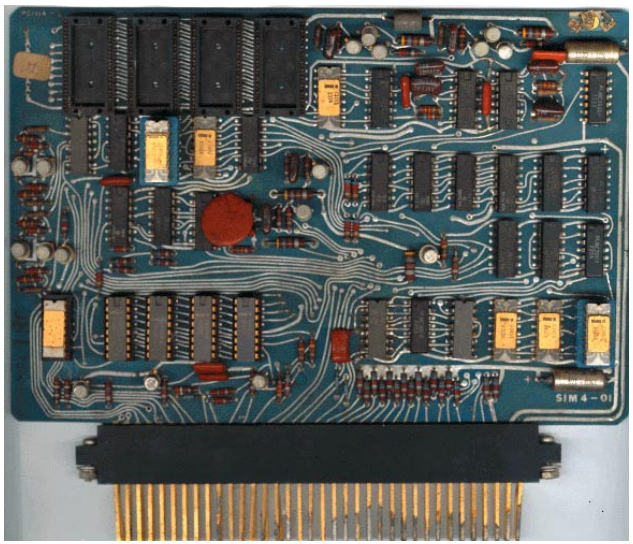
An integrated circuit is a collection of electronic devices such as transistors, diodes, capacitors, and resistors in a small(~1-20 cm^2, thin (0.5-1 mm) semiconducting substrate such as Si or GaAs. The devices are interconnected using metal lines ("wires") to perform a variety of functions (microprocessors) or to store information (memory).

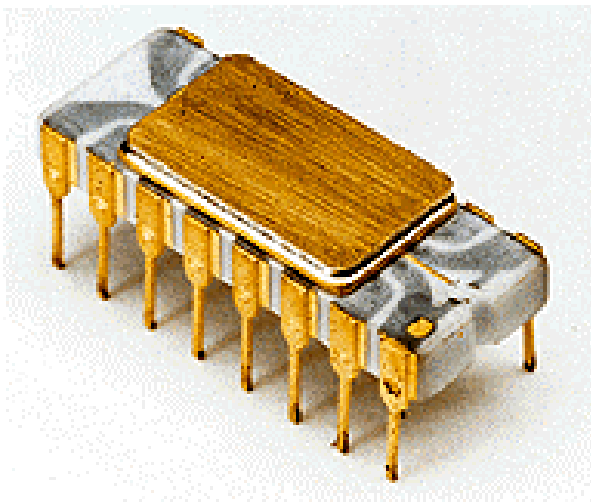
http://www.ti.com/corp/docs/company/history/tihistory.htm

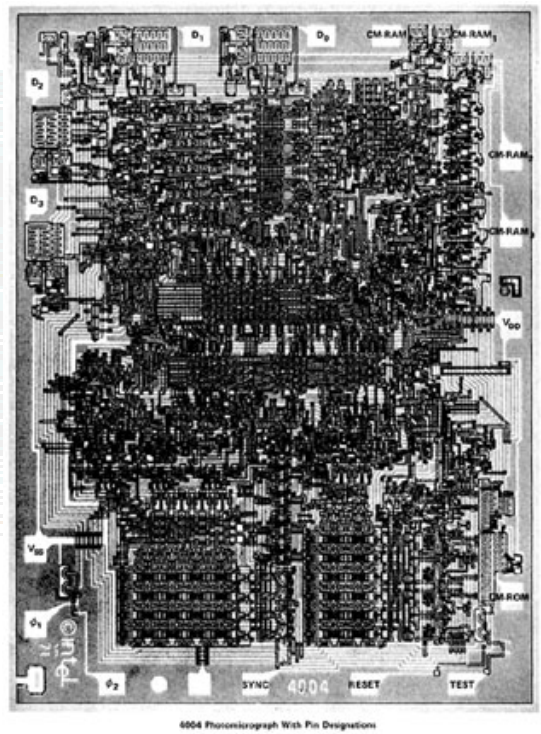
Intel and the First Microprocessor

- 1965: Andy Grove and Bruce Deal study Silicon Oxidation
- 1968: First use of plasmas in integrated circuit fabrication
- 1968: Robert Noyce, Gordon Moore and Andy Grove leave Fairchild to cofound Intel (short for integrated electronics). Grove later becomes the CEO.
- 1971: A Japanese company named BUSICOM hired Intel to build a circuit to run its calculators.
- 1971: In response to BUSICOM Ted Hof invents the first microprocessor at Intel 4004. 1/8" × 1/16" with 2300 transistors on silicon. 4004 was as powerful as ENIAC; ENIAC weighed 30 tons and had 18,000 vacuum tubes.
- 1971: A bad business decision; BUSICOM, unsatisfied with slow progress, asks for their investment refund. Intel gives their $ 40,000 back and retain all the rights to the microprocessor.

The First Microprocessor: Intel 4004



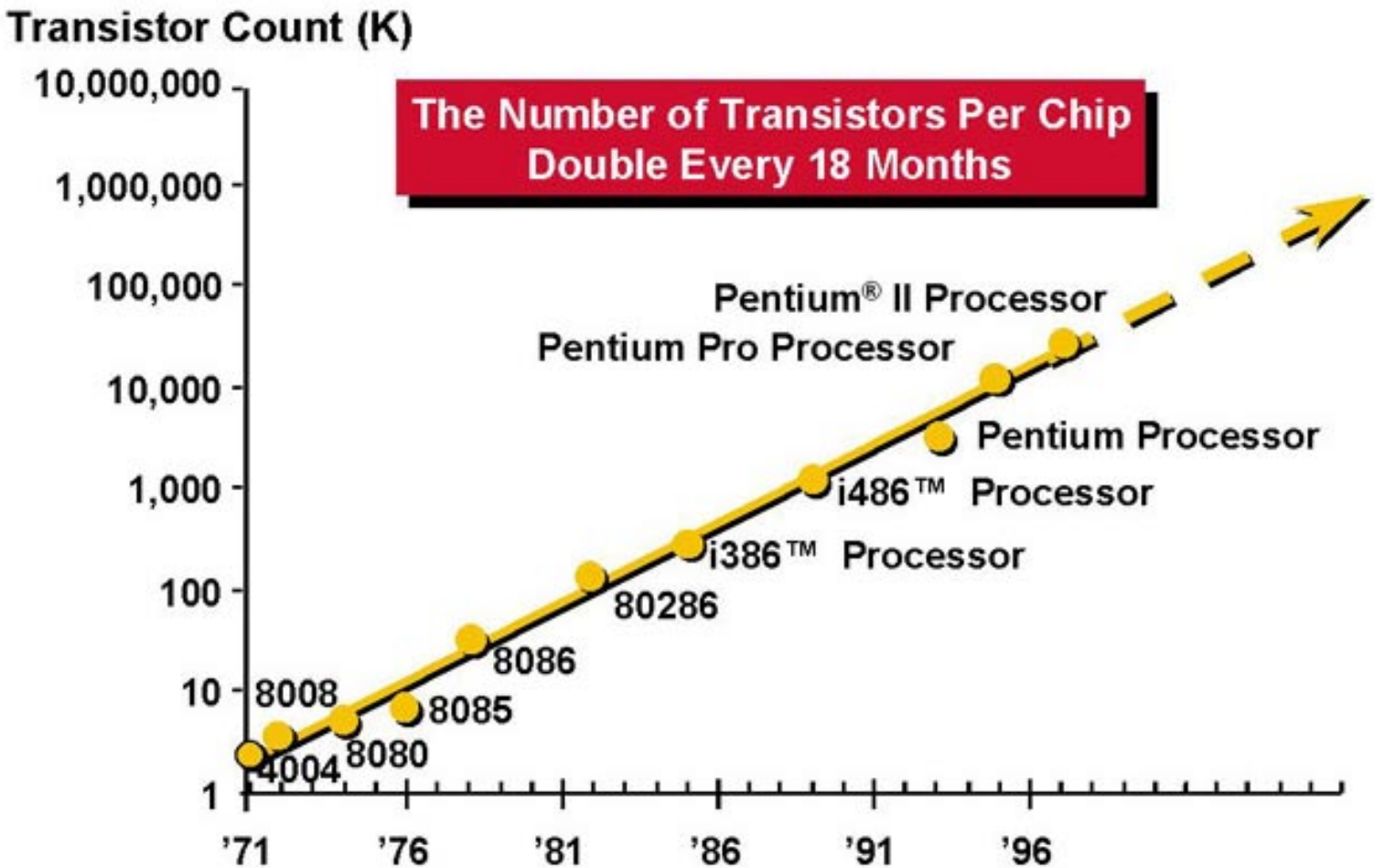




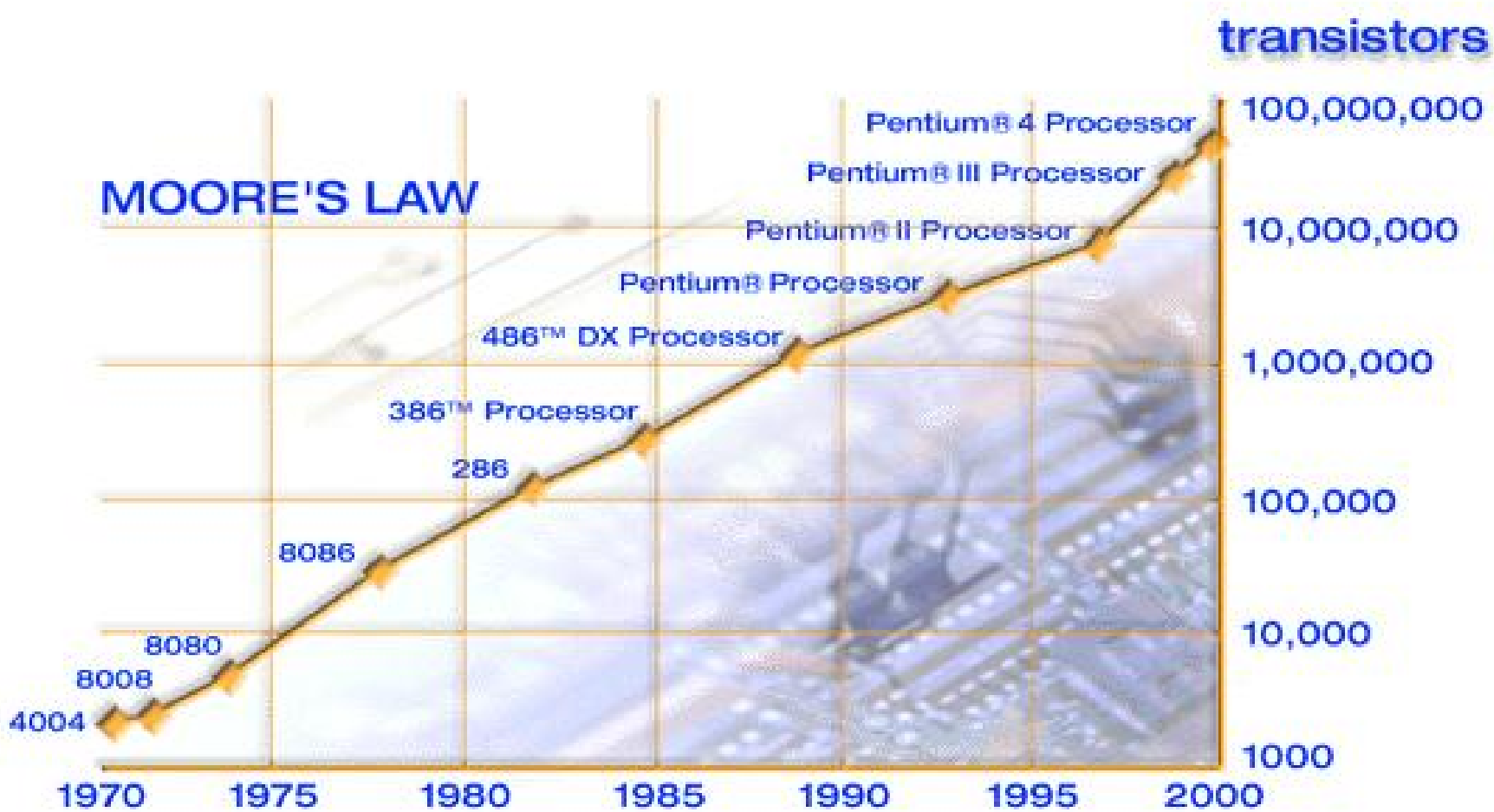
4004 Photomicrograph With Pin Designations

- *The 4-bit Intel 4004 ran at a clock speed of 108 kHz and contained 2300 transistors. The 4004 addressed up to 1 Kb of program memory and up to 4 Kb of data memory.*

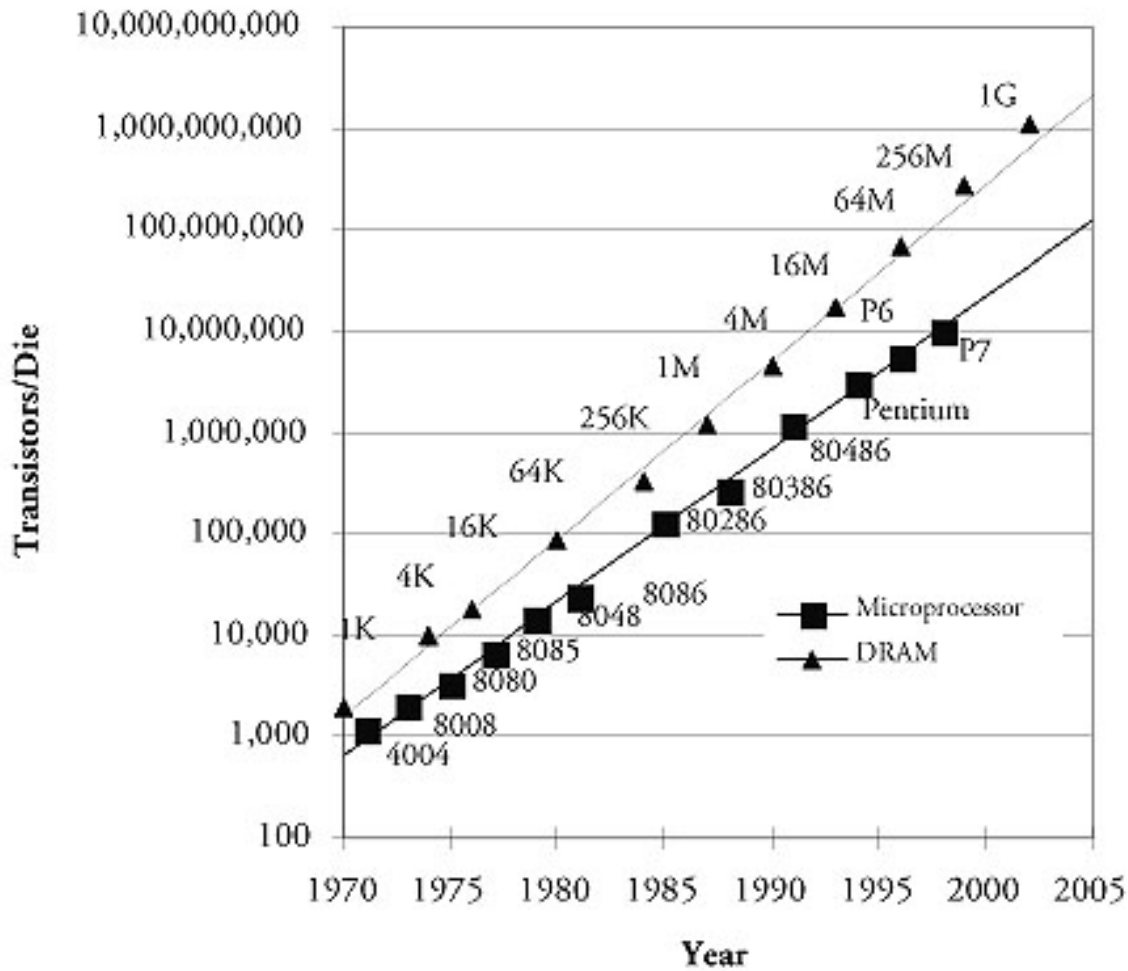
Moore's law


Transistor Count (K)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
The Number of Transistors Per Chip
Double Every 18 Months
Pentium® II Processor
Pentium Pro Processor
Pentium Processor
i486™ Processor
i386™ Processor
80286
8086
8085
8080
8008
4004
'71
'76
'81
'86
'91
'96

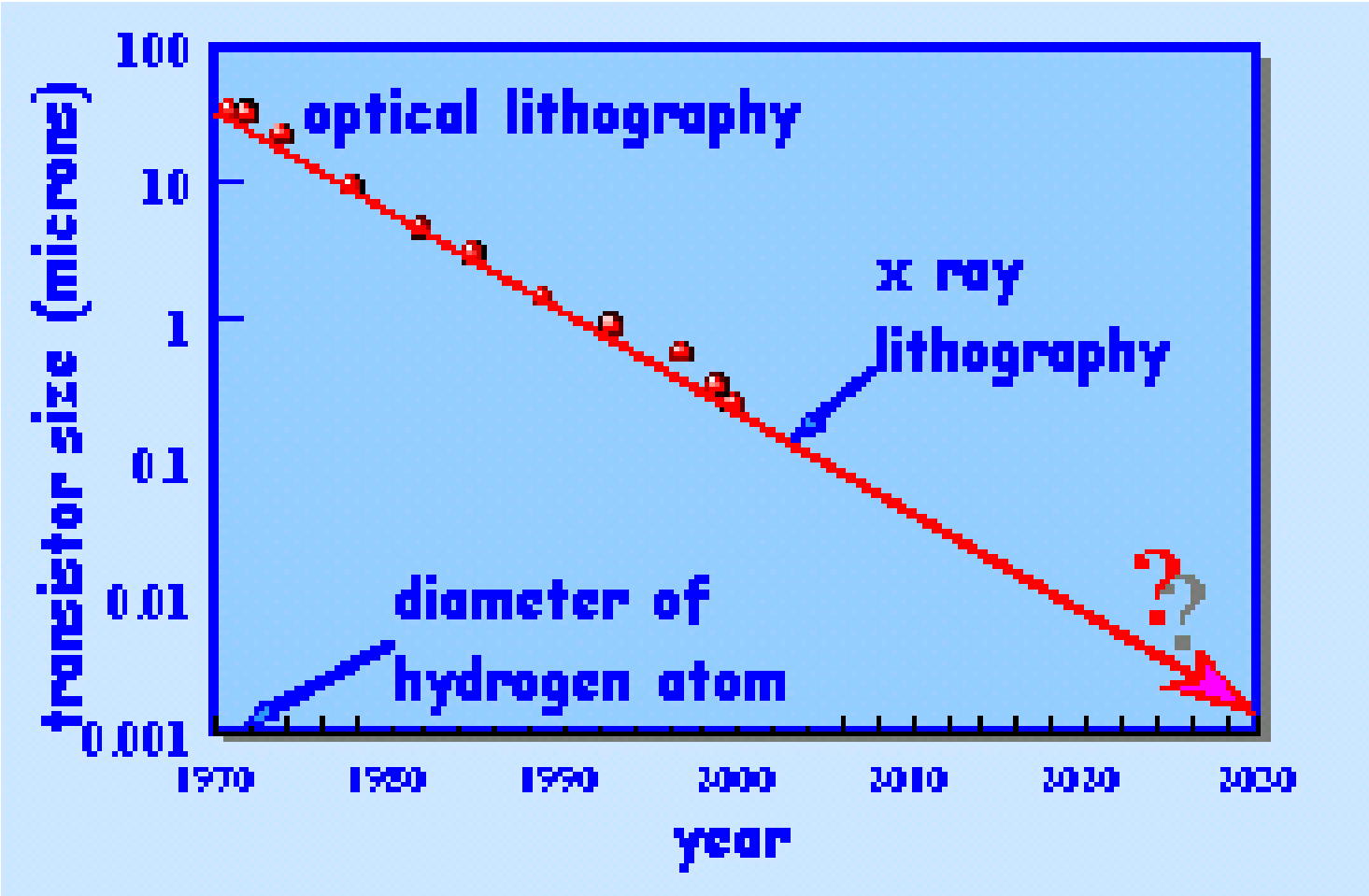
Moore's law


transistors
MOORE'S LAW
Pentium® 4 Processor
Pentium® III Processor
Pentium® II Processor
Pentium® Processor
486™ DX Processor
386™ Processor
286
8086
8080
8008
4004
100,000,000
10,000,000
1,000,000
100,000
10,000
1000
1970
1975
1980
1985
1990
1995
2000

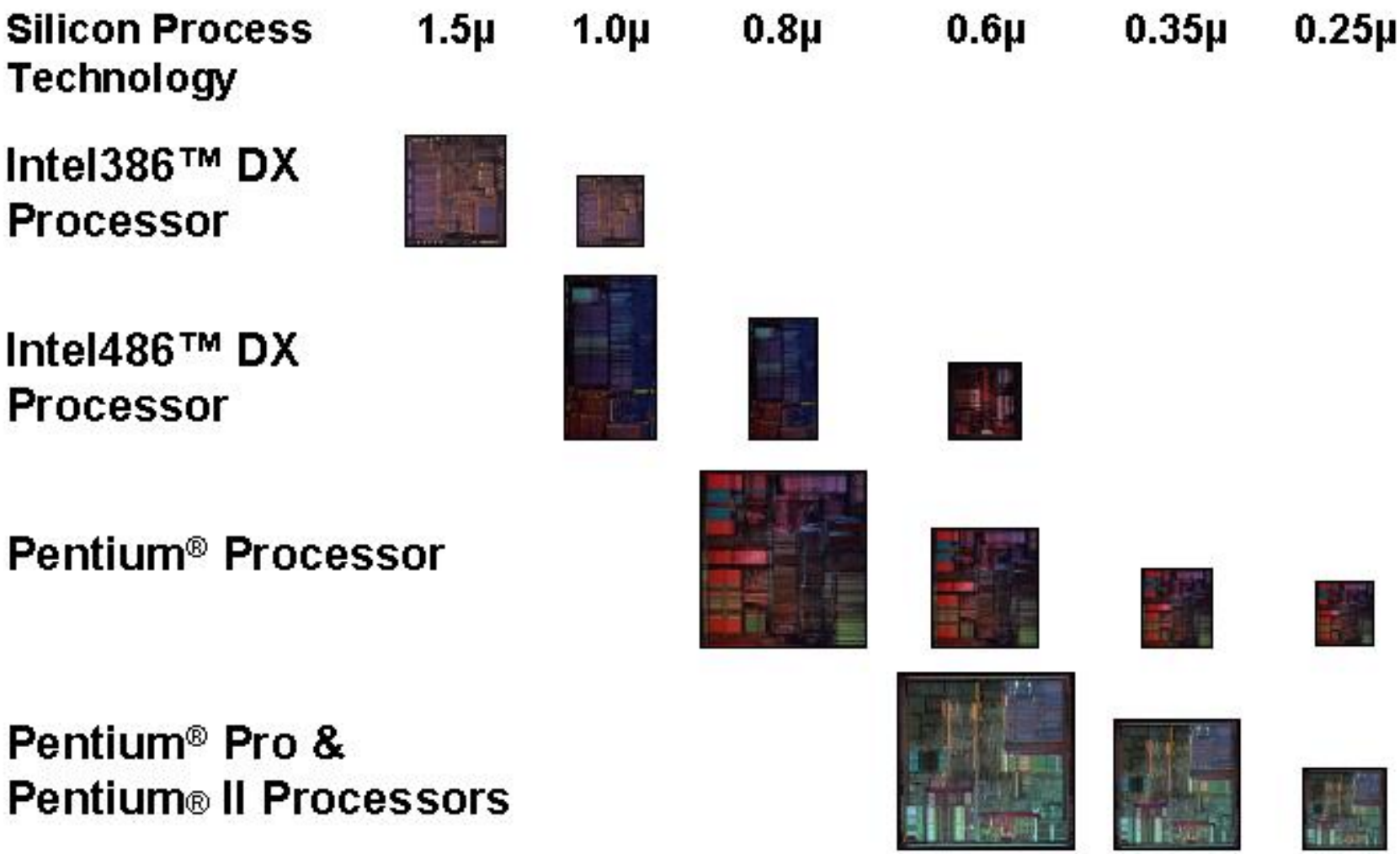
Memory


10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
Transistors/Die
1970
1975
1980
1985
1990
1995
2000
2005
Year
1G
256M
64M
16M
4M
1M
256K
64K
16K
4K
1K
P6
P7
Pentium
80486
80386
80286
8086
8048
8085
8080
8008
4004
Microprocessor
DRAM

Decreasing transistor size

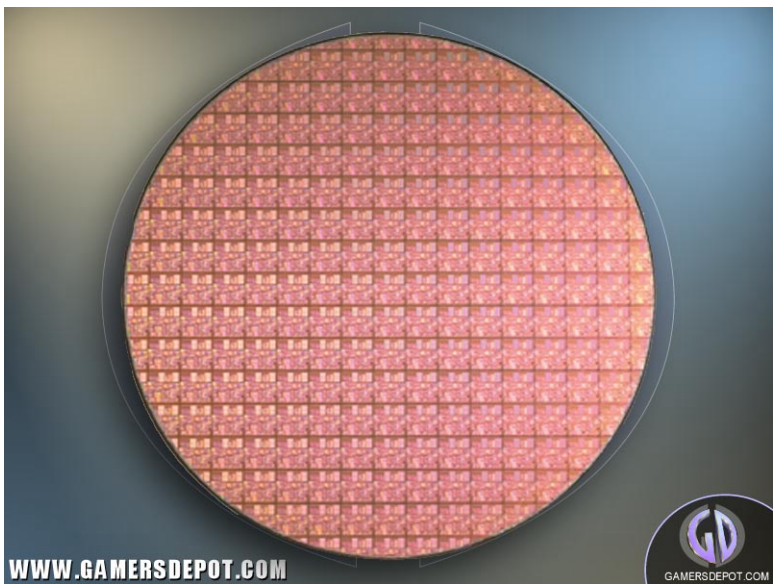


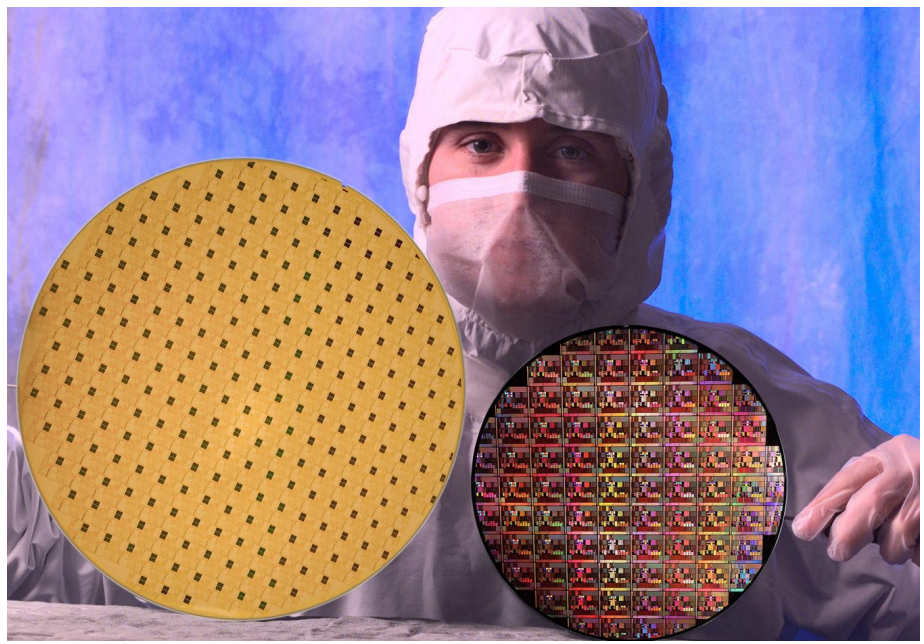
Microprocessor "Technology"



Microelectronics Manufacturing: Overview

- ICs are produced layer by layer on the top few microns (10^{-6} m) of a ~ 0.5 mm thick substrate using a series of processing steps.
- In 99% of the ICs the substrate is Si. Glass (for displays) and GaAs are the next common substrates.

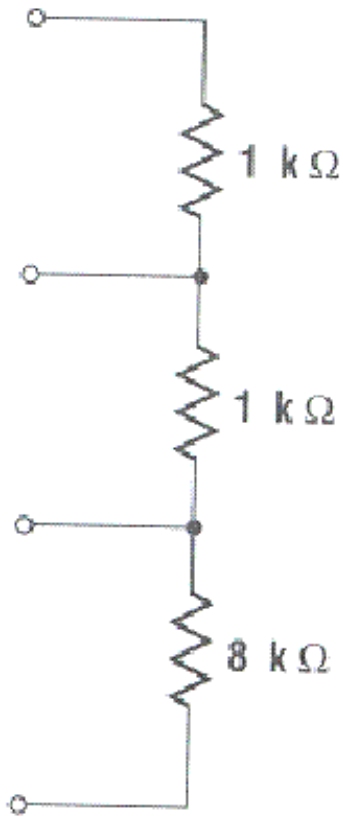


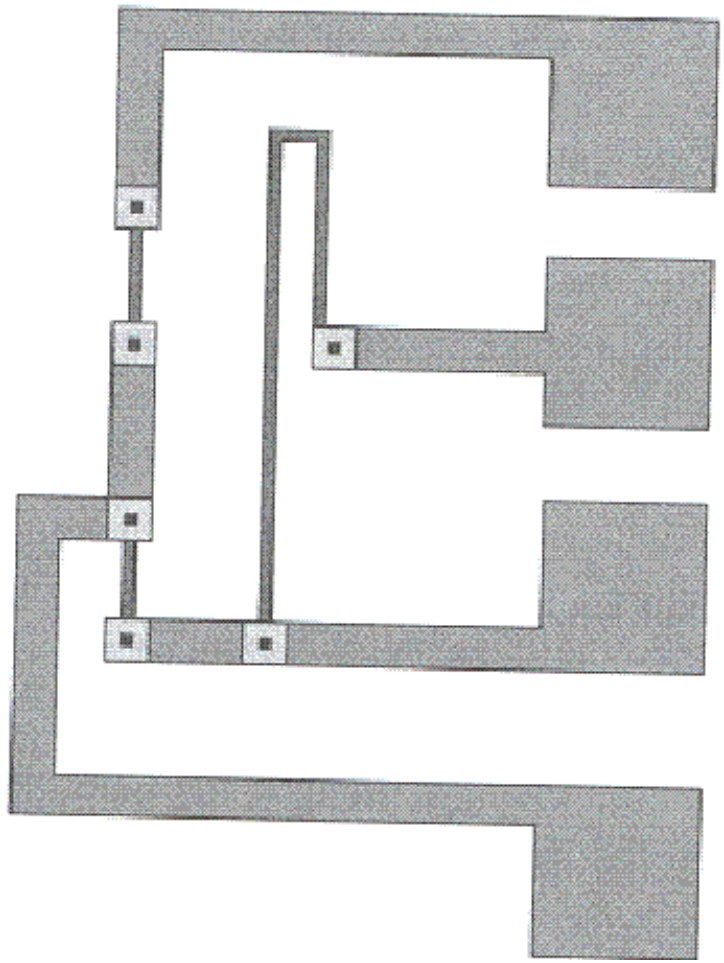


Unit Operations of Microelectronics Manufacturing

- Crystal Growth
- Oxidation
- Chemical Vapor Deposition (Thermal CVD)
- Plasma Enhanced Chemical Vapor Deposition (PECVD)
- Epitaxy
- Lithography
- Diffusion
- Ion Implantation
- Plasma Etching
- Evaporation
- Sputtering
- Wet Etching/Cleaning
- Electrochemical Deposition
- Chemical-Mechanical Polishing

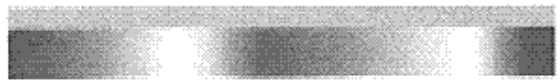
Example: Voltage Divider



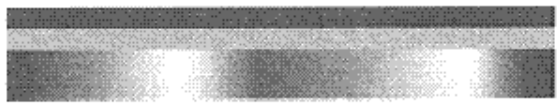


Voltage Divider "Technology"

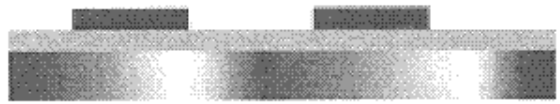
(1) Starting wafer



(2) Grow oxide

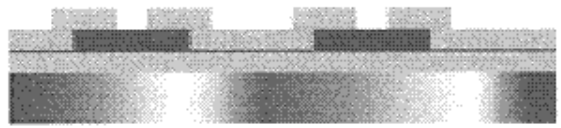


(3) Deposit resistor material

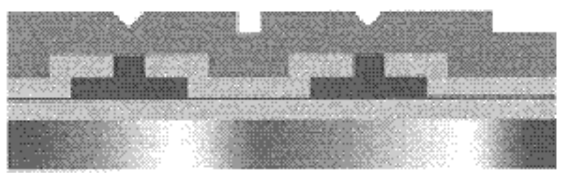


(4) Pattern resistor material

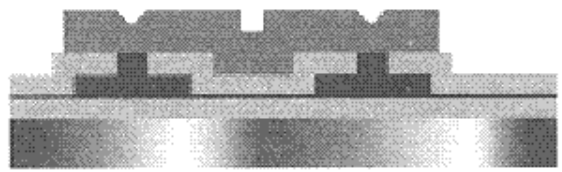
(5) Deposit insulator



(6) Pattern insulator



(7) Deposit metal



(8) Pattern metal

Pattern Transfer Using Lithography