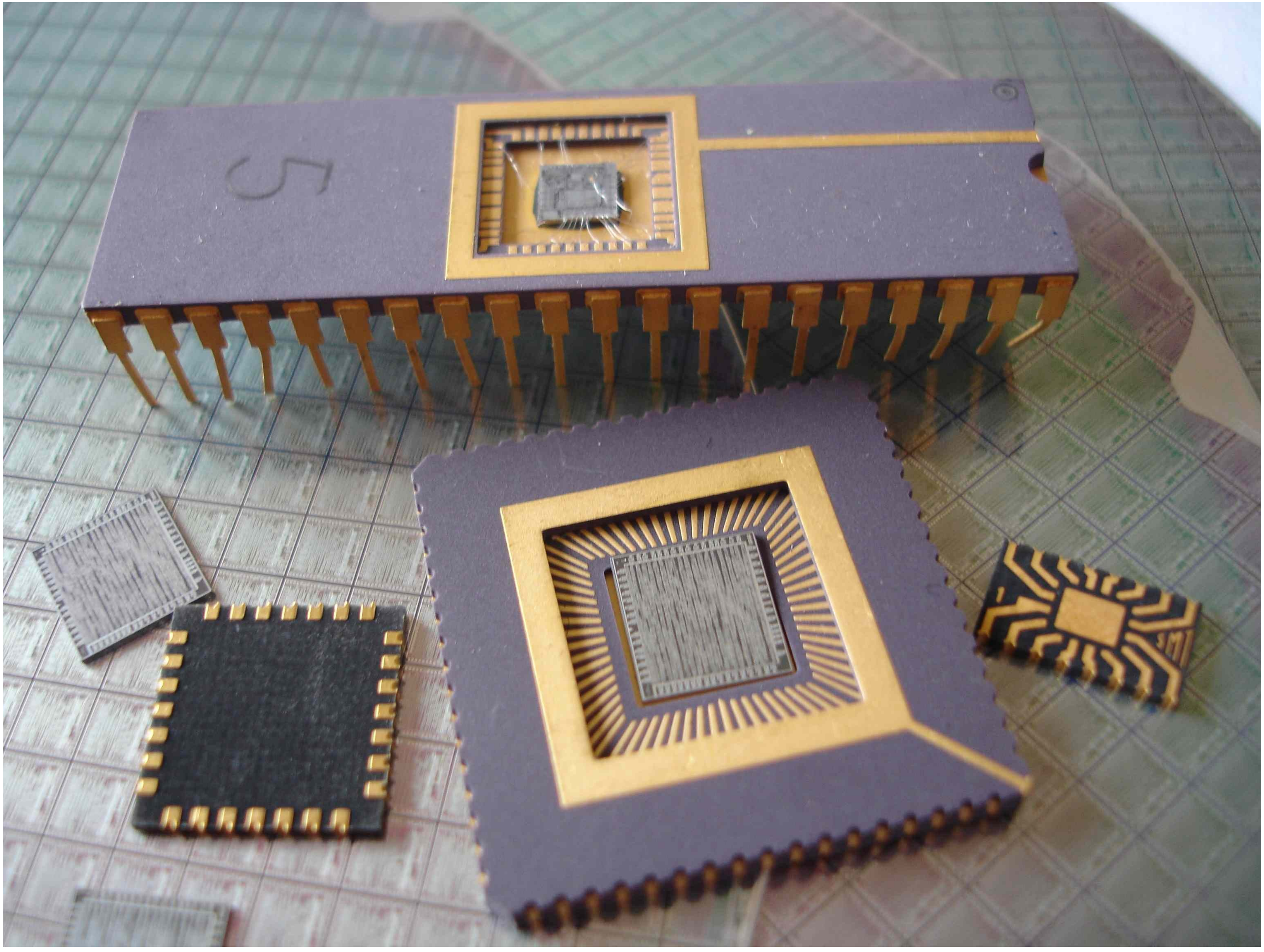
MOORE 's LAW

- The history and evolution of IC
- Collection from various sources
- J.-C. Martin, Gabriel 32, 2034 Peseux
- Jean-Claude.martin@hefr.ch
- jcmartin@net2000.ch
- last update date 13.8.2006 JCM


5

chapitres

- Histoire et vocabulaire
- Évolution (loi de Moore)
- Multimétal
- FPGA
- Téléphones
- Suisse
- Prévisions pour 2015

Some references

- IEEE Spectrum
- http://tcm.org/html/history/timeline/threads/components/index.html
- CEH (presently CSEM), Neuchâtel
- FASELEC (presently Philips) Zürich
- http://www.microwind.org
- - Http://micro.magnet.fsu.edu/chipshot.html

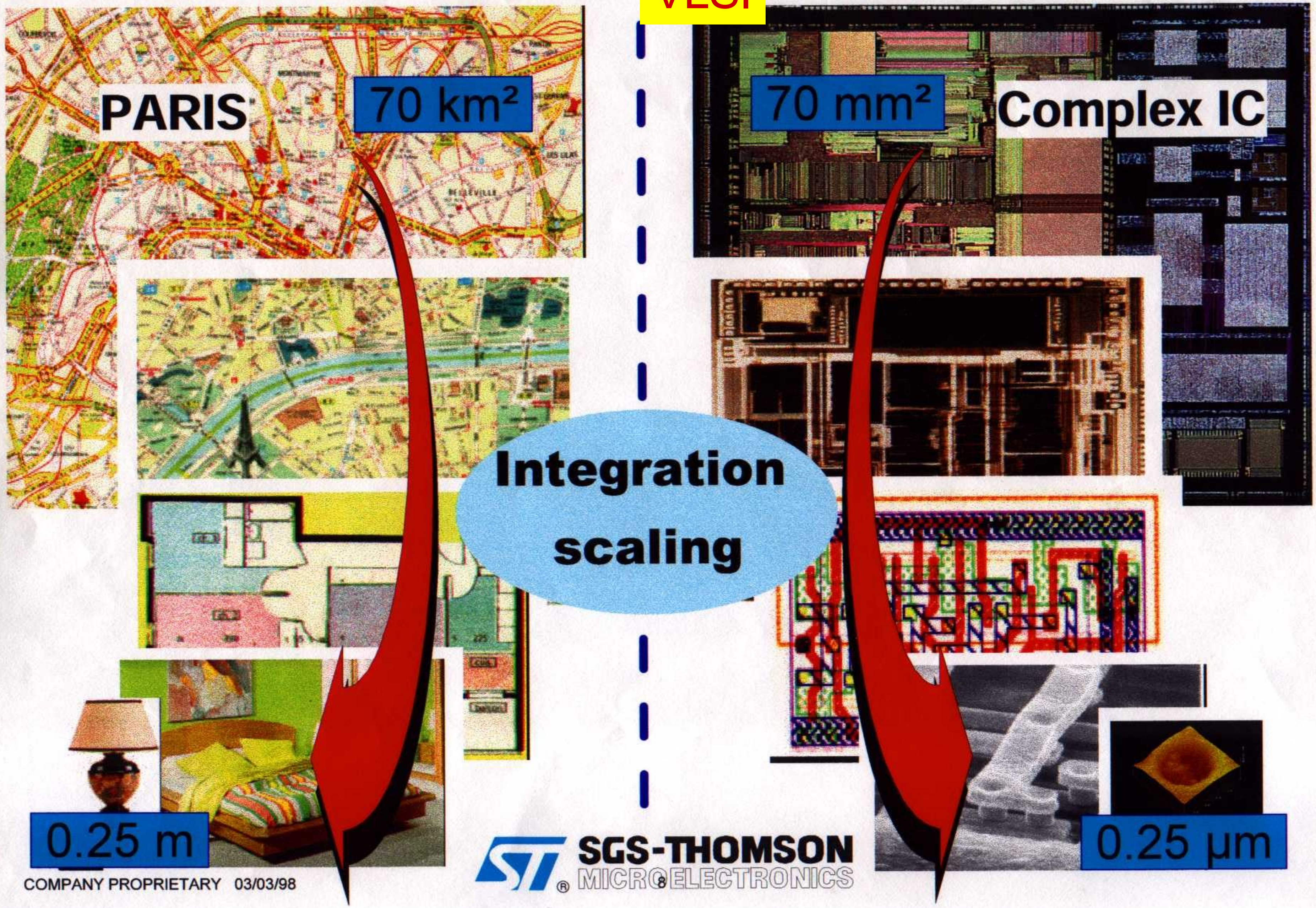
60 ans de microélectronique

- …. Vacuum tubes, discrete components
- 1947 The first integrated transistor (Bell Telephone Laboratories)
- 1959 The first bipolar planar transistor
- 1961 The first integrated circuit available as a monolithic chip (flip-flop)
- 1965 The first op-amp
- 1971 The first 4bit microprocessor (Intel 4004)
- 1972 The first 8bit microprocessor (Intel 8008)
- 1981 The first IBM PC
- 1987 Microprocessor Motorola 68030
- 2006 Moore law still valid

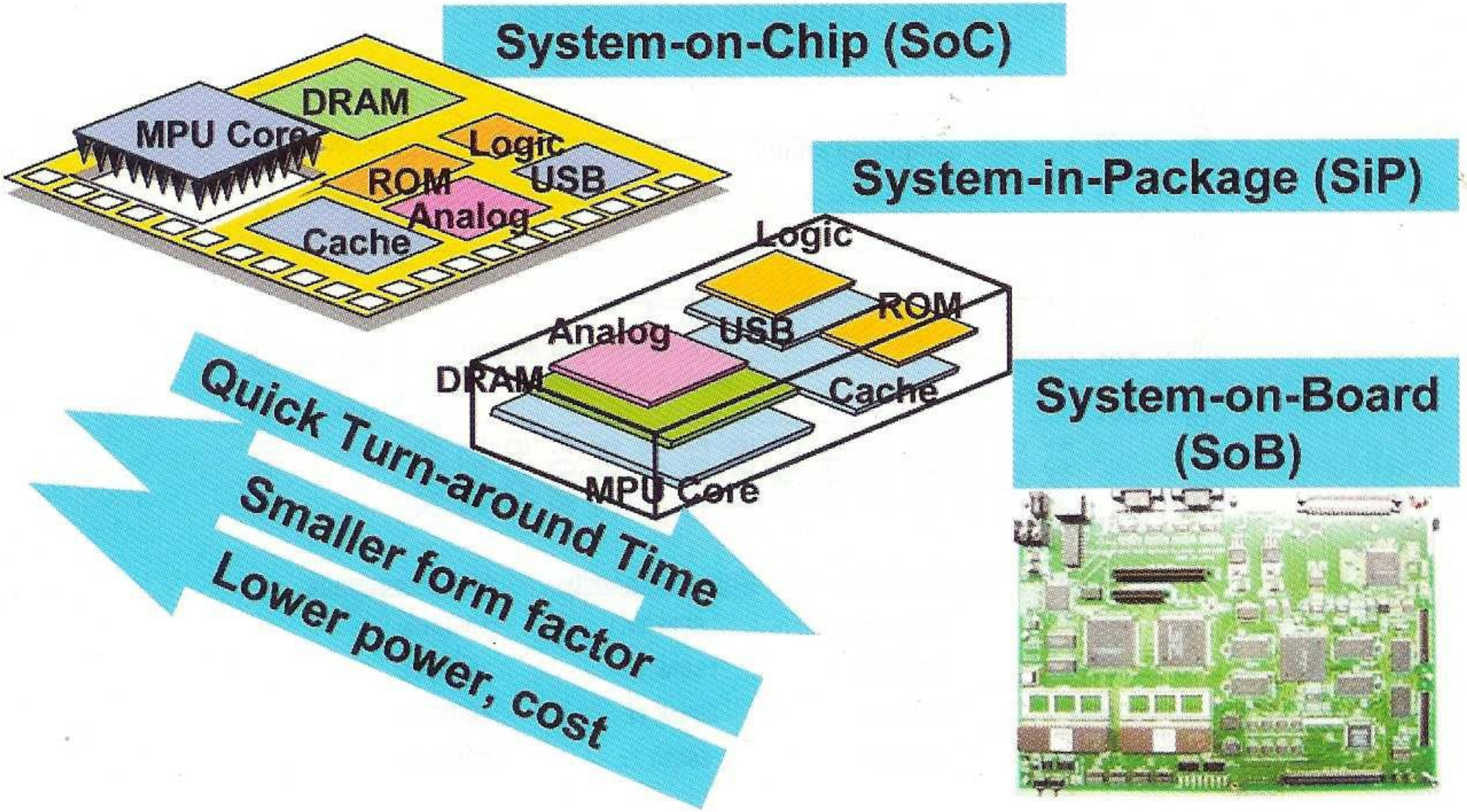
Vocabulaire des IC

- VLSI Very Large Scale Integration
- SoC System-on Chip
- SiP System-in Package
- SoB System-on Board
- IP Intellectual Property (reuse)
- ASIC Application Specific IC

VLSI


PARIS
70 km²
70 mm²
Complex IC
Integration
scaling
0.25 m
0.25 µm

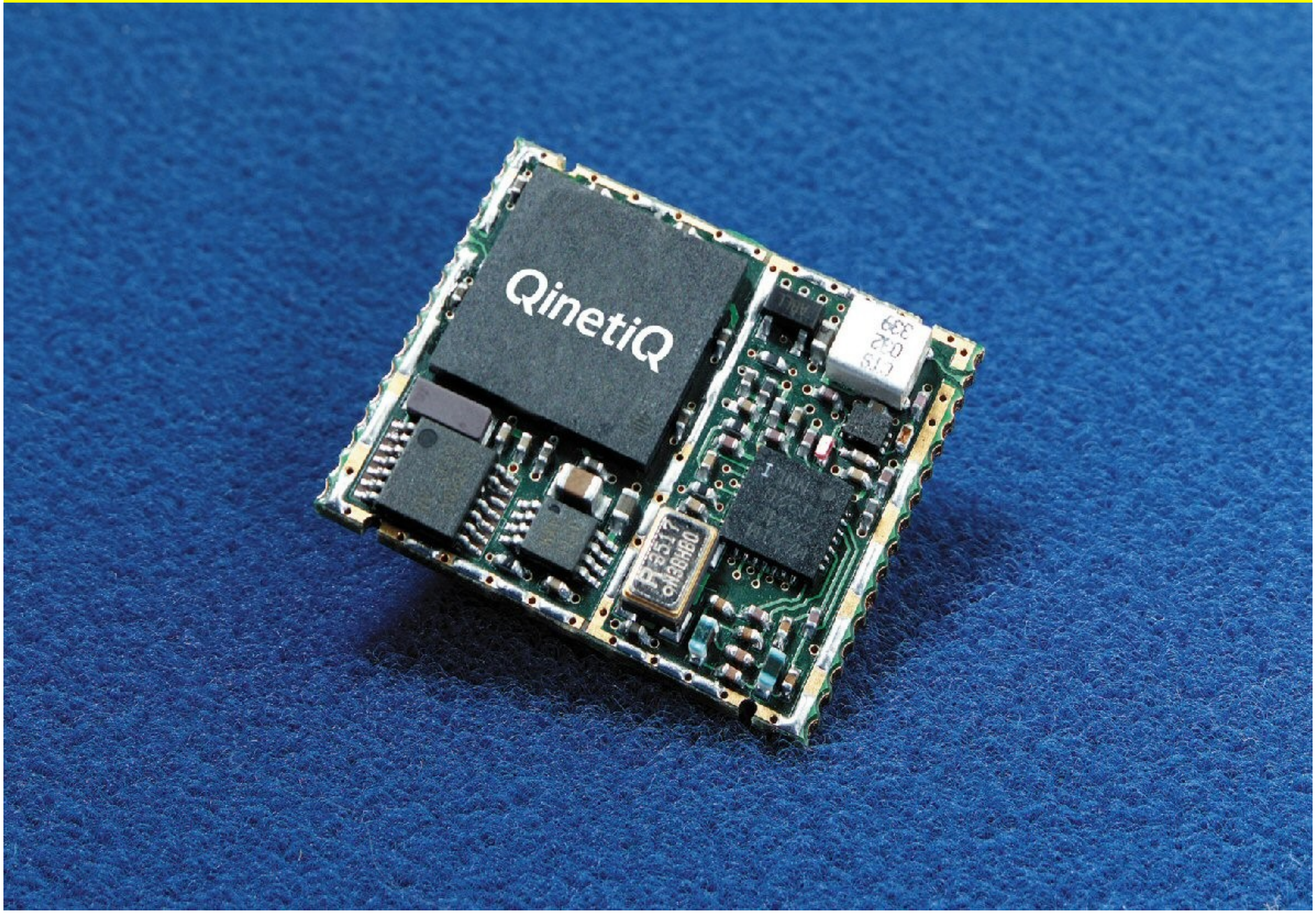
SoC SiP SoB



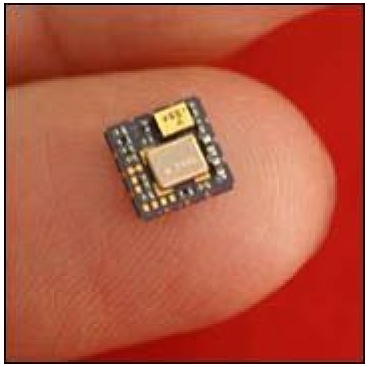
Proceeding IEEE june 2006

Exemple du GPS

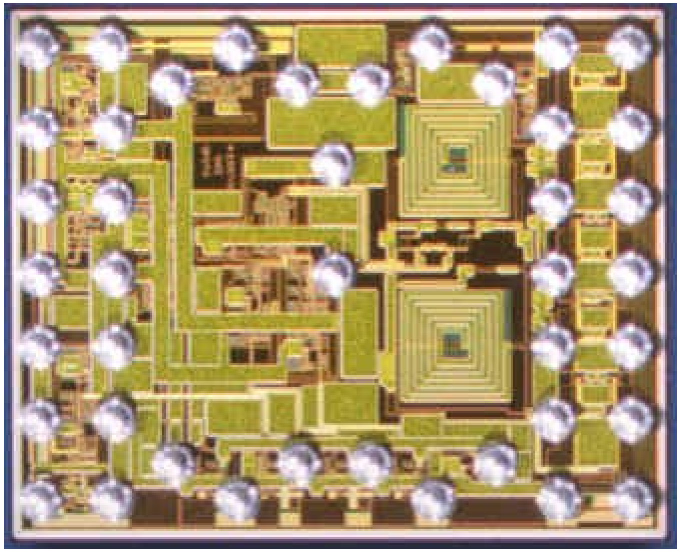
Exemple d'un produit GPS



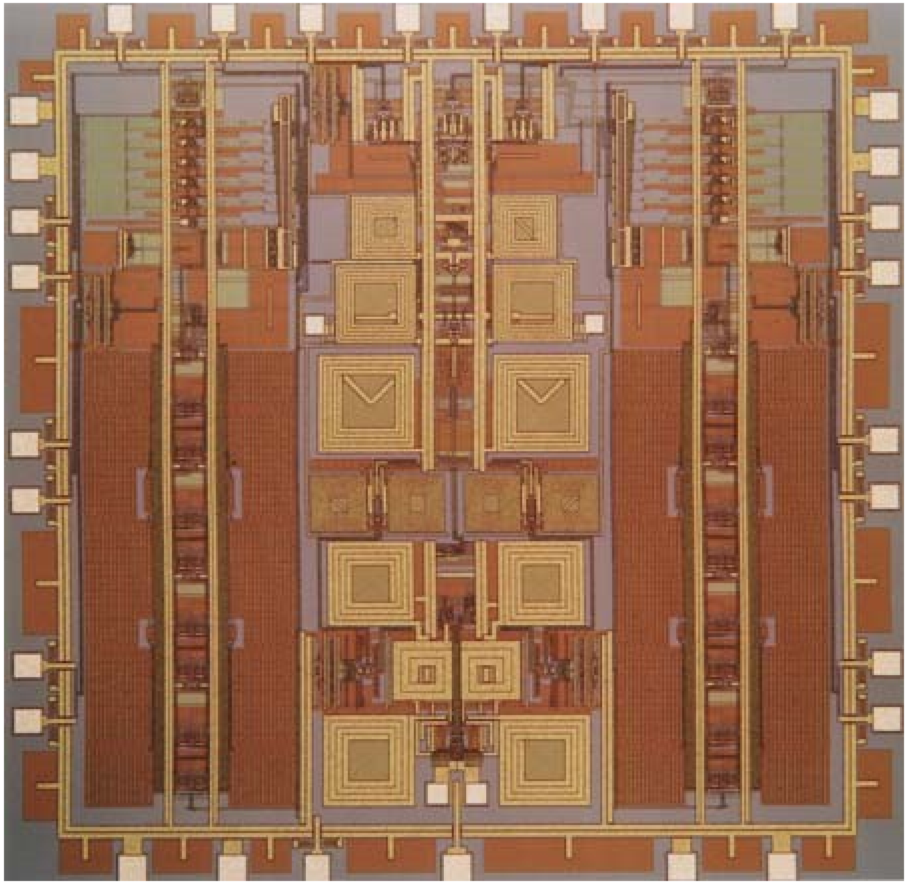
Exemples de composants GPS



Module



SiGe



Circuit récepteur

Module GPS complet

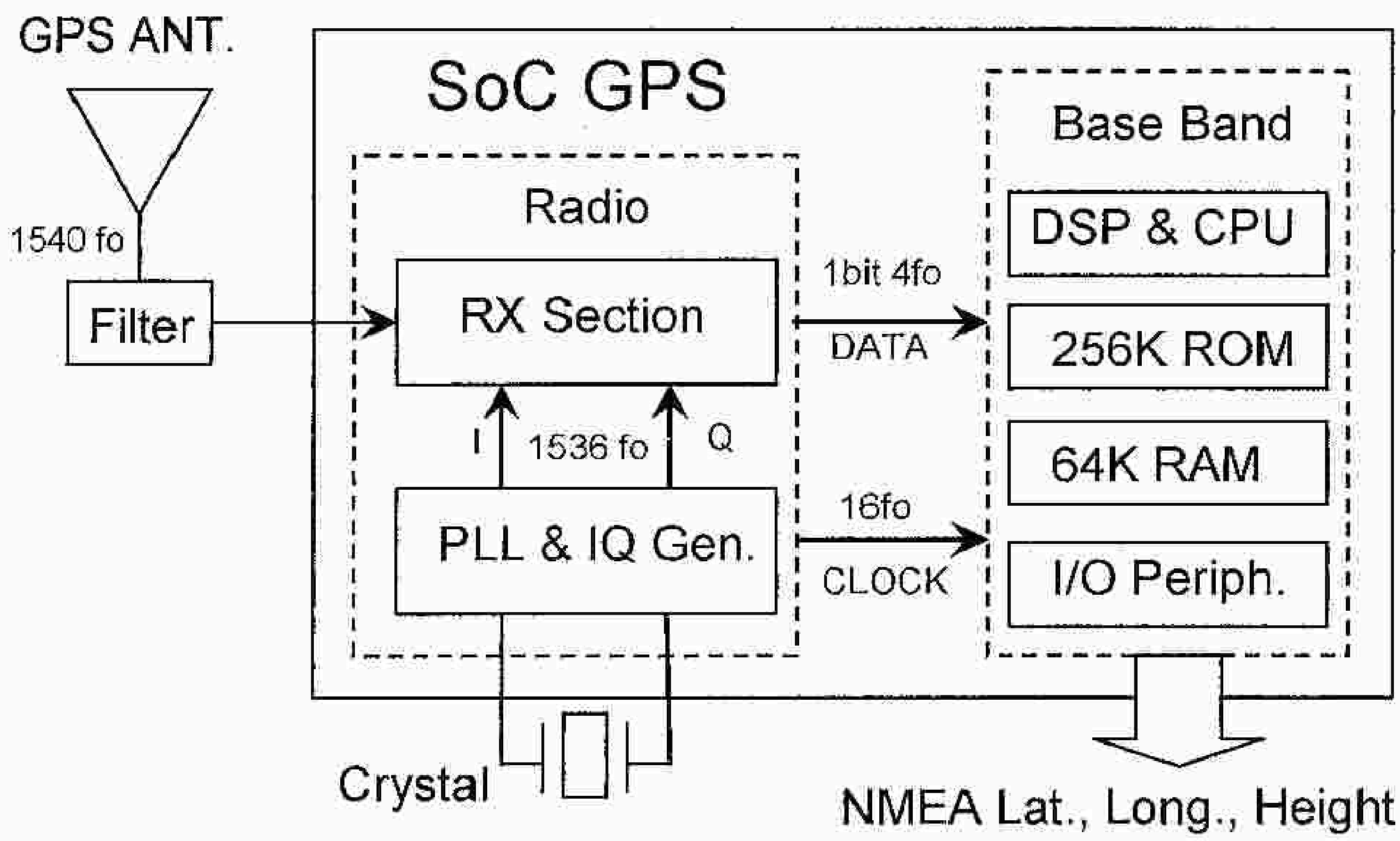


Fig. 1. SoC GPS and required external components.

SoB, CMOS 180nm GPS

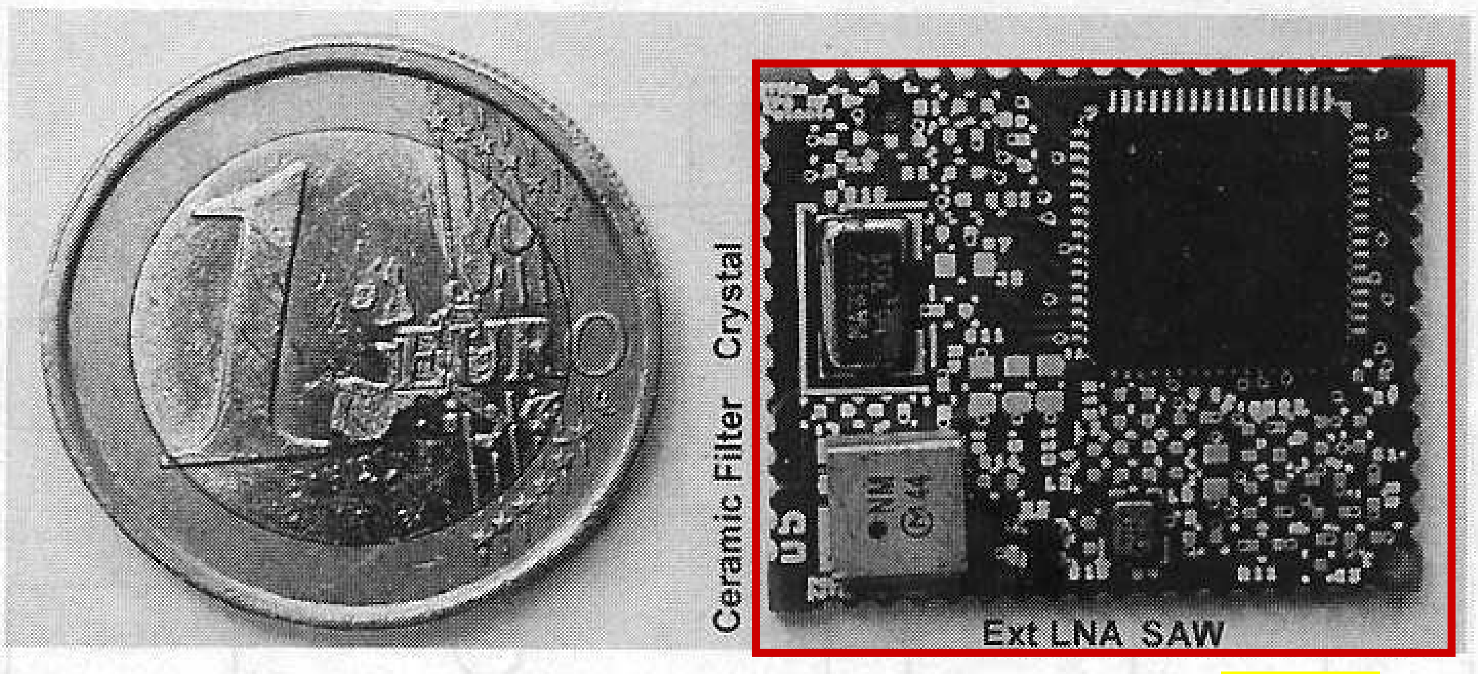


Fig. 18. Board layout for automotive application.

IEEE JSSC march 2006, STMicroelectronics

SoB, CMOS GPS

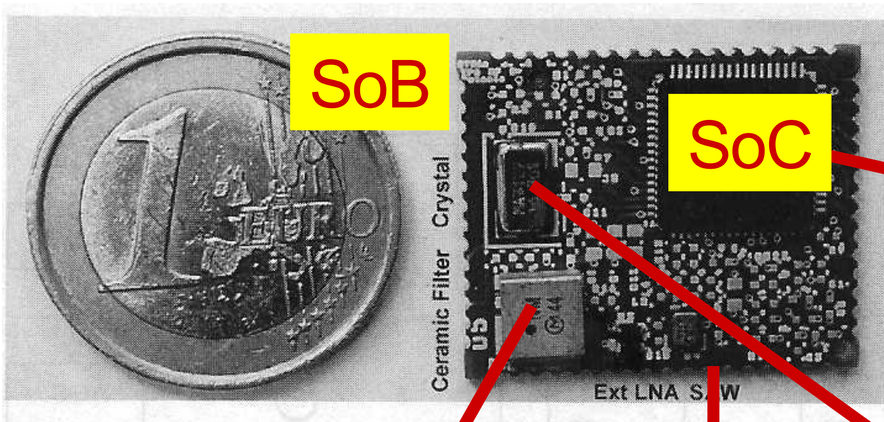


Fig. 18. Board layout for automotive application.

SoC

Quartz crystal 16.368 MHz

Filtre et antenne 1.54 GHz

Longitude, latitude, hauteur

SoC, CMOS IC

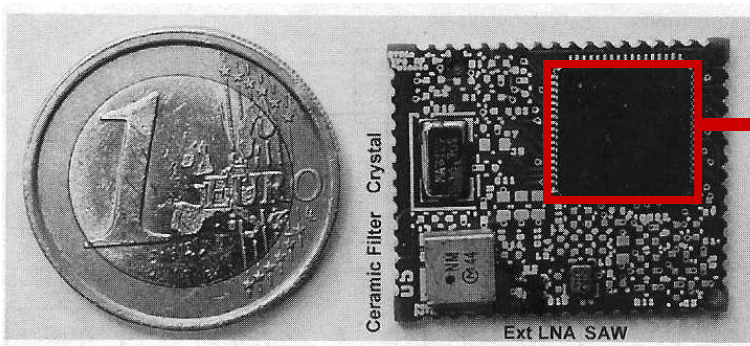
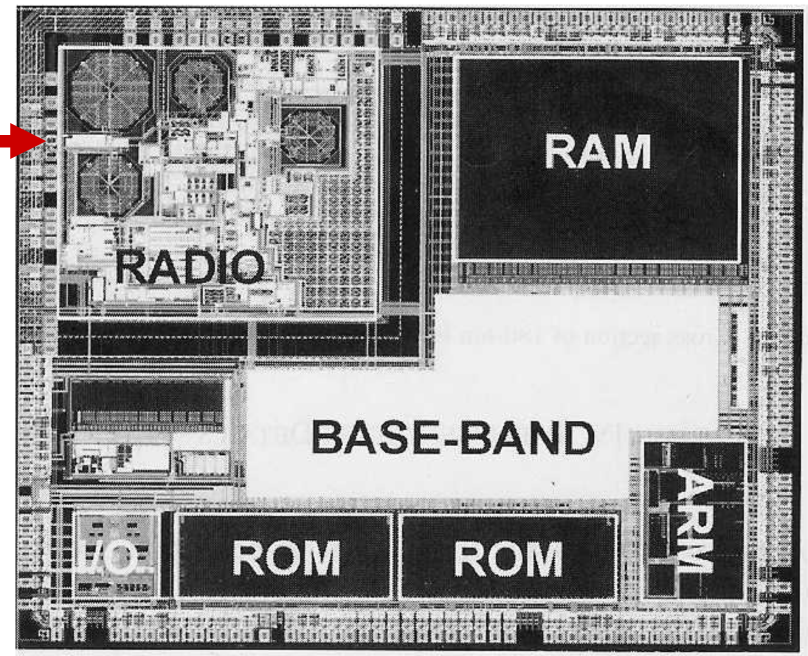


Fig. 18. Board layout for automotive application.

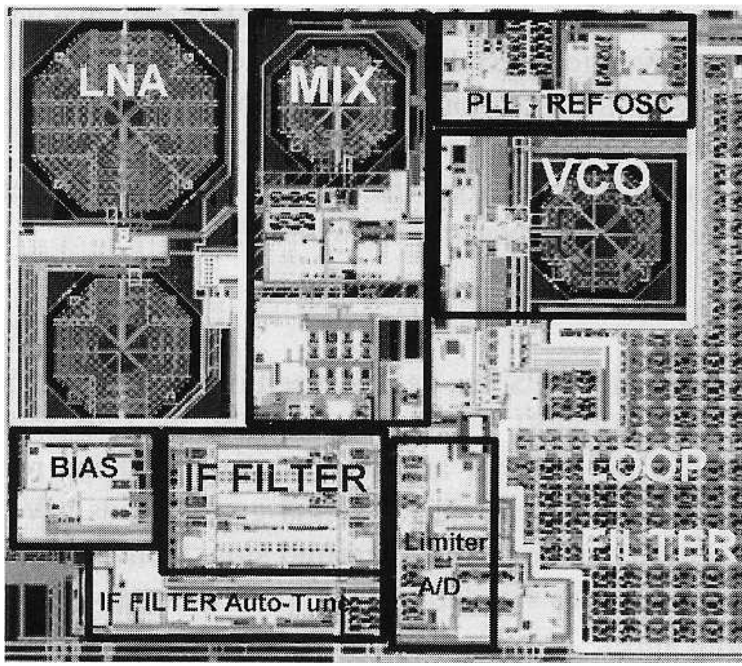


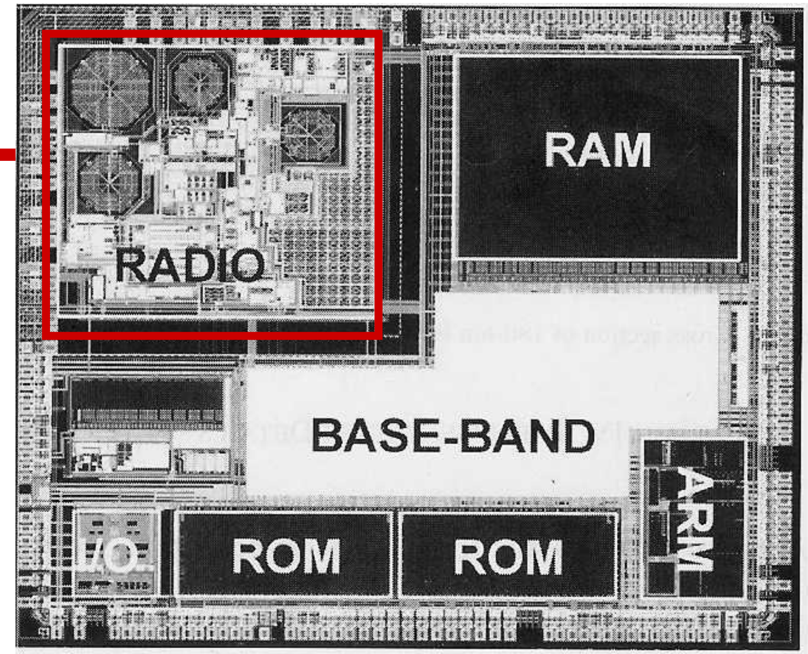
SoC

Environ 5mm

CMOS IC 56mW 23mm3

SoC, CMOS IC with radio





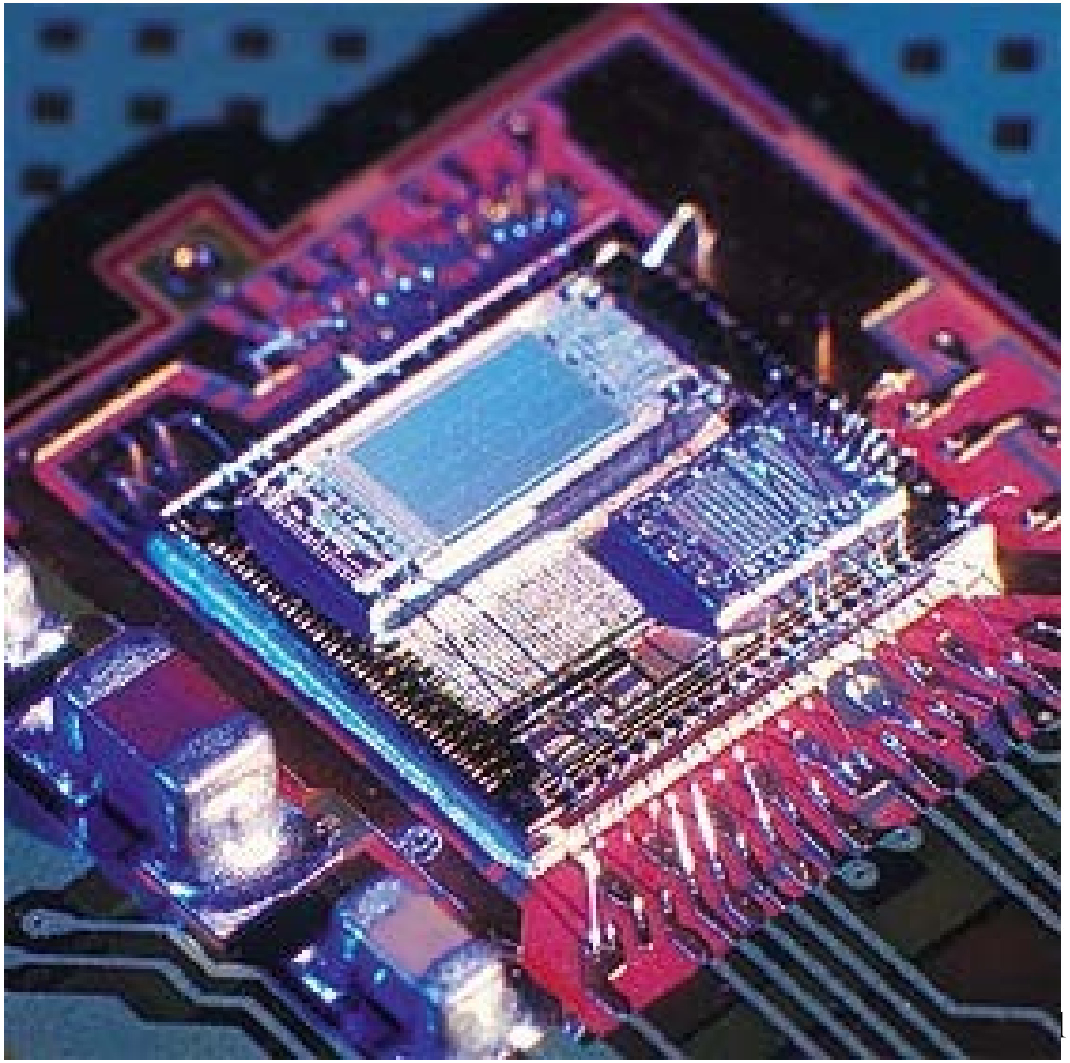
Environ 5mm

CMOS radio 2.2x1.8mm

SiP

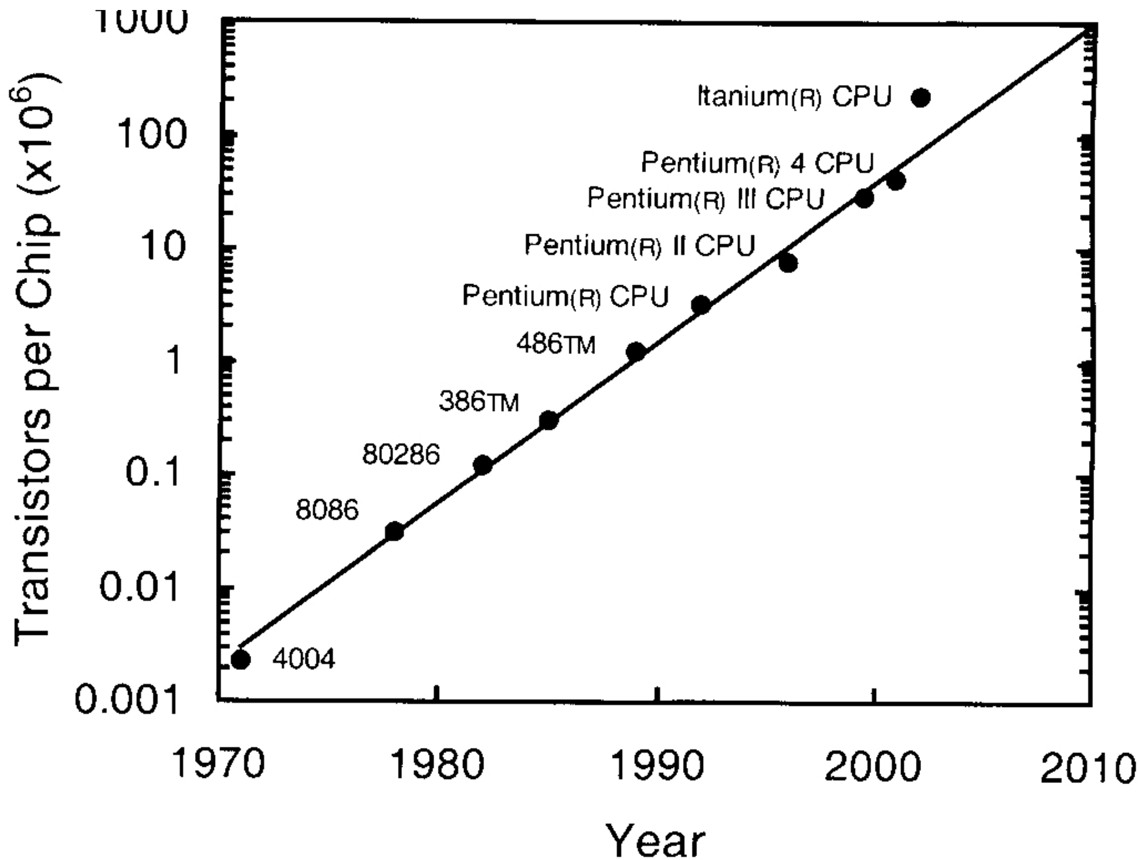
Microdul

- COC
- MD100
- MD300
- bonding

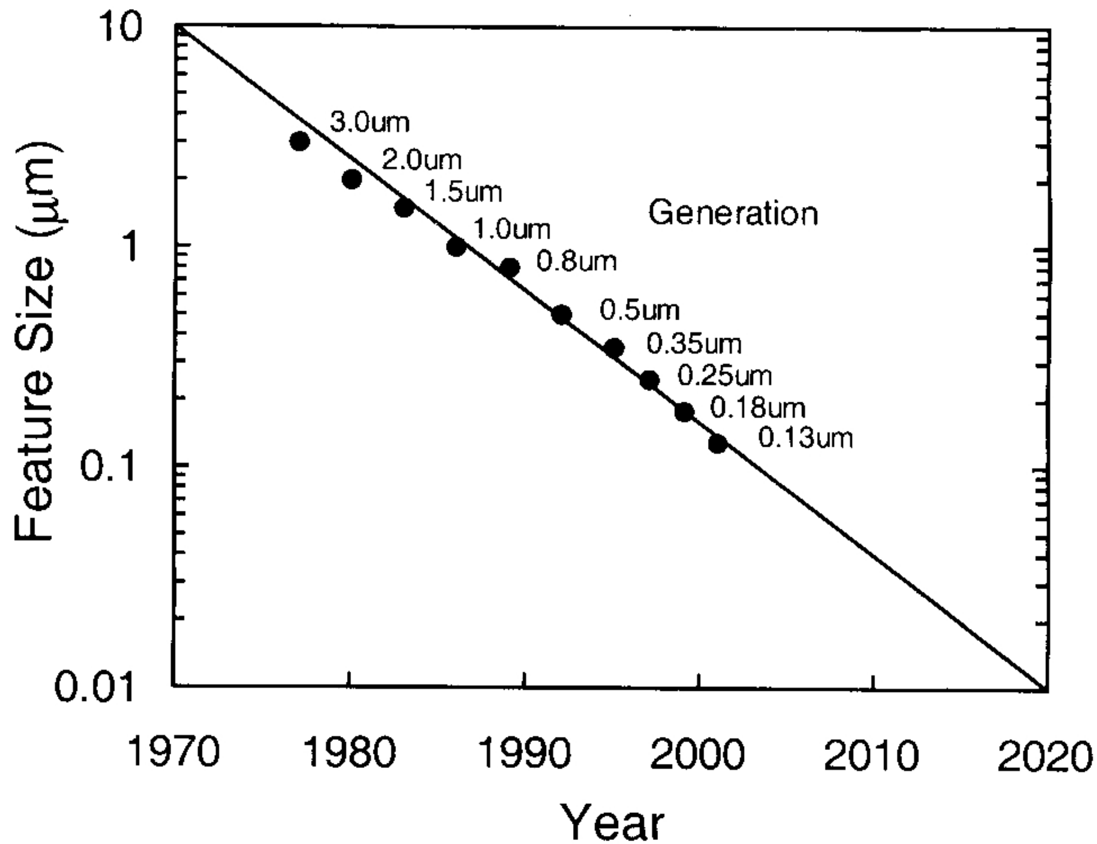


Evolution of IC

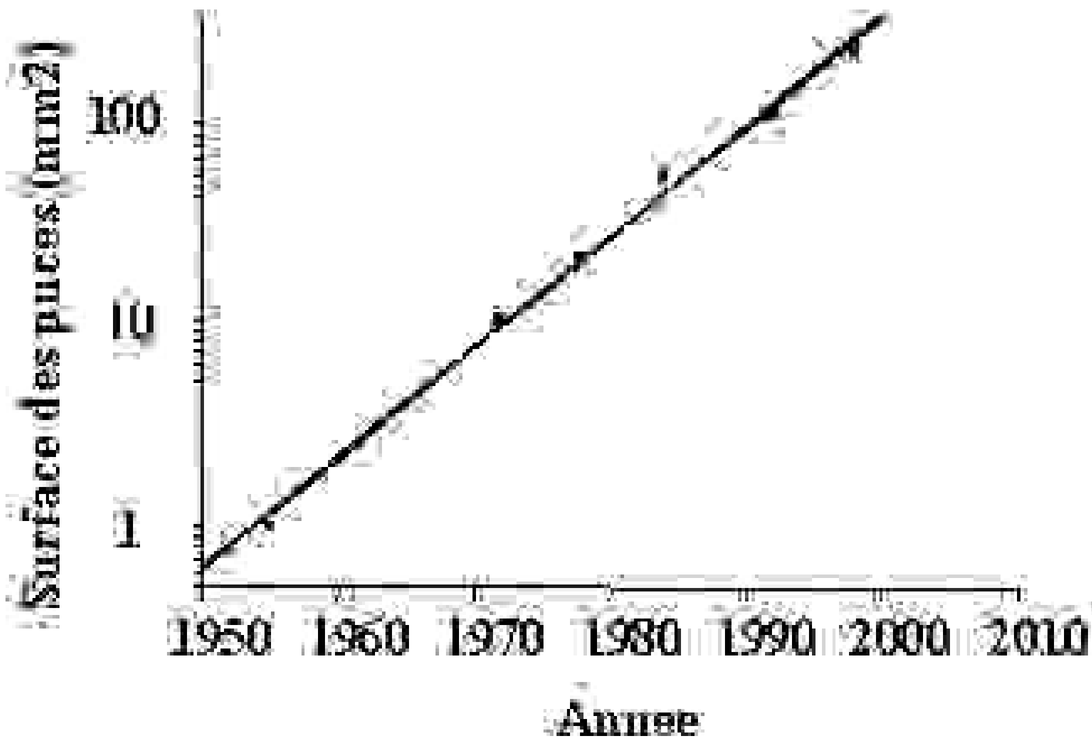
Evolution of complexity



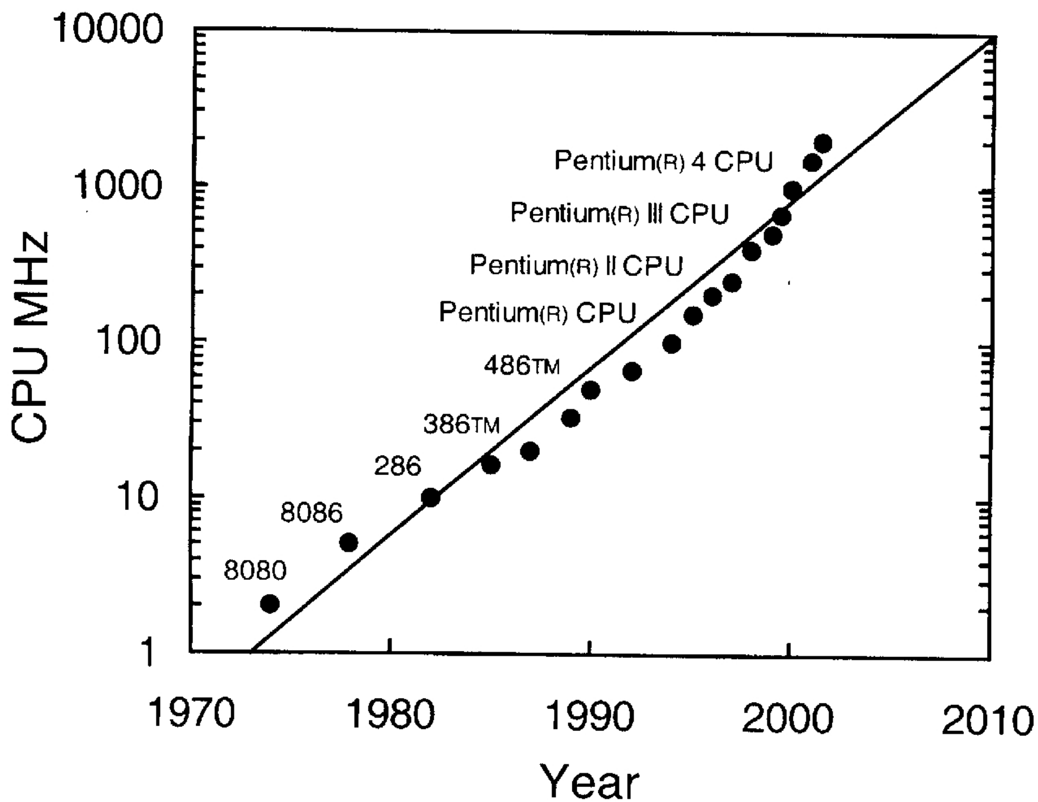
Evolution of technology



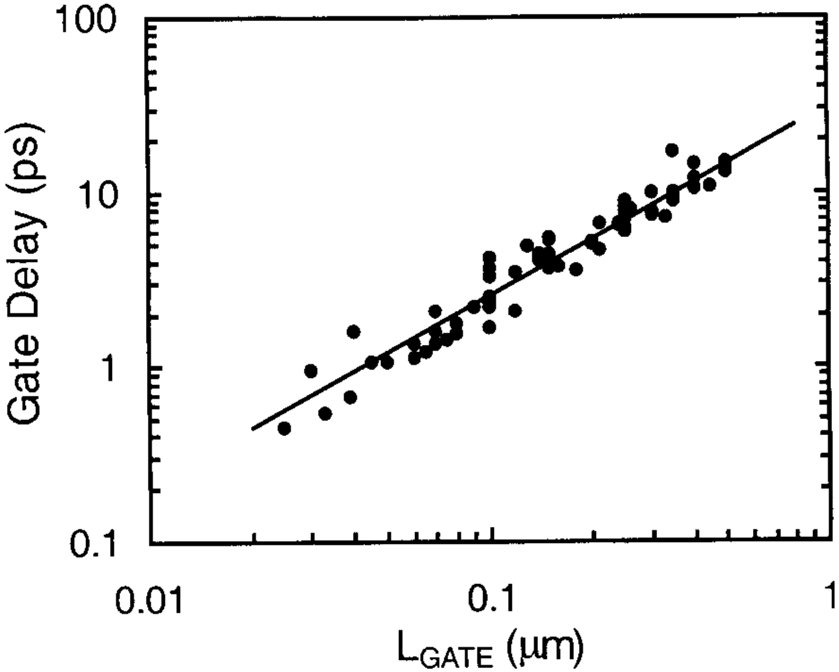
Evolution of chip size

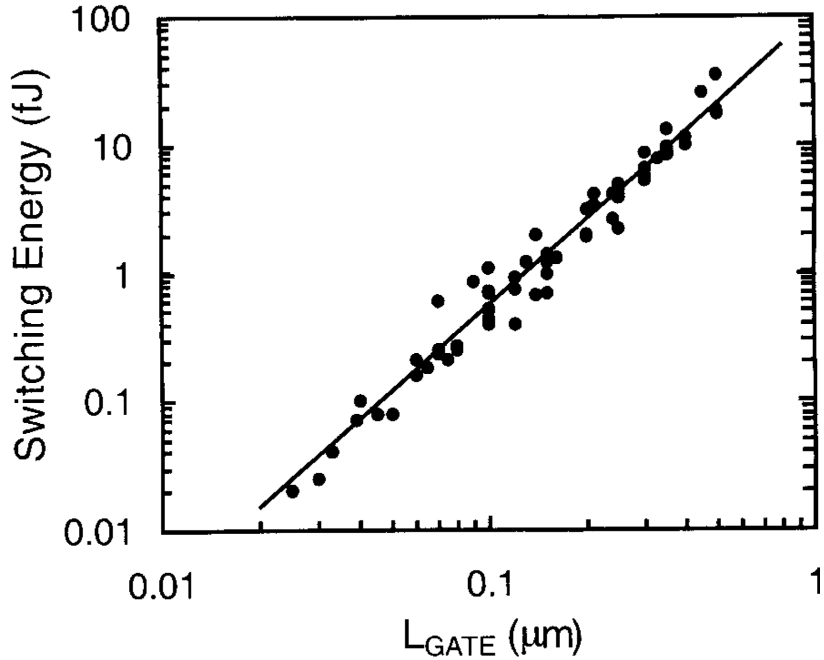


Frequence of PC's

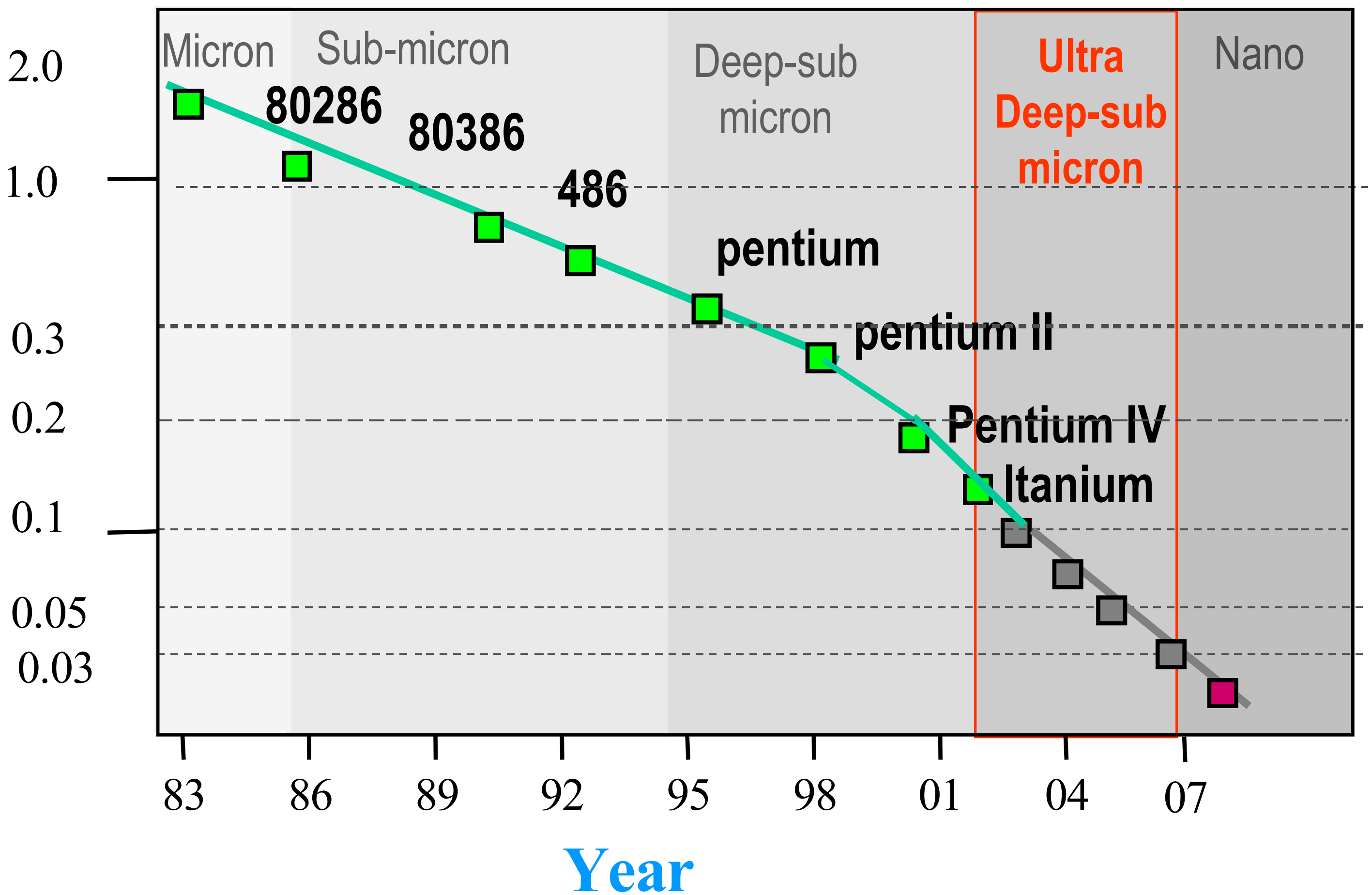


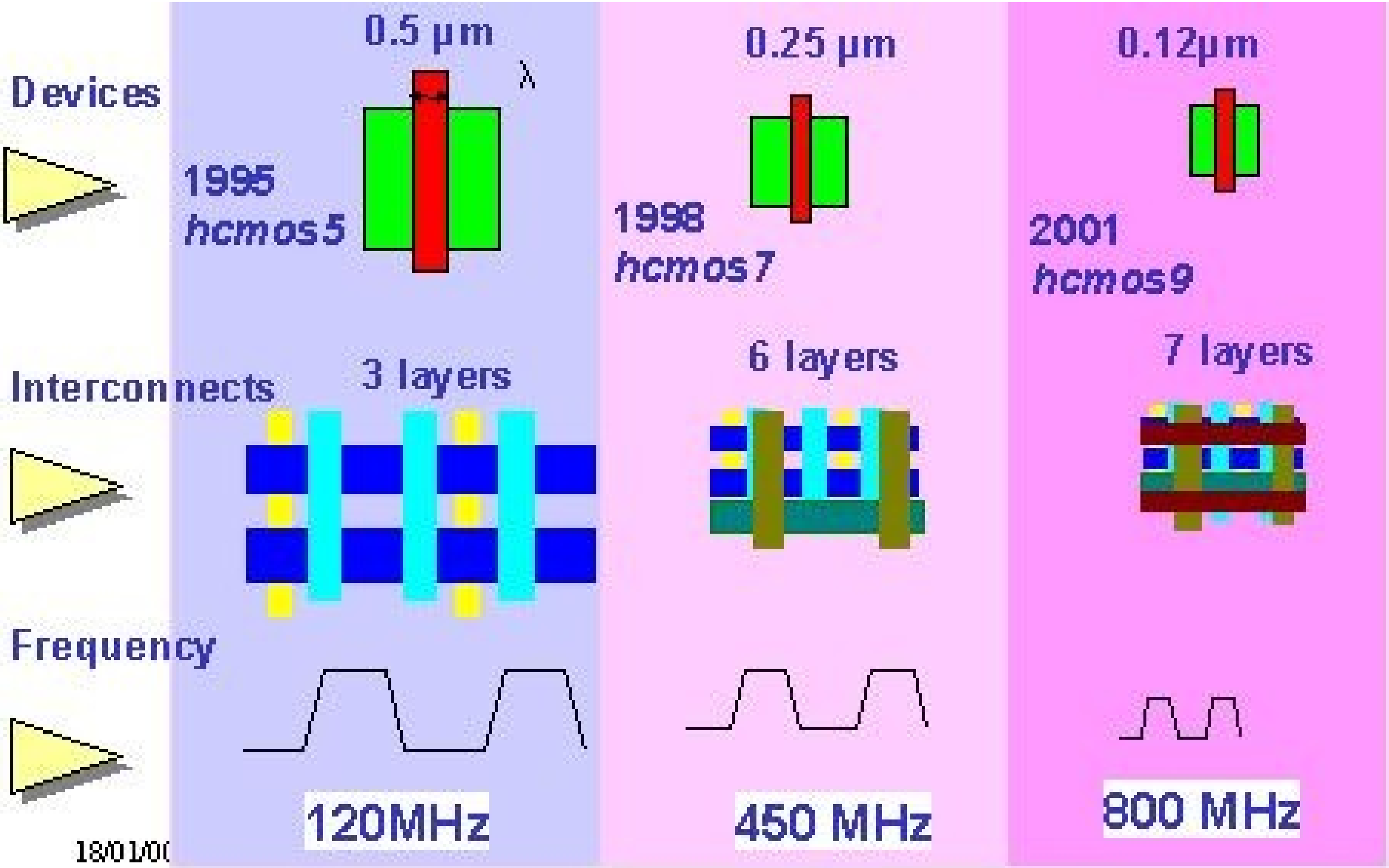
L(gate)


100
10
1
0.1
Gate Delay (ps)
0.01
0.1
1
L_{GATE} (μm)


100
10
1
0.1
0.01
Switching Energy (fJ)
0.01
0.1
1
L_{GATE} (μm)

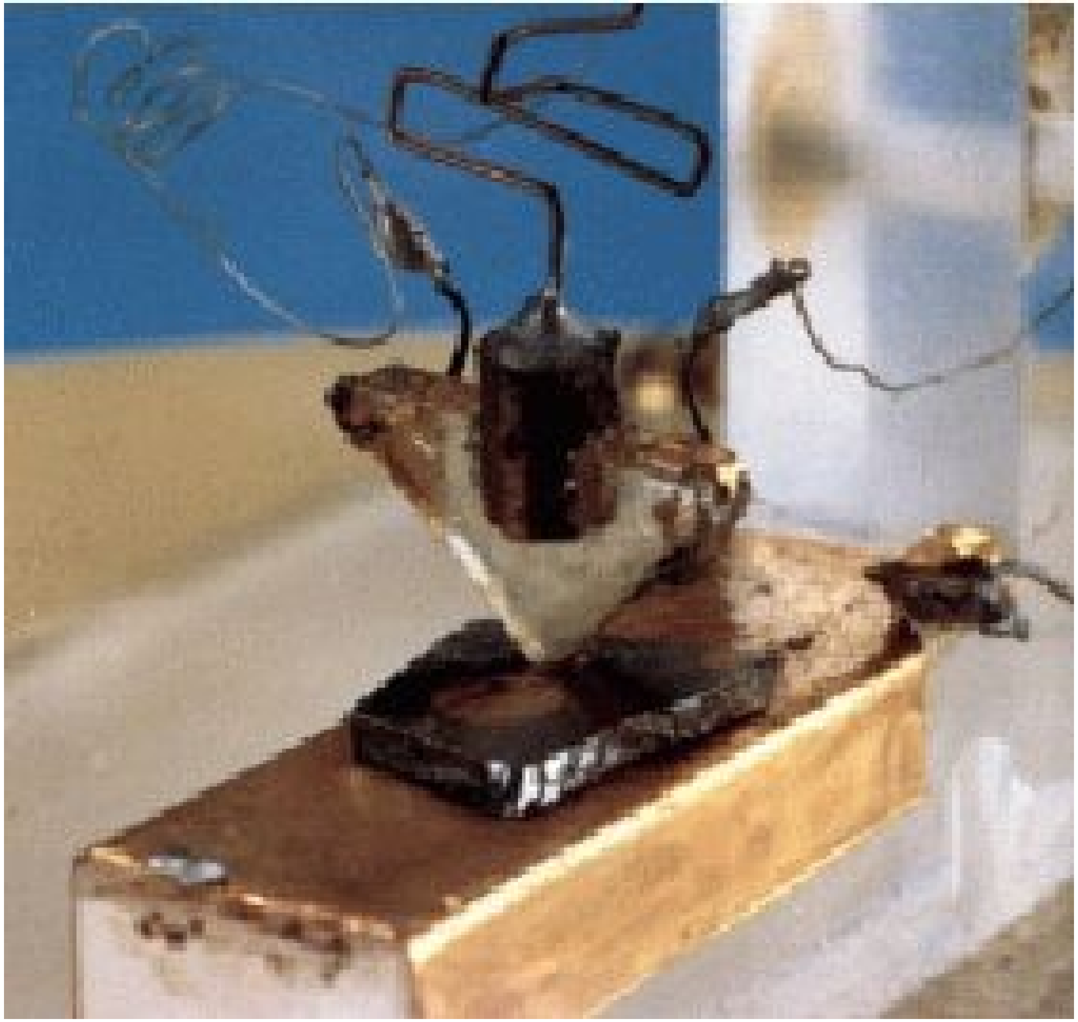
Loi de Moore

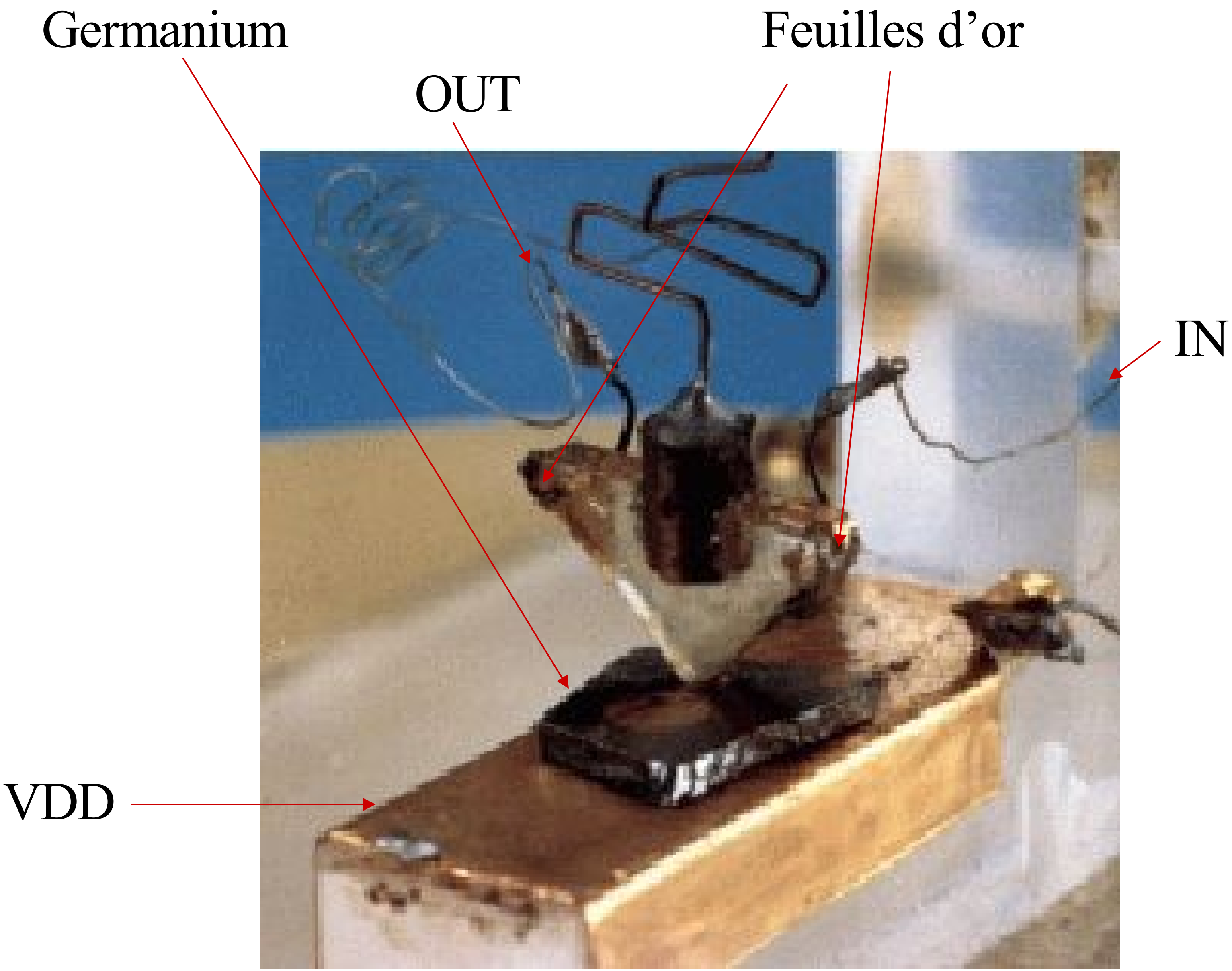

Micron
Sub-micron
Deep-sub micron
Ultra Deep-sub micron
Nano
2.0
1.0
0.3
0.2
0.1
0.05
0.03
80286
80386
486
pentium
pentium II
Pentium IV
Itanium
83
86
89
92
95
98
01
04
07
Year

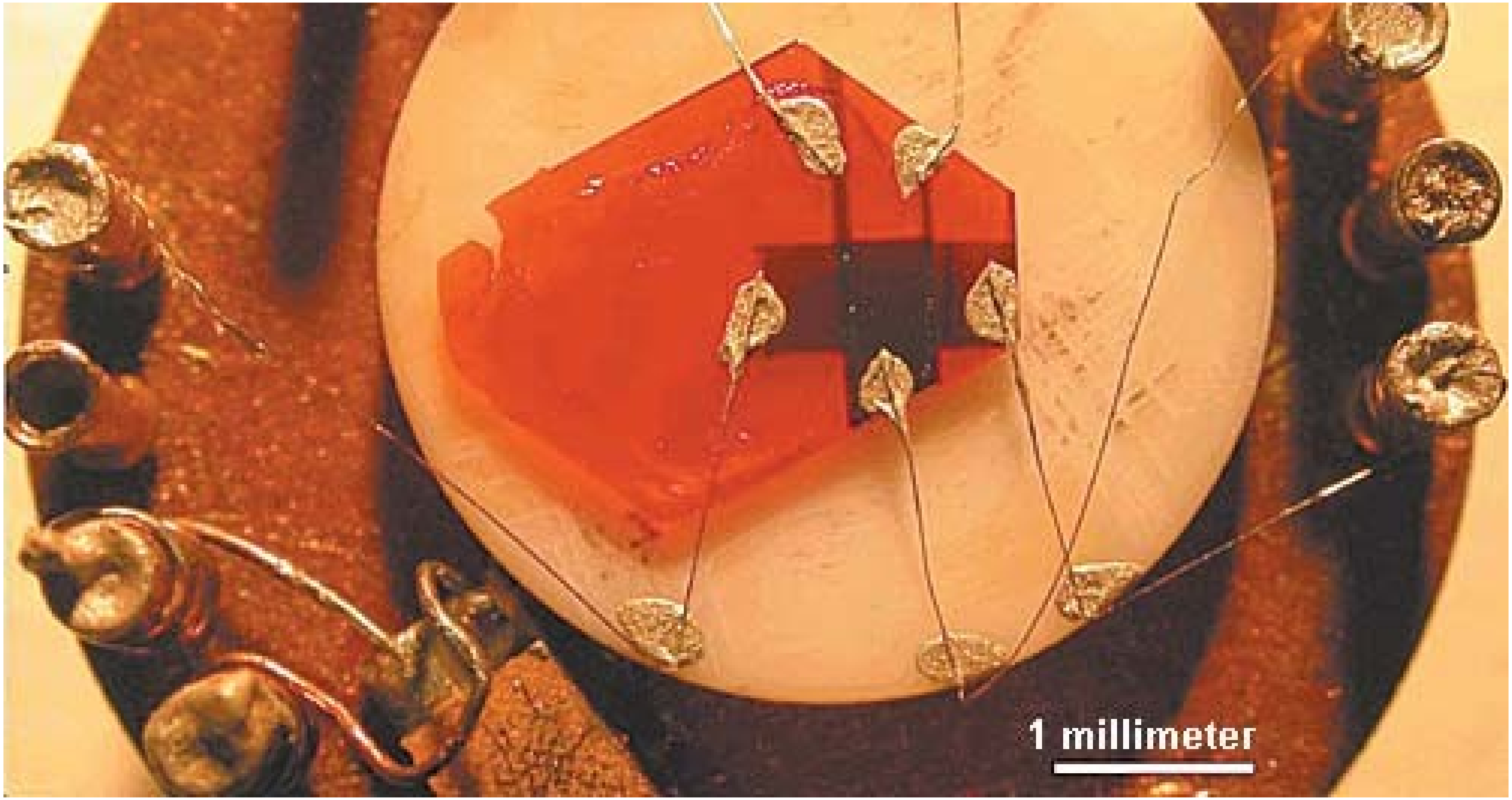

Devices
Interconnects
Frequency
0.5 µm
λ
1995
hcmos5
3 layers
120MHz
0.25 µm
1998
hcmos7
6 layers
450 MHz
0.12µm
2001
hcmos9
7 layers
800 MHz
18/01/00

History of chips

1947 bipolar transistor




Germanium
OUT
Feuilles d'or
IN
VDD

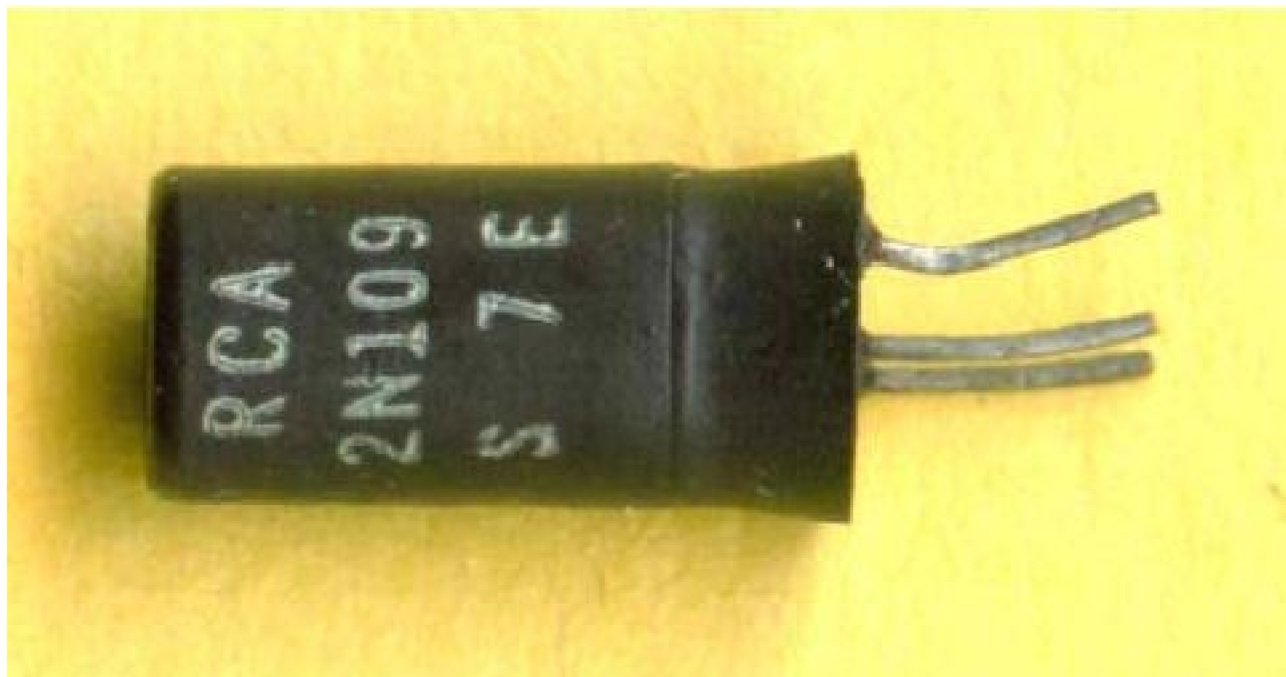


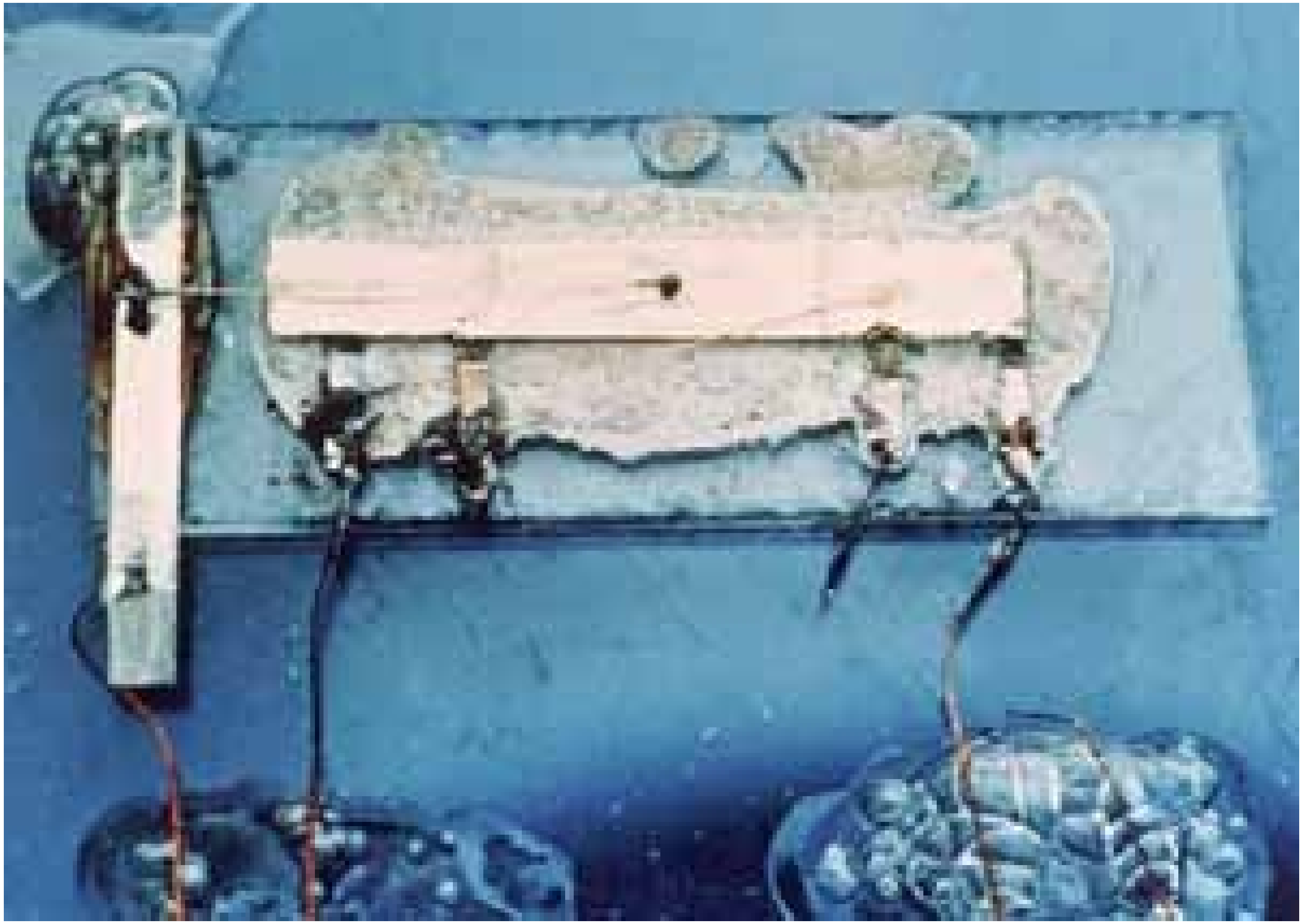
This single-crystal organic field-effect transistor, created by researchers at Rutgers University, in New Jersey is based on a rubrene single crystal [red hexagon] and is shown wired to the pins of a sample holder.
It is the first organic transistor to be light-switchable.

IEEE Spectrum aug.2005

RCA 2N109 (1955)

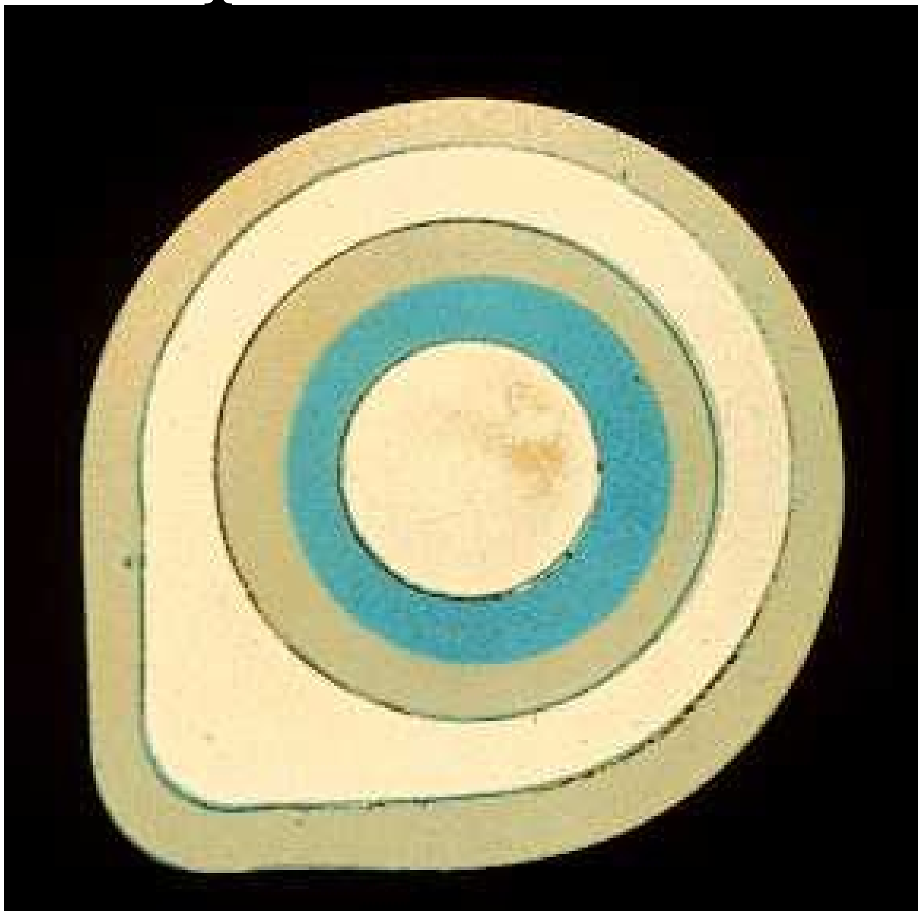
- Pour radios
- PNP
- Ge
- 2.5$



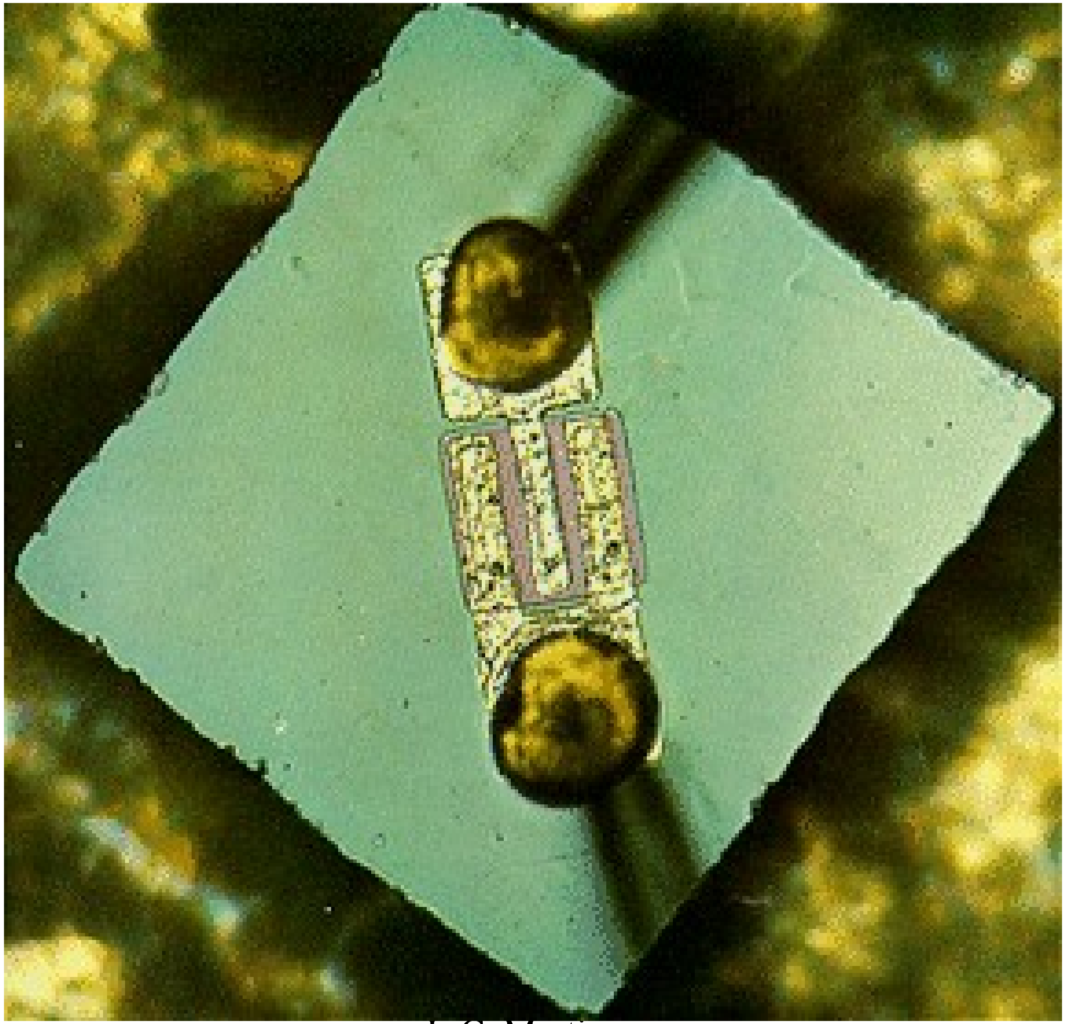


Jack Kilby of Texas Instruments made this, the first integrated circuit, in 1958.

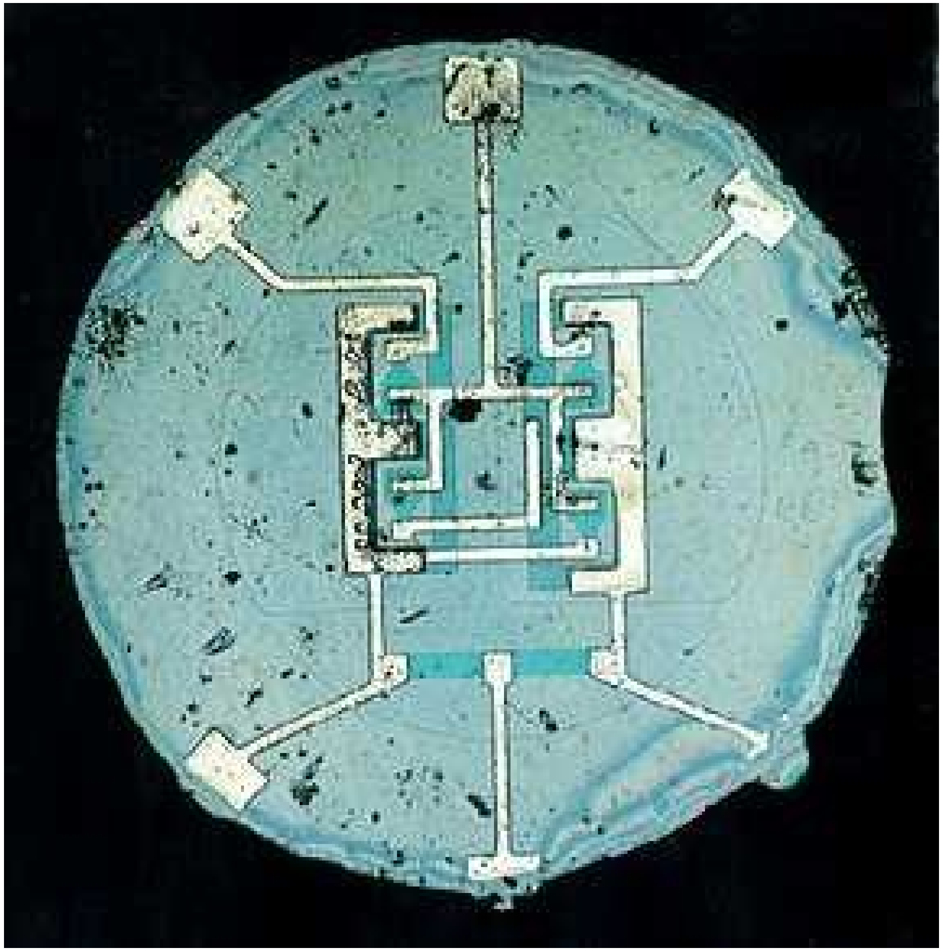
1959 planar transistor



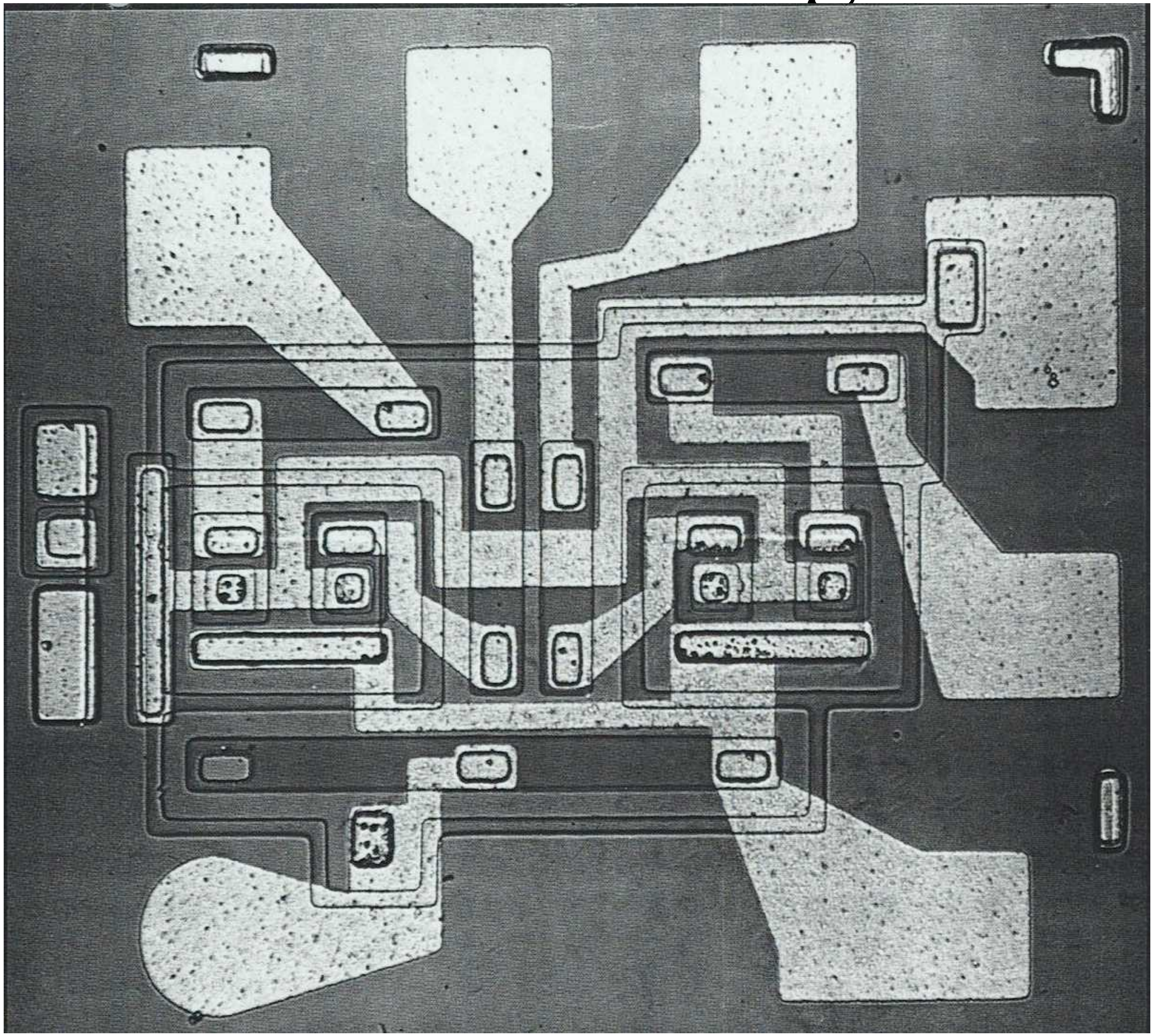
NPN transistor



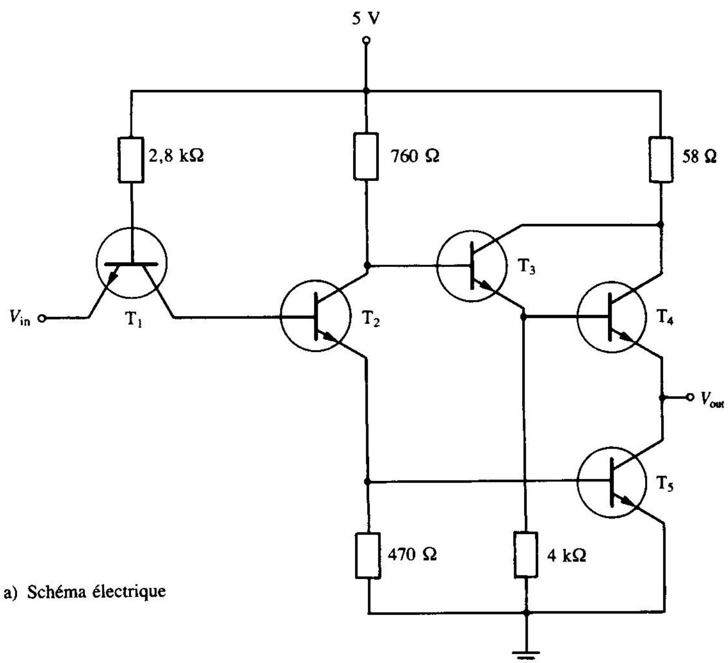
1961 integrated circuit



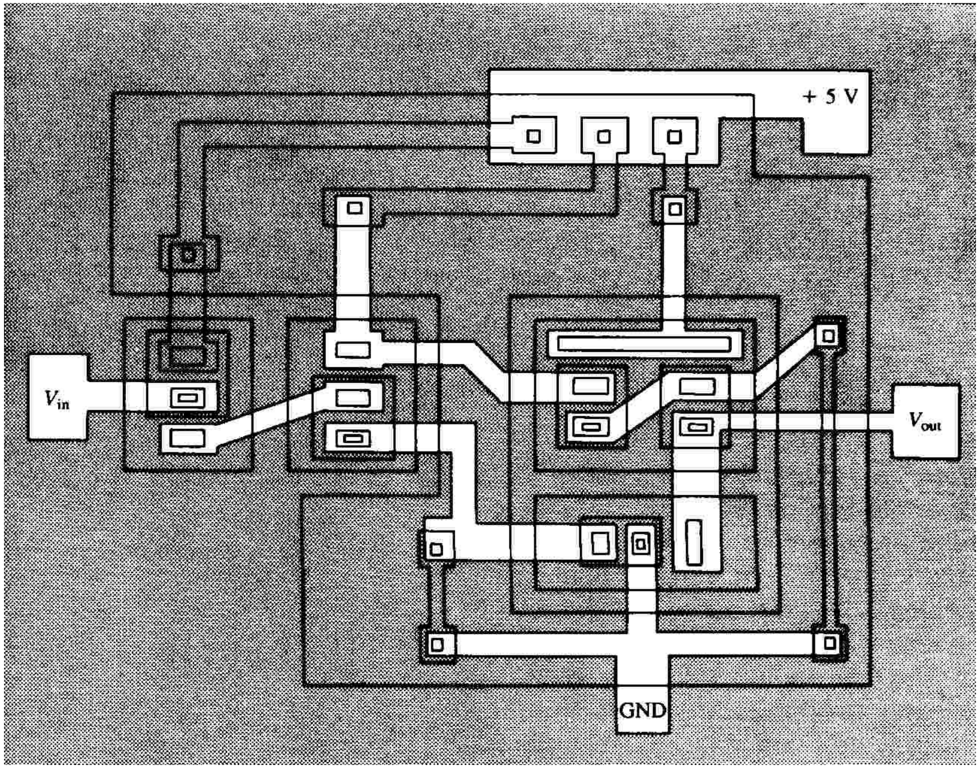
1963 RTL logic



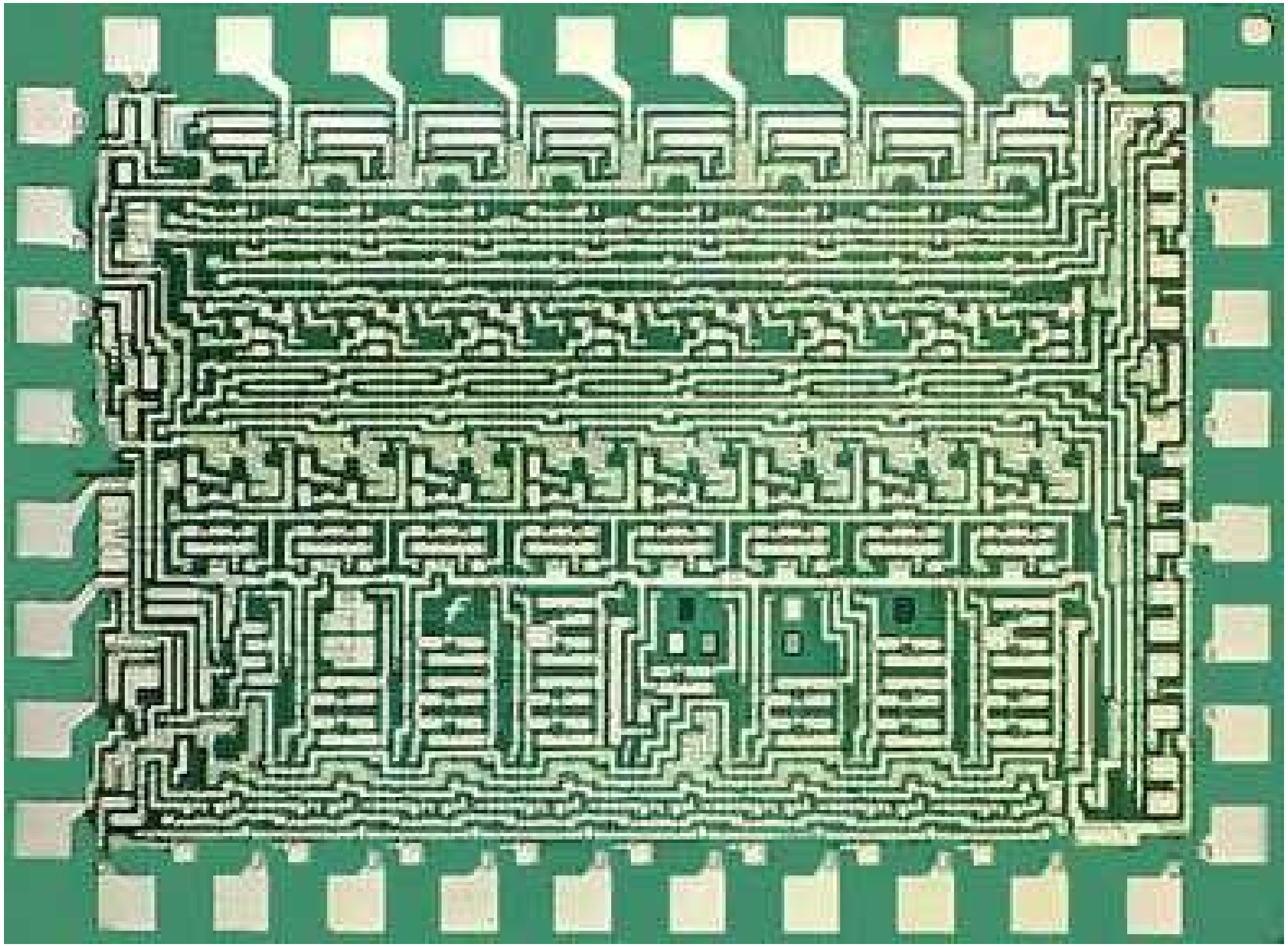
TTL



a) Schéma électrique

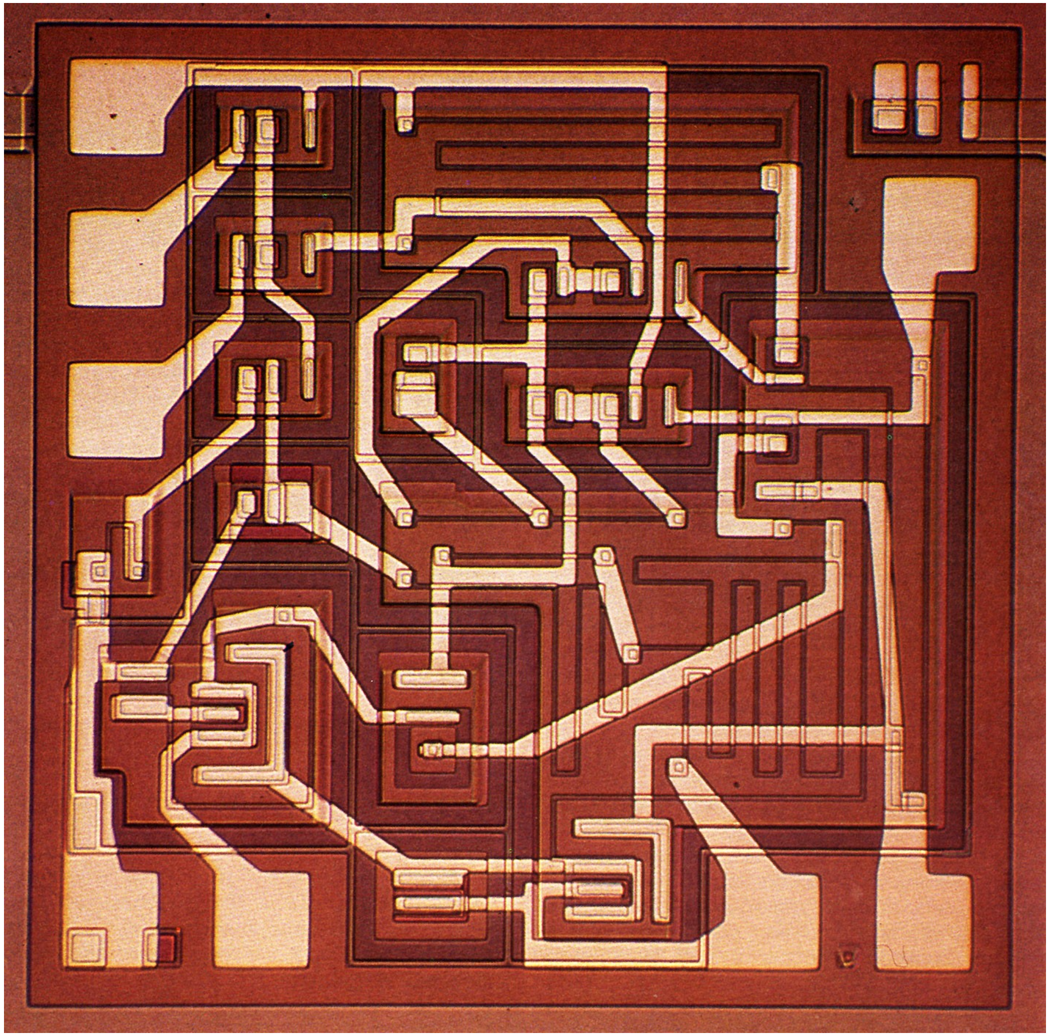


1967 MOS

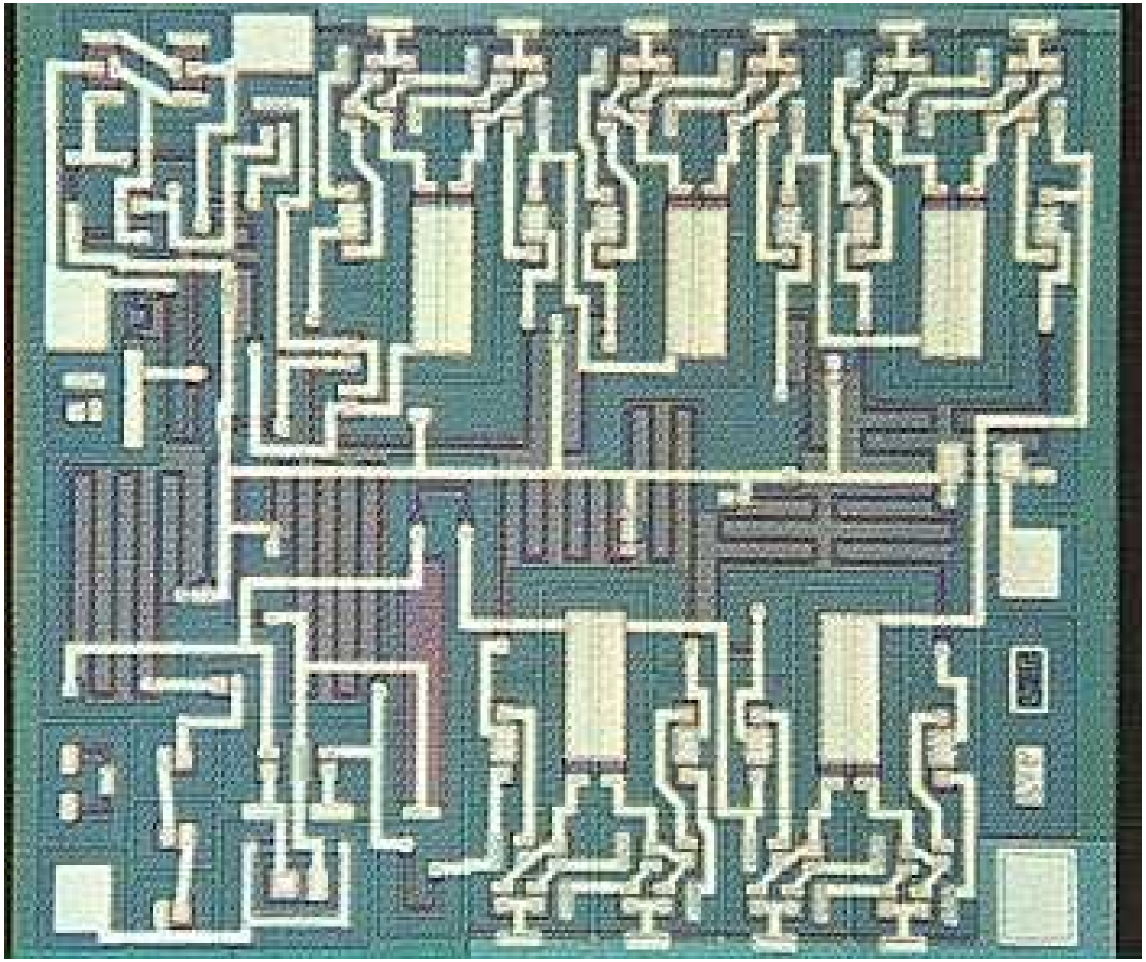


Ampli Op

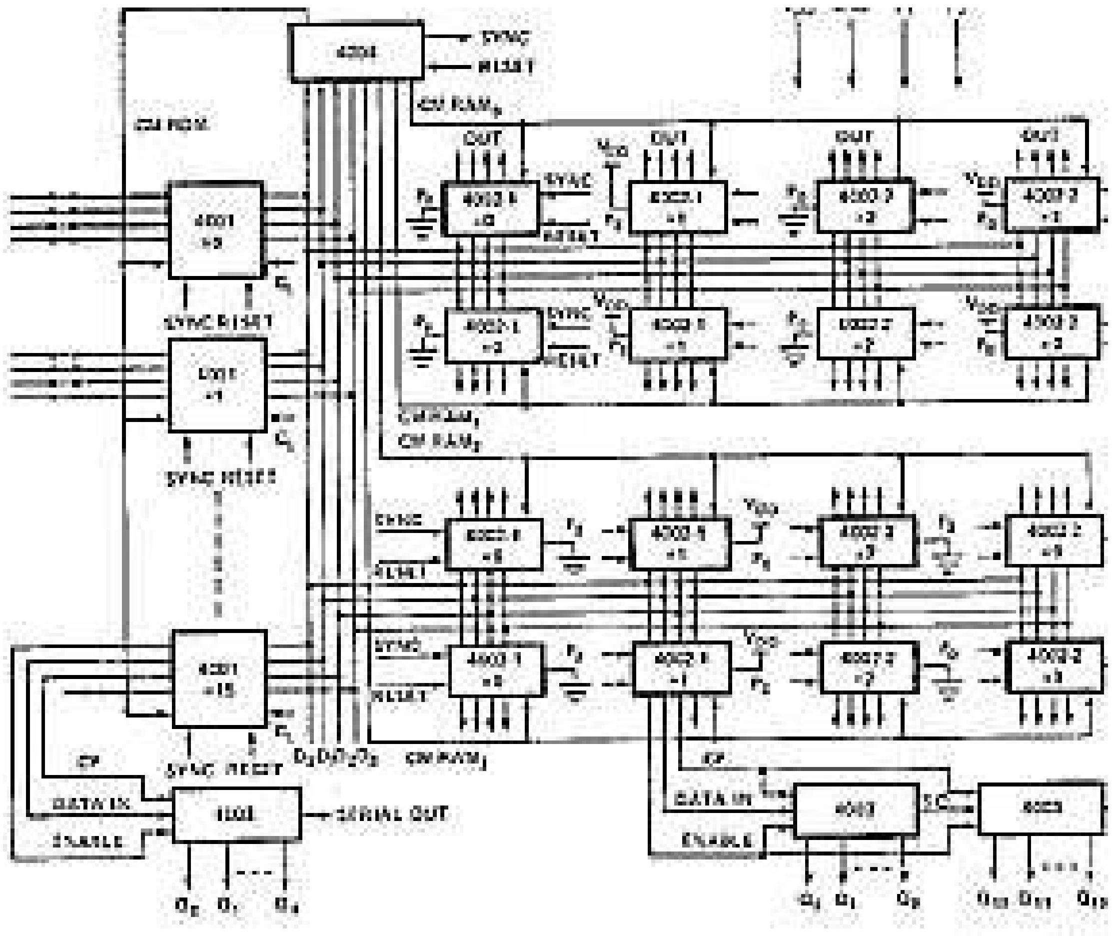
- bipolaire

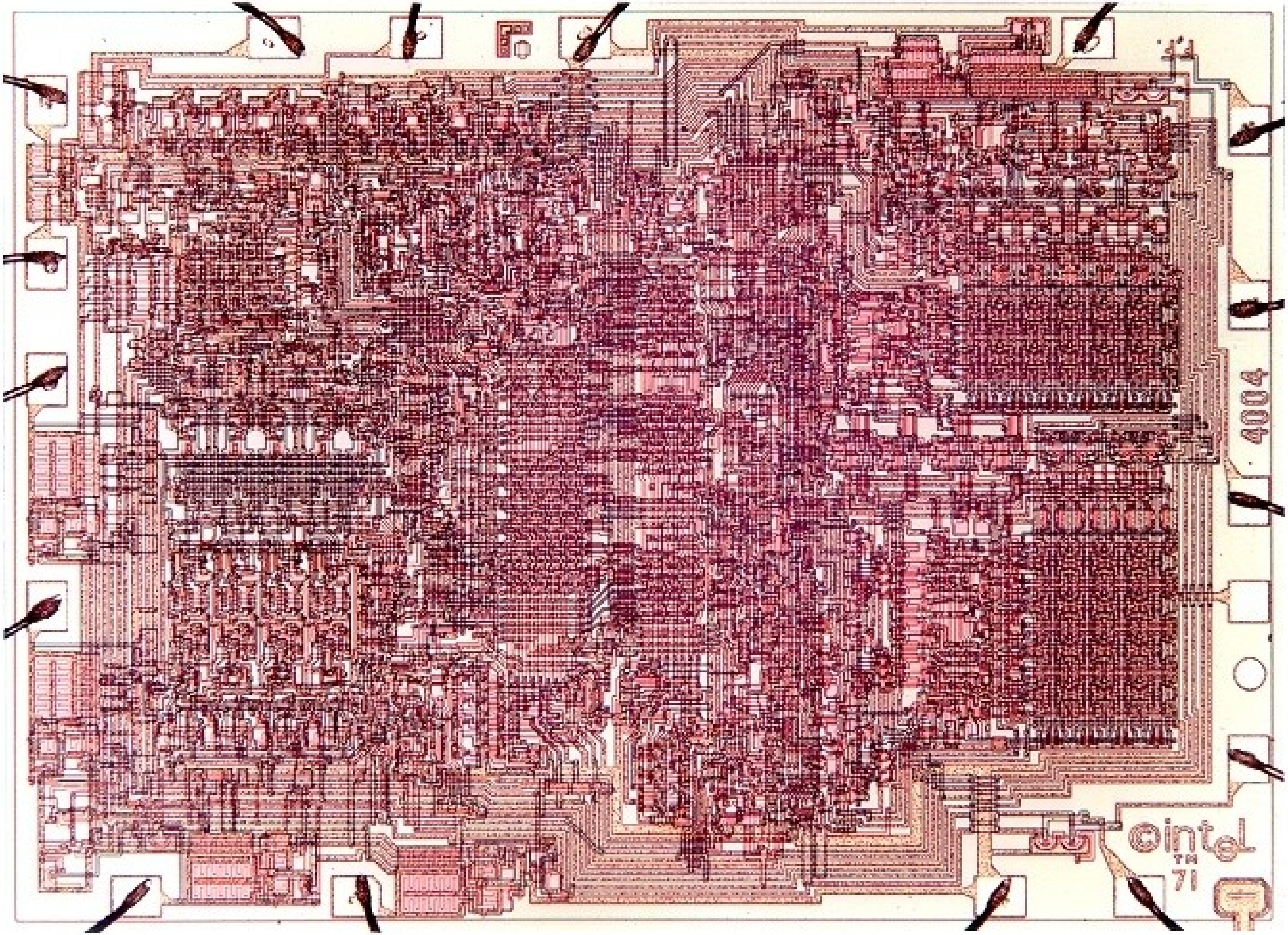


1967 first quartz watch (CEH)

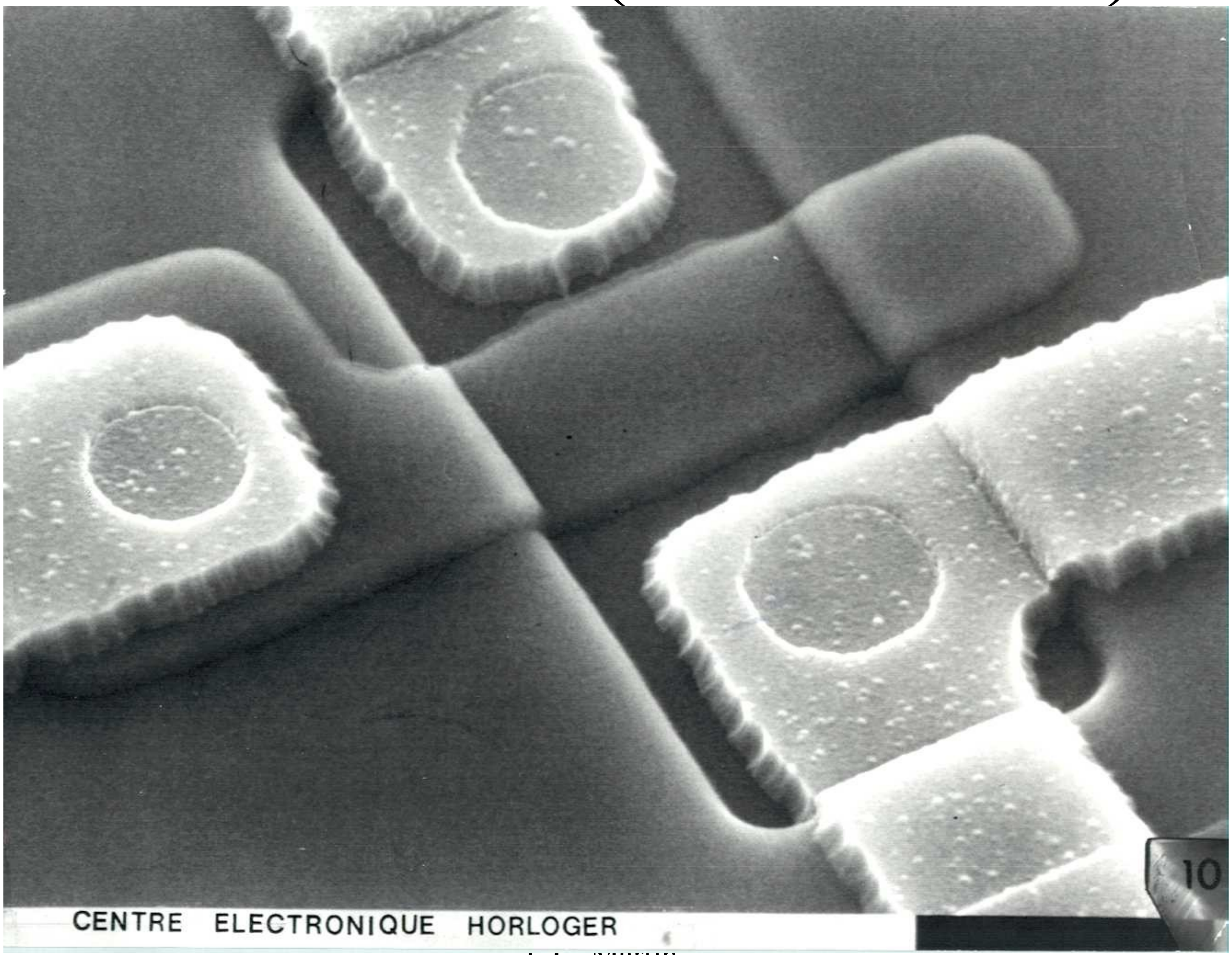


1971 Intel 4004

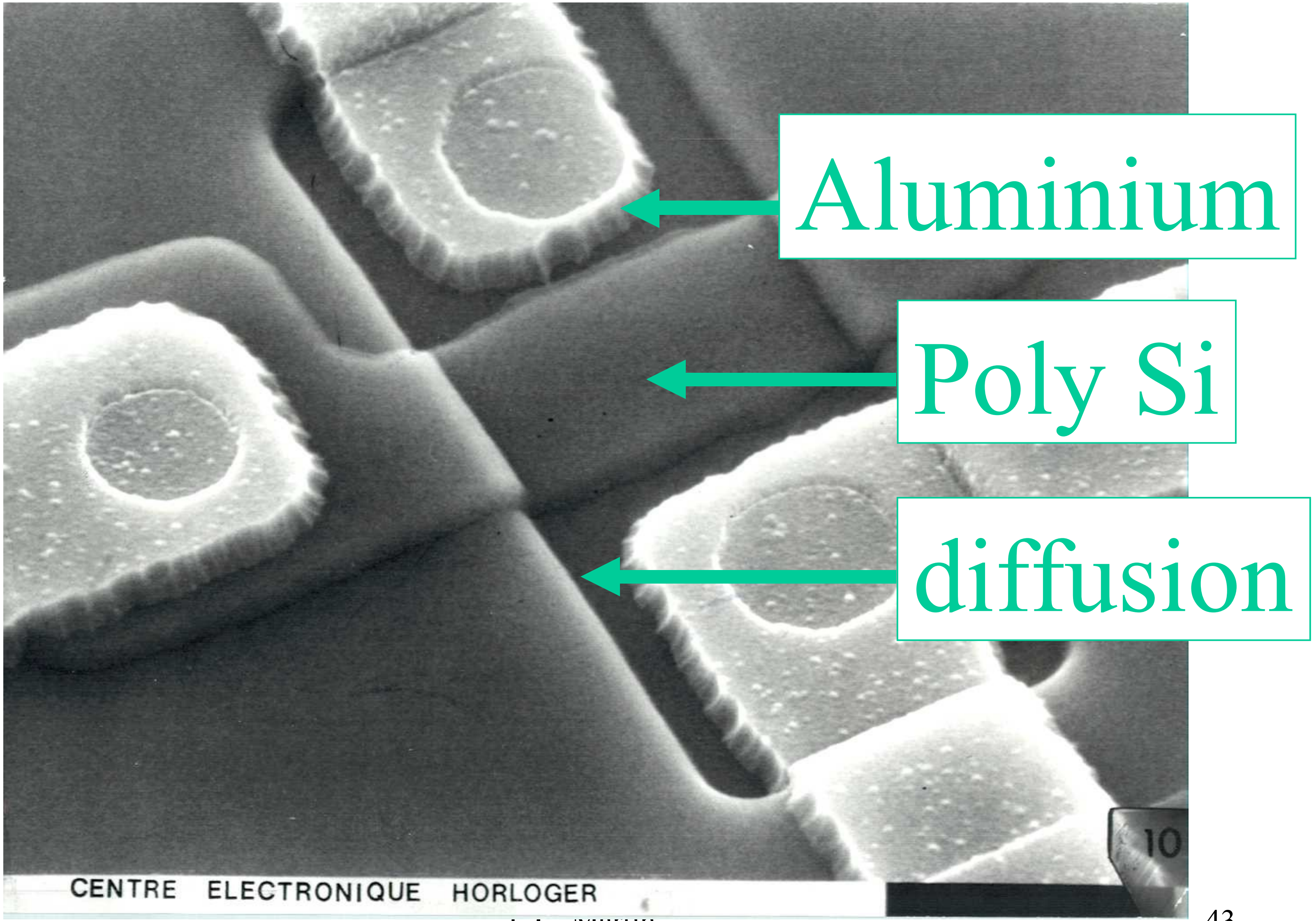



4004
©intel
TM
71

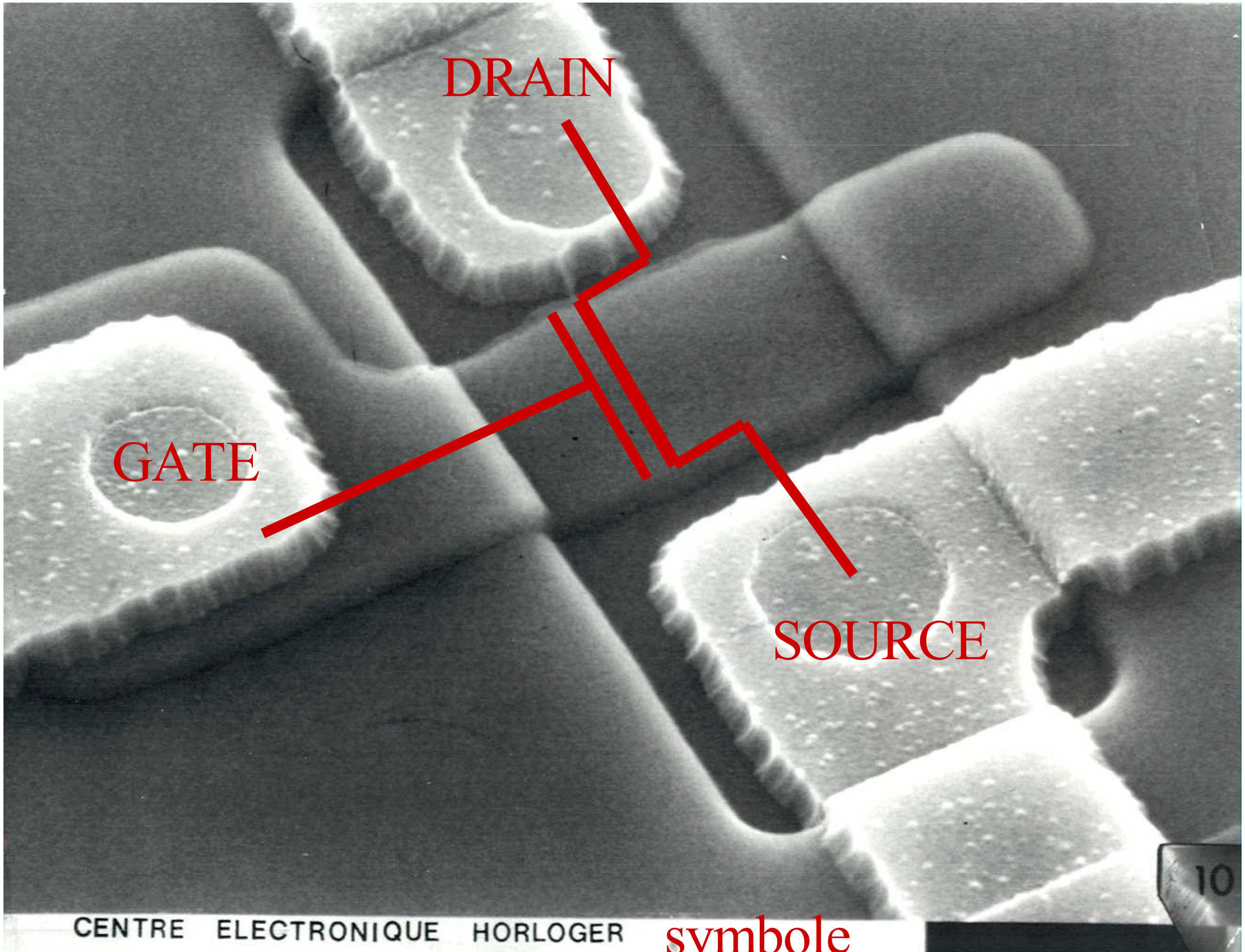
1972 CMOS (Switzerland)



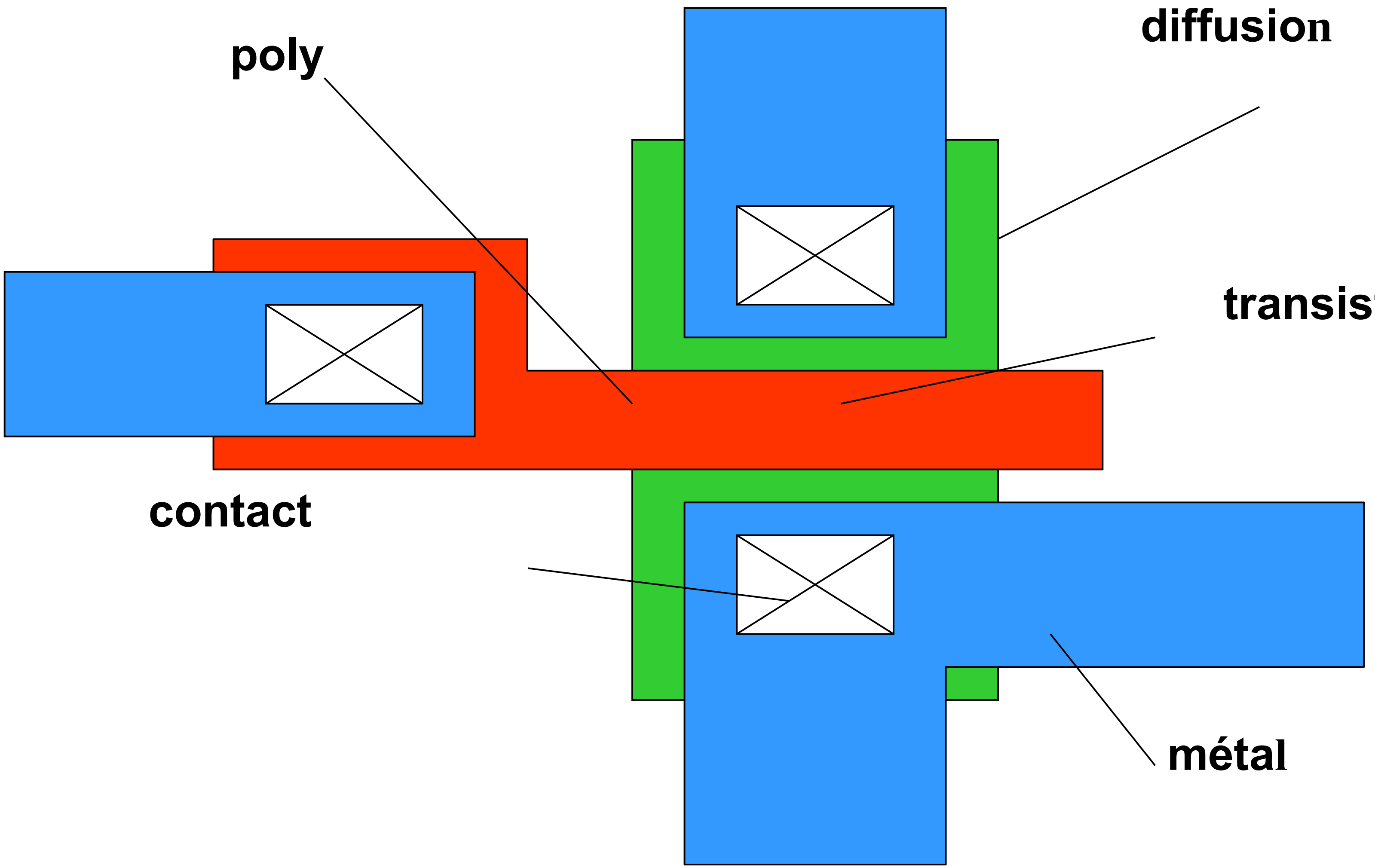
Transistor MOS

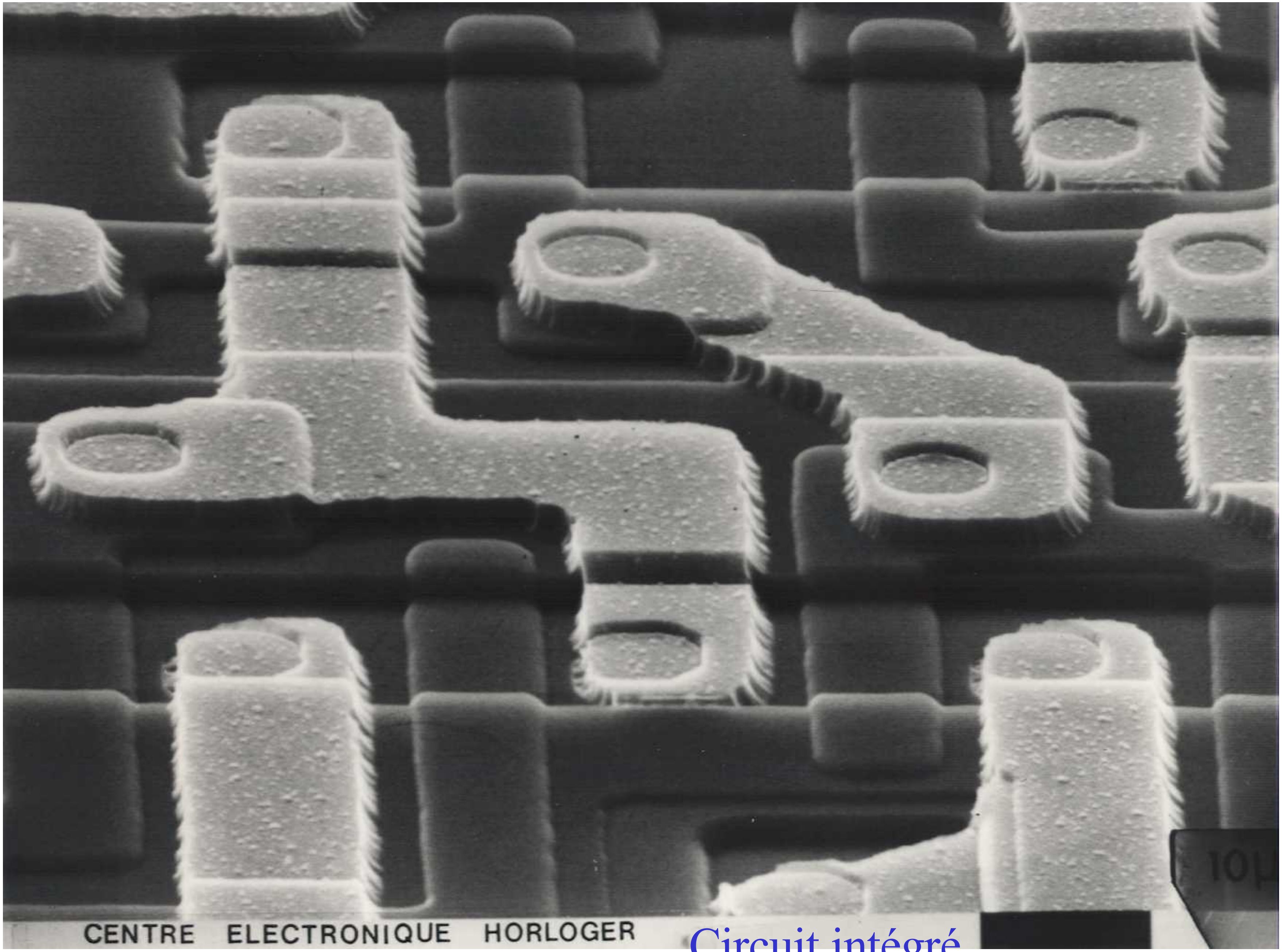


Transistor MOS

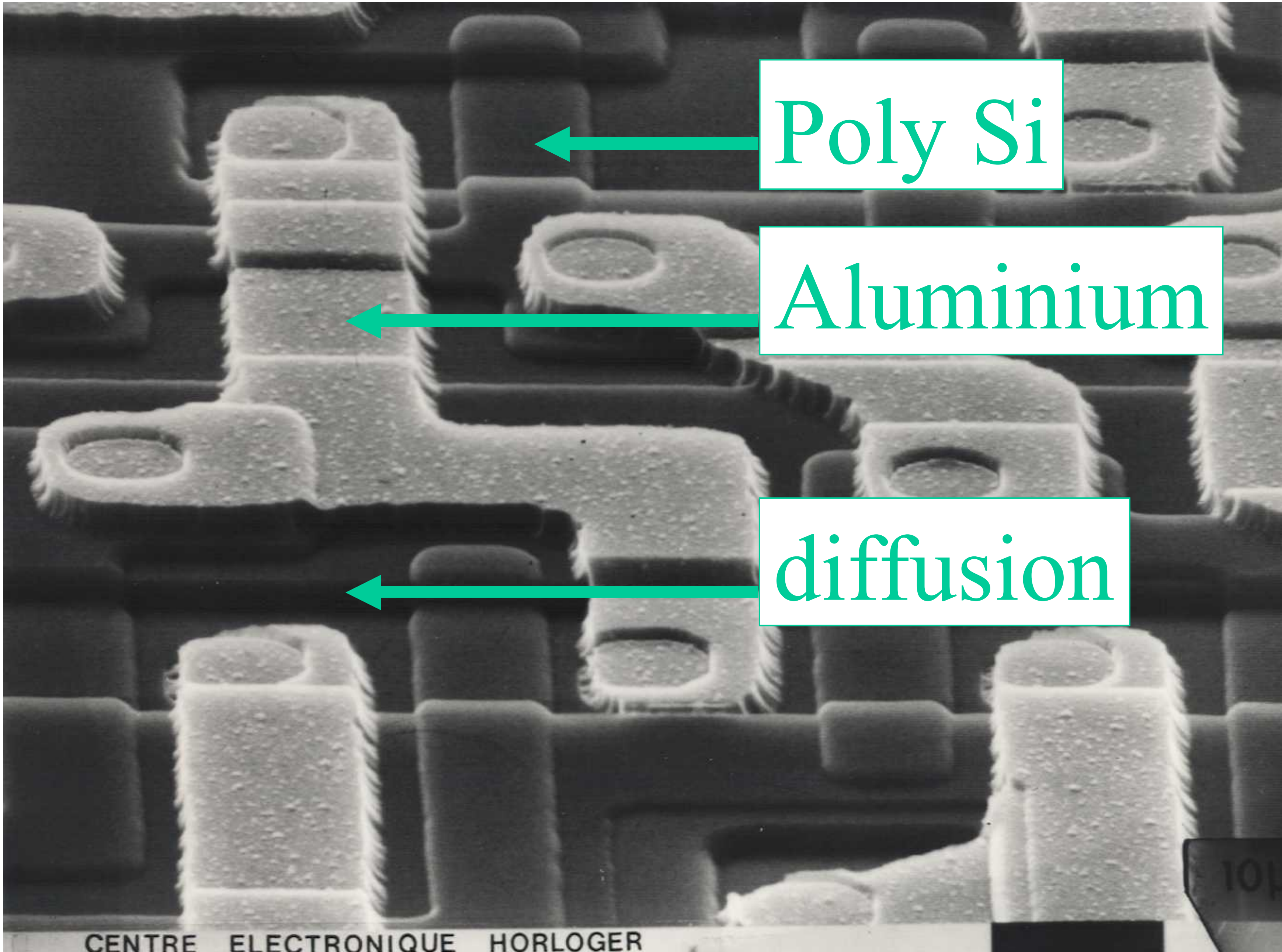


MOS, layout (masques)

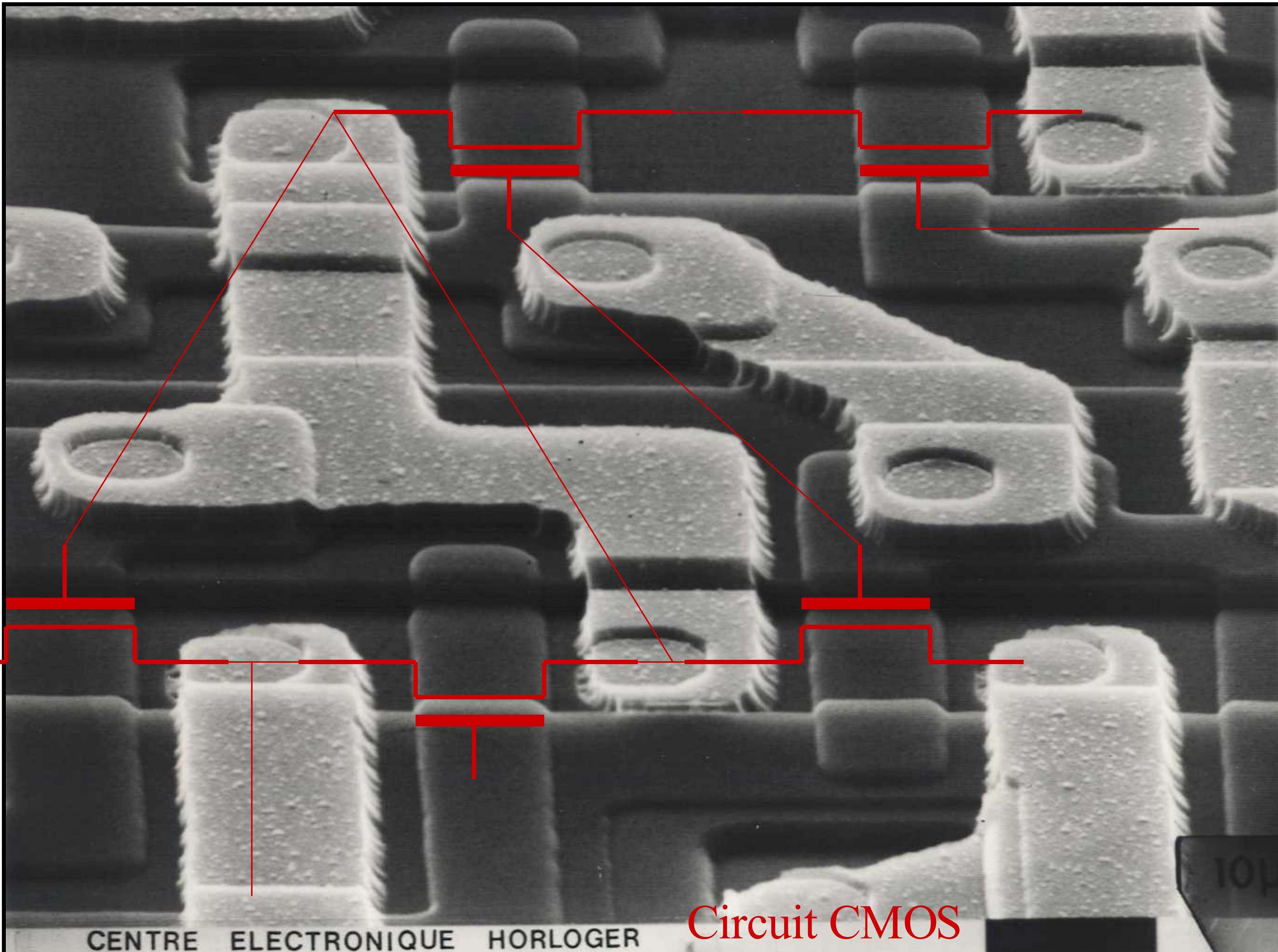




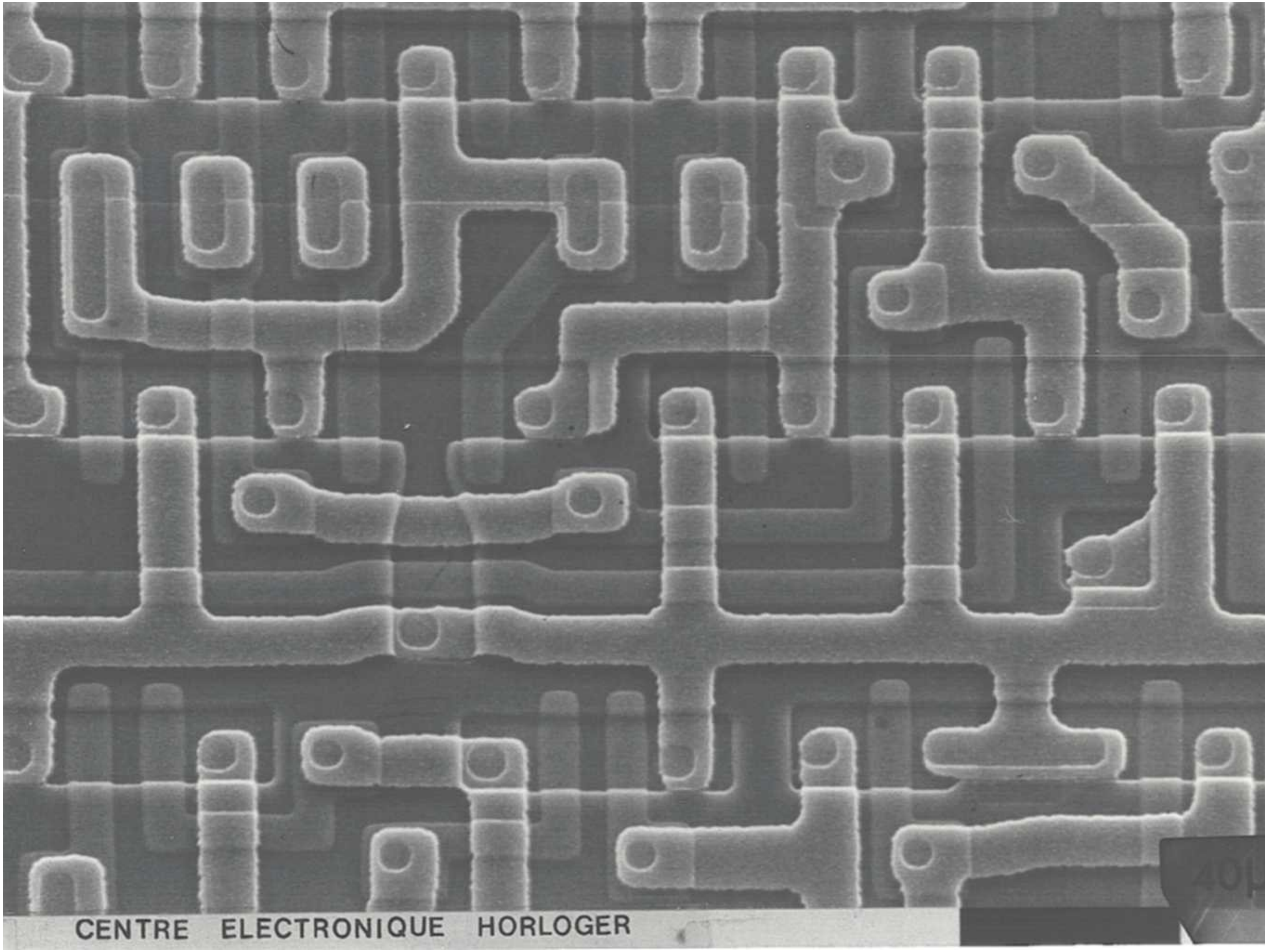
Circuit intégré

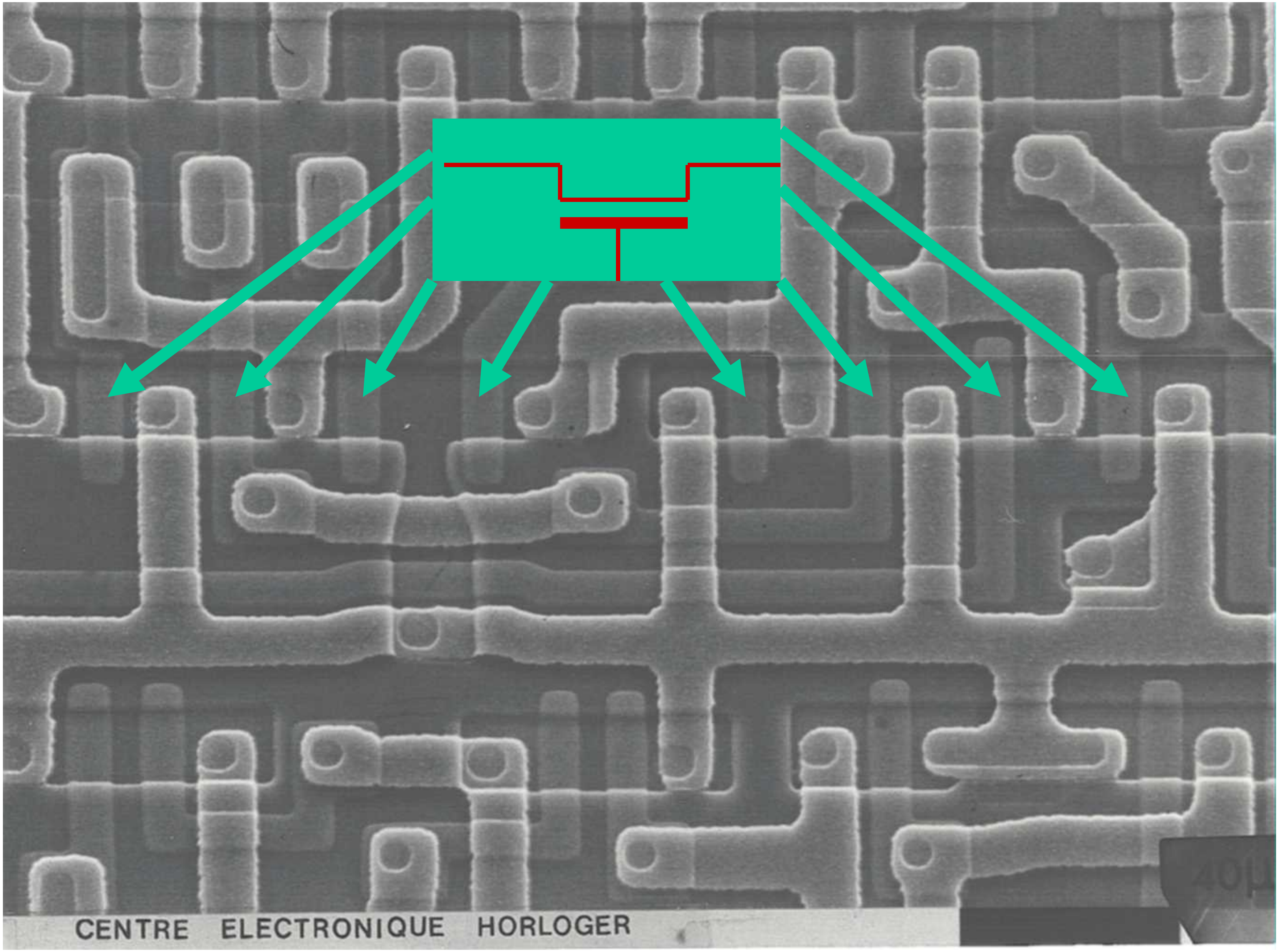


Circuit intégré

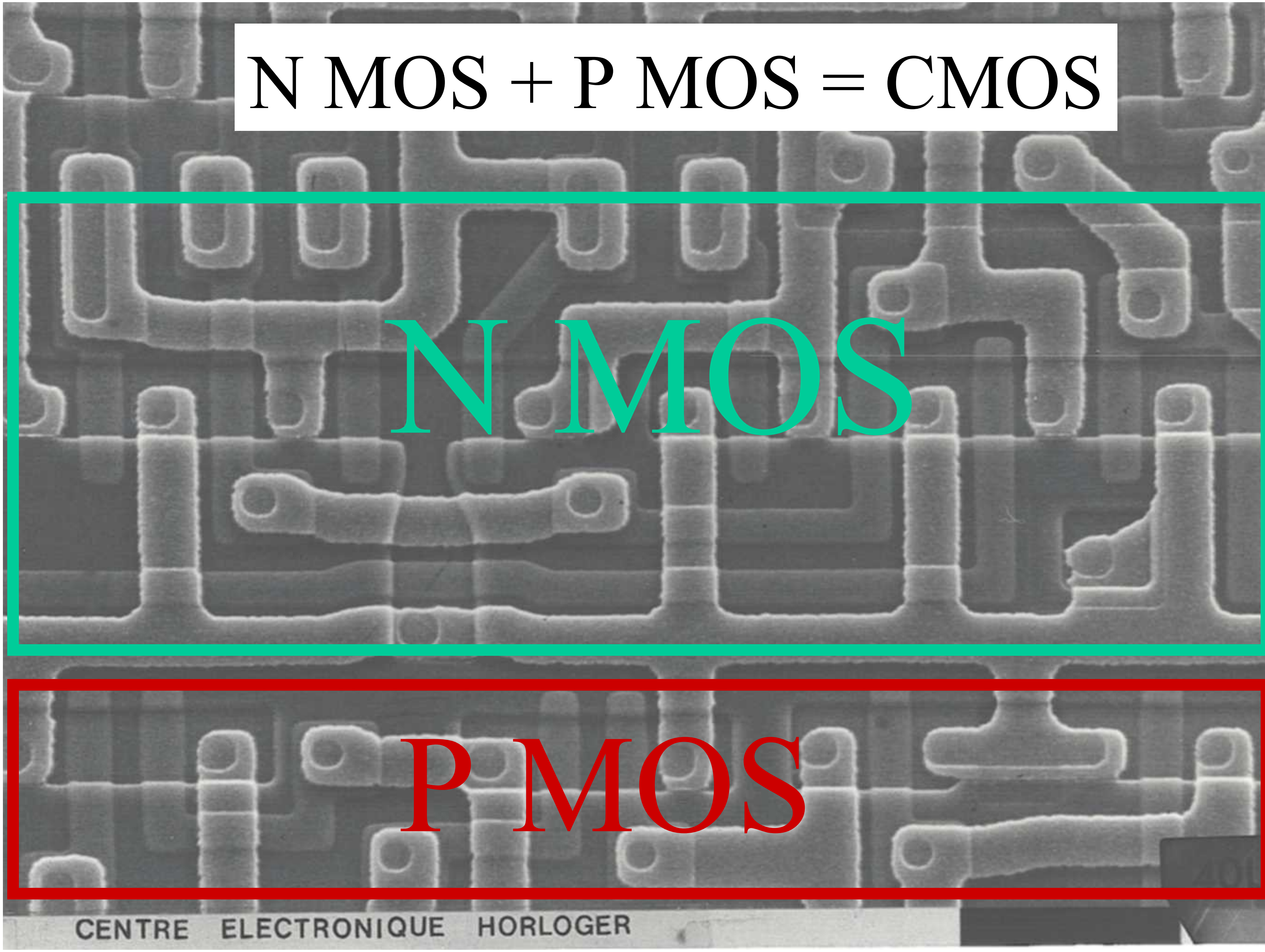


Circuit CMOS

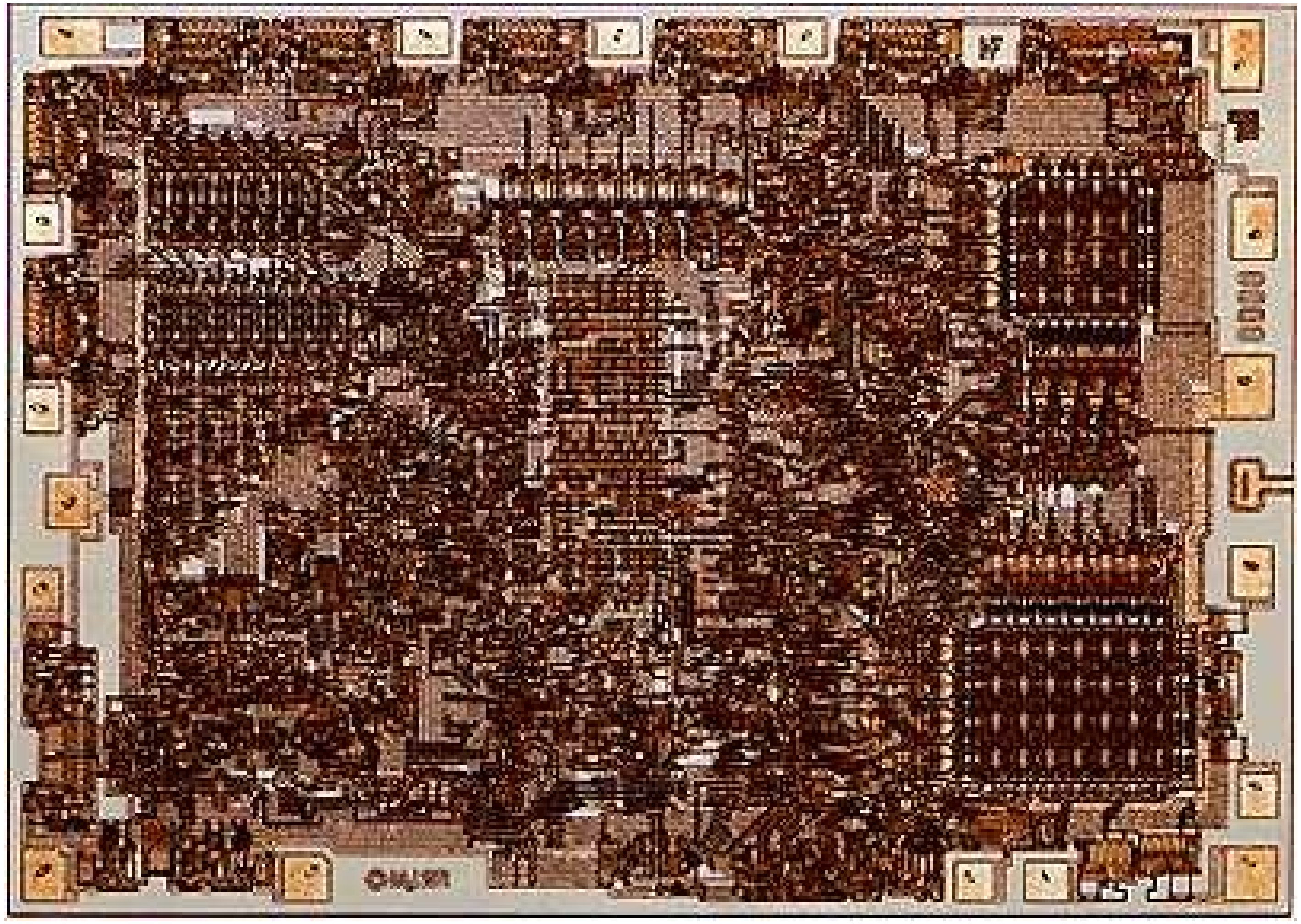

40µ
CENTRE ELECTRONIQUE HORLOGER


CENTRE ELECTRONIQUE HORLOGER

N MOS + P MOS = CMOS

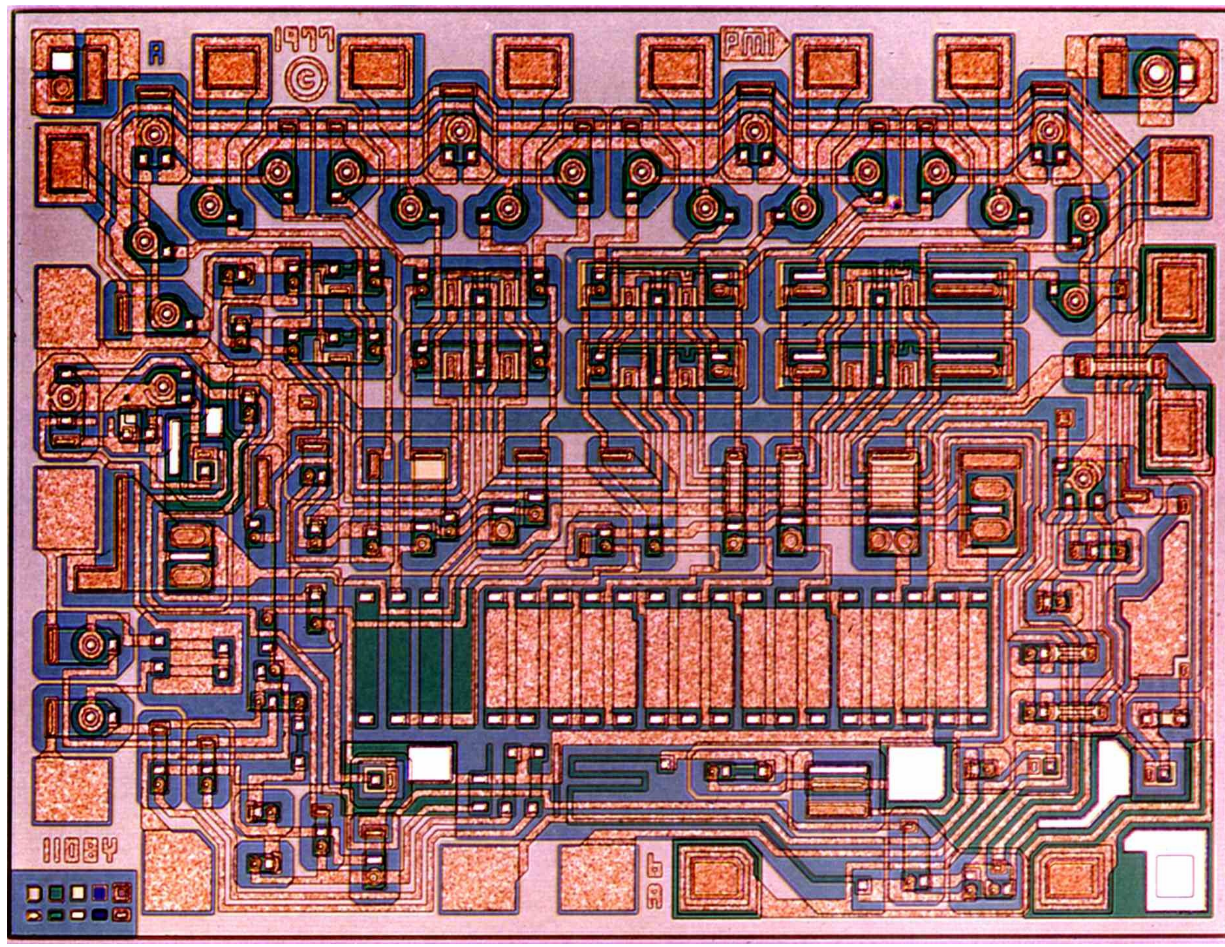


1972 INTEL8008

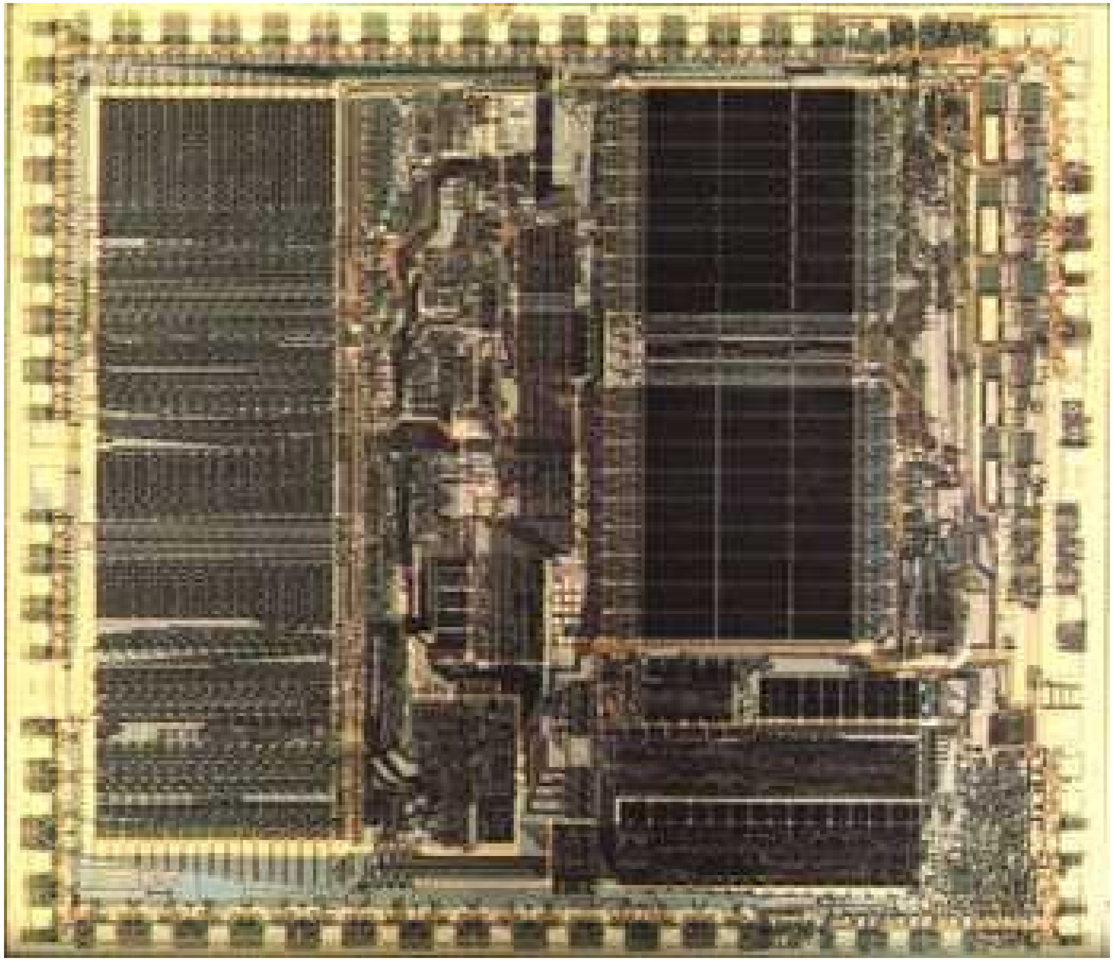


Convertisseur D/A

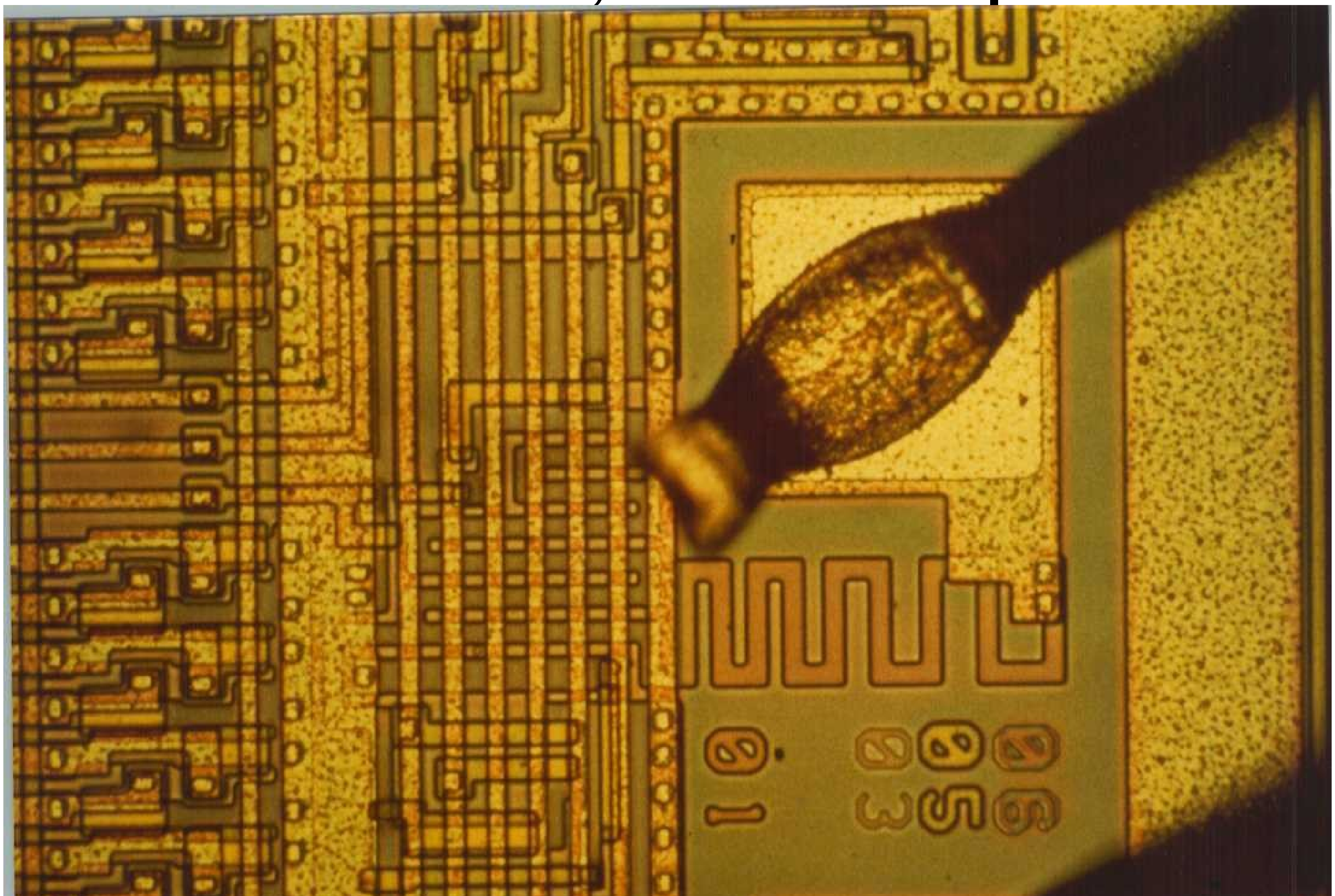
- DAC-08 de PMI
- 1974-77
- 1.55 x 2.15 mm,
- 100 Transistors
- 40 R
- 8 Bit, 5 MHz



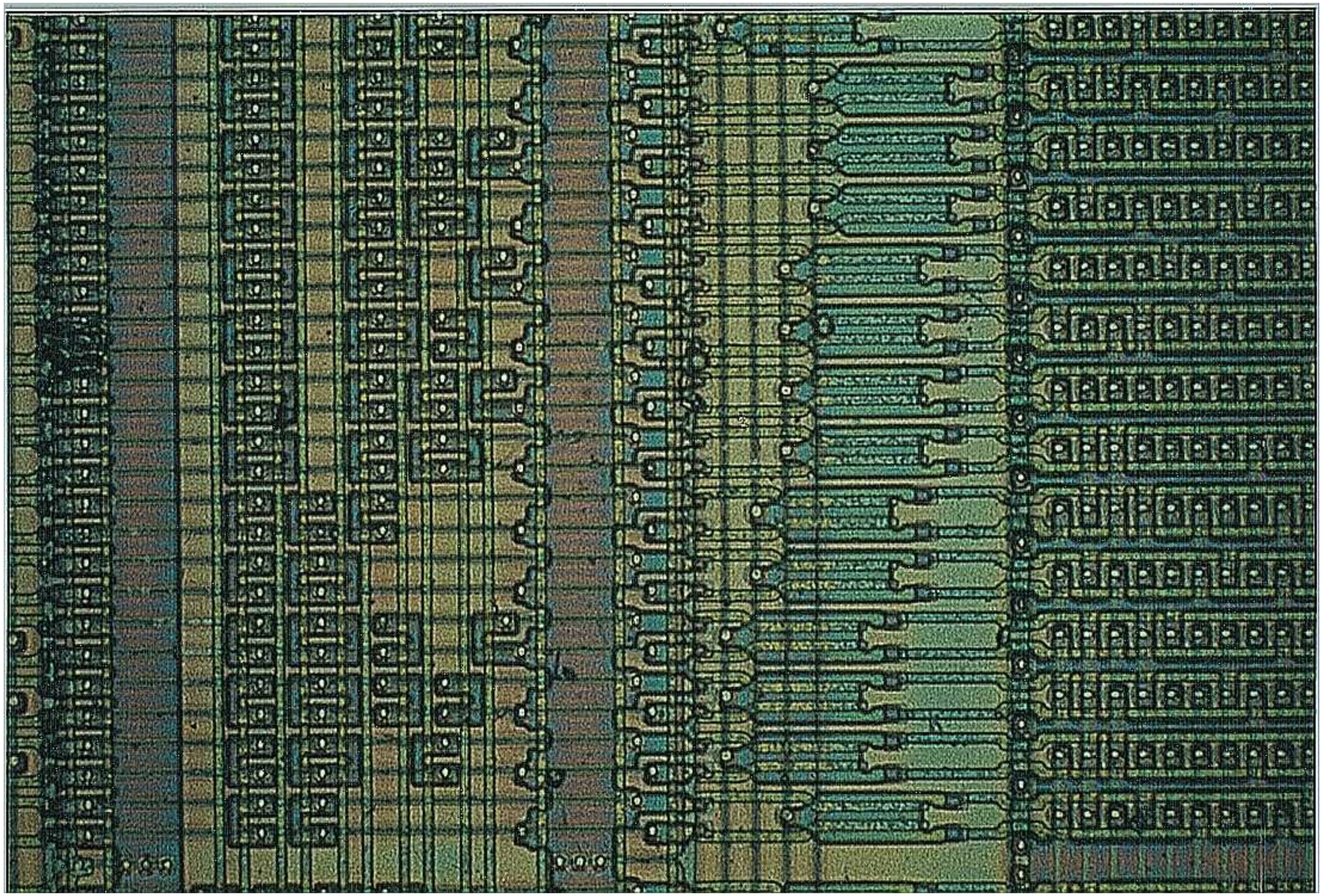
1979 M68000



M68000, detail of pad

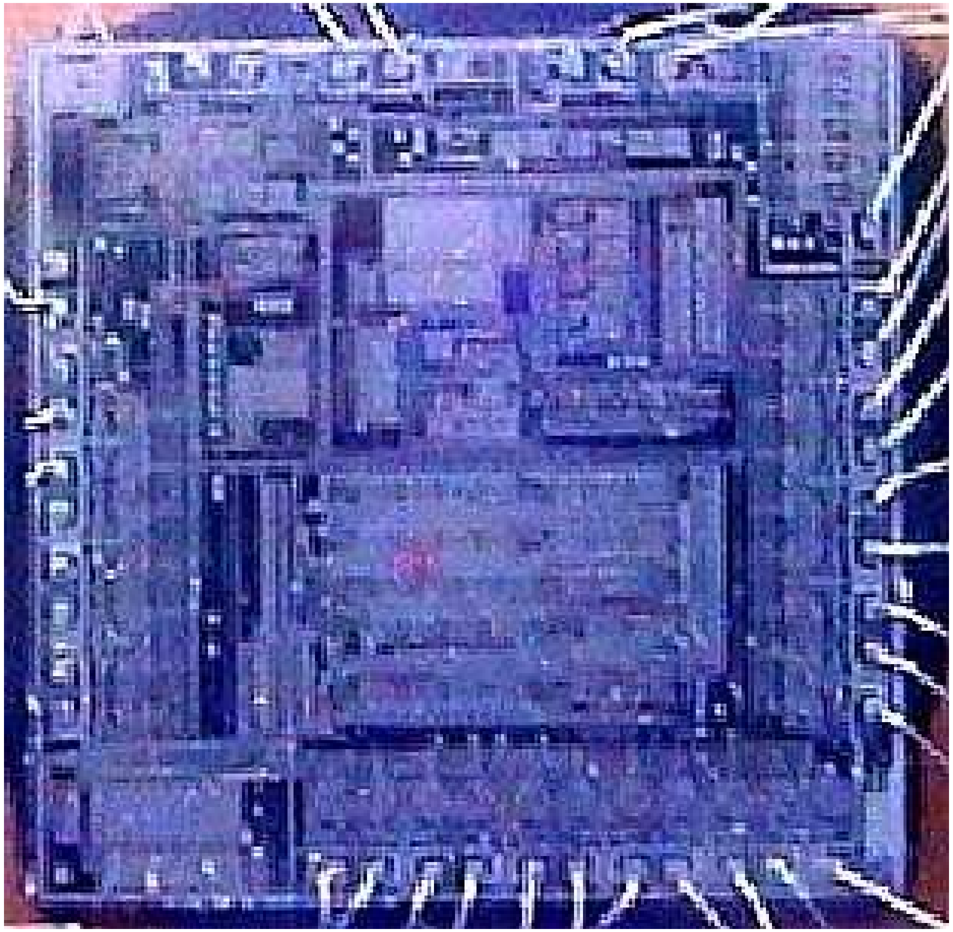


M68000, detail of ROM

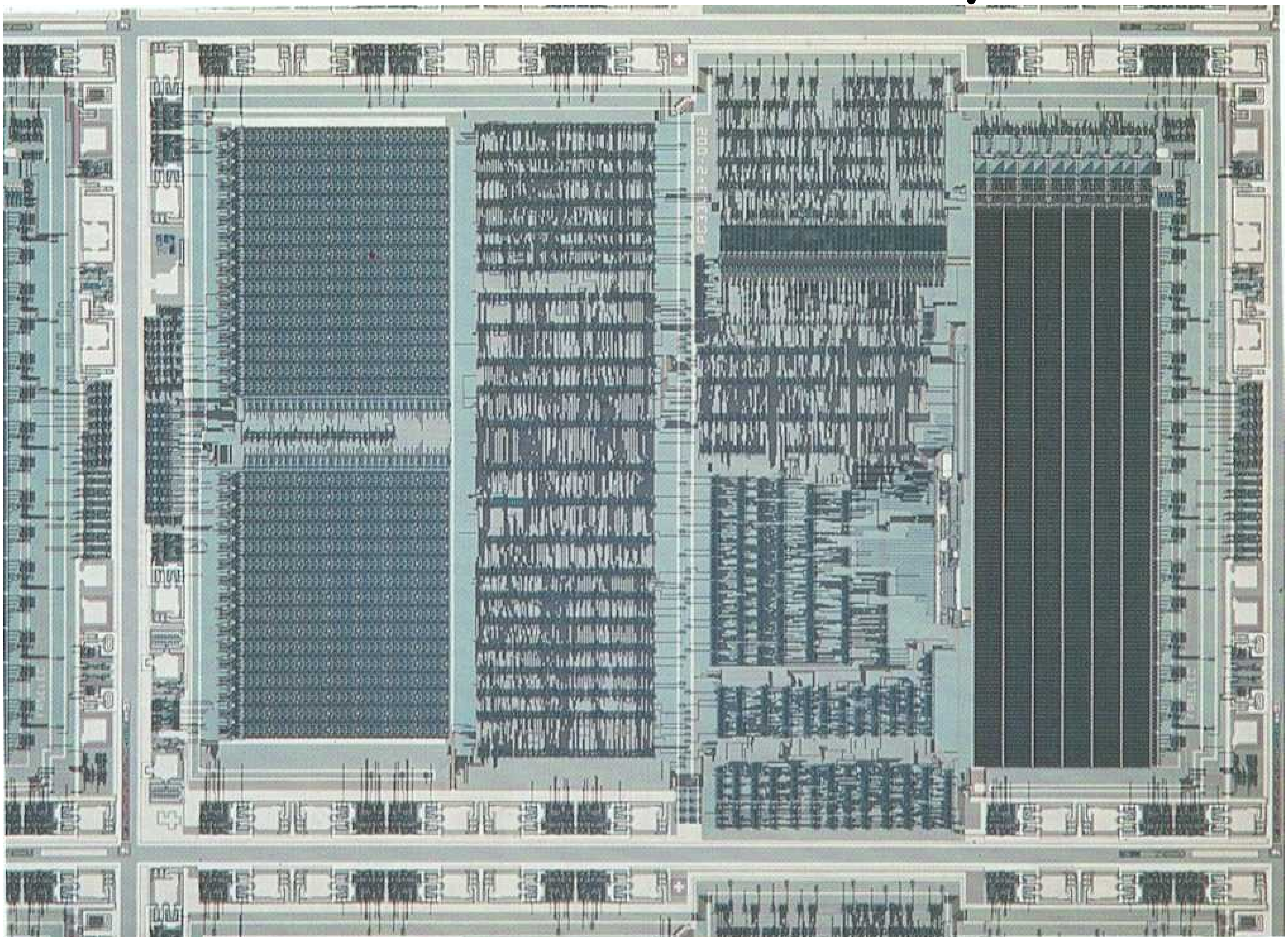


HCMOS 3μm (EM 1985)

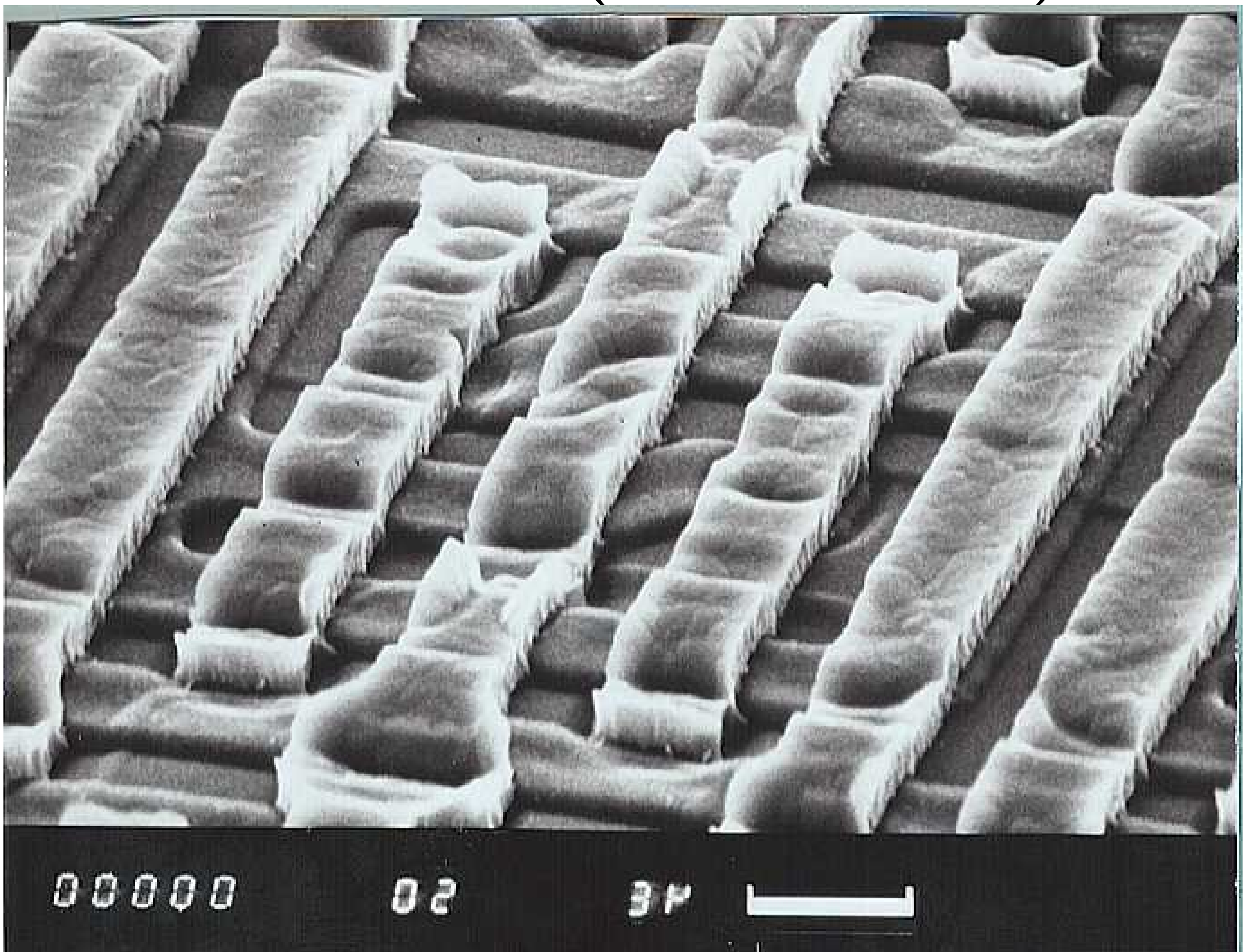
- Car clock



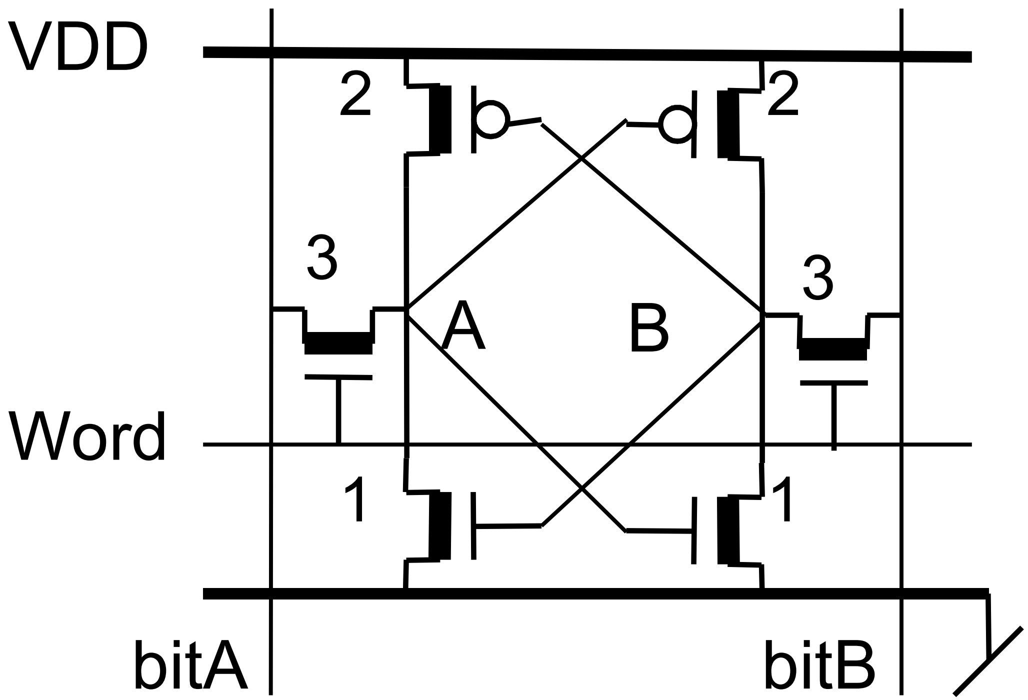
1987 SACMOS 3μm



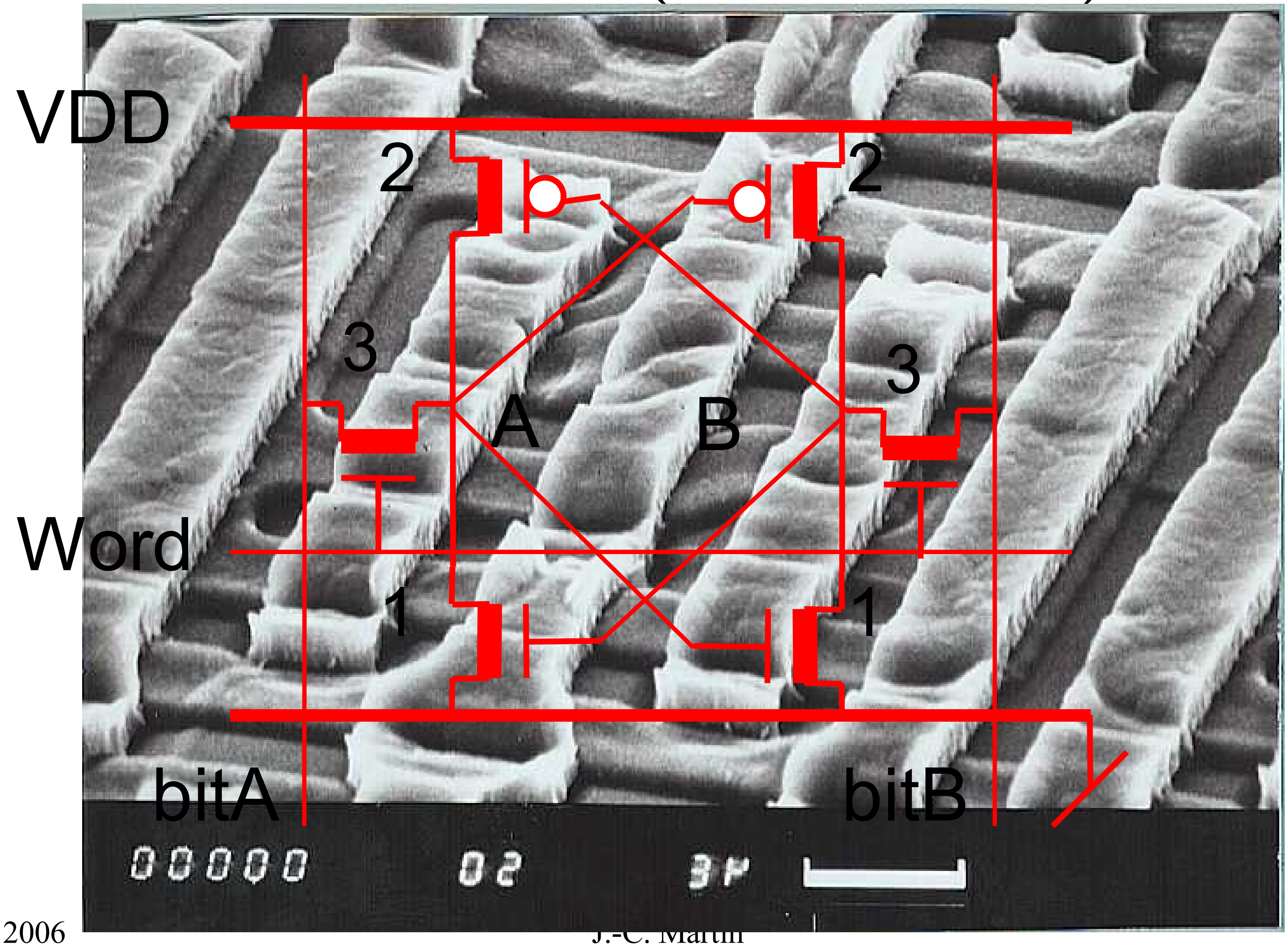
RAM cell (SACMOS)



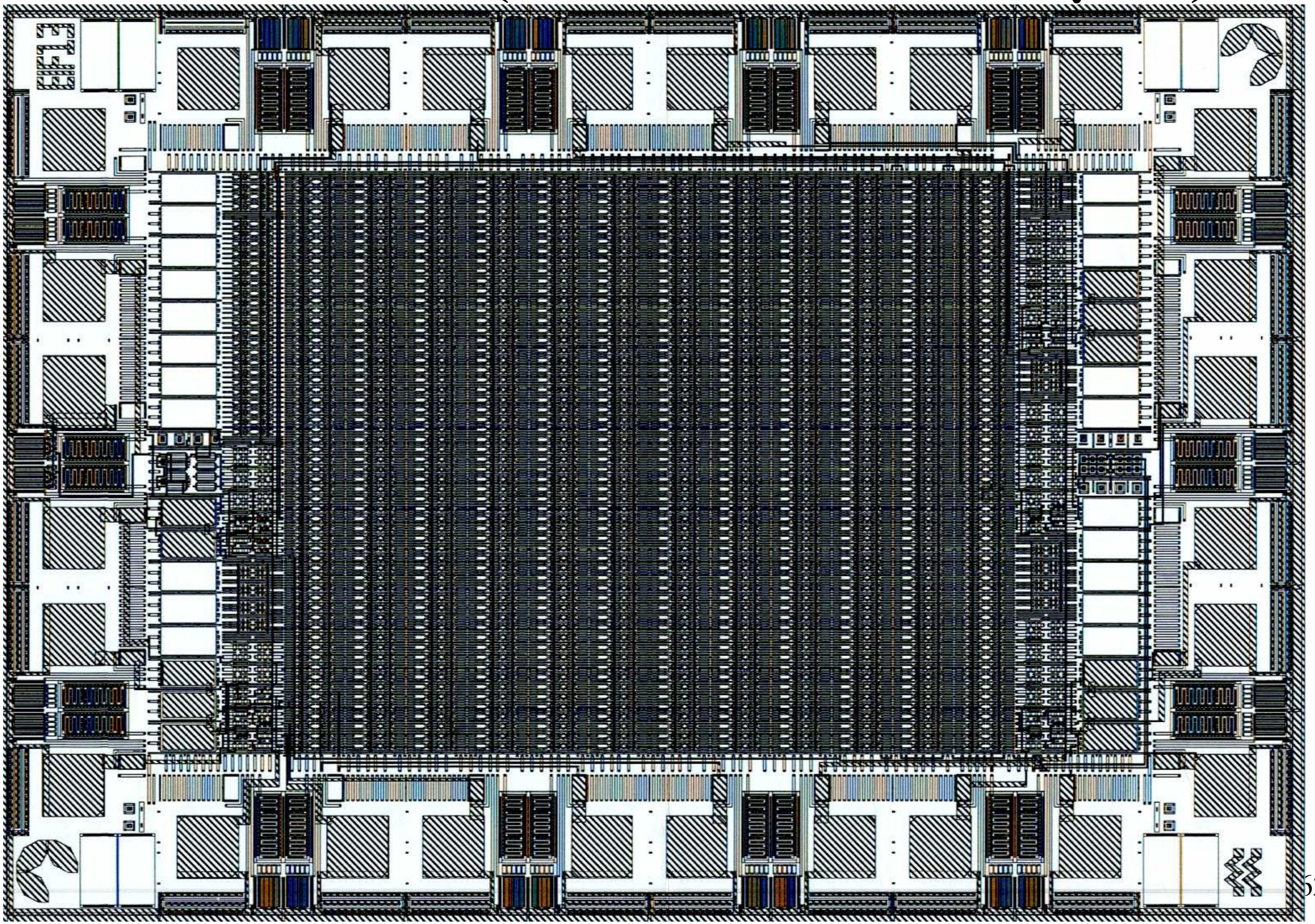
RAM statique (6 MOS)



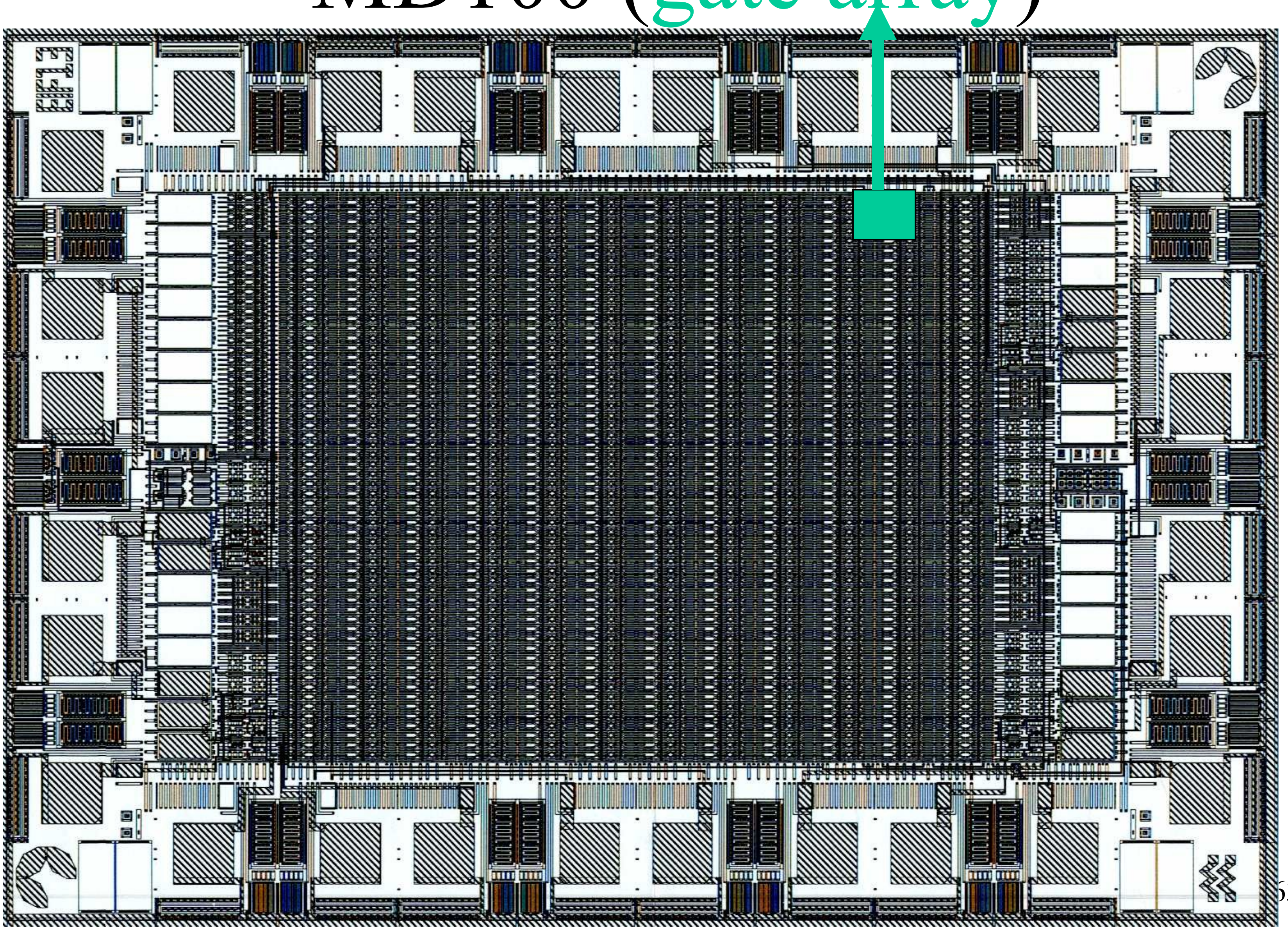
RAM cell (SACMOS)



MD100 (Faselec SAC 2μm)

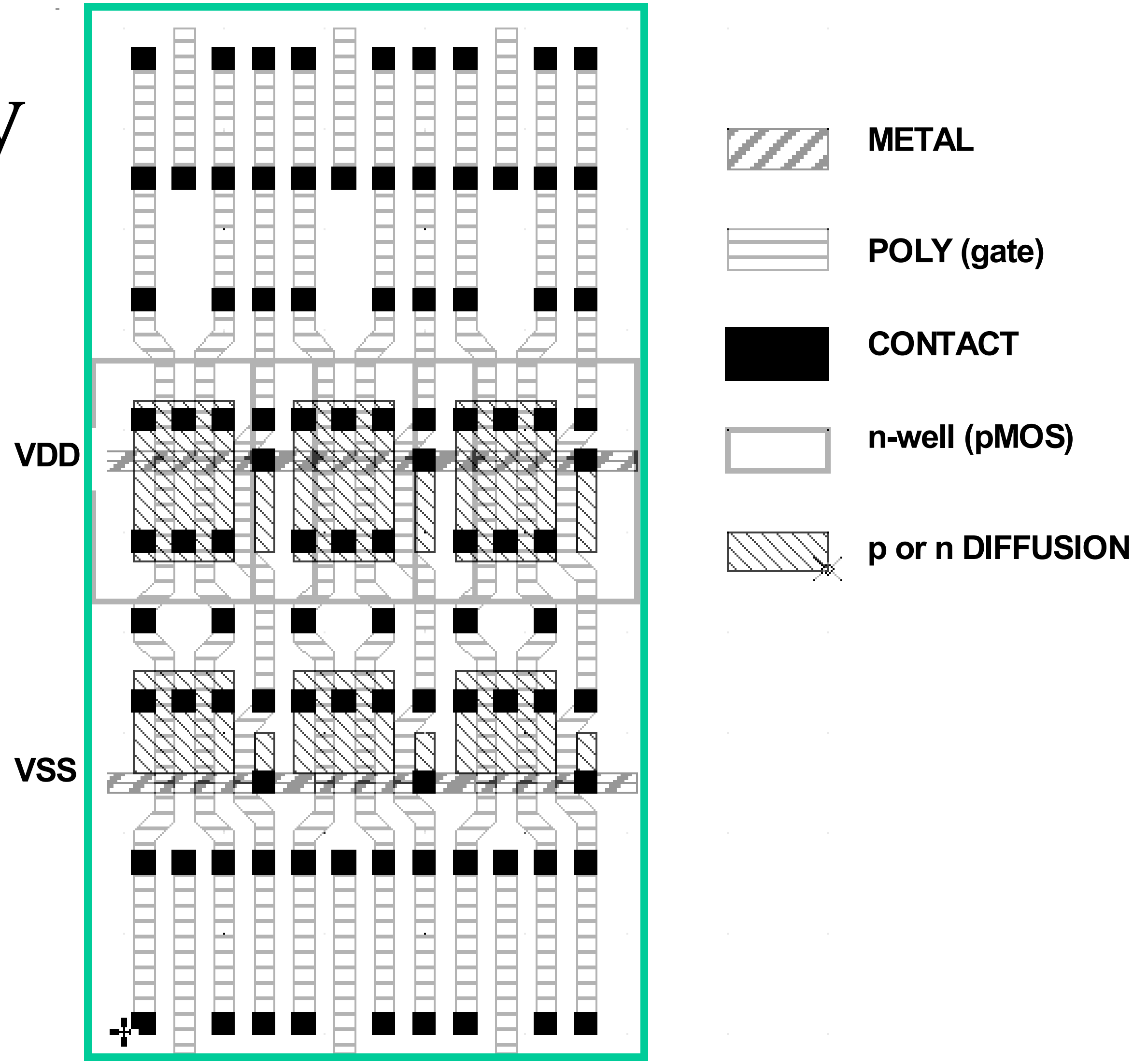


MD100 (gate array)



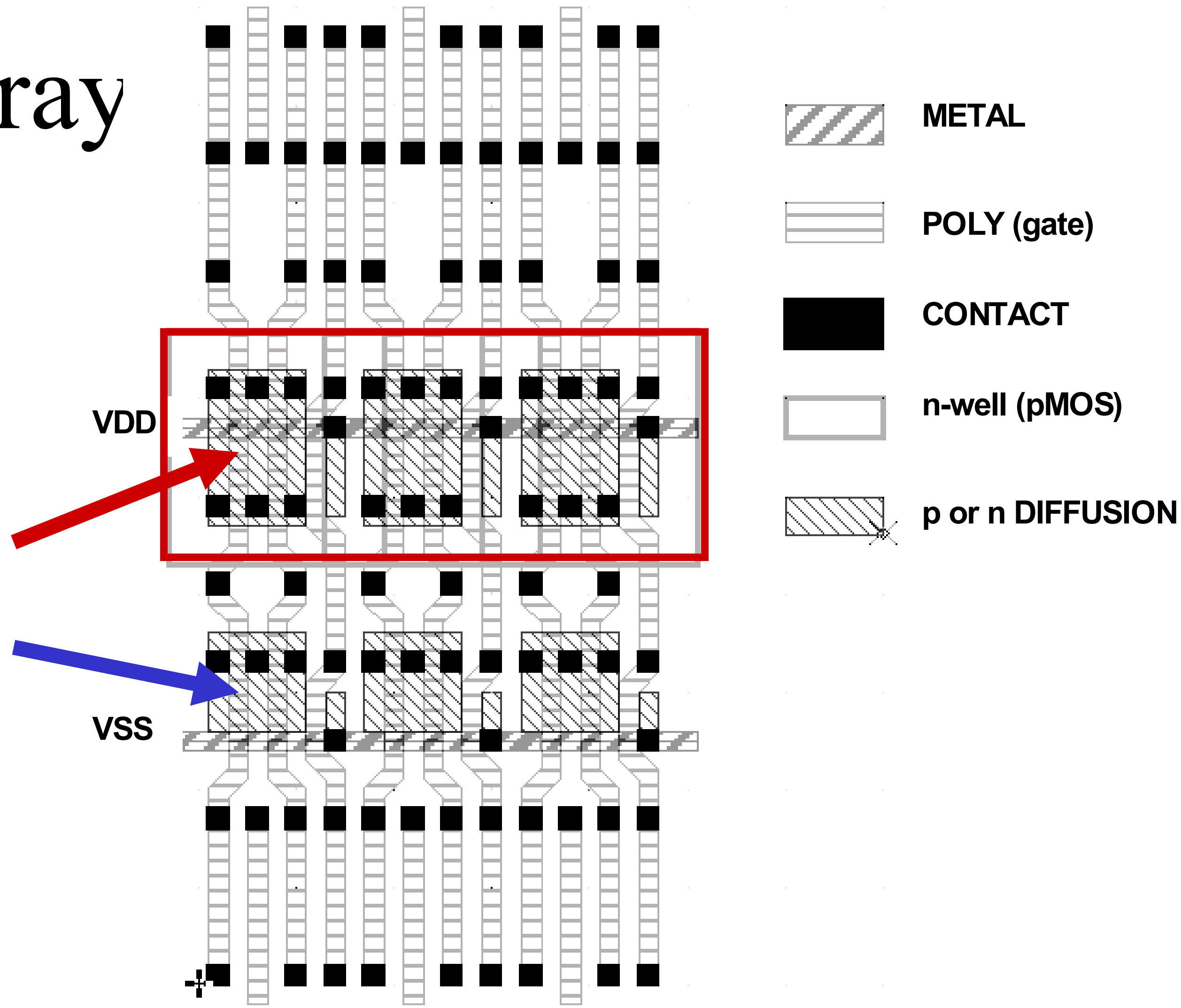
Gate Array

- MD100 cell
- programmation
- Masque métal

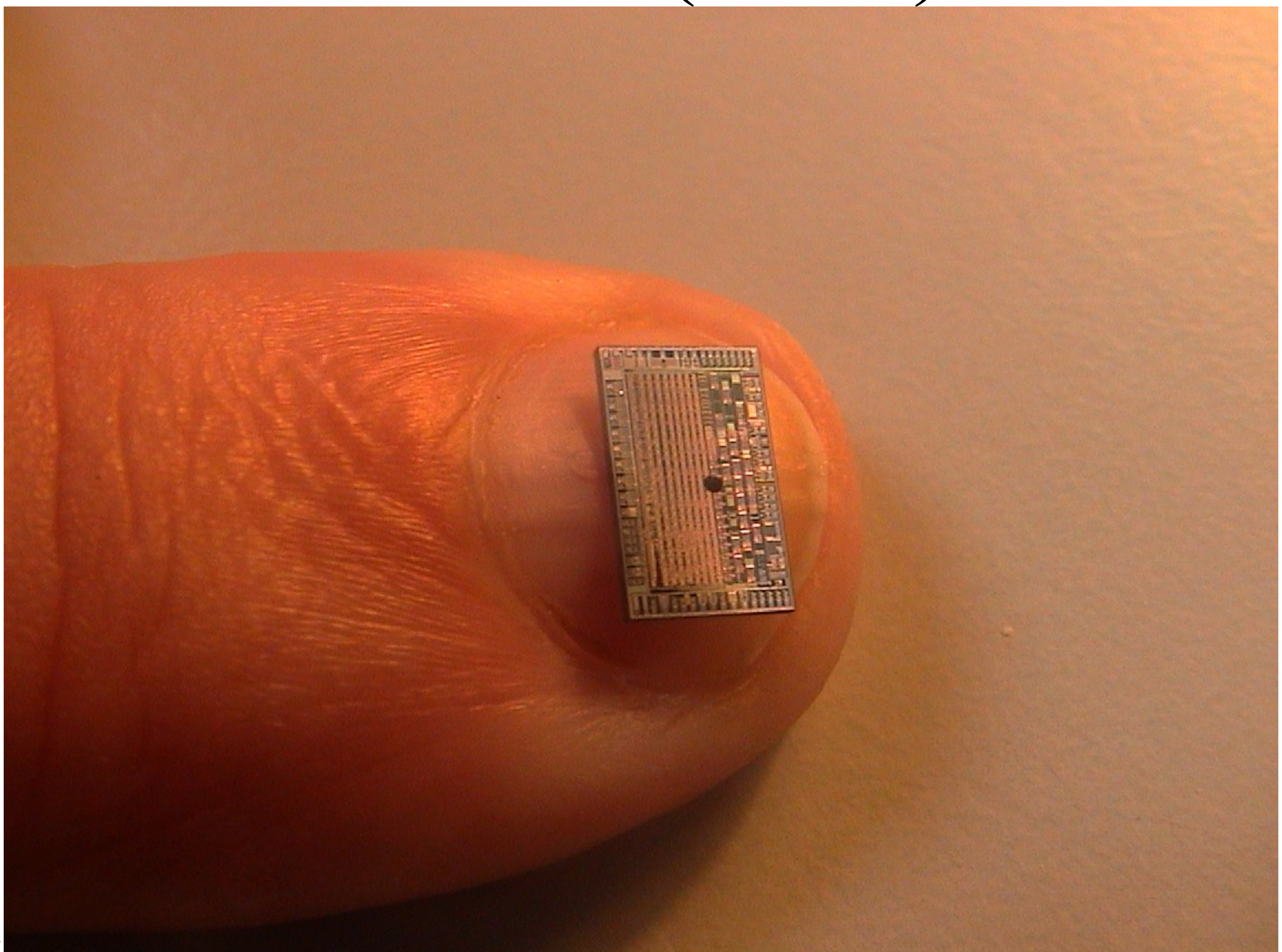


Gate Array

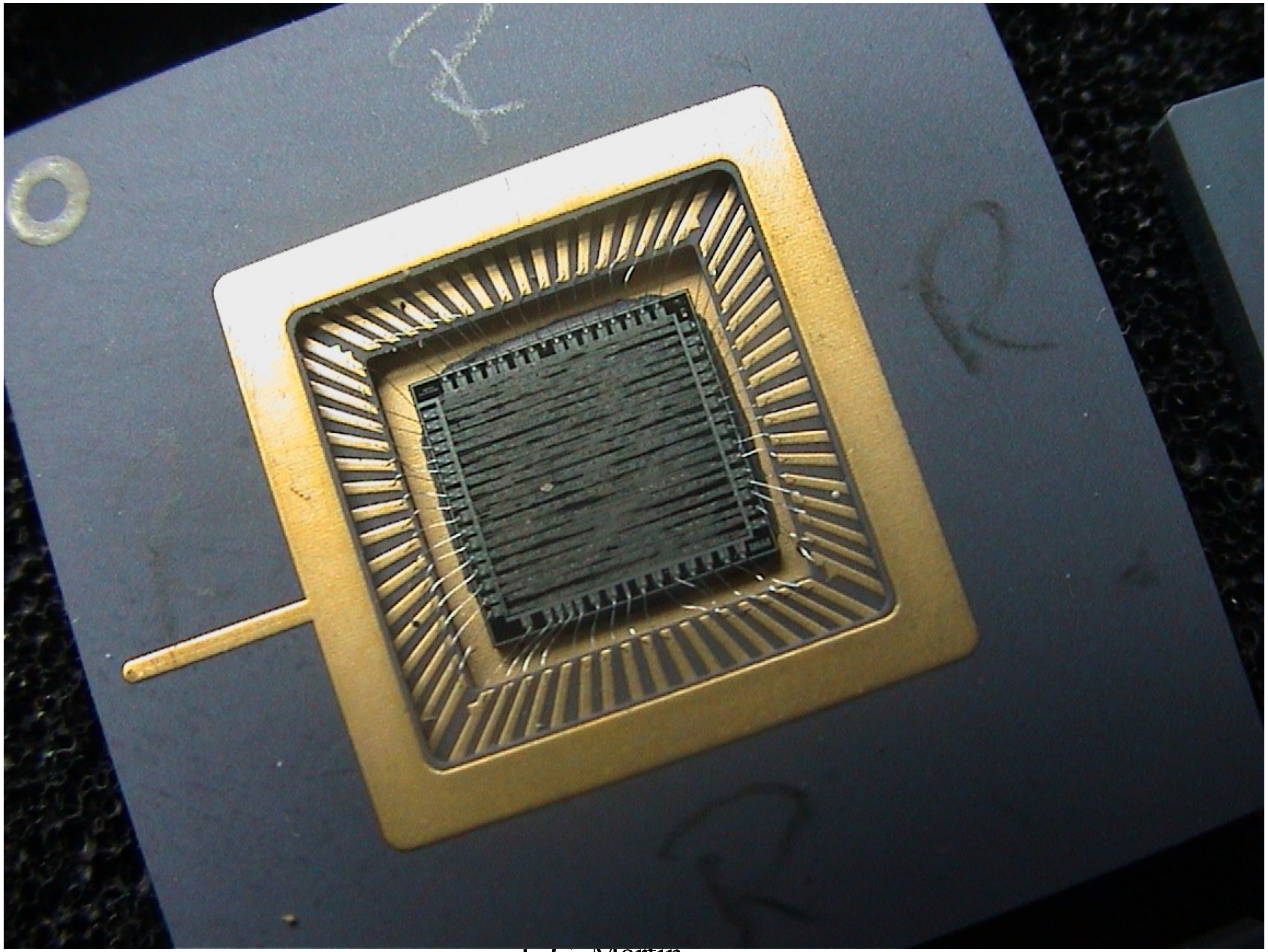
- MD100
- Metal
- 6 pMOS
- 6 nMOS



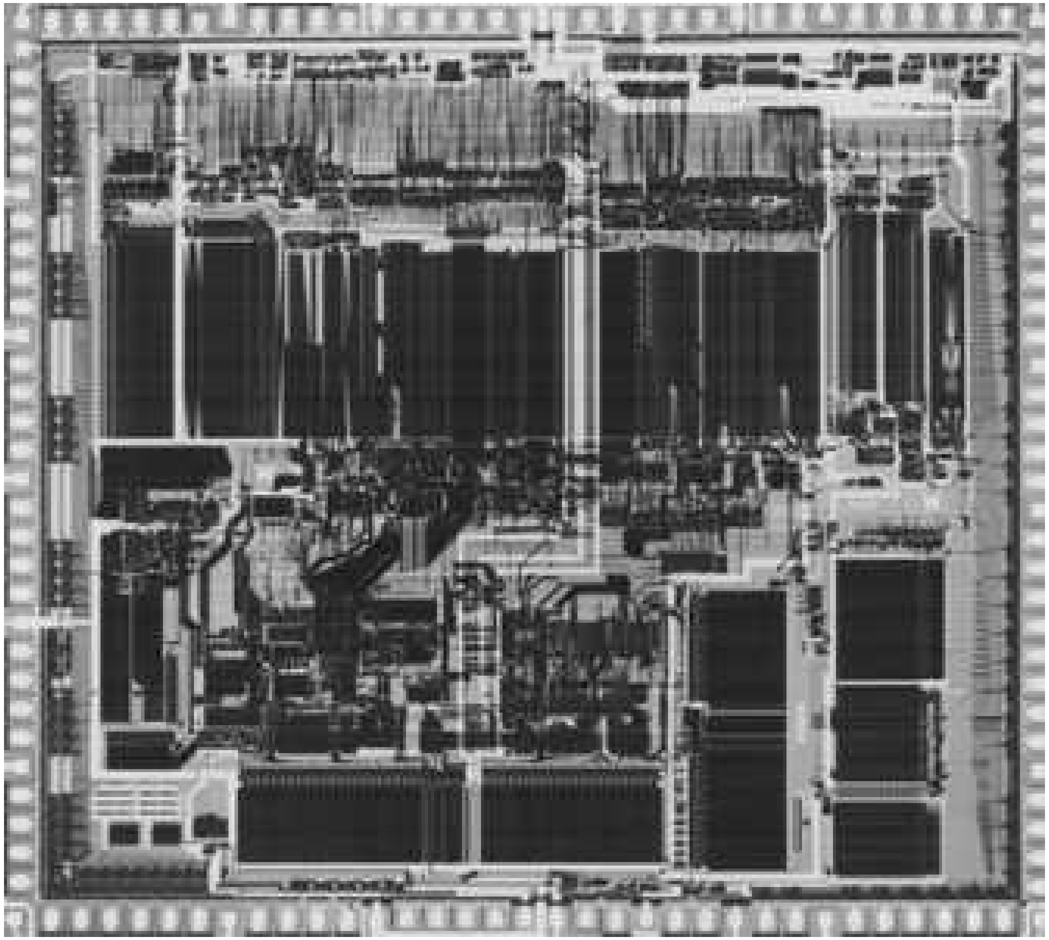
ASIC (1987)



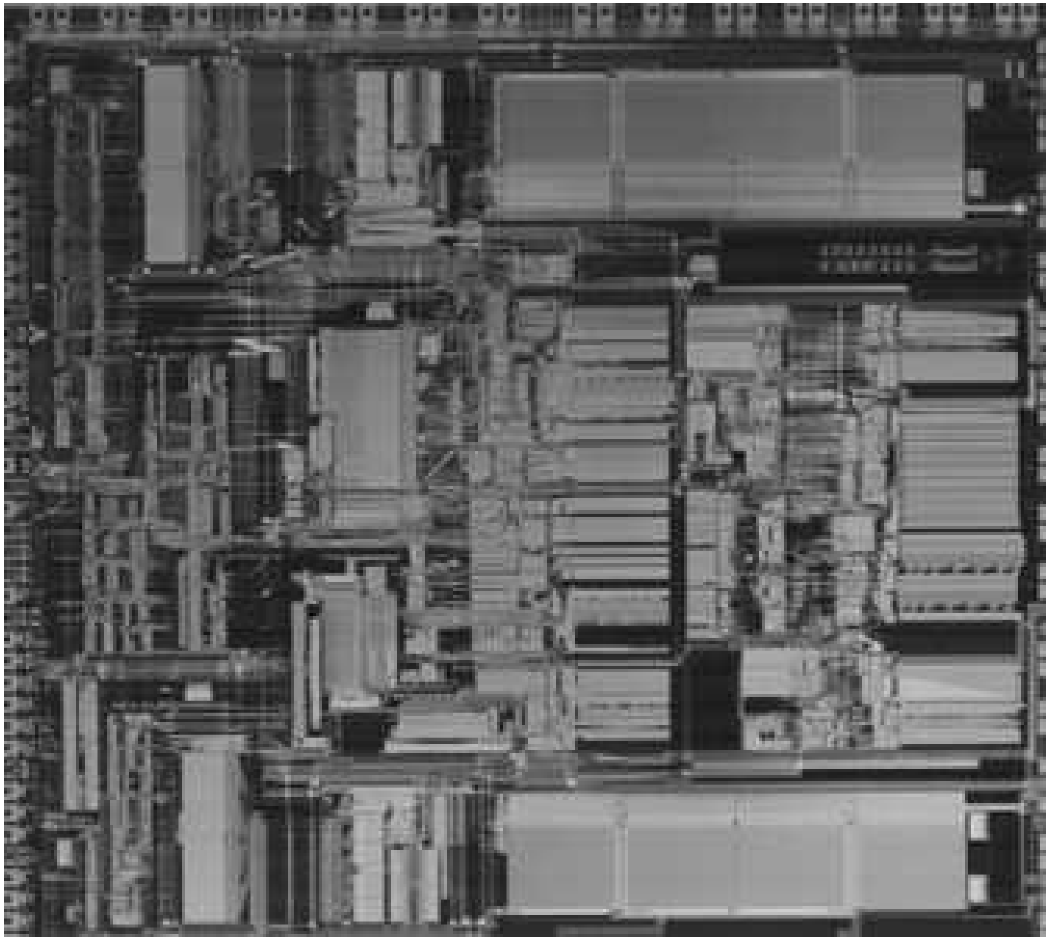
Standard cells



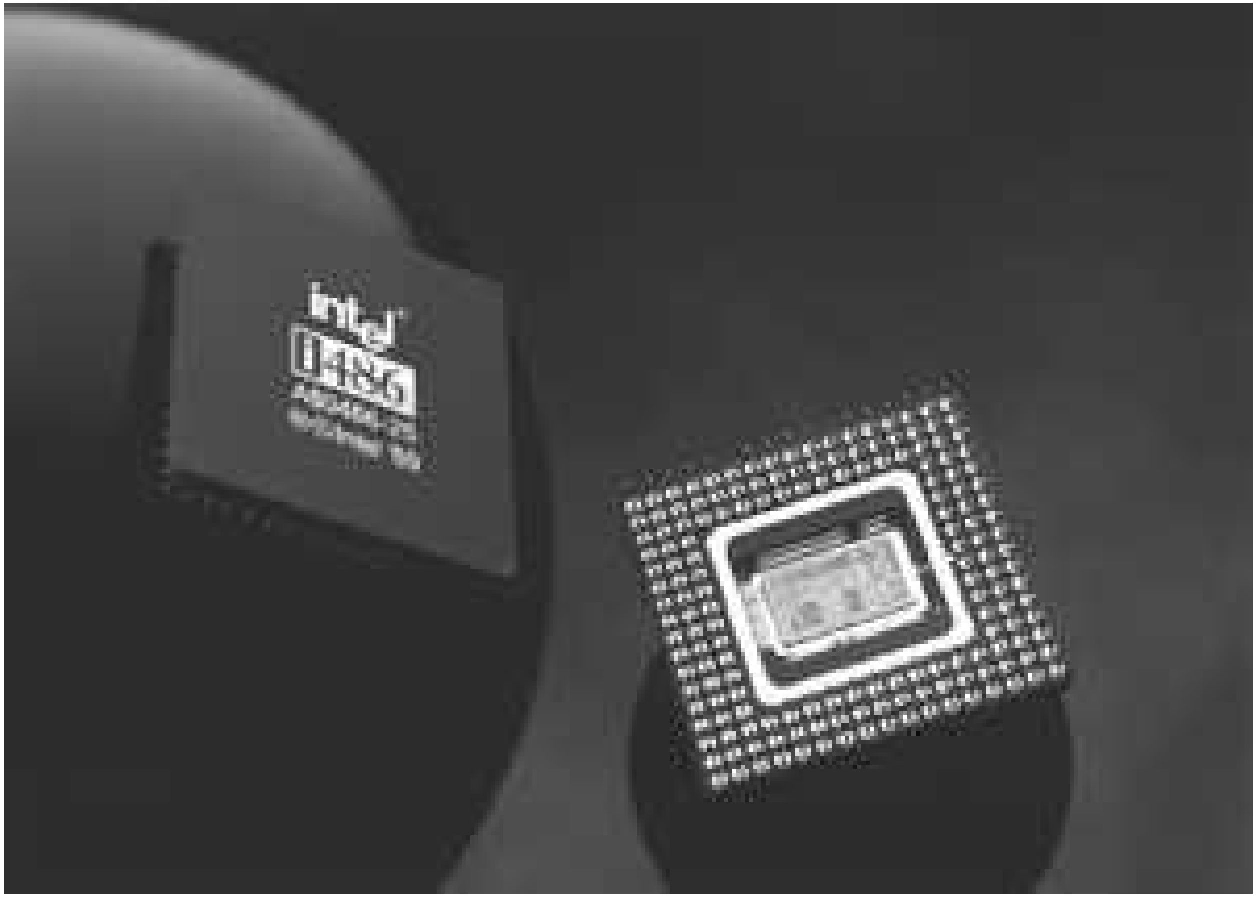
1987 M68030



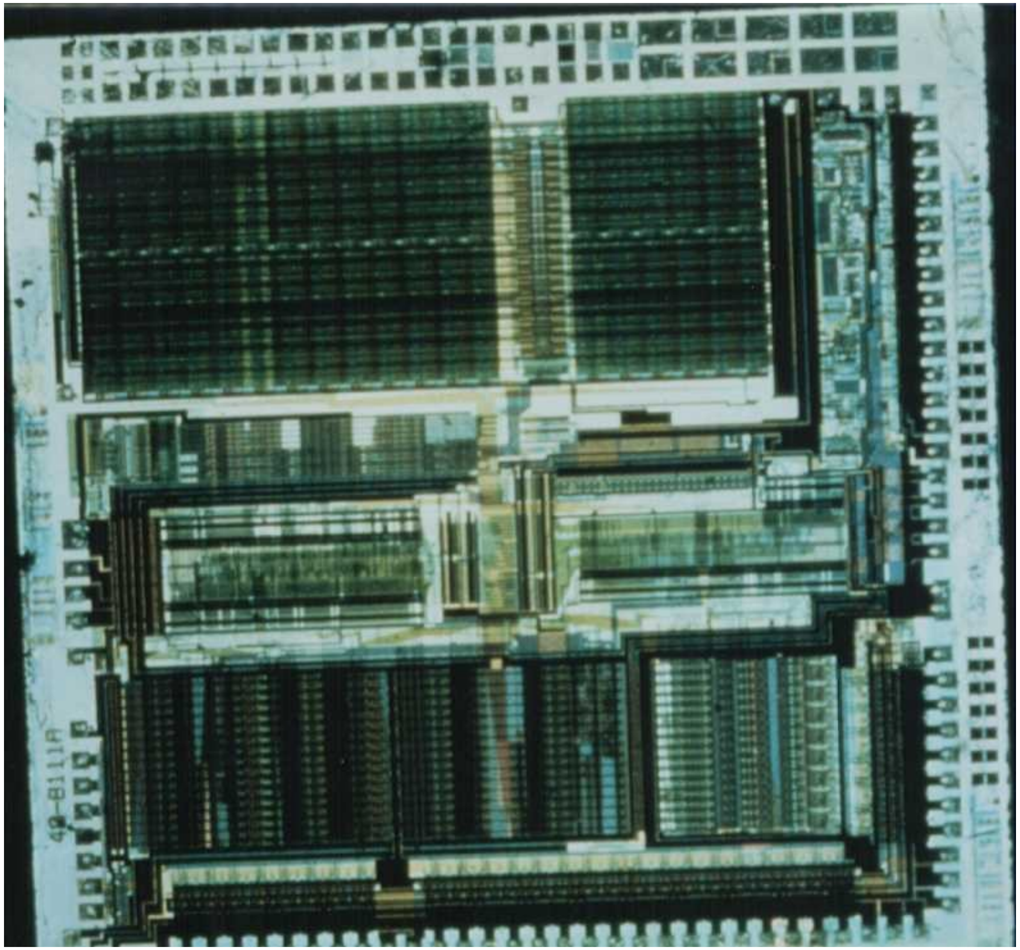
1989 M68040



1989 Intel 80486/i860



HP9000



Intel processors

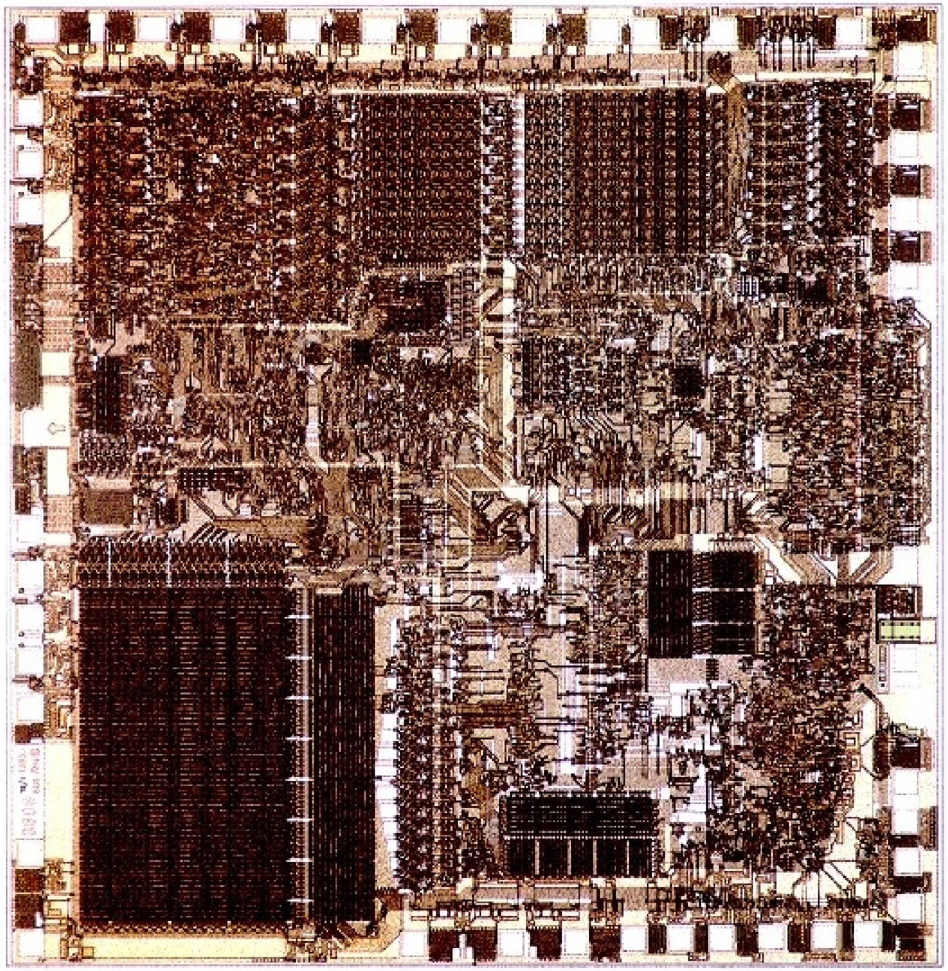
- 4004 (1971) bus 4 bits 108kHz 2k3-MOS 10u
- 8008 (1972) bus 8 bits 200kHz 3k5-MOS 10u
- 8088 (1979) bus 8 bits 1MHz 29K-MOS 3u
- I386 (1988) bus 16 bits 33MHz 275K-MOS 1u
- I486 (1989) bus 32 bits 50MHz 1.2M-MOS 0.8u
- Pentium (1993) 64 bits 66MHz 3.1M-MOS 0.8u
- Pentium 2 (97) 64 bits 300MHz 7.5M-MOS 0.35u
- Pentium 4 (00) 1.5GHz 42M-MOS 0.18u

Intel processors de 1971 à 2000

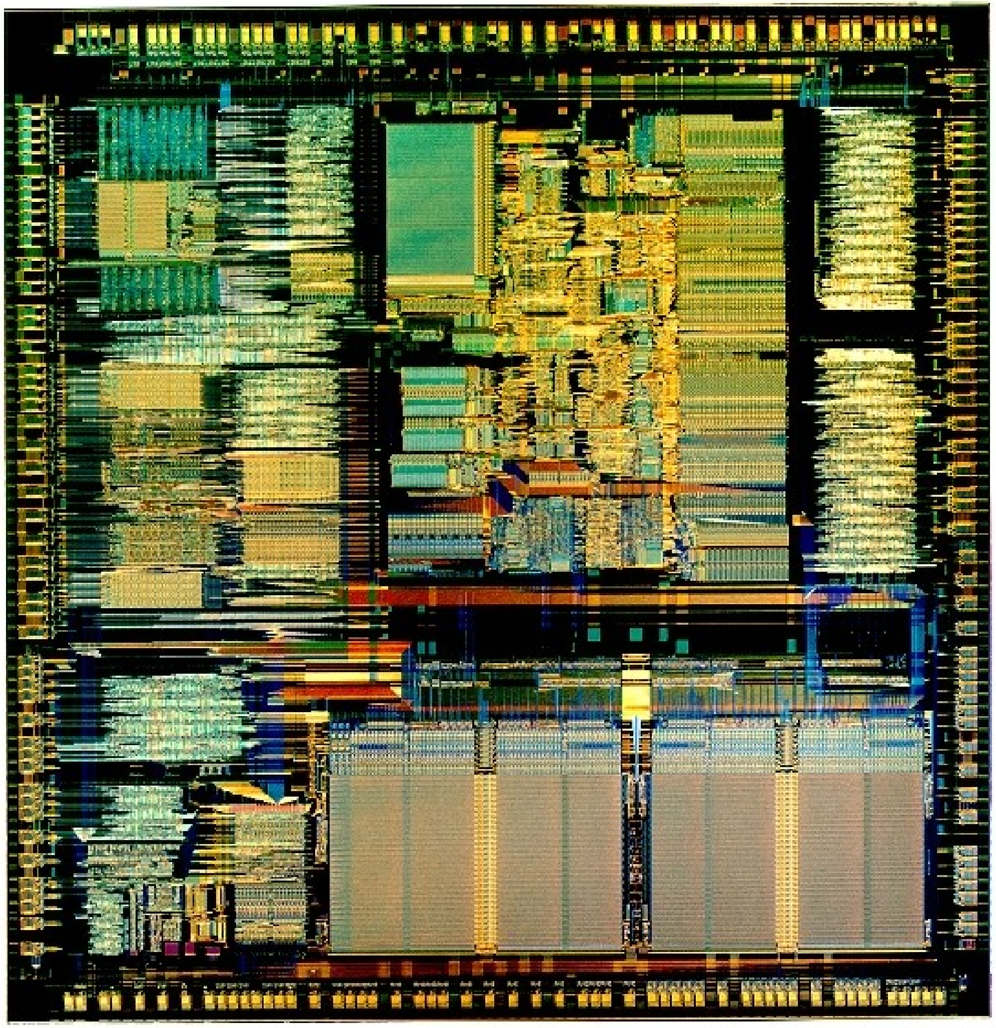
- BUS 4 à 64 bits
- Fréquence de 100 à 2G Hz
- Lignes de 10 à 0.1 micromètres
- Nb MOS de 2000 à 42 millions

1978: 8086-8088

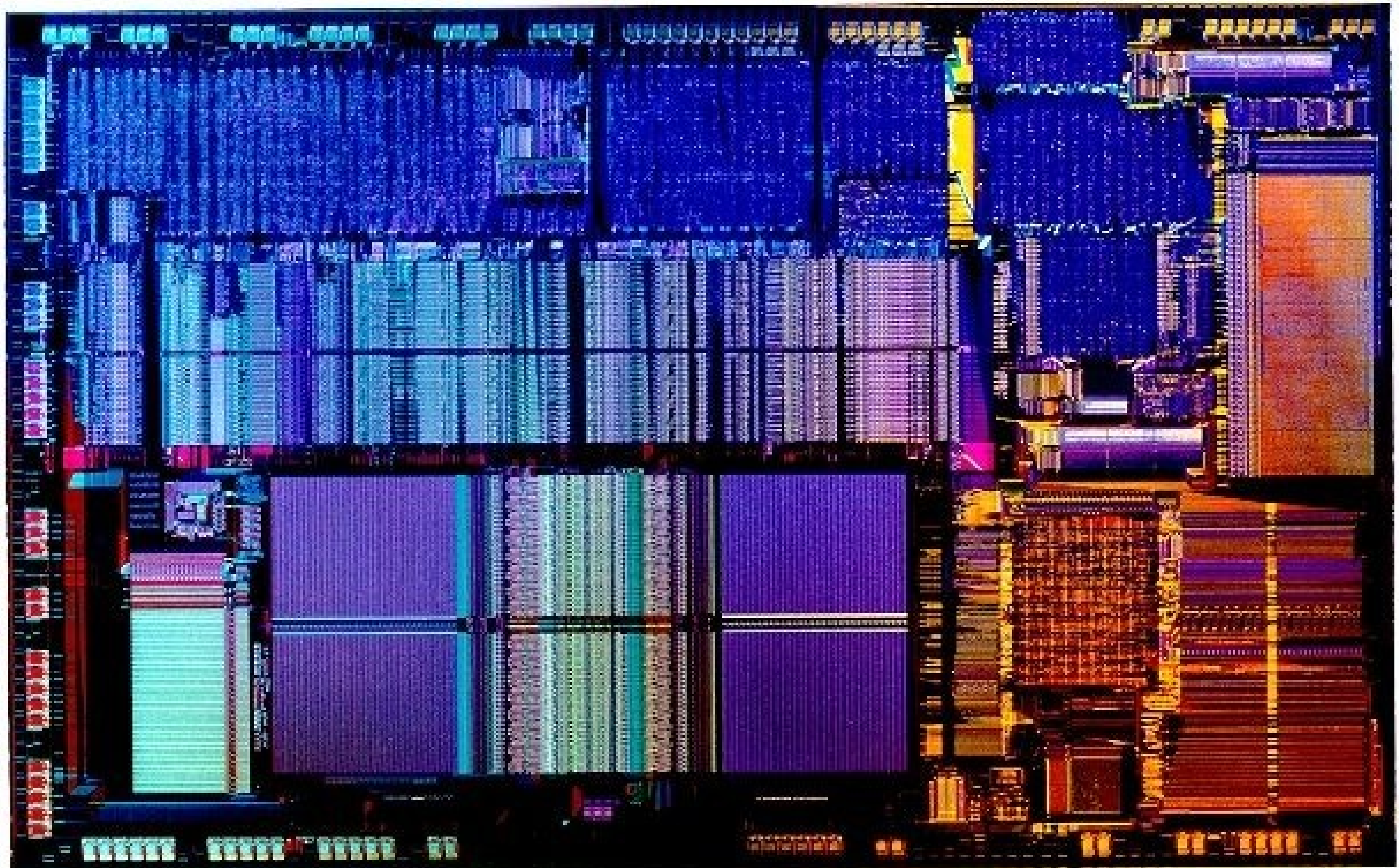
- Intel 8088
- the brains of IBM
- the IBM PC



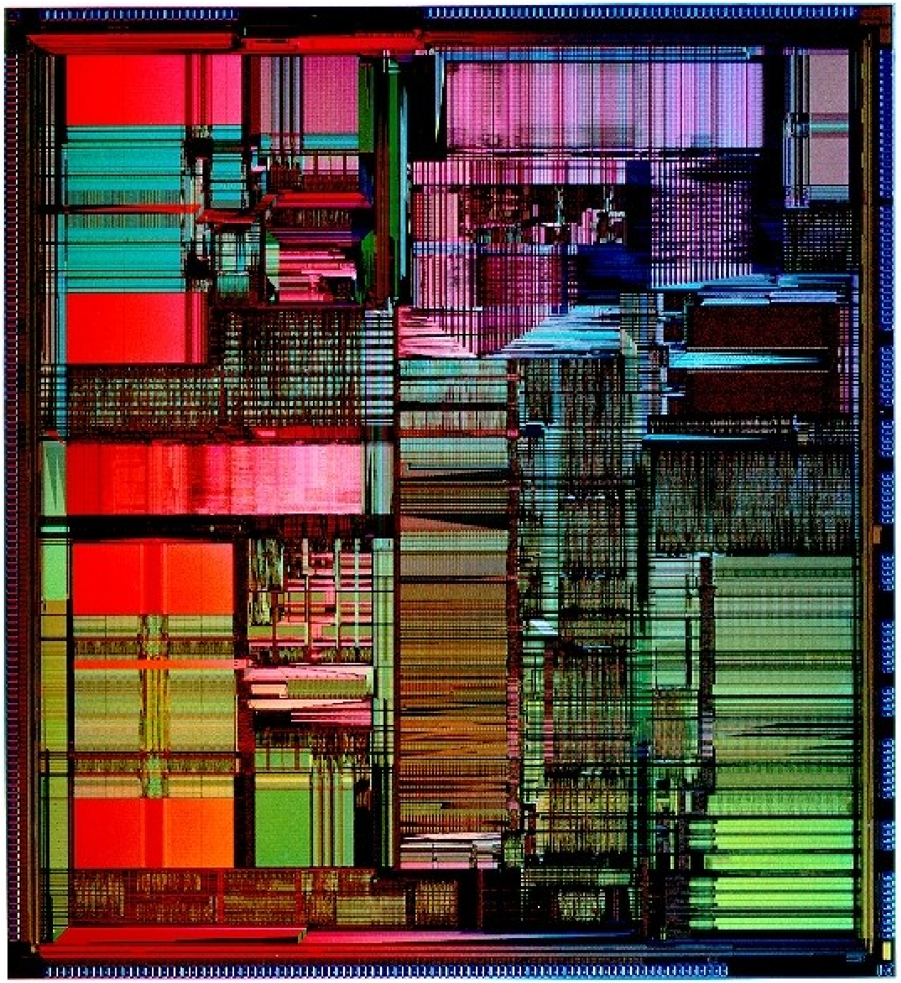
1985 Intel 386



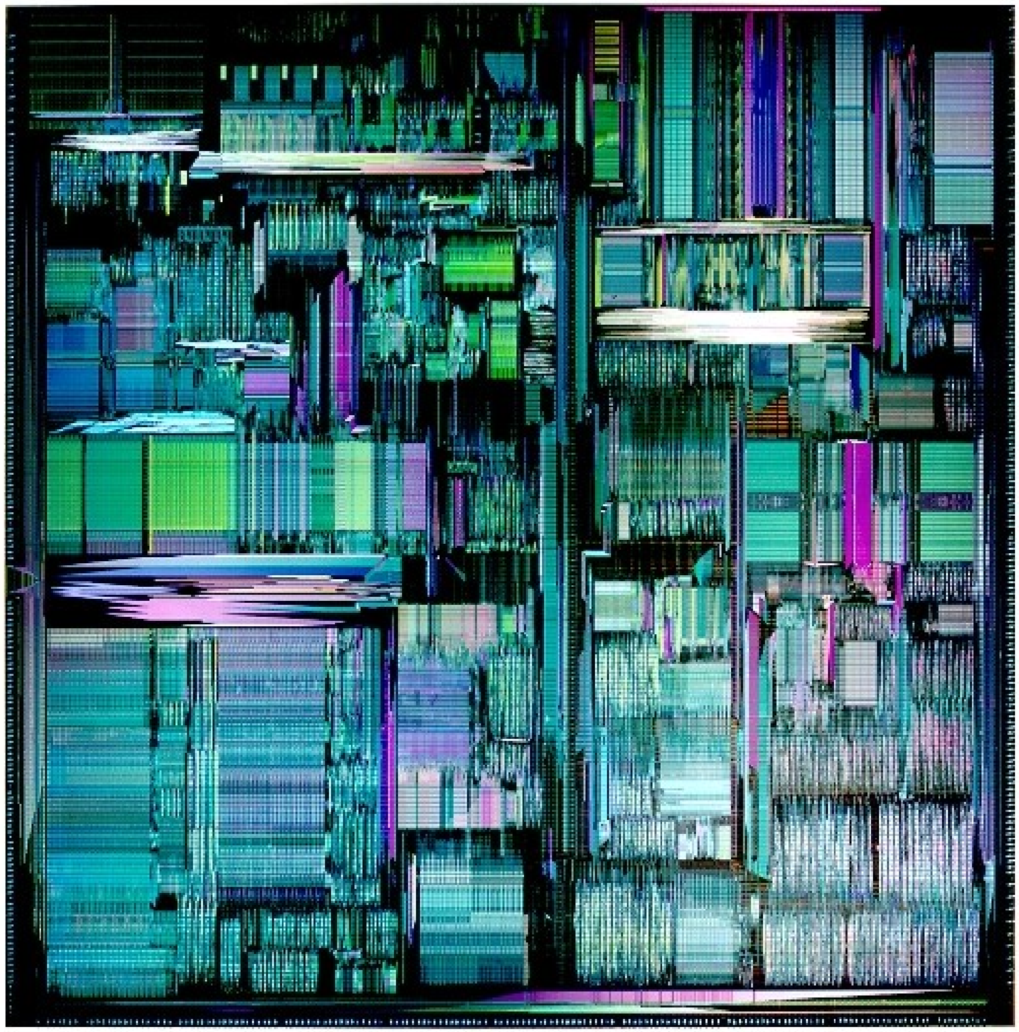
1989: Intel 486TM DX CPU



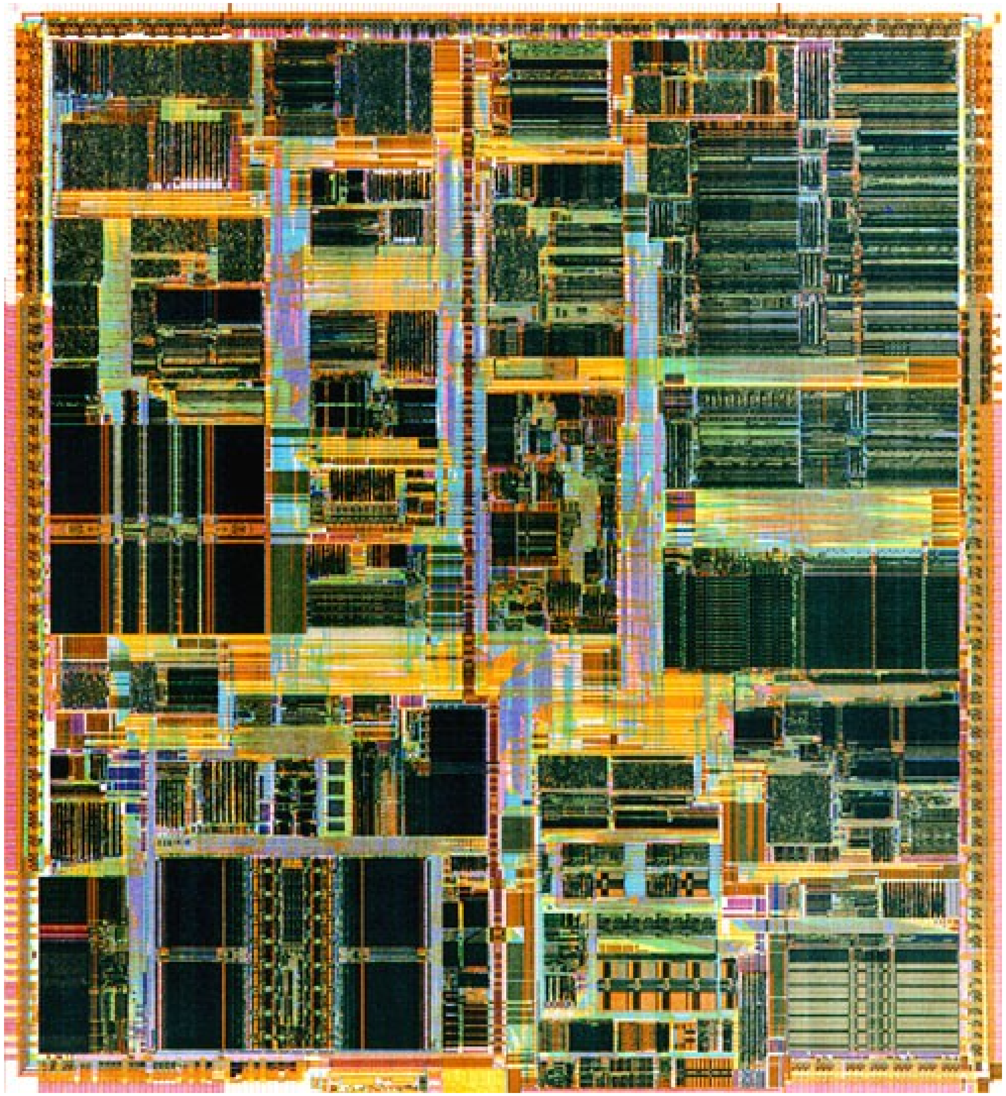
1992 Intel Pentium



1995 Intel Pentium pro

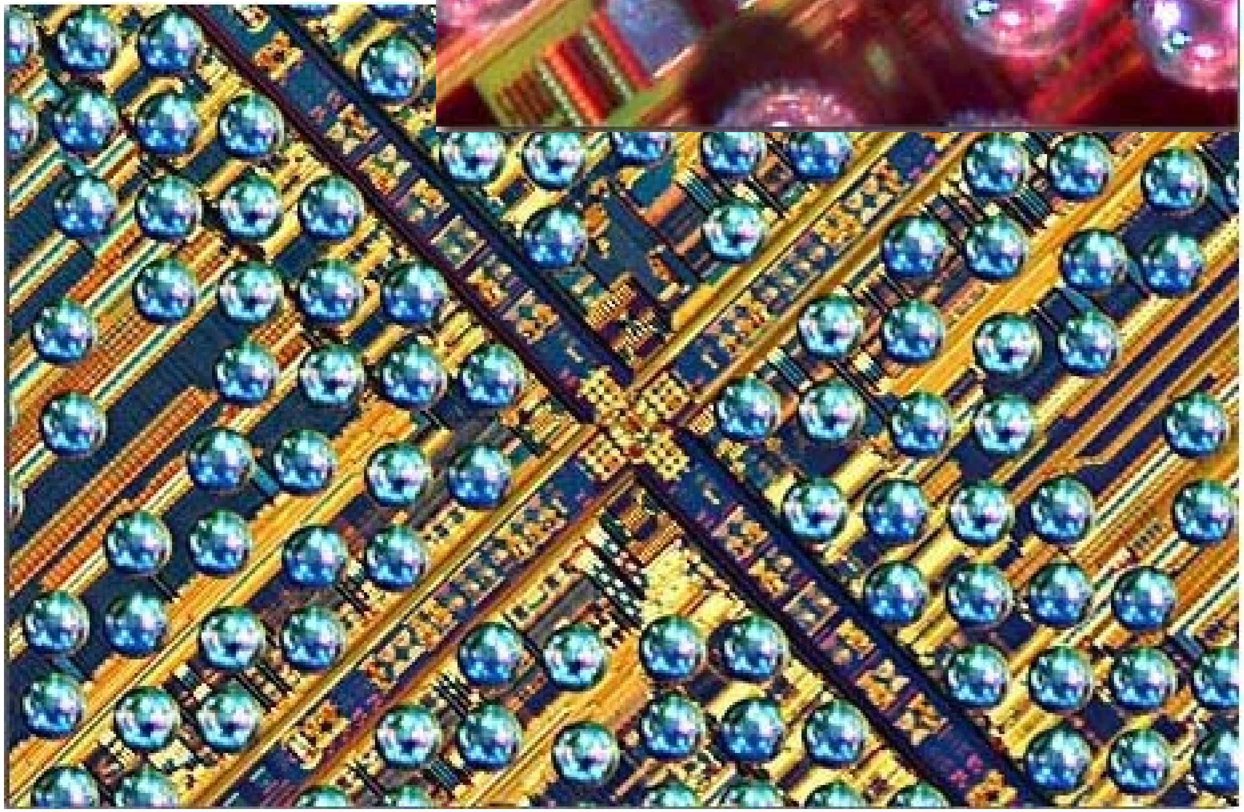


1997 Intel Pentium2

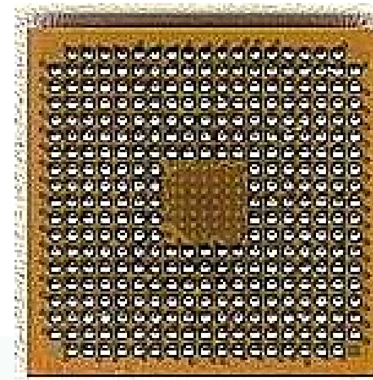


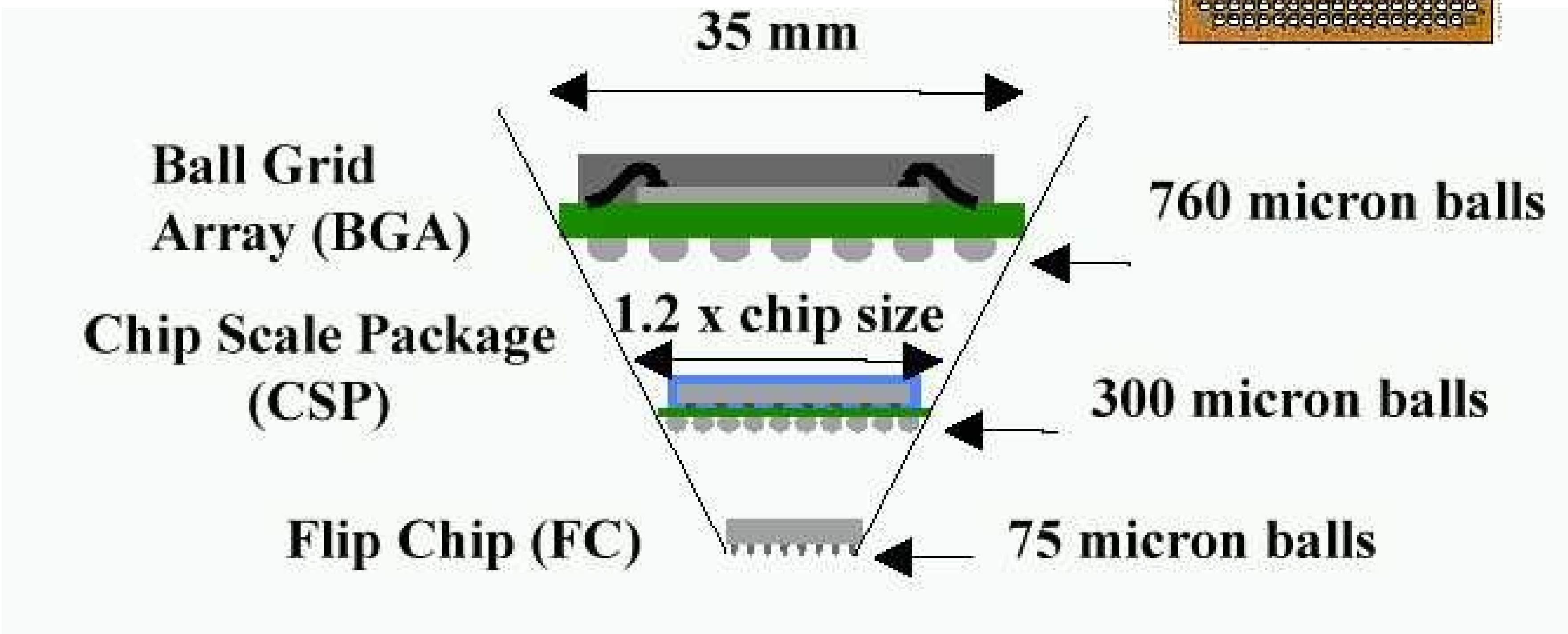
Pentium III

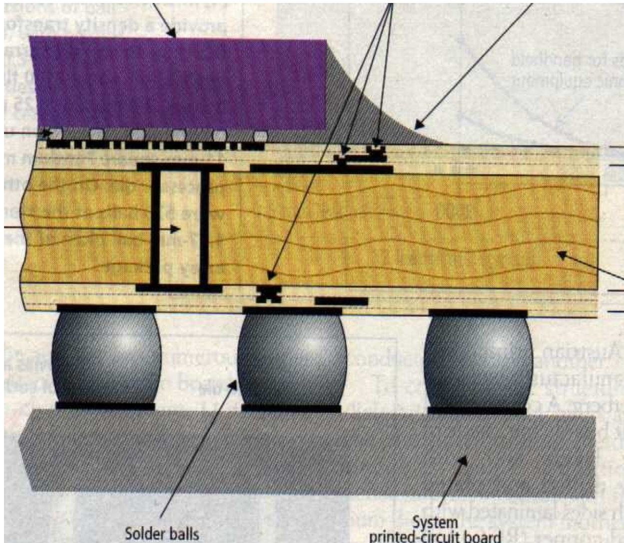
- Scribe
- solder



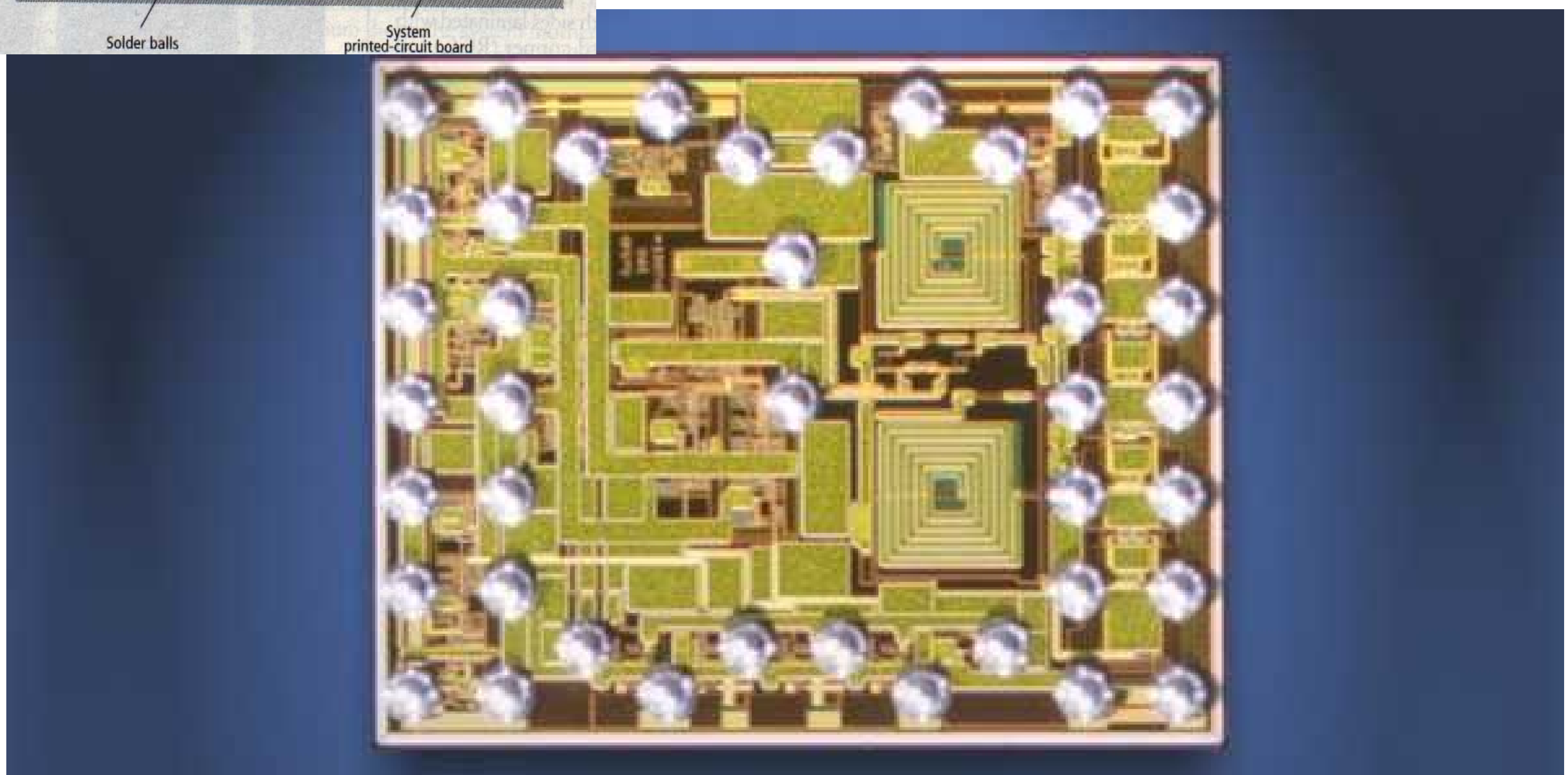
encapsulations





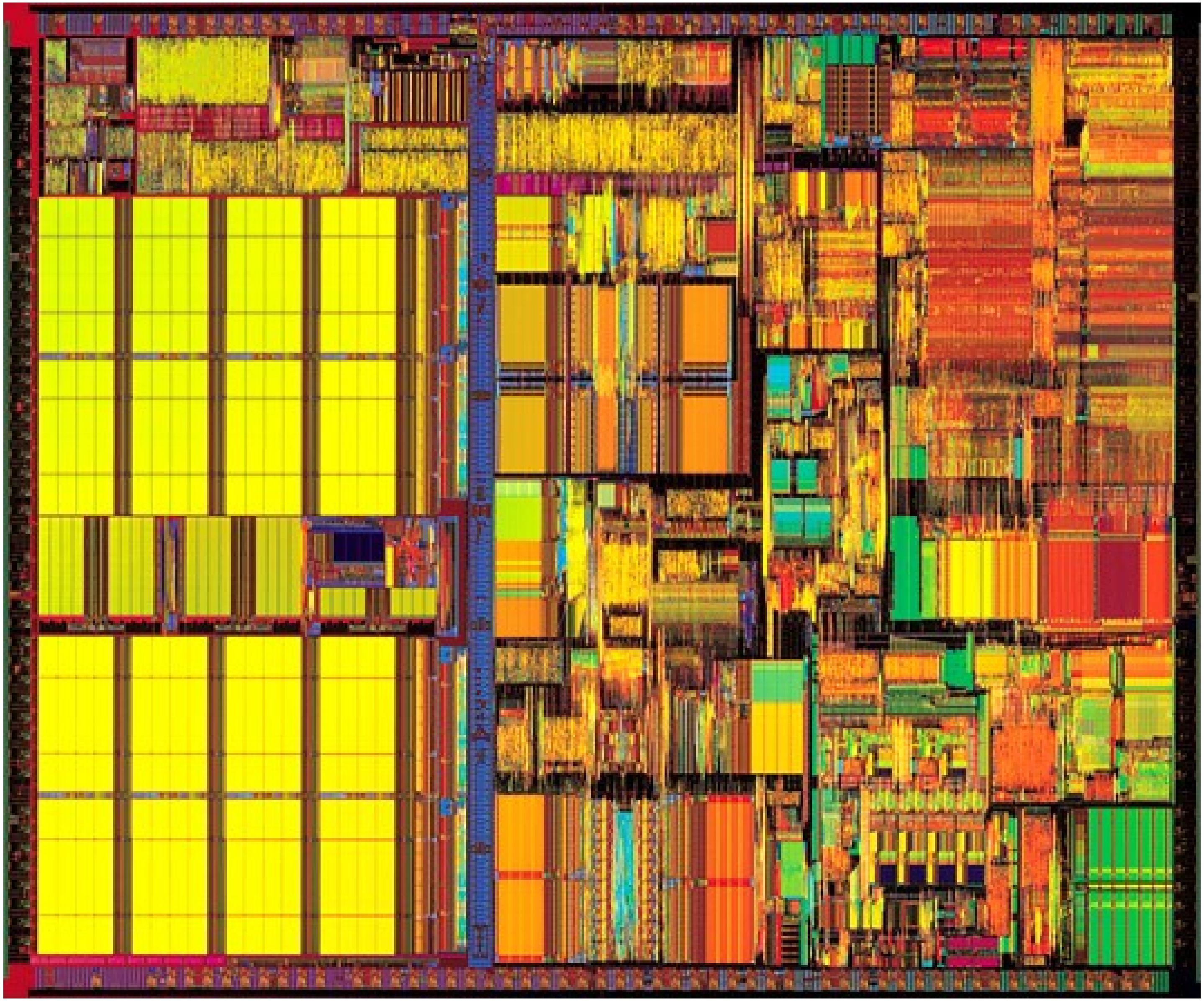


BGA



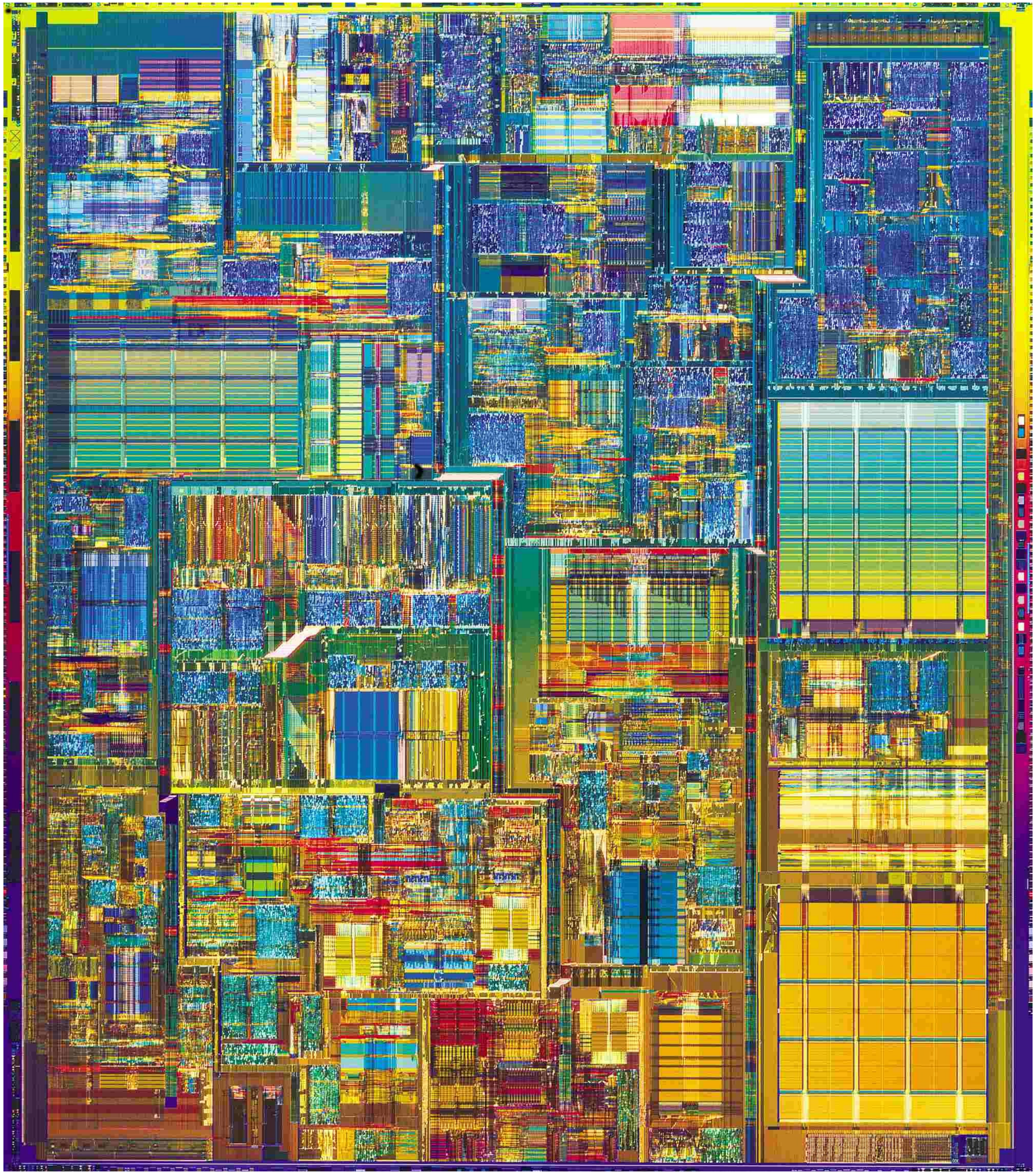
1999: Pentium® III Processor

- The Pentium® III processor features 70 new
- instructions--Internet Streaming SIMD extensions-- that
- dramatically enhance the performance of advanced imaging,
- 3-D, streaming audio, video and speech recognition
- applications. It was designed to significantly enhance Internet
- experiences, allowing users to do such things as browse
- through realistic online museums and stores and download
- high-quality video. The processor incorporates **9.5 million**
- **transistors**, and was introduced using **0.25-micron**
- technology.

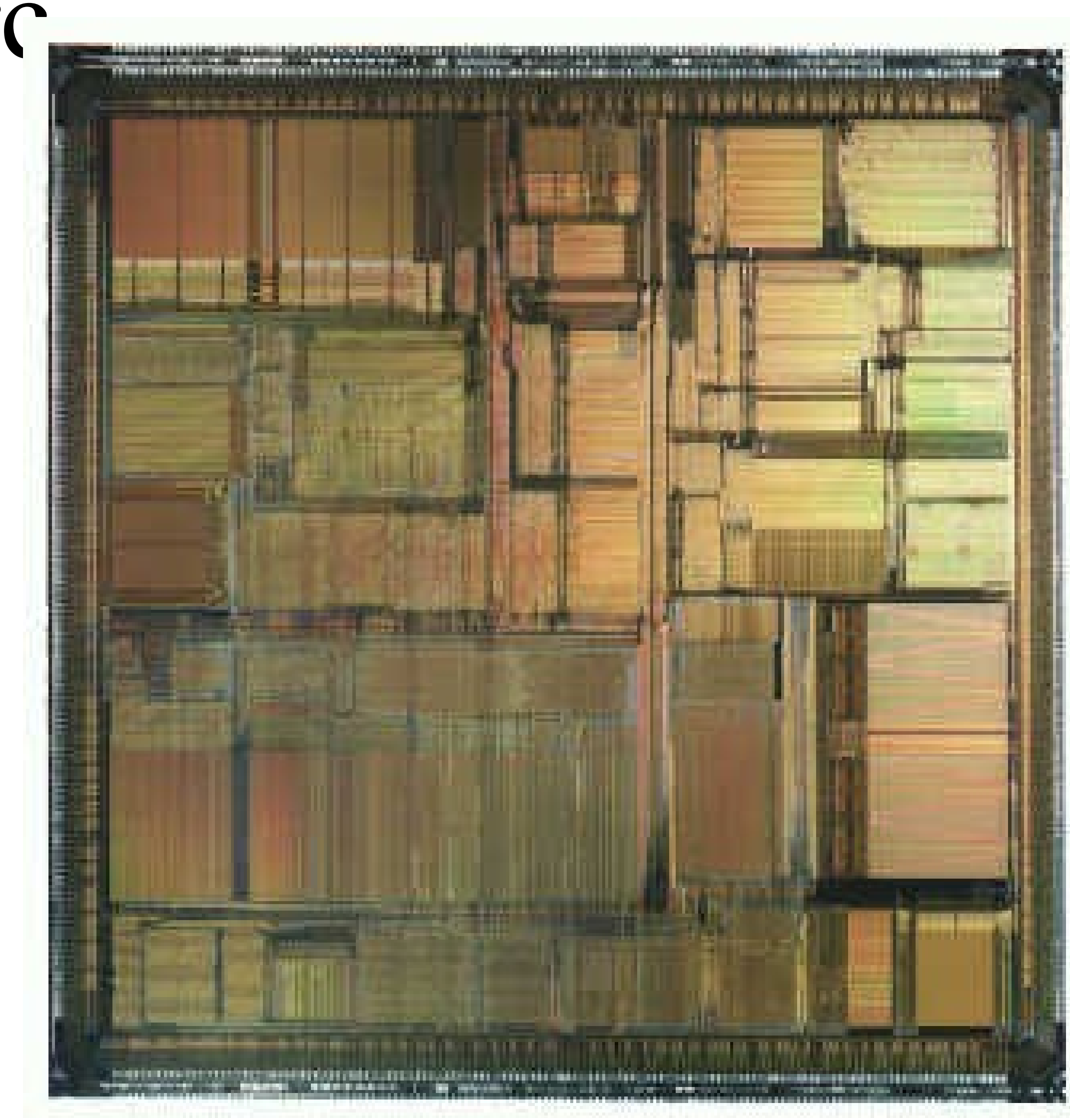


2000: Pentium® 4 Processor

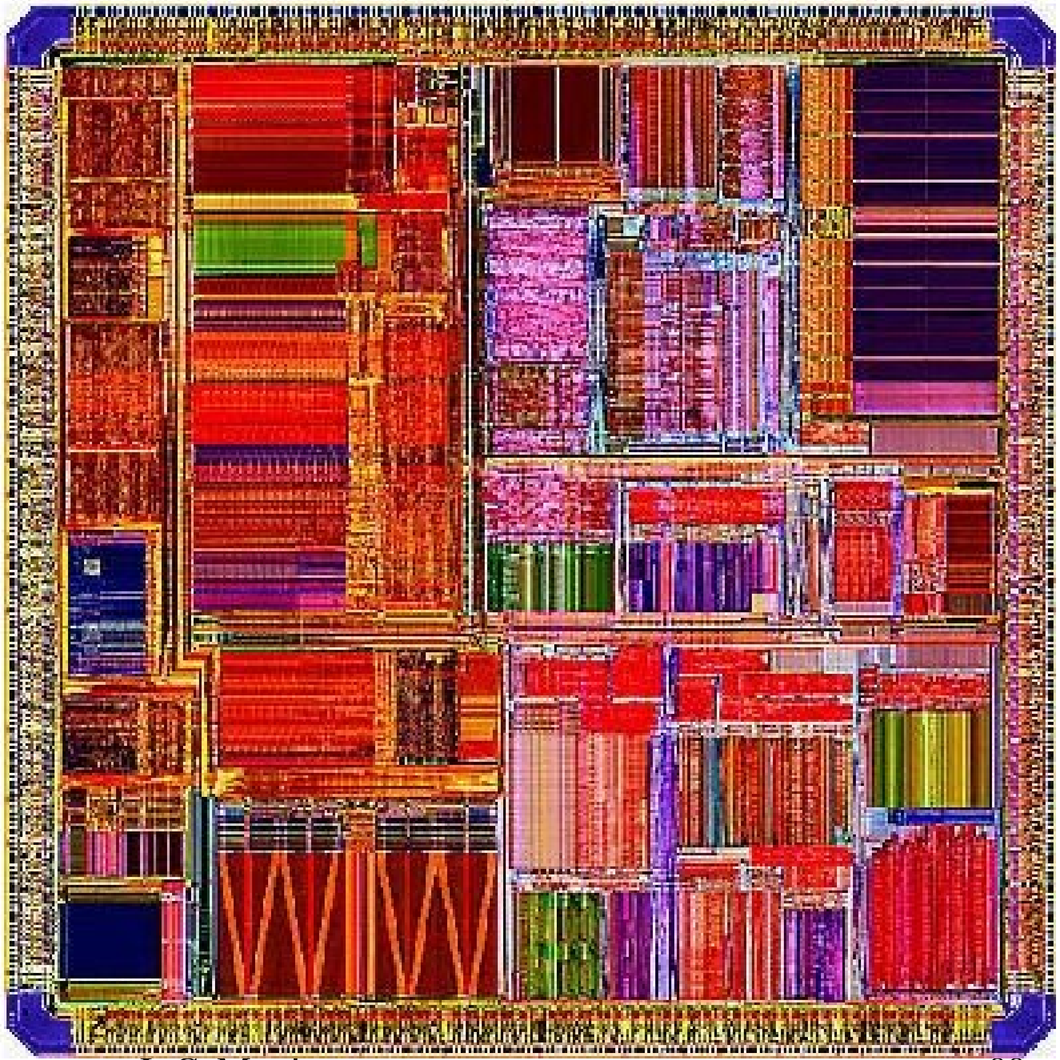
- Users of Pentium® 4 processor-based PCs can create
- professional-quality movies; deliver TV-like video via the
- Internet; communicate with real-time video and voice; render
- 3D graphics in real time; quickly encode music for MP3
- players; and simultaneously run several multimedia
- applications while connected to the Internet. The processor
- debuted with **42 million transistors** and circuit lines of **0.18**
- **microns**. Intel's first microprocessor, the 4004, ran at 108
- kilohertz (108,000 hertz), compared to the Pentium® 4
- processor's initial speed of **1.5 gigahertz** (1.5 billion hertz). If
- automobile speed had increased similarly over the same
- period, you could now drive from San Francisco to New York
- in about 13 seconds.



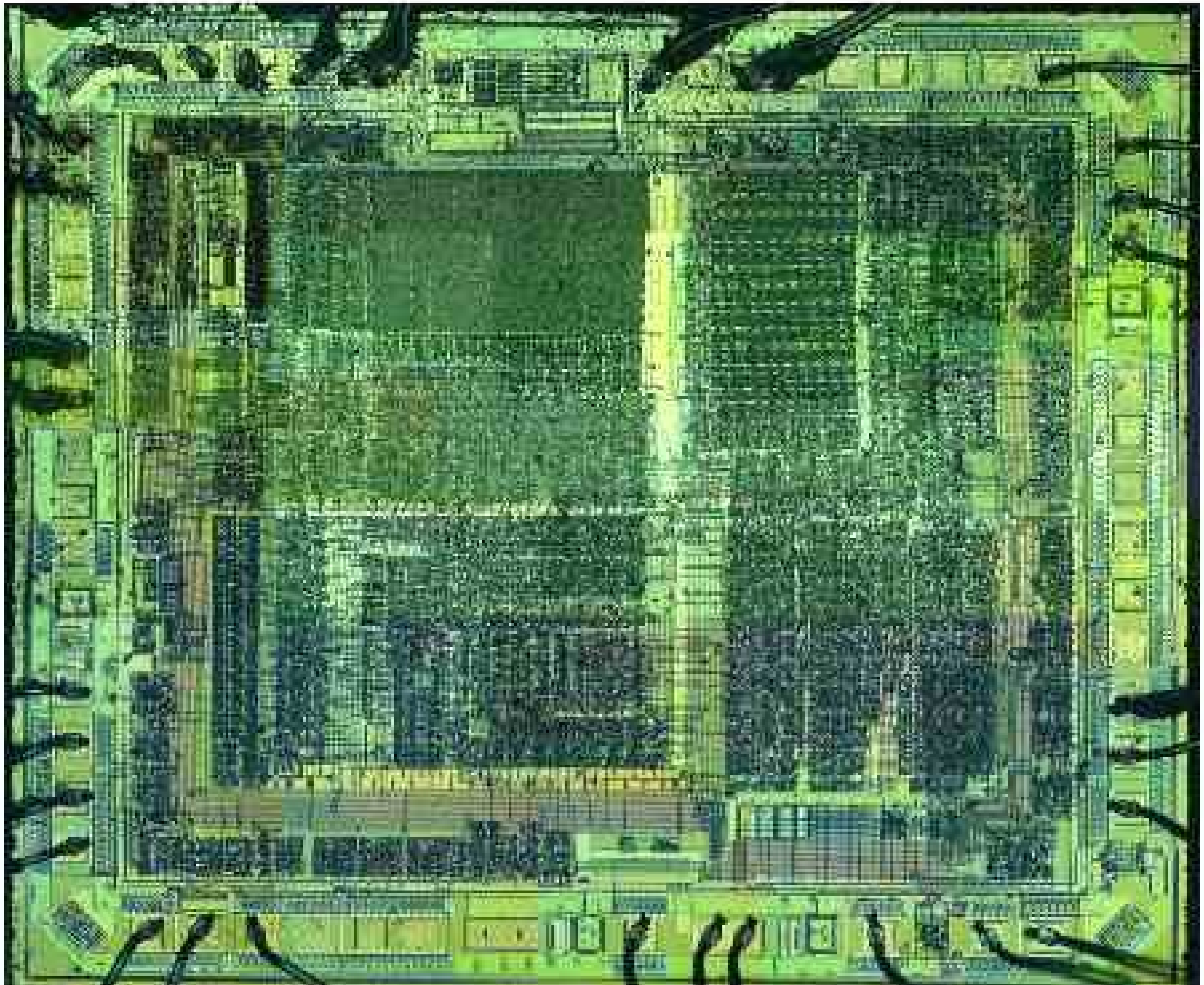
Ultra Sparc



UltraSPARC



Microcontroleur PIC16C62A / JW

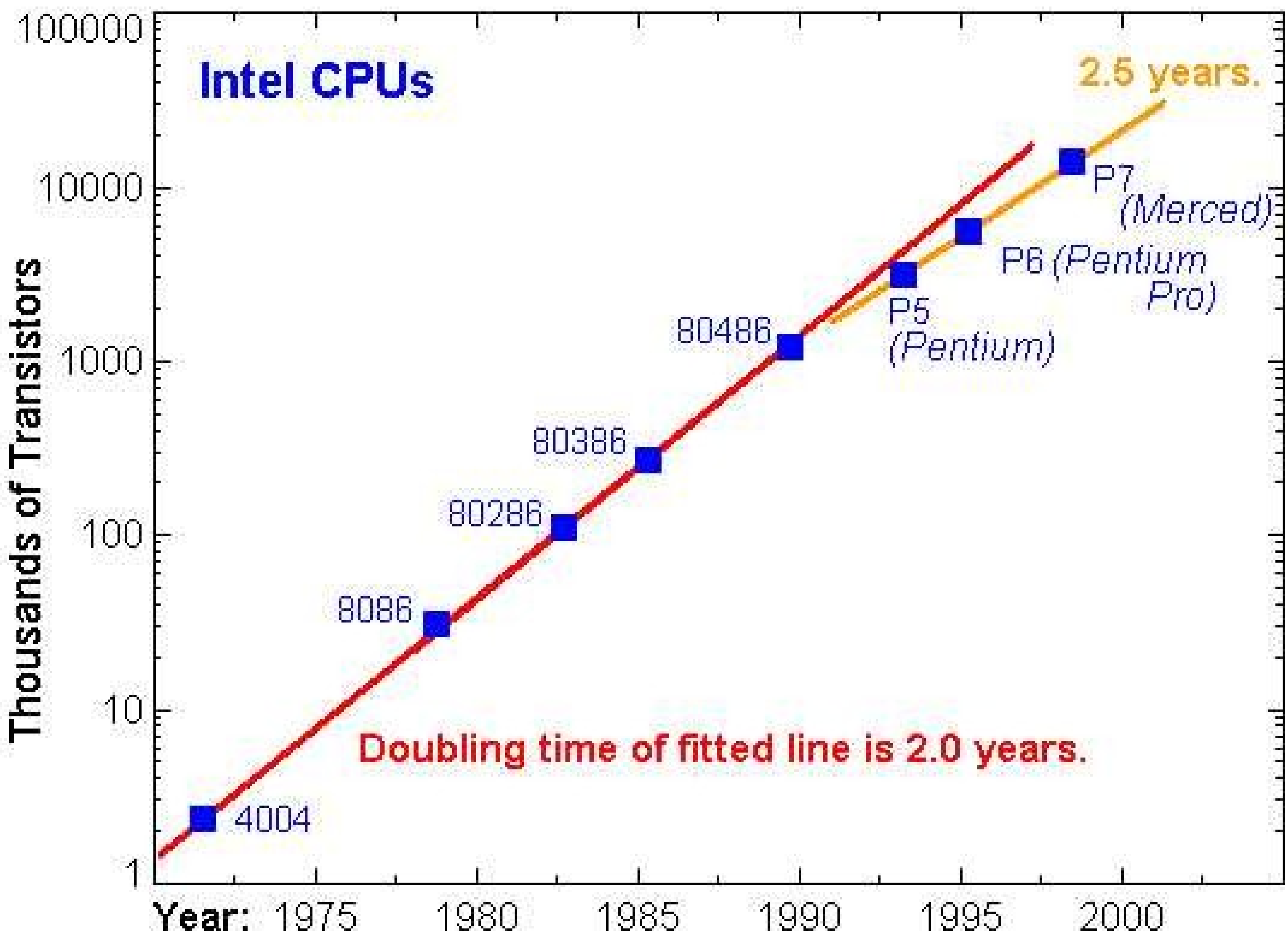


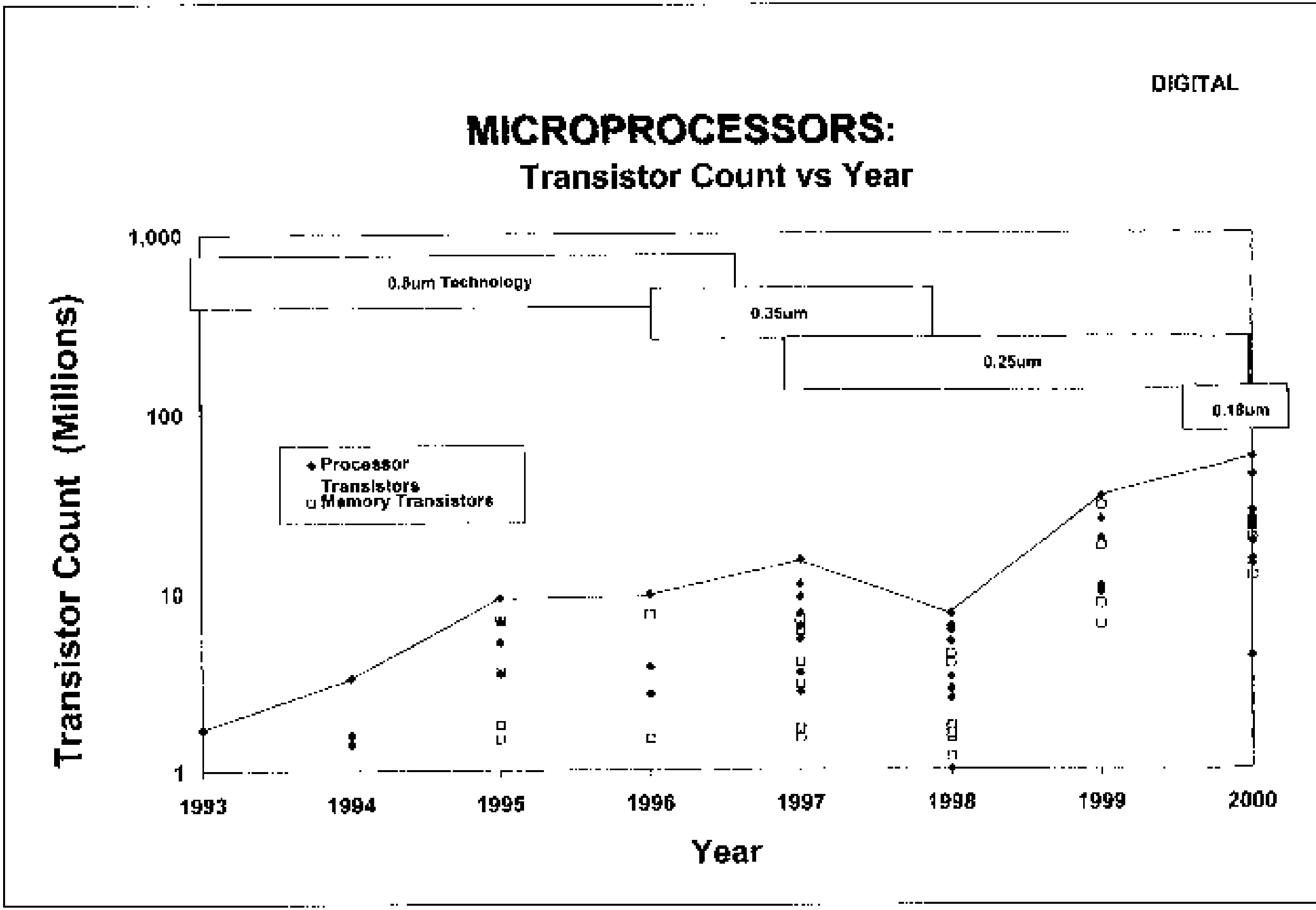
Projet de Semaines X
10. octobre 2002

Gorbaye Roky
Encadré par J.-C. Martin

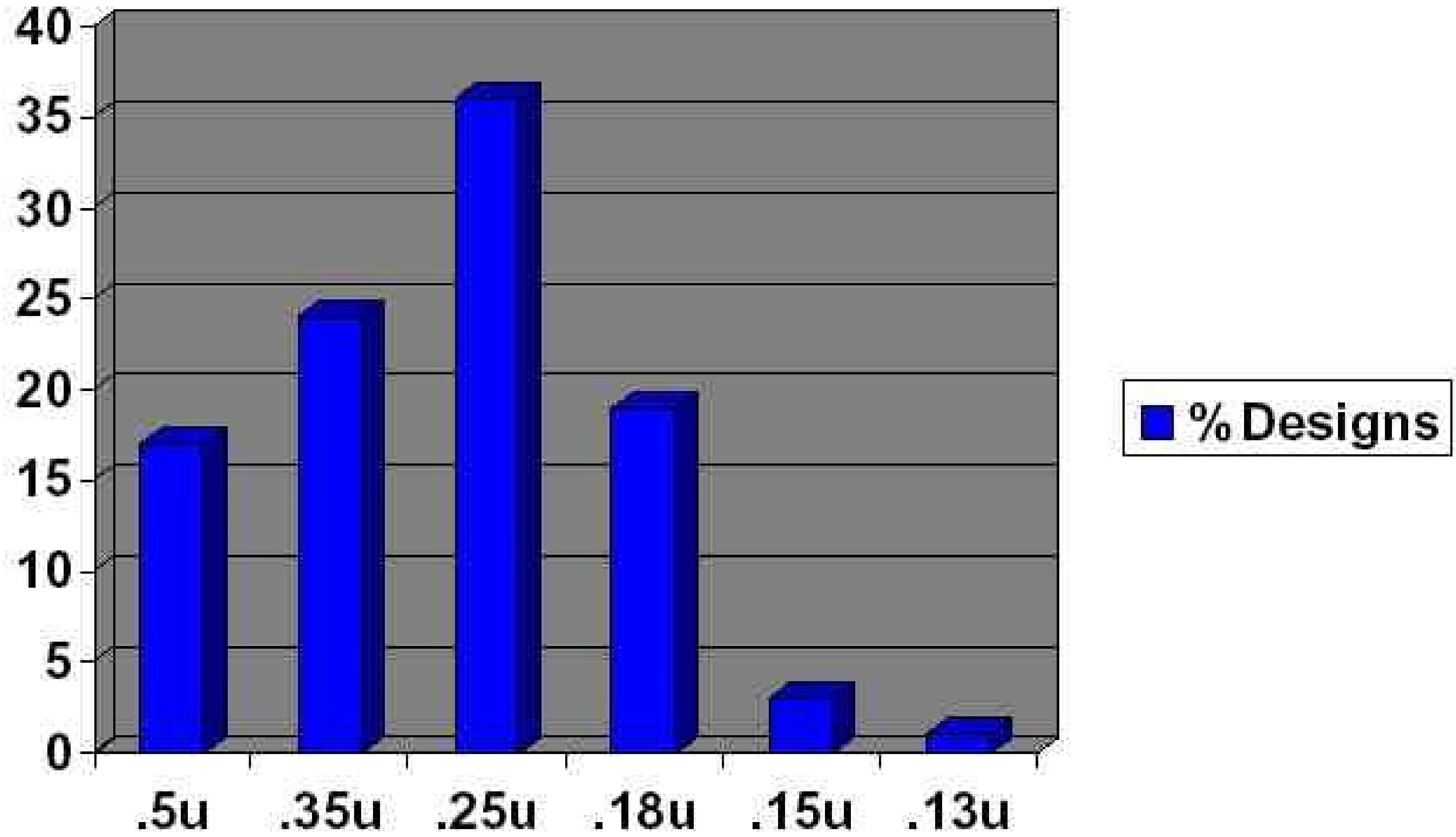
A l'aide de Riadh Ghezal et Christoph Sudan

Moore's law


Intel CPUs
2.5 years.
Thousands of Transistors
100000
10000
1000
100
10
1
P7
(Merced)
P6 (Pentium
Pro)
P5
(Pentium)
80486
80386
80286
8086
4004
Doubling time of fitted line is 2.0 years.
Year: 1975
1980
1985
1990
1995
2000

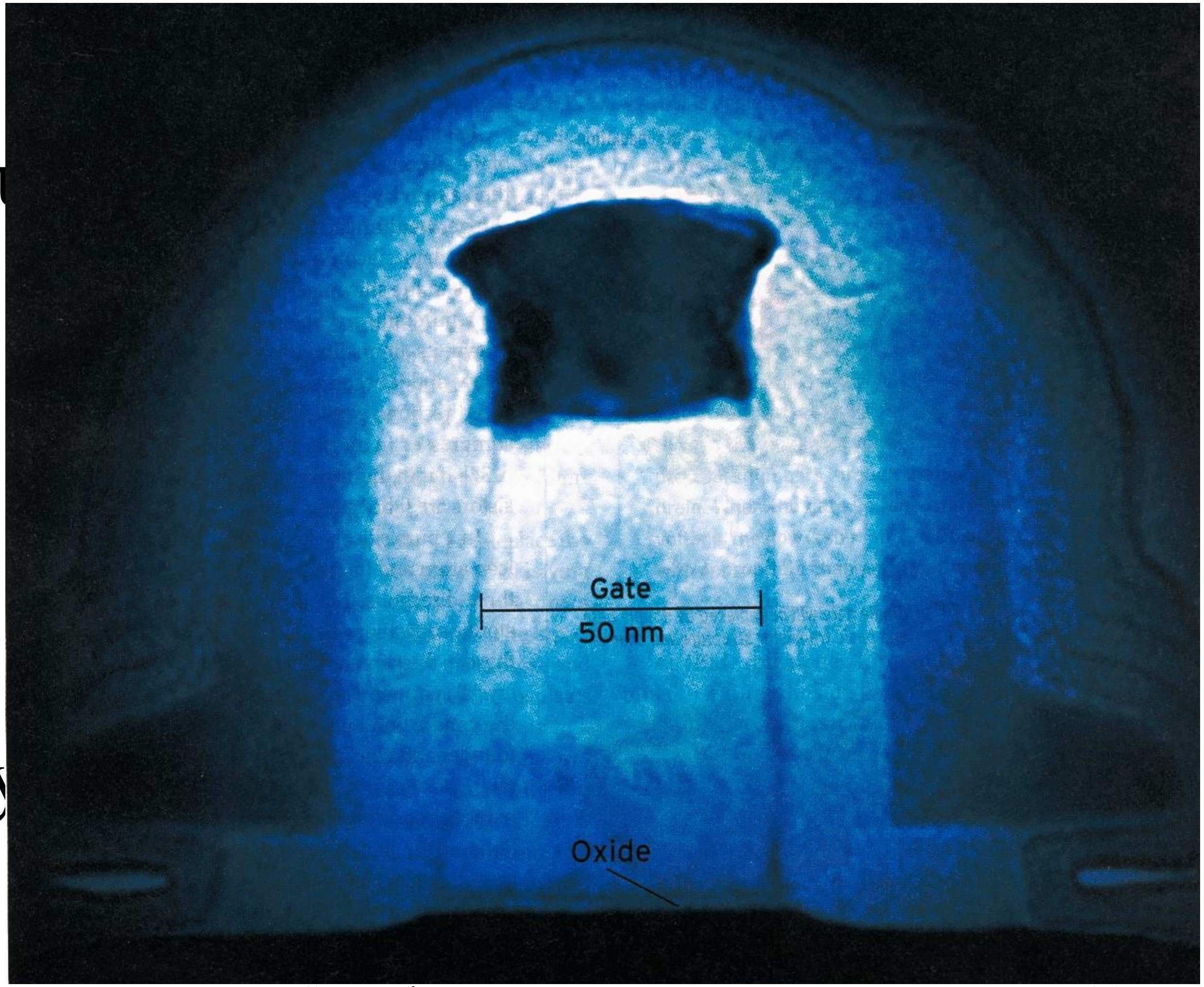

DIGITAL
MICROPROCESSORS:
Transistor Count vs Year
Transistor Count (Millions)
1,000
100
10
1
0.8um Technology
0.35um
0.25um
0.18um
Processor Transistors
Memory Transistors
1993
1994
1995
1996
1997
1998
1999
2000
Year

Transistor size in 2000

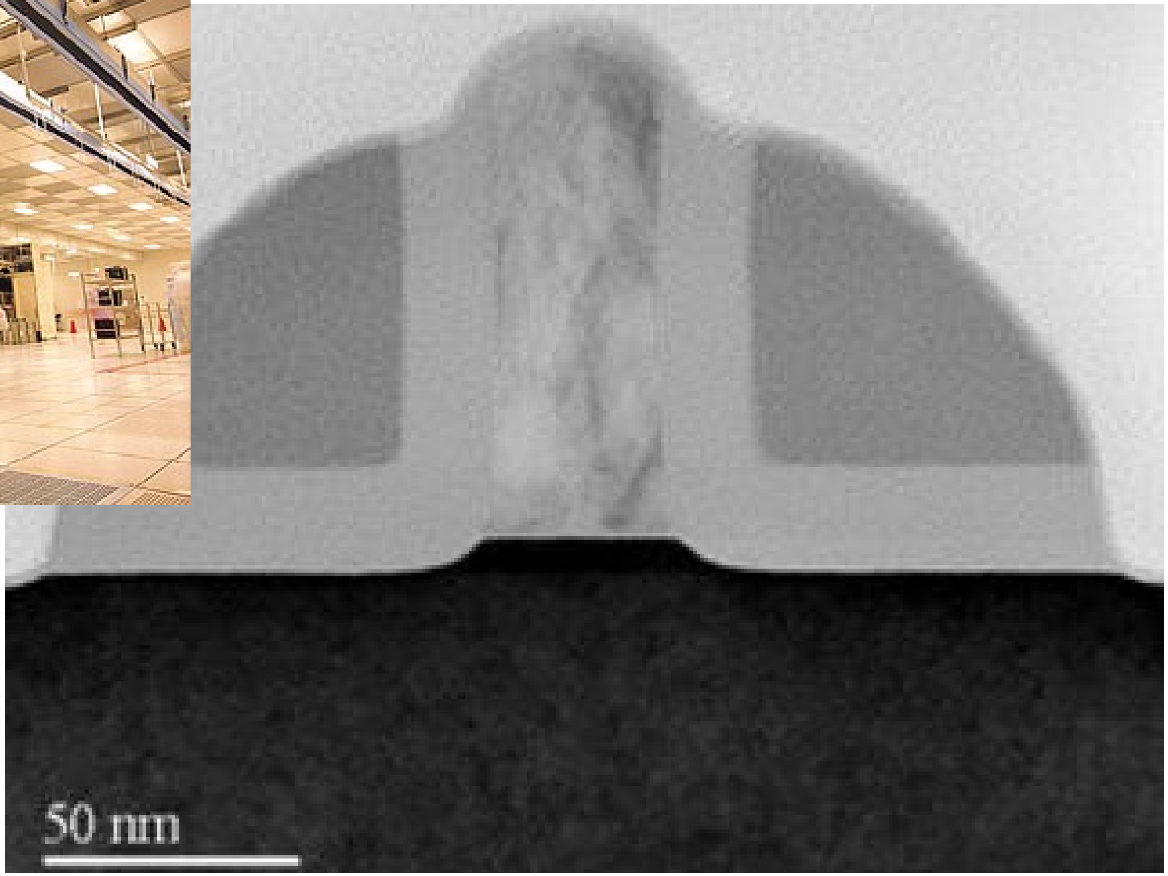


Nano MOS

- IEEE Spectru
- oct. 2002
- Intel
- prod. 2003
- L=50nm
- tox=5 at. Lay

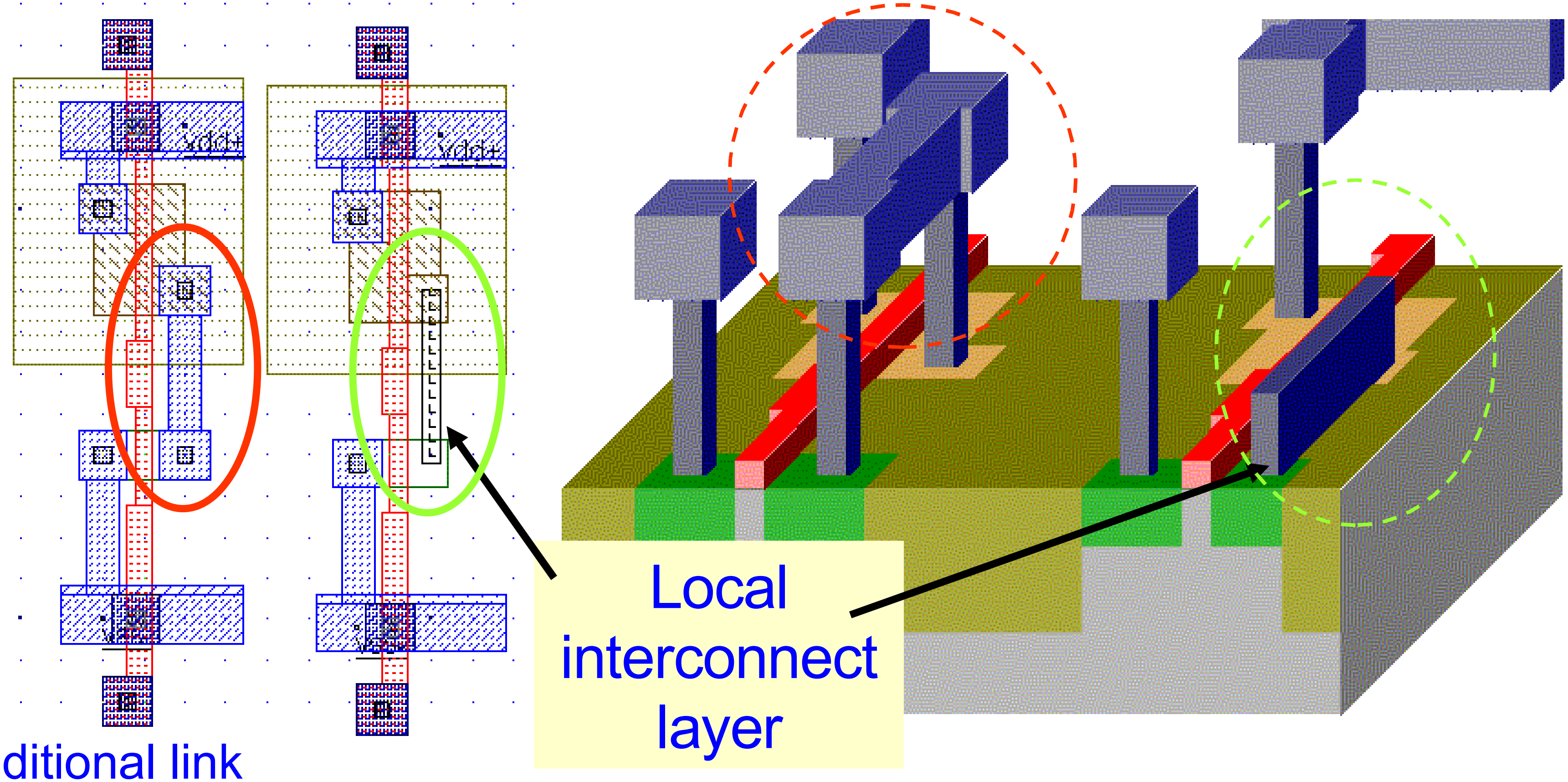


Méga usines pour nm !



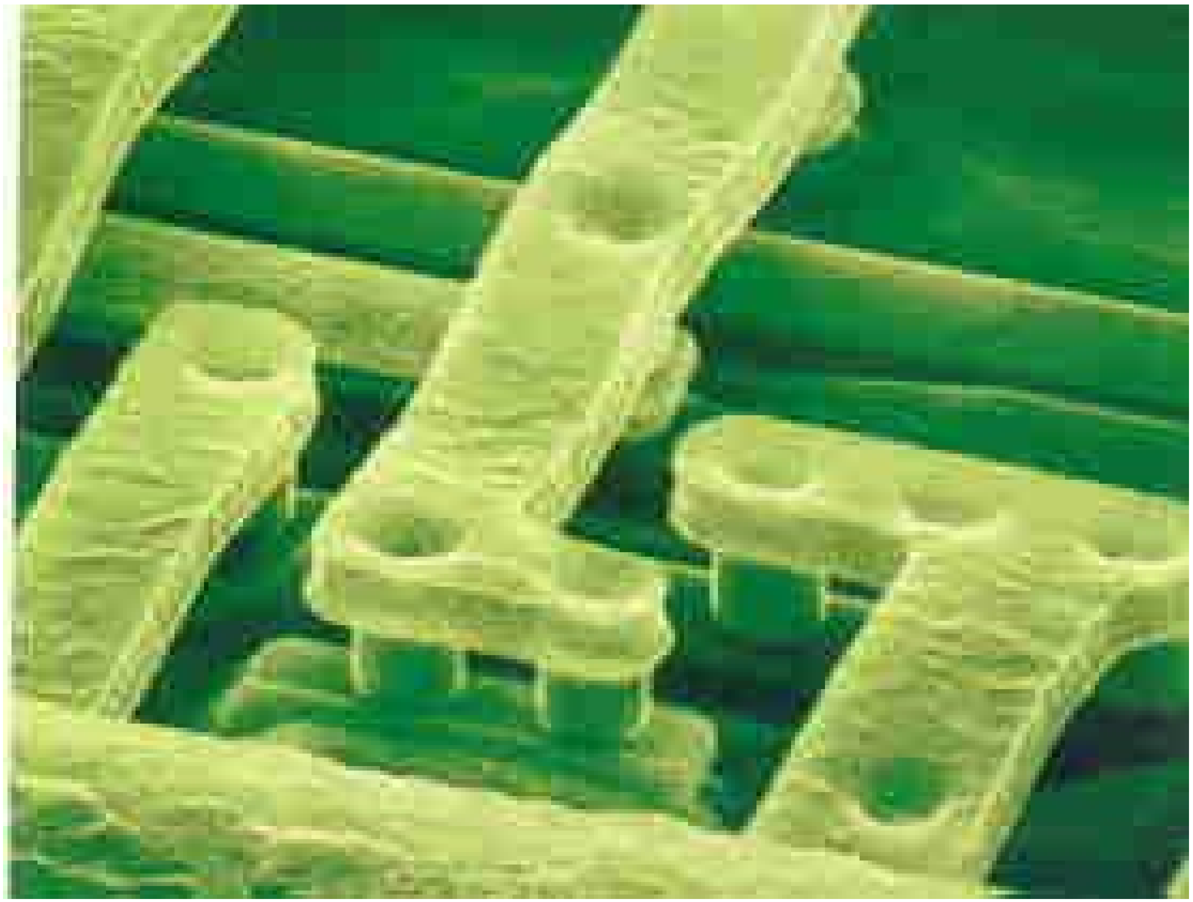
Multi metal

Ultra Deep Submicron features

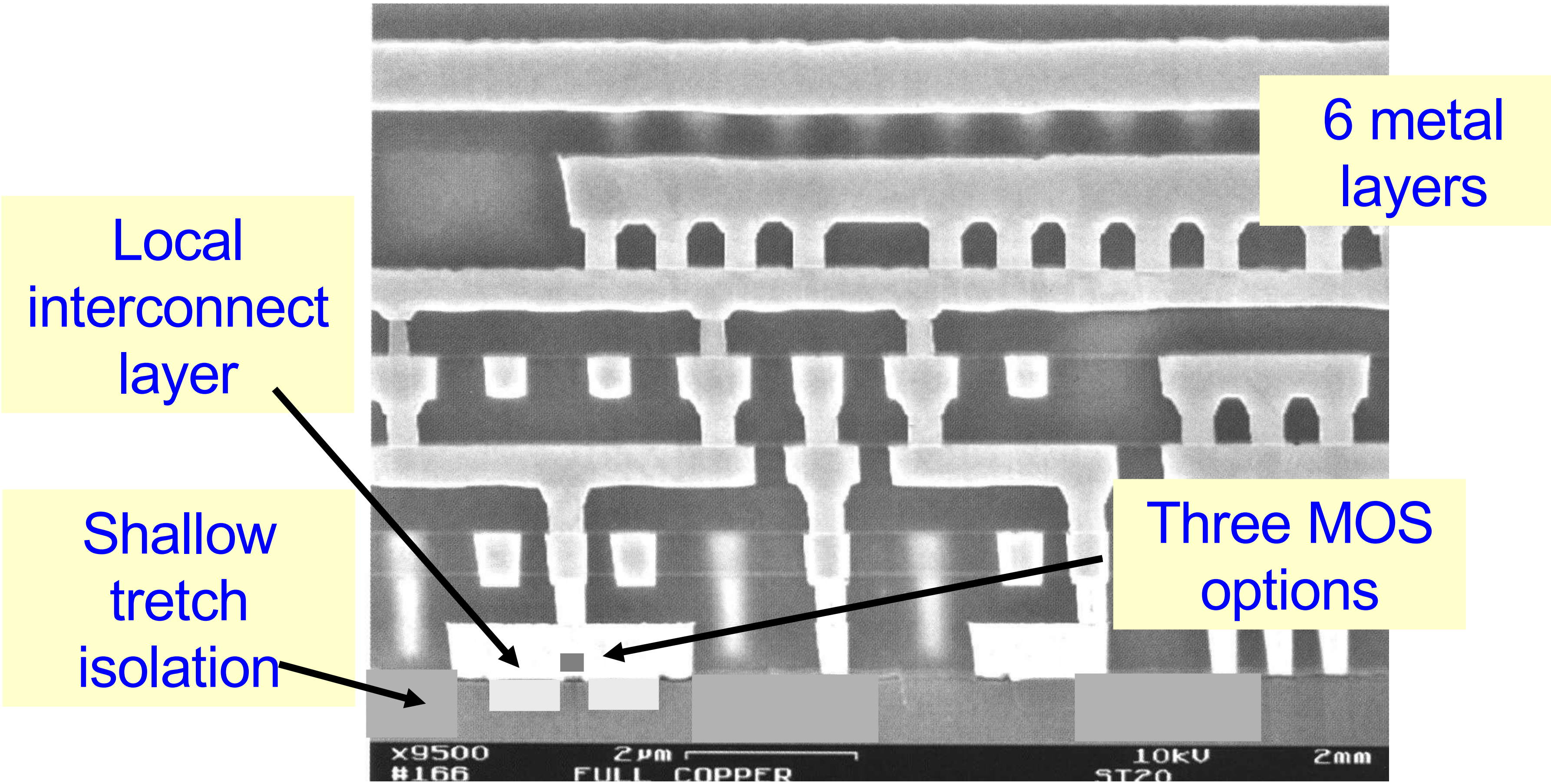


Traditional link nMOS/pMOS

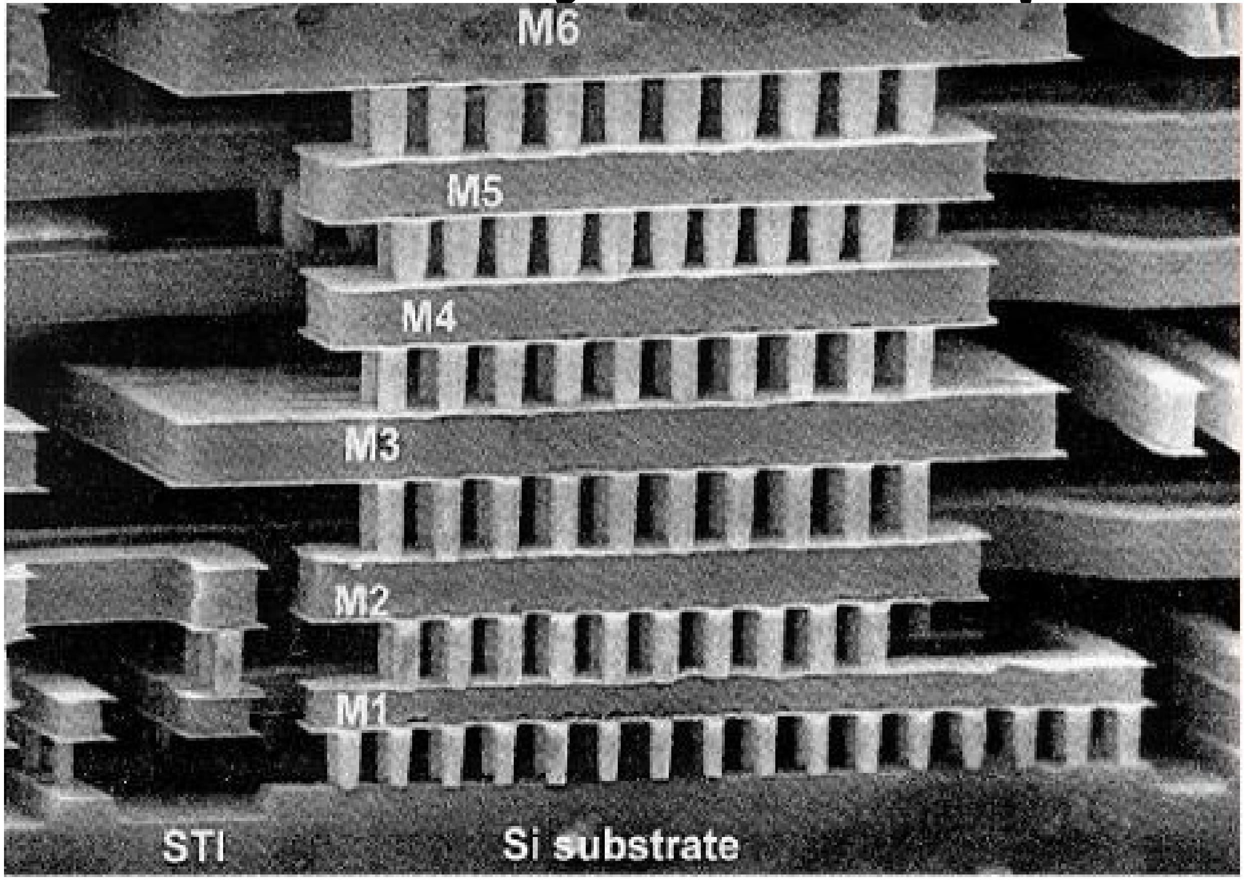
EPROM 4M (see via)

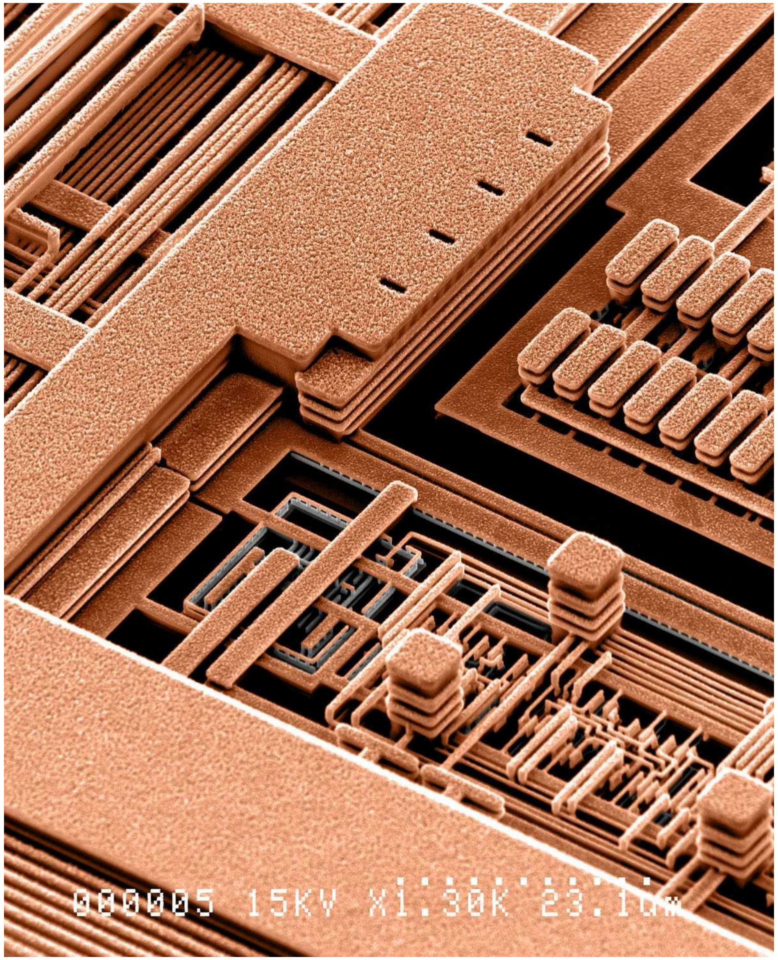
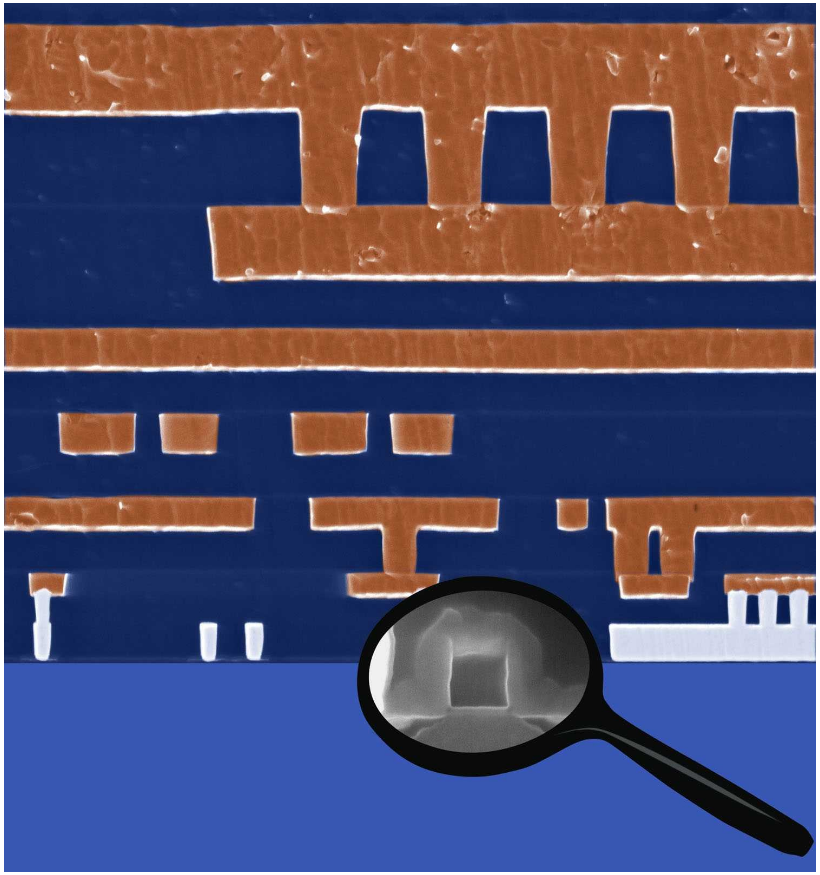


Ultra Deep Submicron features



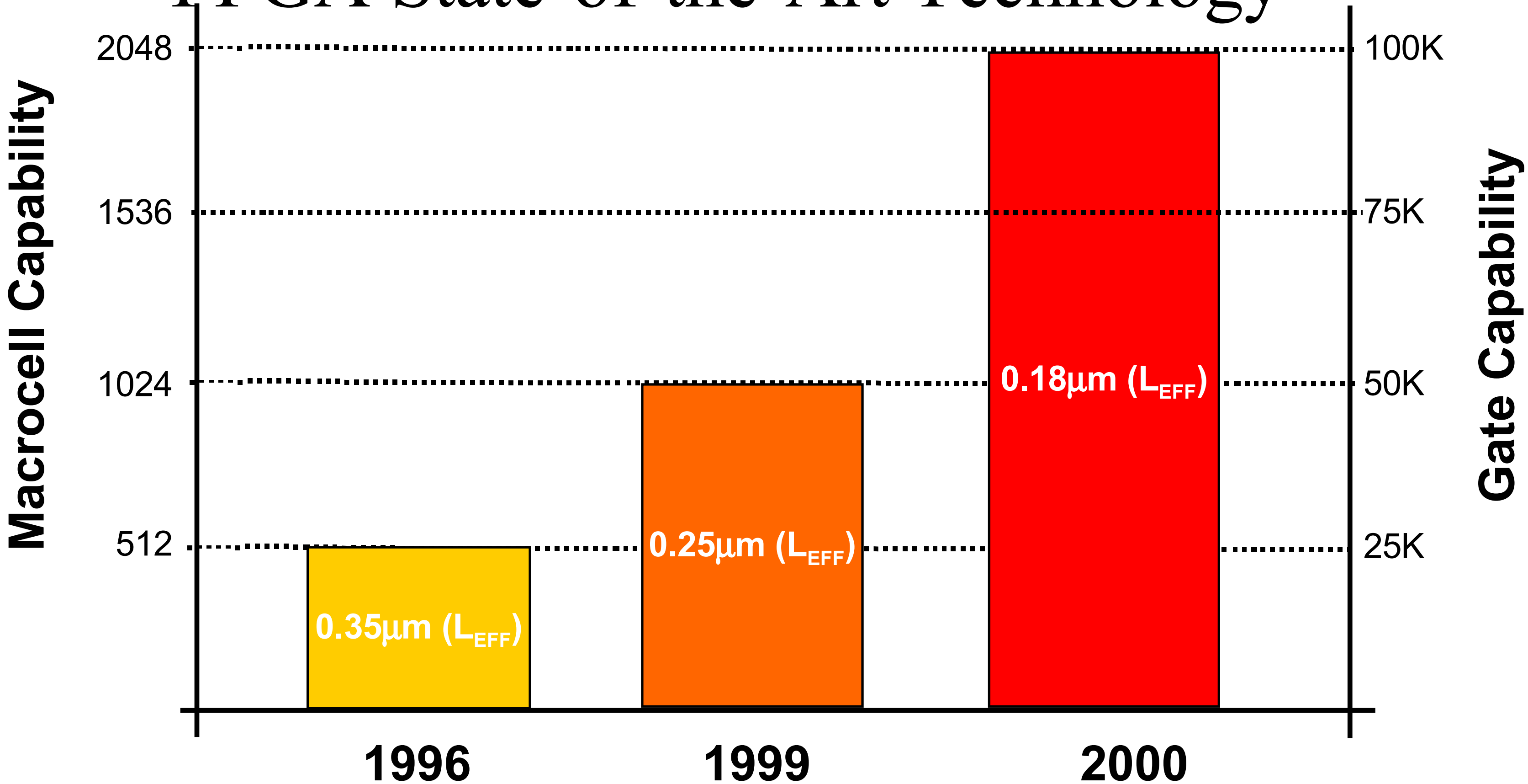
6 metal layers, 0.25μm




000005 15KV X1.30K 23.1um


FPGA

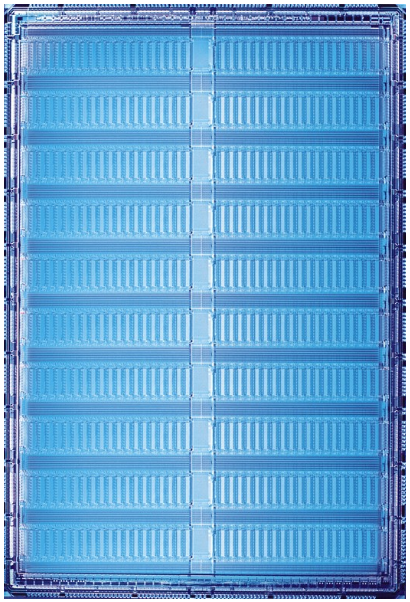
FPGA State-of-the-Art Technology

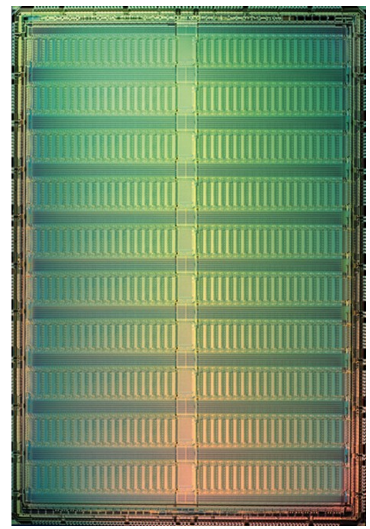


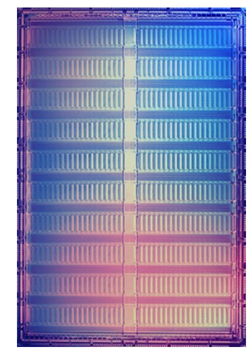
Core Voltage	3V	3V / 2.5V	1.8V
Vcc Support	5V / 3V	5V / 3V / 2.5V	3V / 2.5 / 1.8V
I/O Support	5V / 3V	5V / 3V / 2.5V	5V / 3V / 2.5V / 1.8V

Lattice Semiconductor Corporation

Evolution of fabrication (Altera)



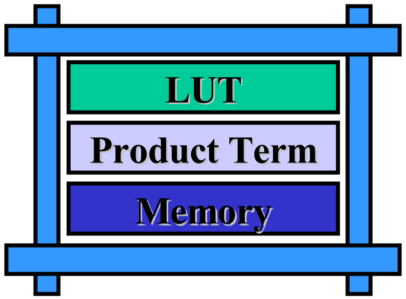




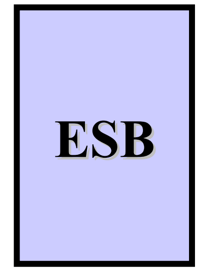
	EPF10K50	**EPF10K50**	**EPF10K50A**
	0.6-Micron Triple-Layer Metal	0.5-Micron Triple-Layer Metal	0.35-Micron Quad-Layer Metal
Relative Die Size:	1.0	0.78	0.32

APEX Architectural Innovation

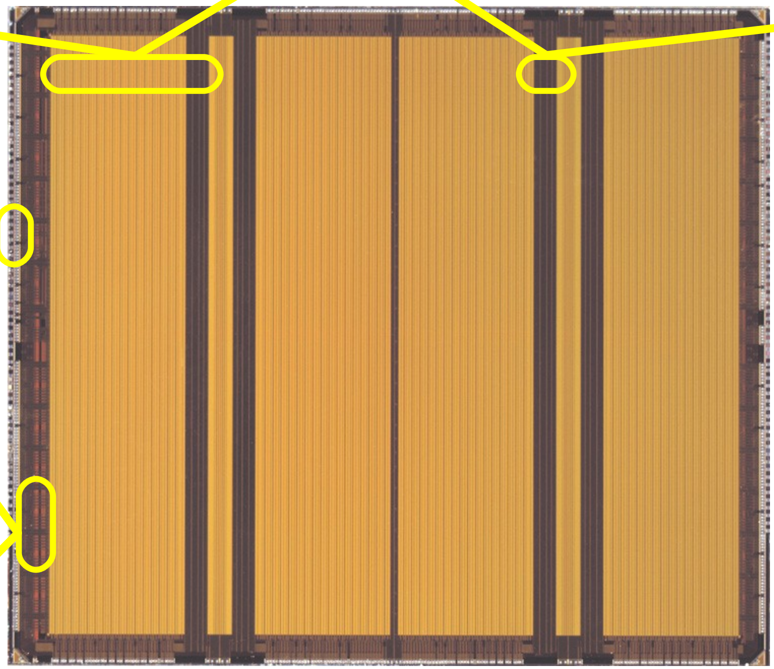
MultiCore™ Architecture



Embedded System Block (ESB)



- Product Term
- Dual-Port RAM
- ROM
- CAM



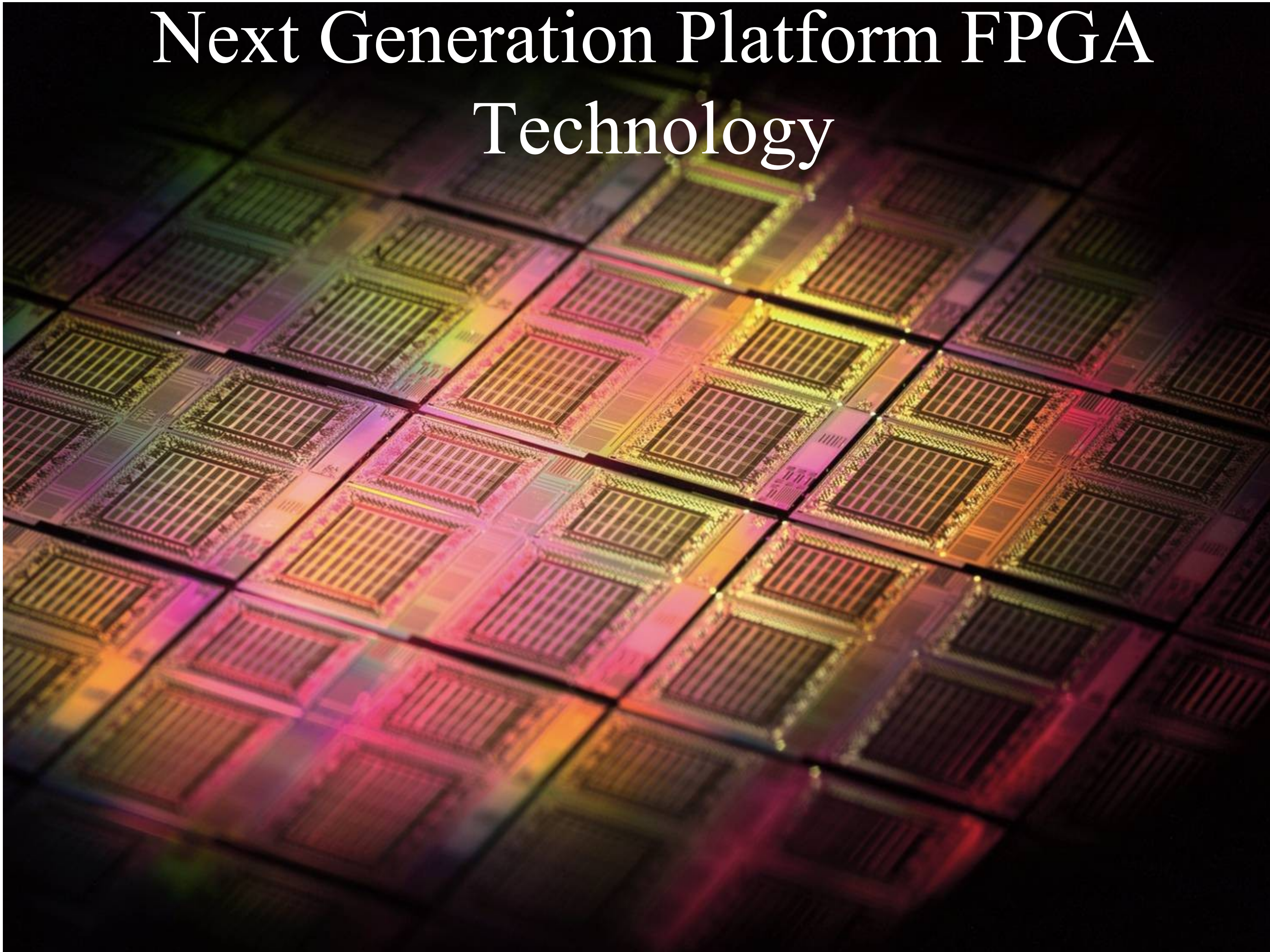
I/O Features

- LVDS
- MultiVolt I/O
- GTL+
- CTT
- AGP
- SSTL-3/-2
- HSTL

Clock Management

- Up to 4 PLLs
- ClockShift™ Circuitry
- ClockBoost™ Circuitry
- ClockLock™ Circuitry

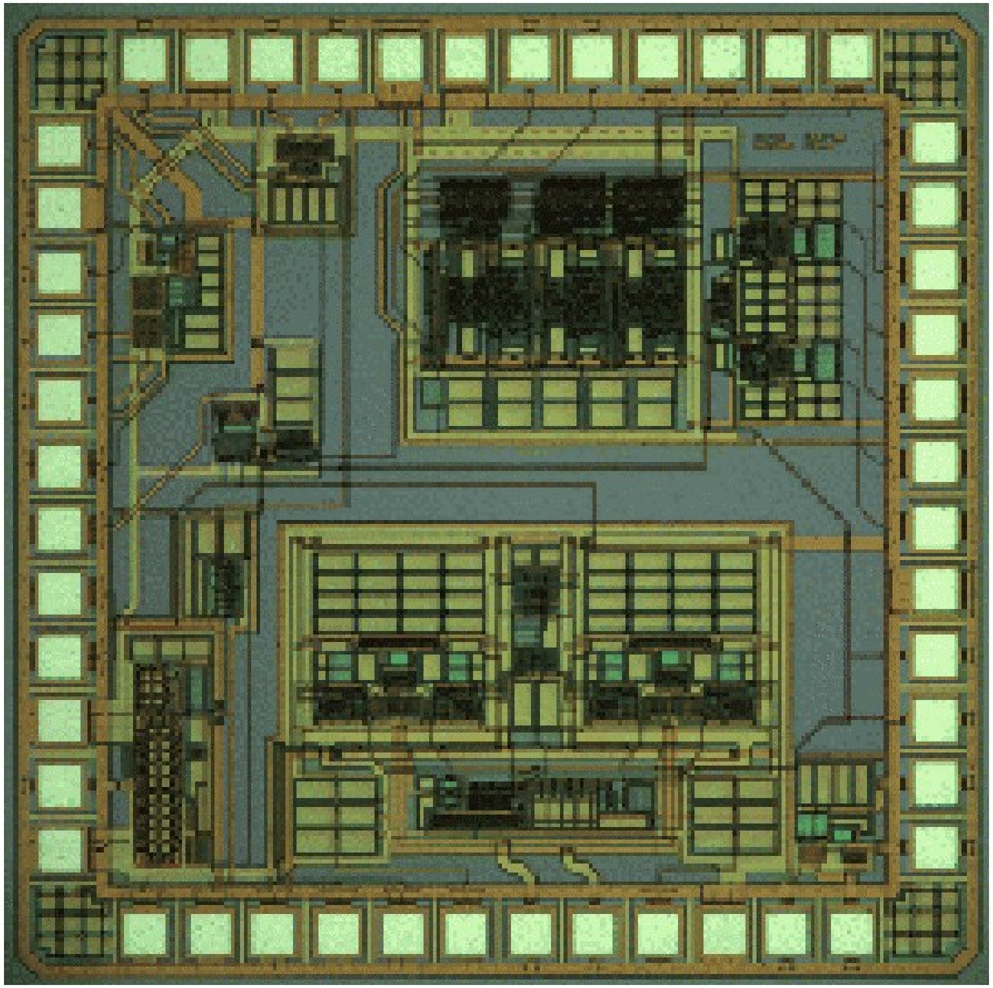
Next Generation Platform FPGA Technology



Phone

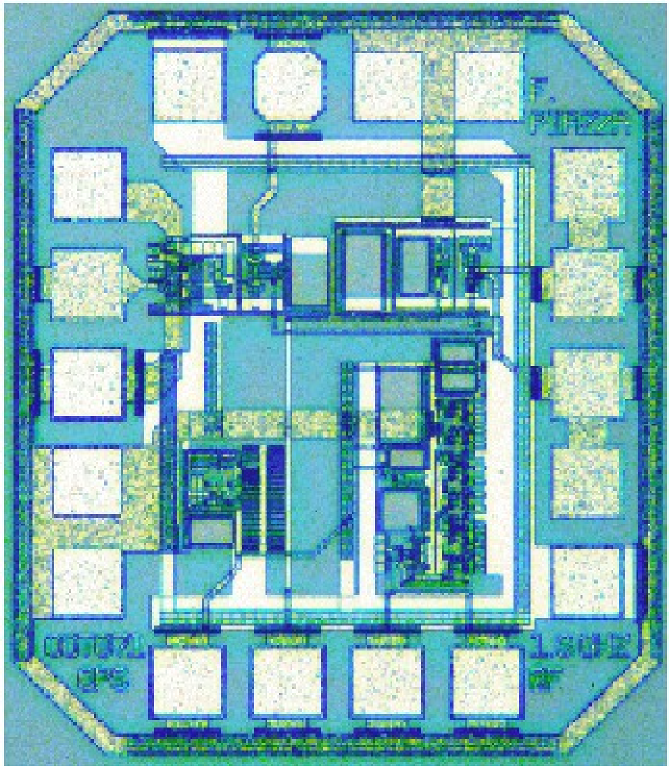
Tchip Semiconductor SA

GSM transciever 0.25uCMOS



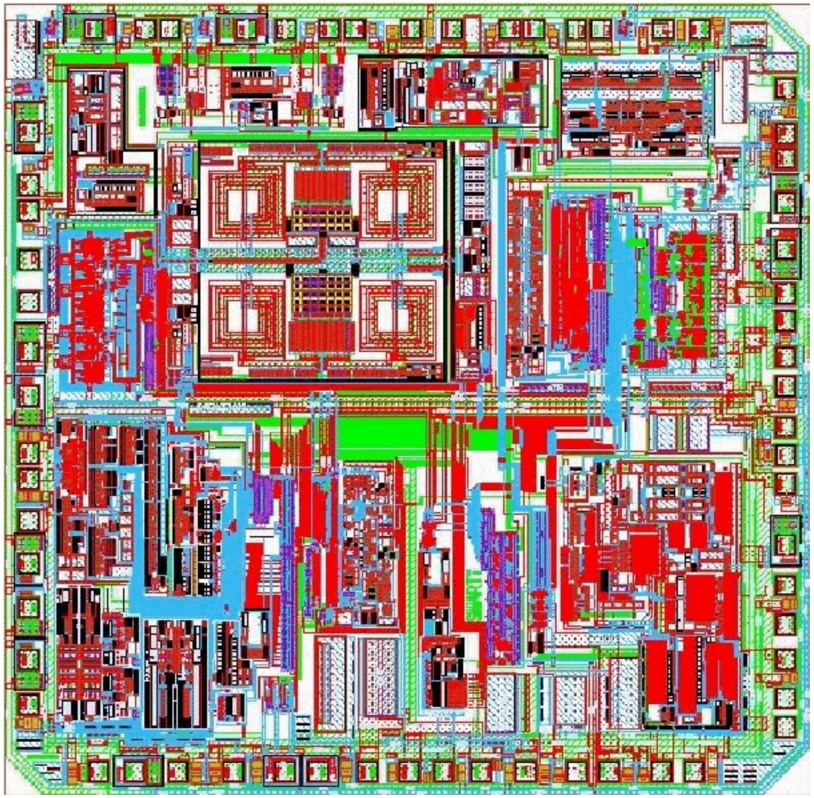
Tchip Semiconductor SA

- GPS receiver front end, 1μm BiCMOS



BiCMOS

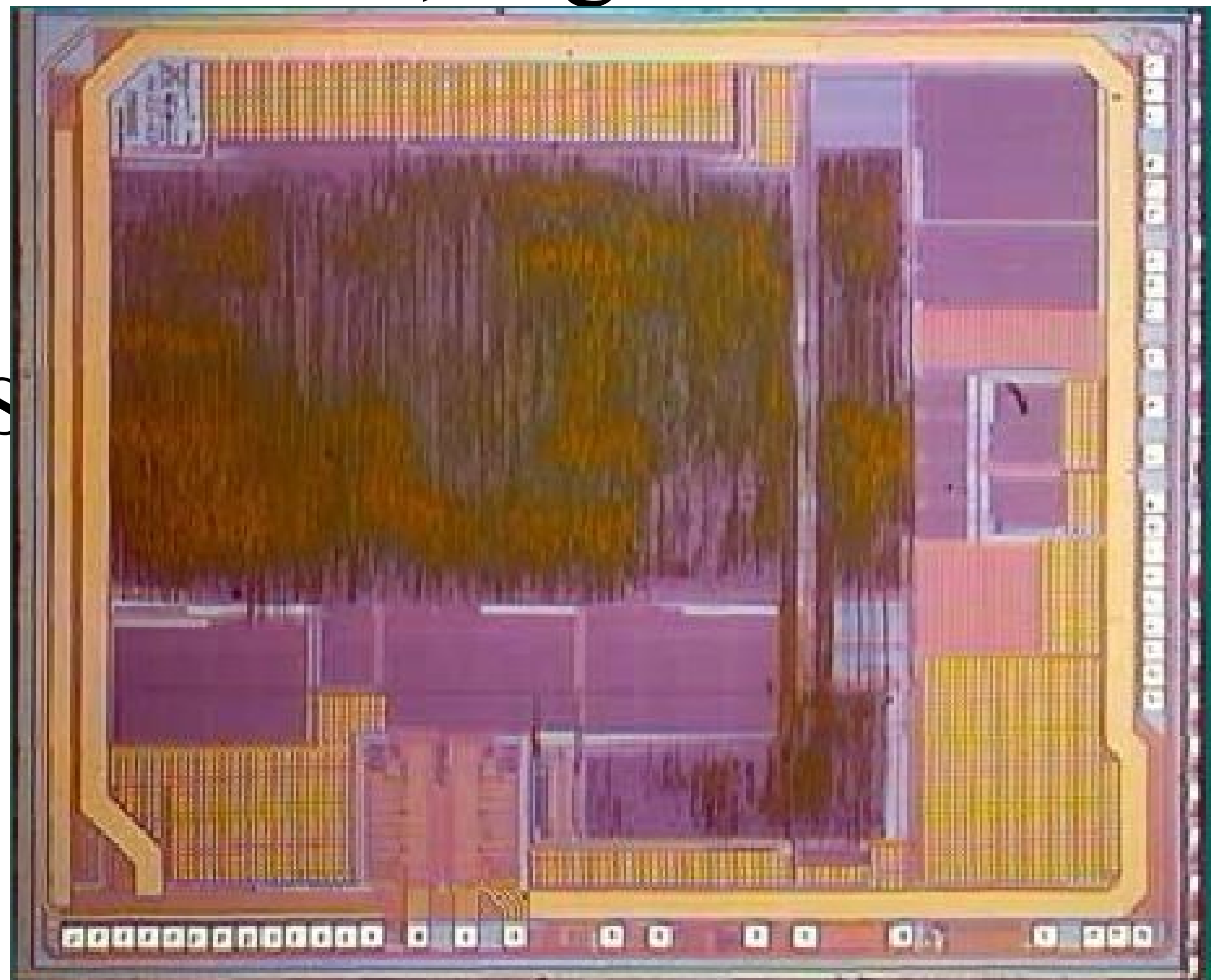
- GSM transciever (12 000 composants, Infinion TLD2000)



IC in Switzerland

Neuchâtel (EM, CSEM)

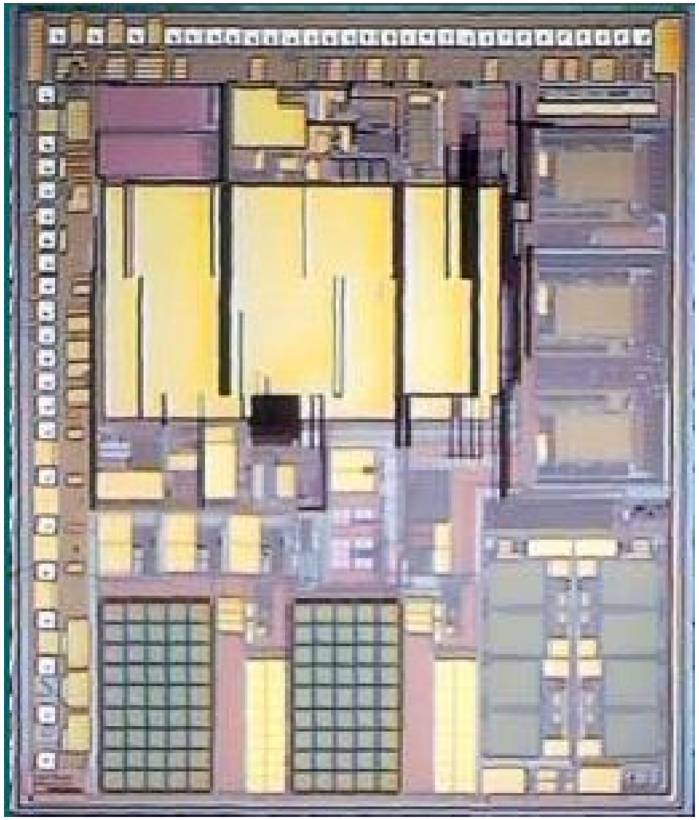
PHONAK, digital



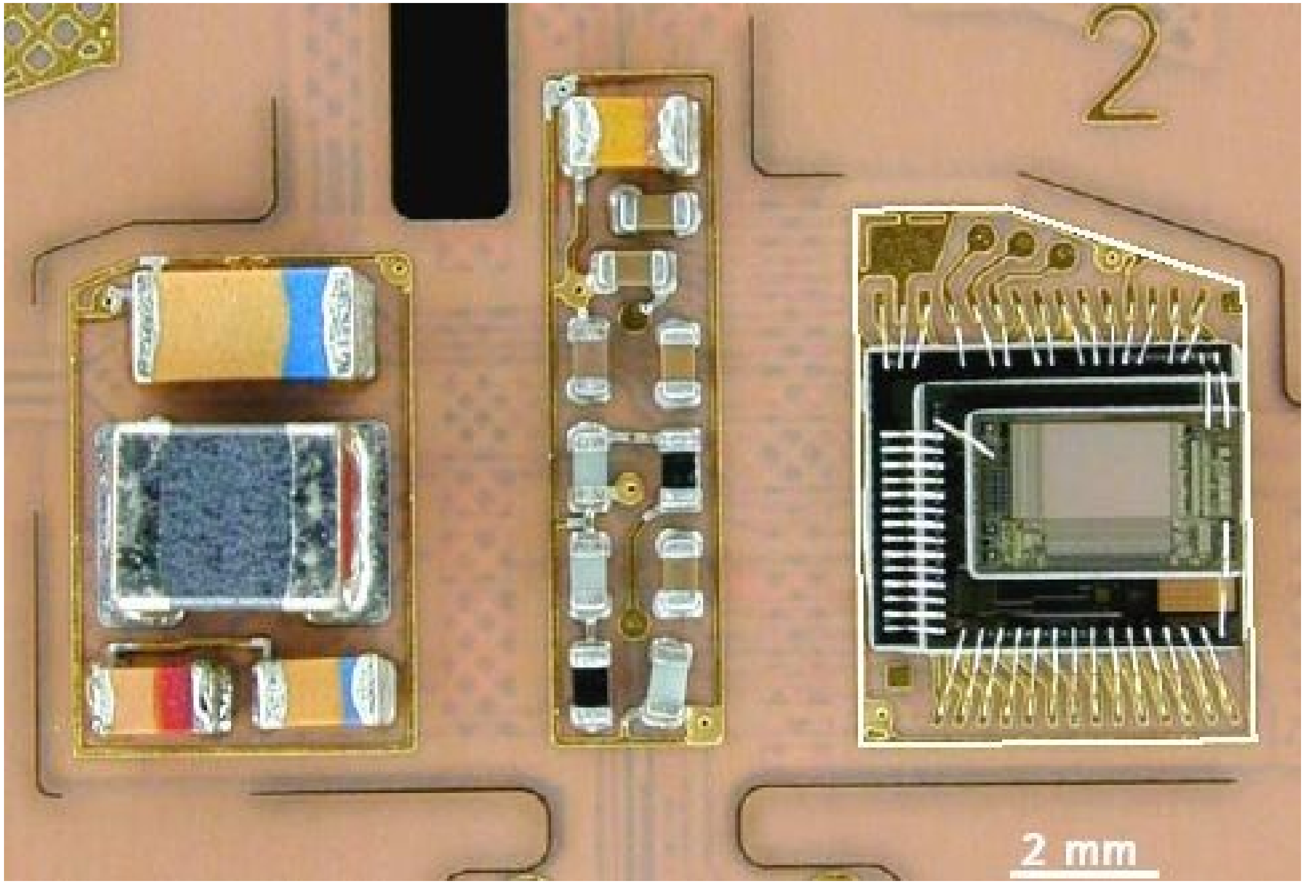
- 0.25µm
- $20mm^2$
- 1.3M MOS
- 2.5MHz
- 1V
- 720µW

Phonak, analog et EEPROM

- A/D
- D/A
- EEPROM

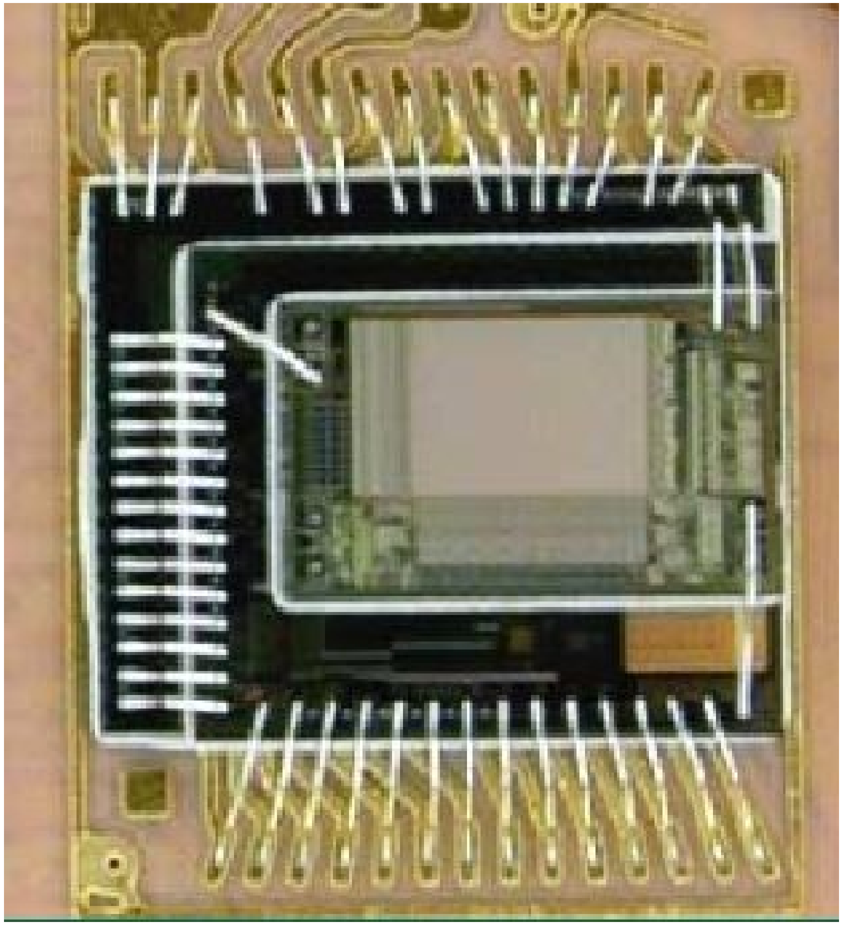


Phonak, PCB



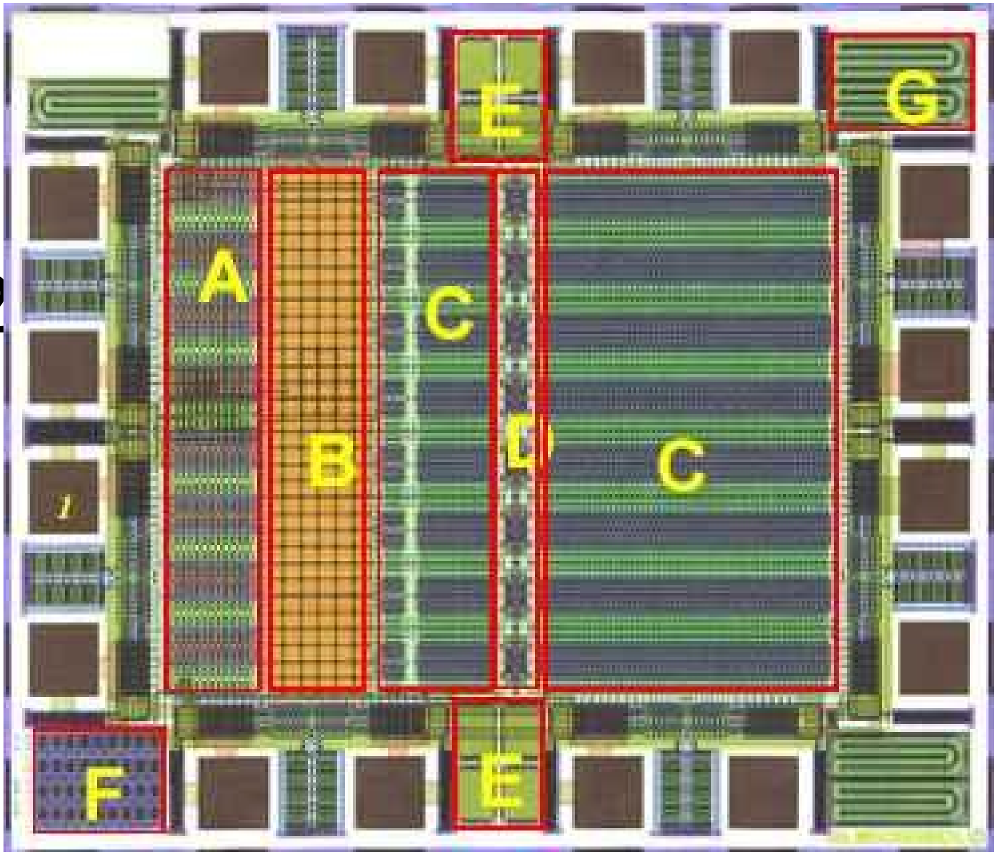
Phonak, stacked chips

- 3 IC
- digital
- analog
- memory

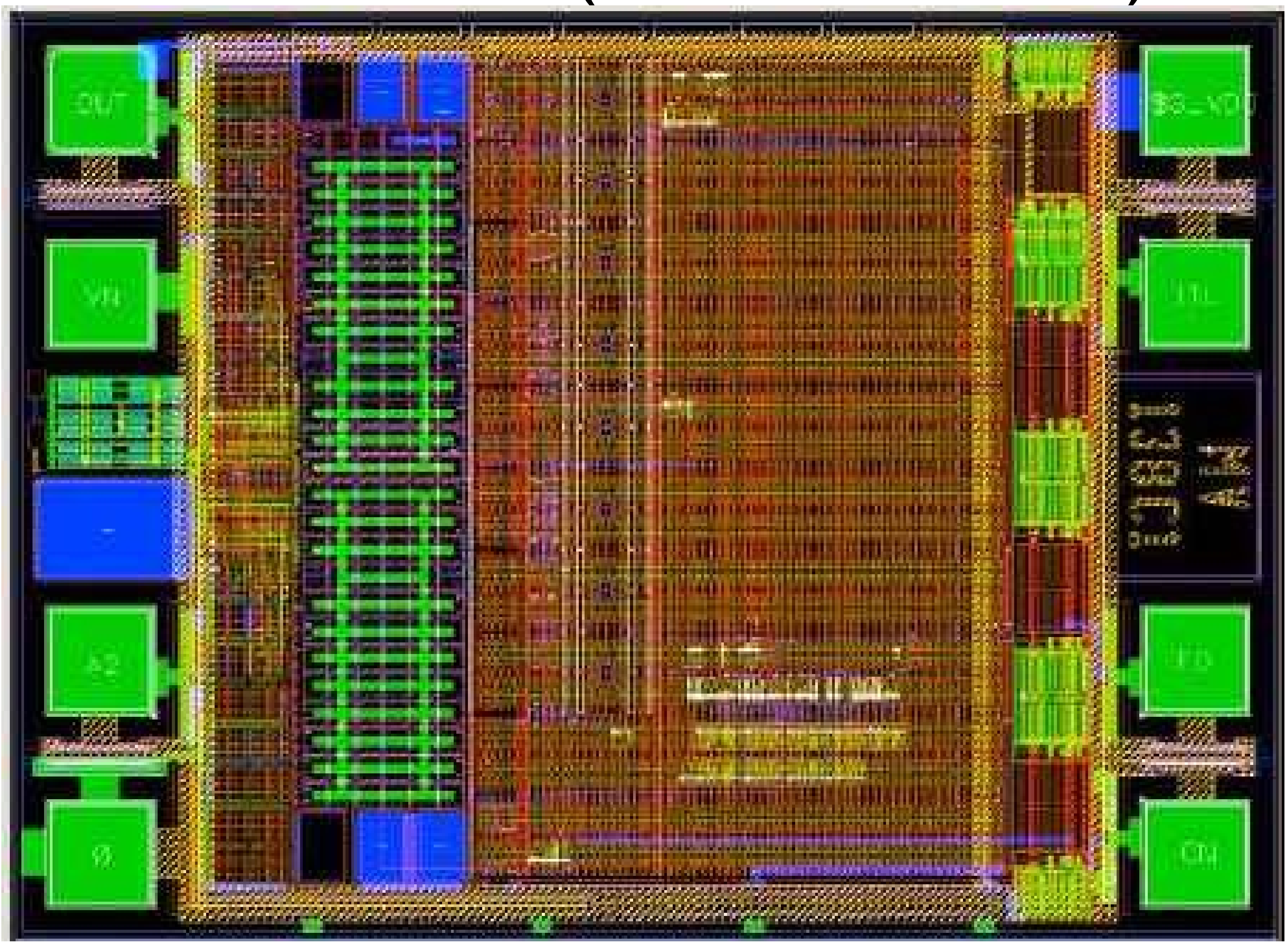


MD300

- ~ CHF 2.-
- 1µm CMOS
- 1.44 *1.20 mm2
- EEPROM (D)
- PNP (F)
- Capa (B)

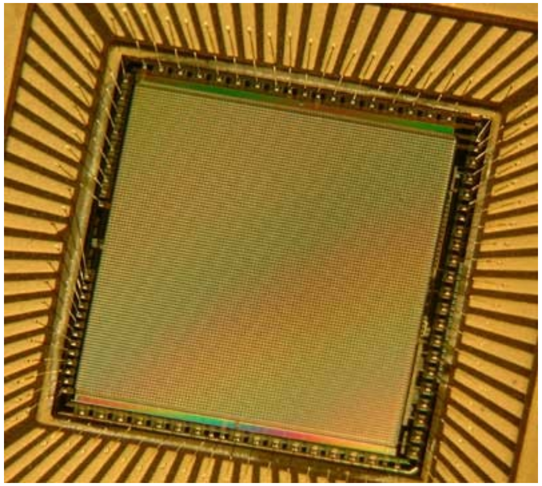


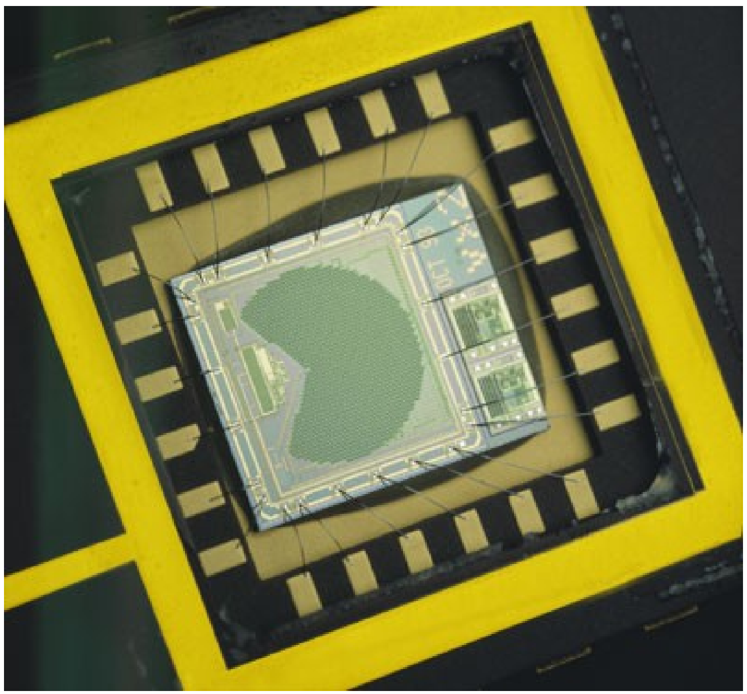
MD400 (1um CMOS)

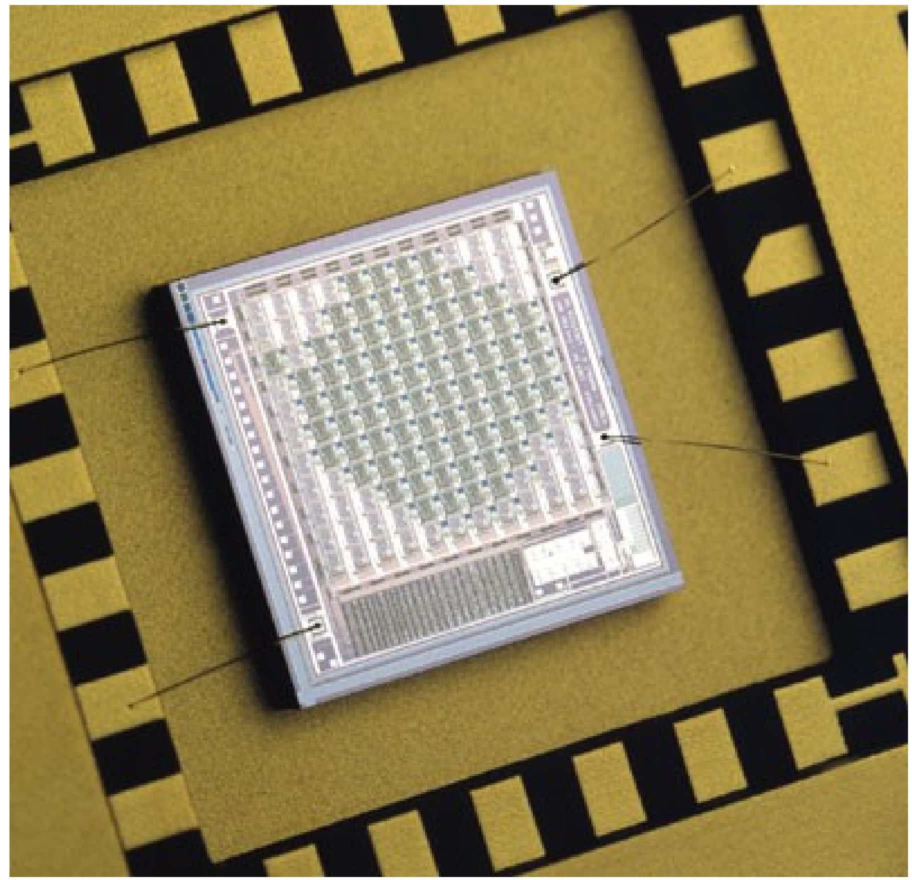


csem

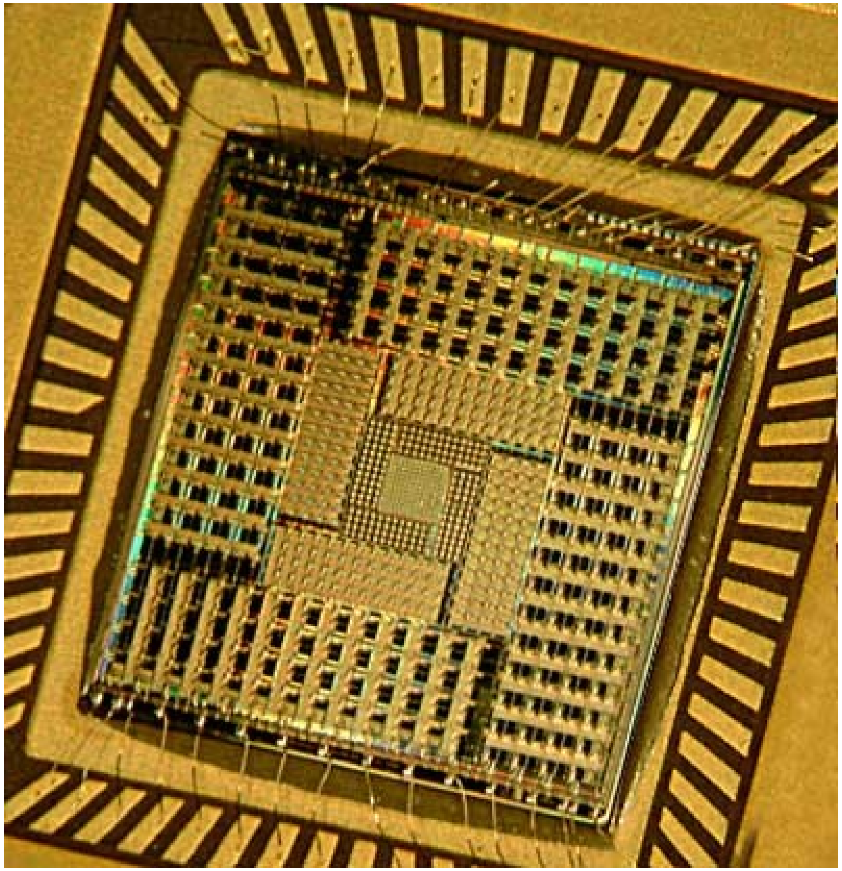
Swiss Center for Electronics and Microtechnology

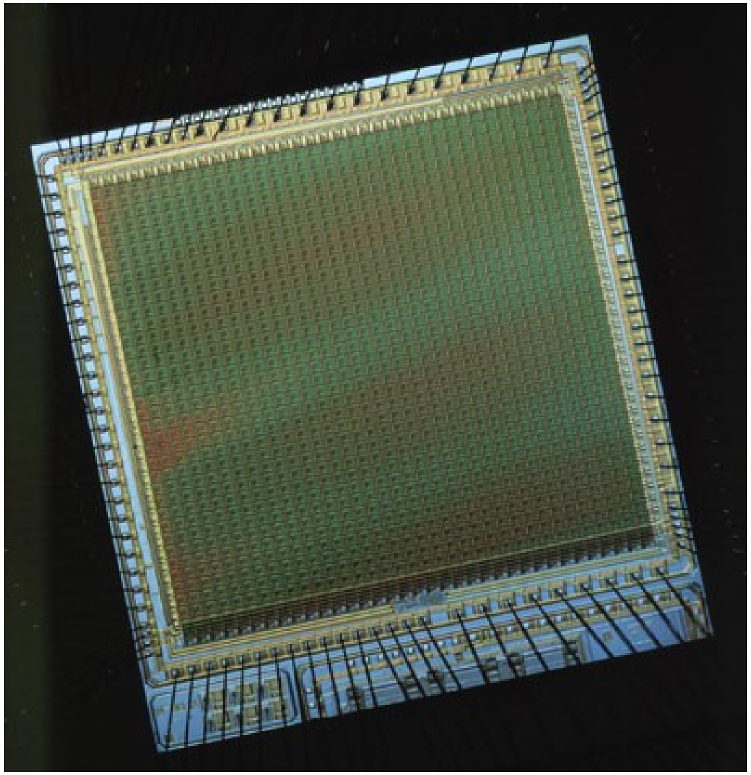






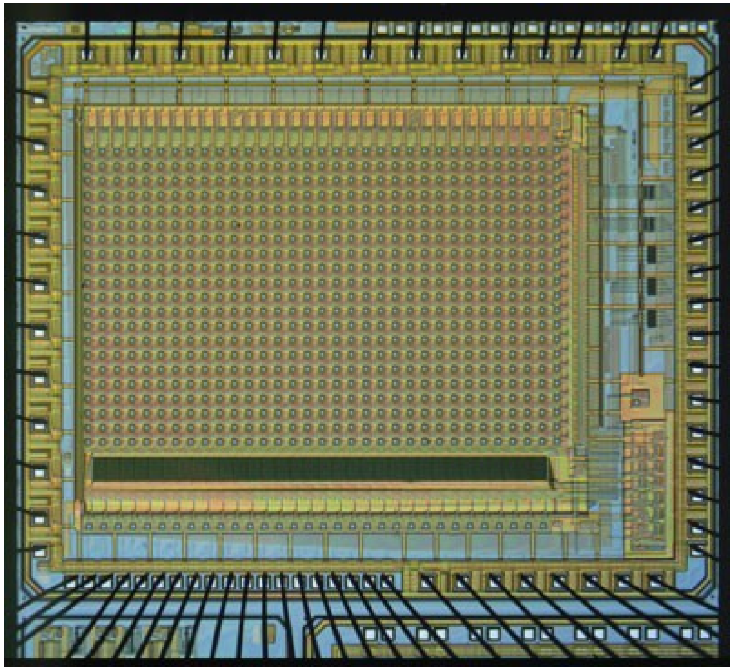
CSEM

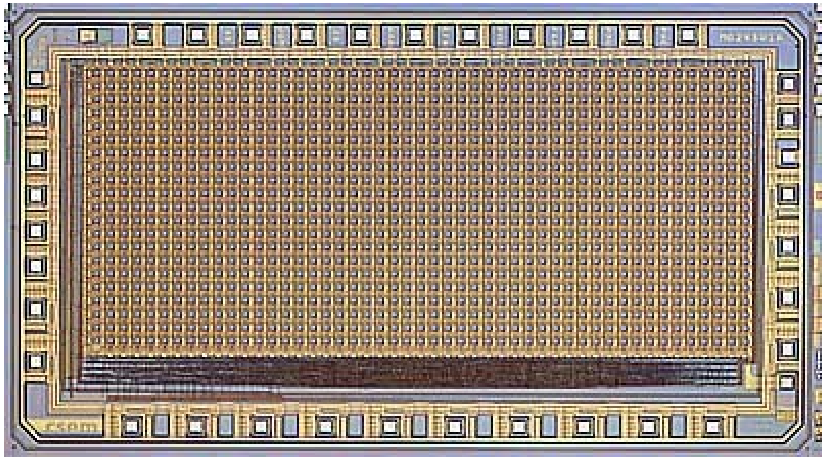




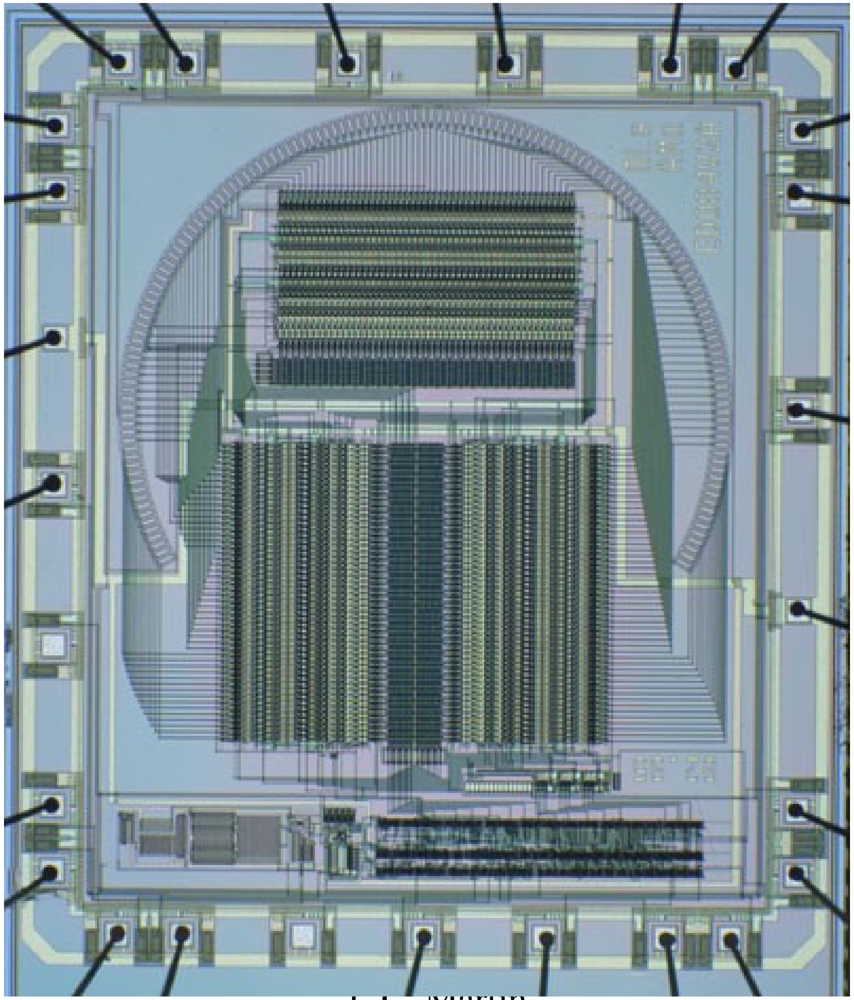
CSEM, Si retina

- 0.5 μm CMOS
- 2 poly
- 3 metal





CSEM 270° view angle retina



XEMICS


XEMICS
XE1201
J723HM
9806
Ultra Low Power
Wireless
Solution
XE12
SERIES

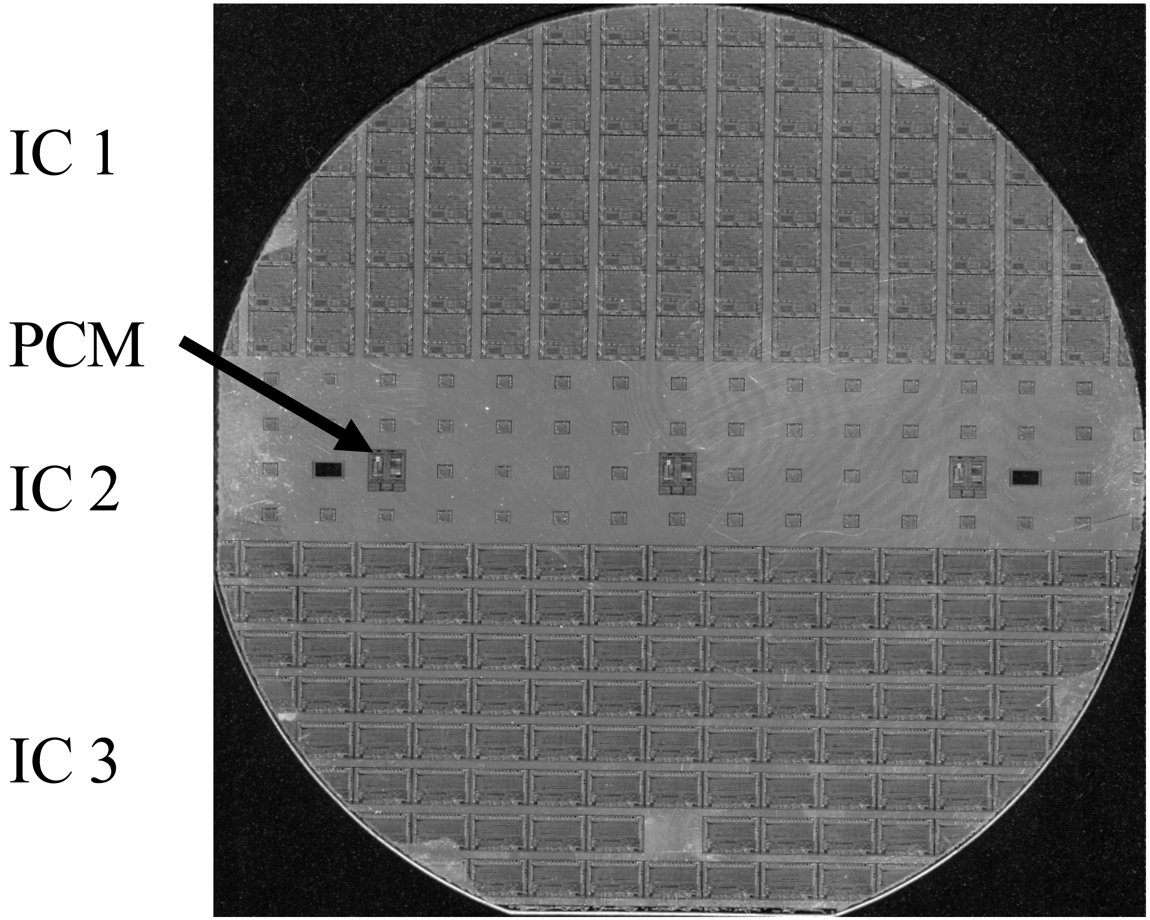
EM MICROELECTRONIC - MARIN SA

A COMPANY OF THE SWATCH GROUP

Your partner for ultra low power

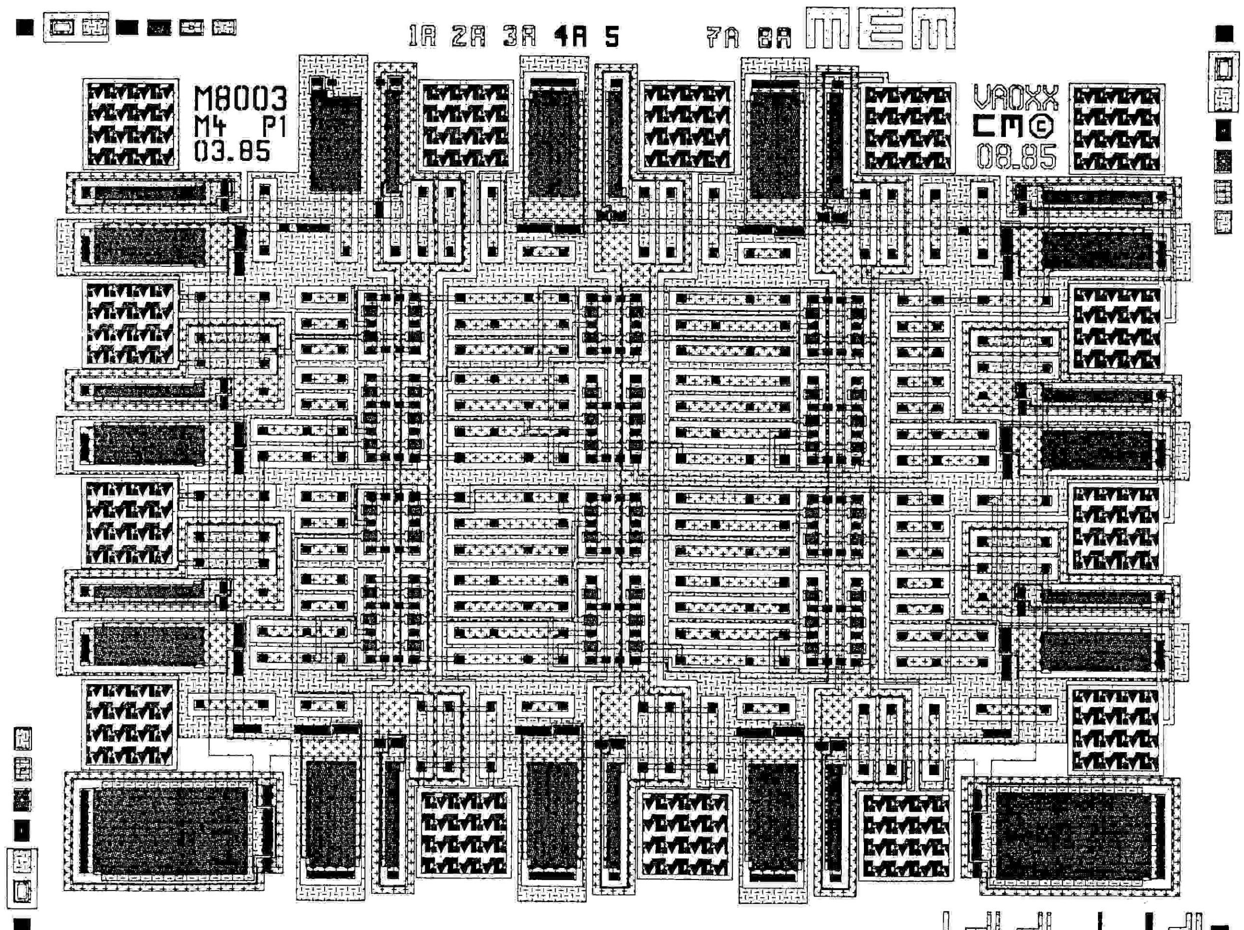
standard and custom ICs and modules

MPW (EM wafer)



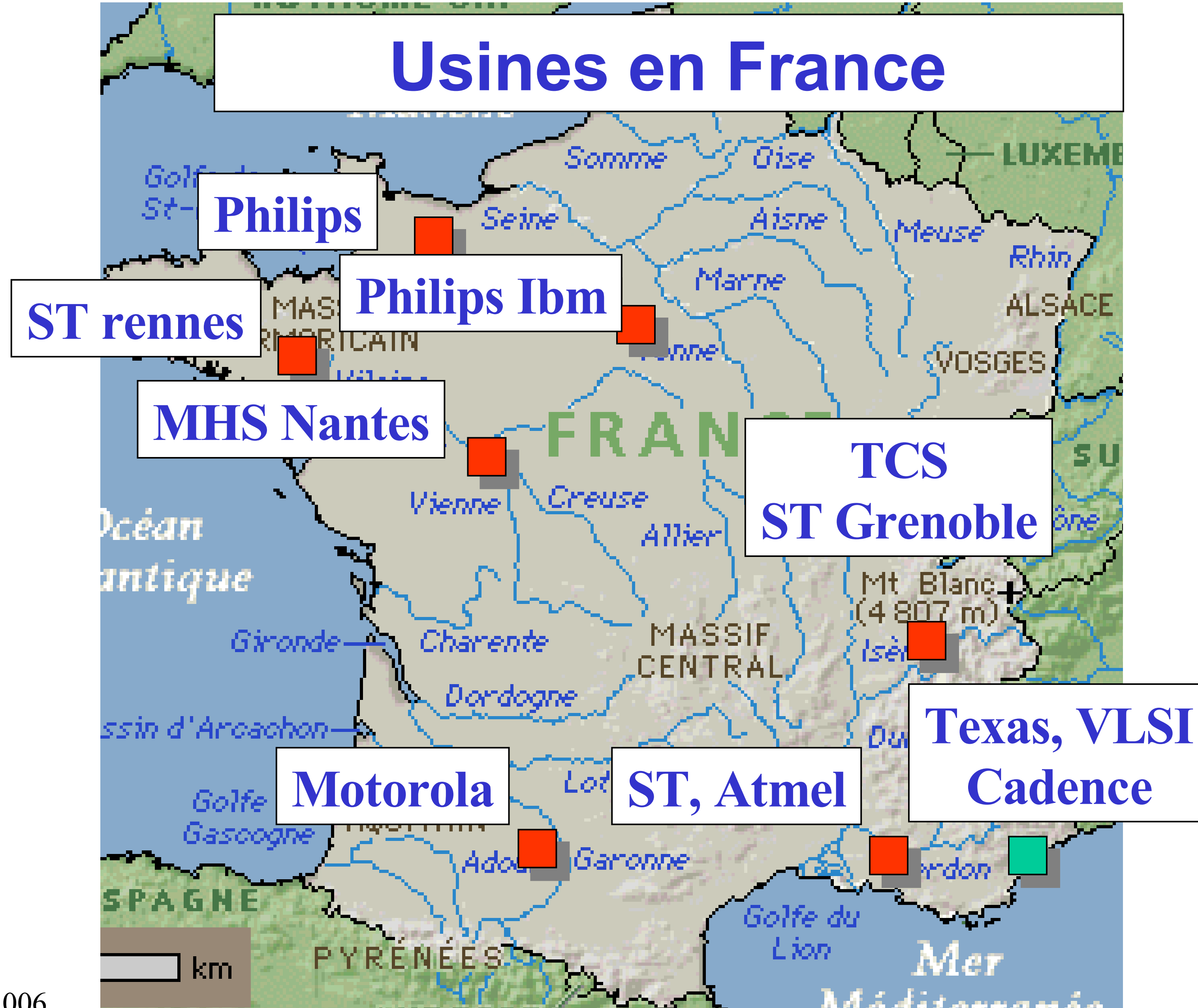
CROSSMOS

- IC design
- GA
- CMOS
- MG
- HV



2006

Usines en France



Conclusions 2002 (ST)

Technology	Year	Metal	Supply (V)	Oxide(A)	Vt (V)	ST technology
1.2µm	1986	2	5.0	250	0.8	
0.7µm	1988	2	5.0	200	0.7	
0.5µm	1992	3	3.3	120	0.6	Hcmos5
0.35µm	1994	5	3.3	75	0.5	Hcmos6
0.25µm	1996	6	2.5	65	0.45	Hcmos7
0.18µm	1998	6	1.9	50	0.40	Hcmos8
0.12µm	2000	7	1.5	40	0.30	Hcmos9
0.10µm	2002	8	1.0	35	0.25	Hcmos10

Increased metal layers

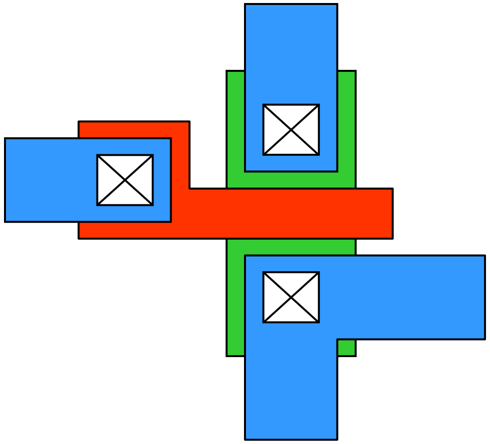
Reduced supply

Reduced oxide

2014

Prévisions …

SIA road map

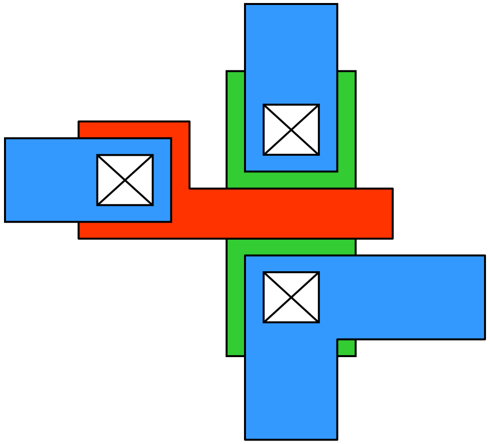


- Taille des transistors
- Longueur du MOS

1999 SIA	1999	2002	2005	2008	2011	2014
	0.18μm	0.13μm	0.10μm	0.07μm	0.05μm	0.035μm

2014

- 0.02 microns
- 20nm
- 10 électrons pour commuter

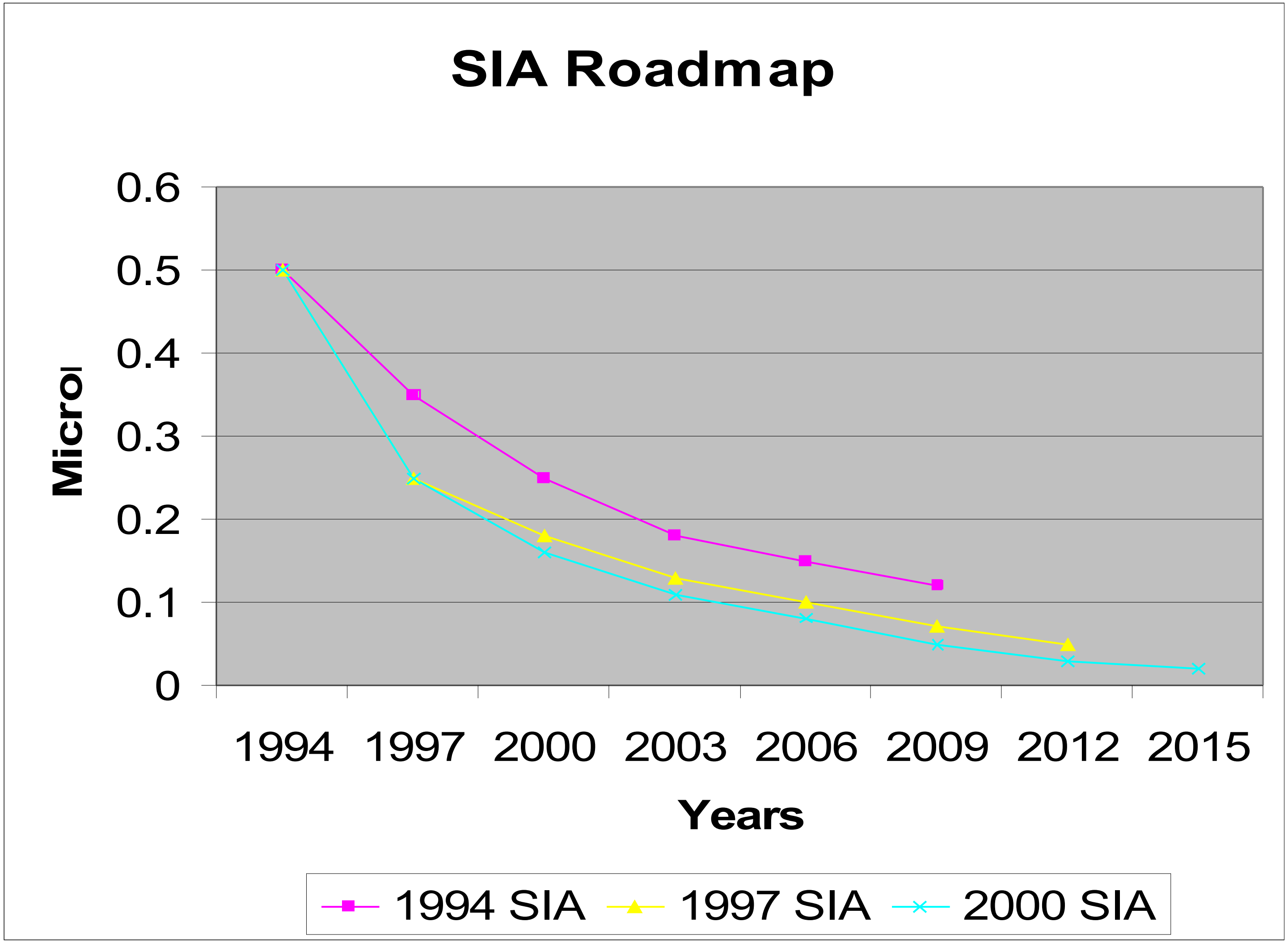


processeurs

- prédictions

1999 SIA	1999	2002	2005	2008	2011	2014
feature	0.18µ m	0.13µ m	0.10µ m	0.07µ m	0.05µ m	0.035µ m
chip size	3.4 cm^2	3.7 cm^2	4 cm^2	4.5 cm^2	5.3 cm^2	6 cm^2
total MOS	25 M	70 M	190 M	500 M	1.5 G	4 G
MOS/mm2	7 K	20 K	50 K	100 K	280 K	650 K
Nb pads	740	1000	1400	1900	2600	3500

Loi de Moore


SIA Roadmap
0.6
0.5
0.4
0.3
0.2
0.1
0
Microı
1994
1997
2000
2003
2006
2009
2012
2015
Years
1994 SIA
1997 SIA
2000 SIA

Moore avant et après

1998

-15

1983: Intel 80286, 130’000 MOS, NMOS 2µm
Motorola 68020, 190’000 MOS, NMOS 2µm
RISC II of Berkeley, NMOS 3µm

8 times smaller

now

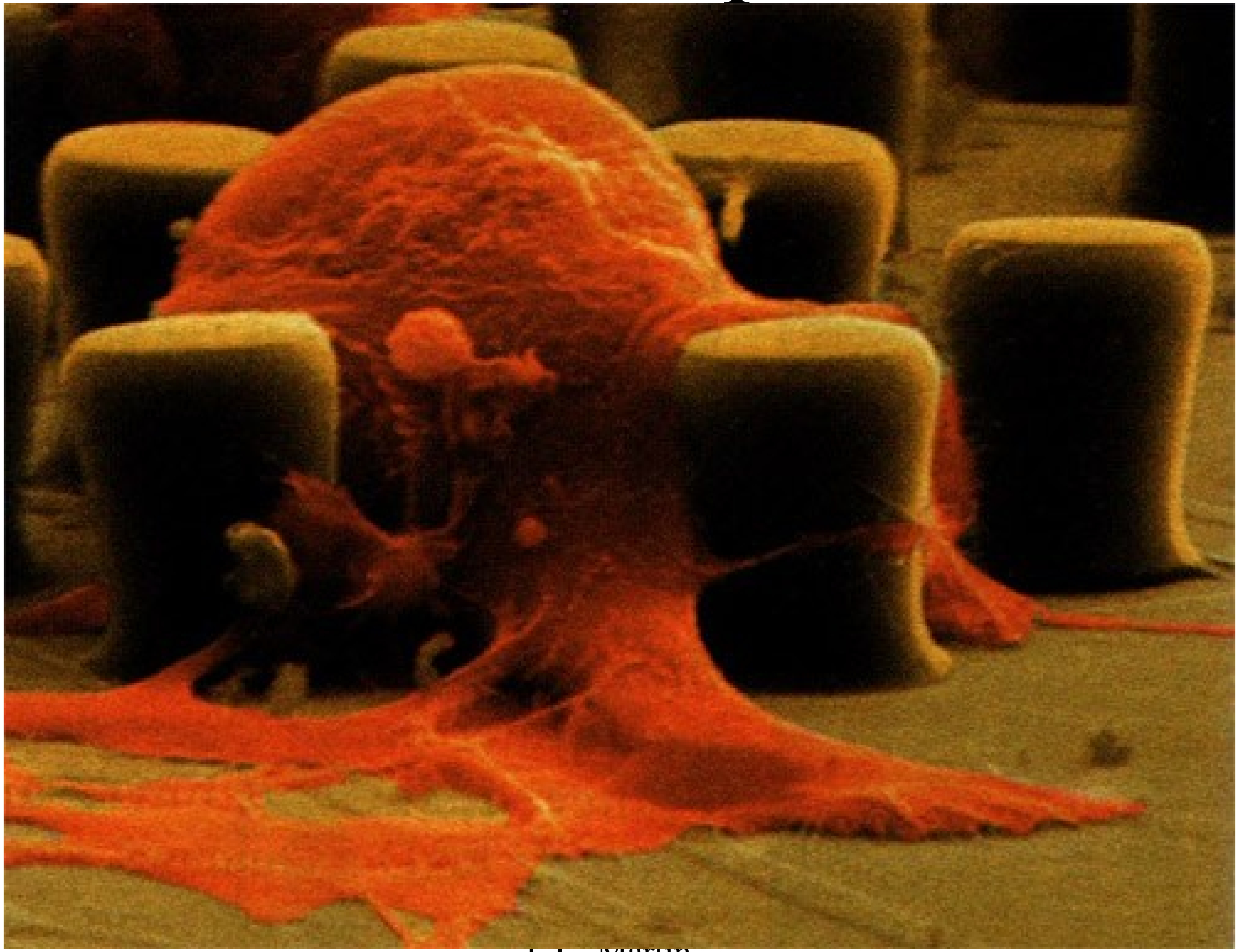
Superscalaire ,10’000’000 MOS, CMOS 0.25 µm

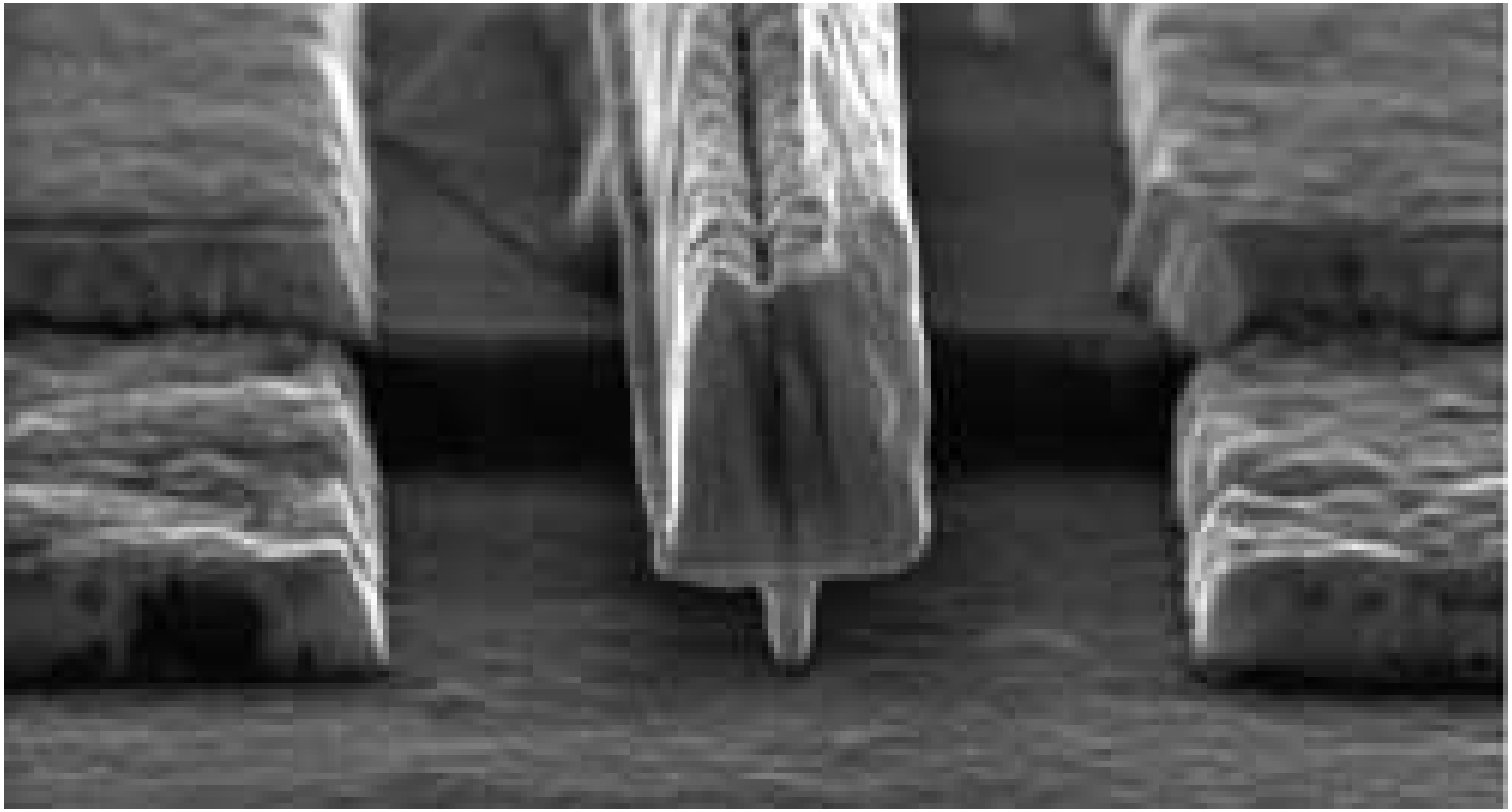
5 times smaller

+15

2012: 1’400’000’000 MOS, CMOS 0.05 µm

Neurones de lapin sur Si





The 60-nm-wide gate is flanked by the indium gallium arsenide source and drain.

IEEE Spectrum april 2004

Popular Mechanics, 1949

“Les futurs ordinateurs ne pèseront peut-être qu’une tonne et demi”

Ken Olsen, CEO of DEC, 1977

“Il n’y a aucune raison que les gens aient un jour un ordinateur chez eux”

Pascale Weil

"En écoutant les prévisions, on en apprend plus sur aujourd'hui que sur demain"