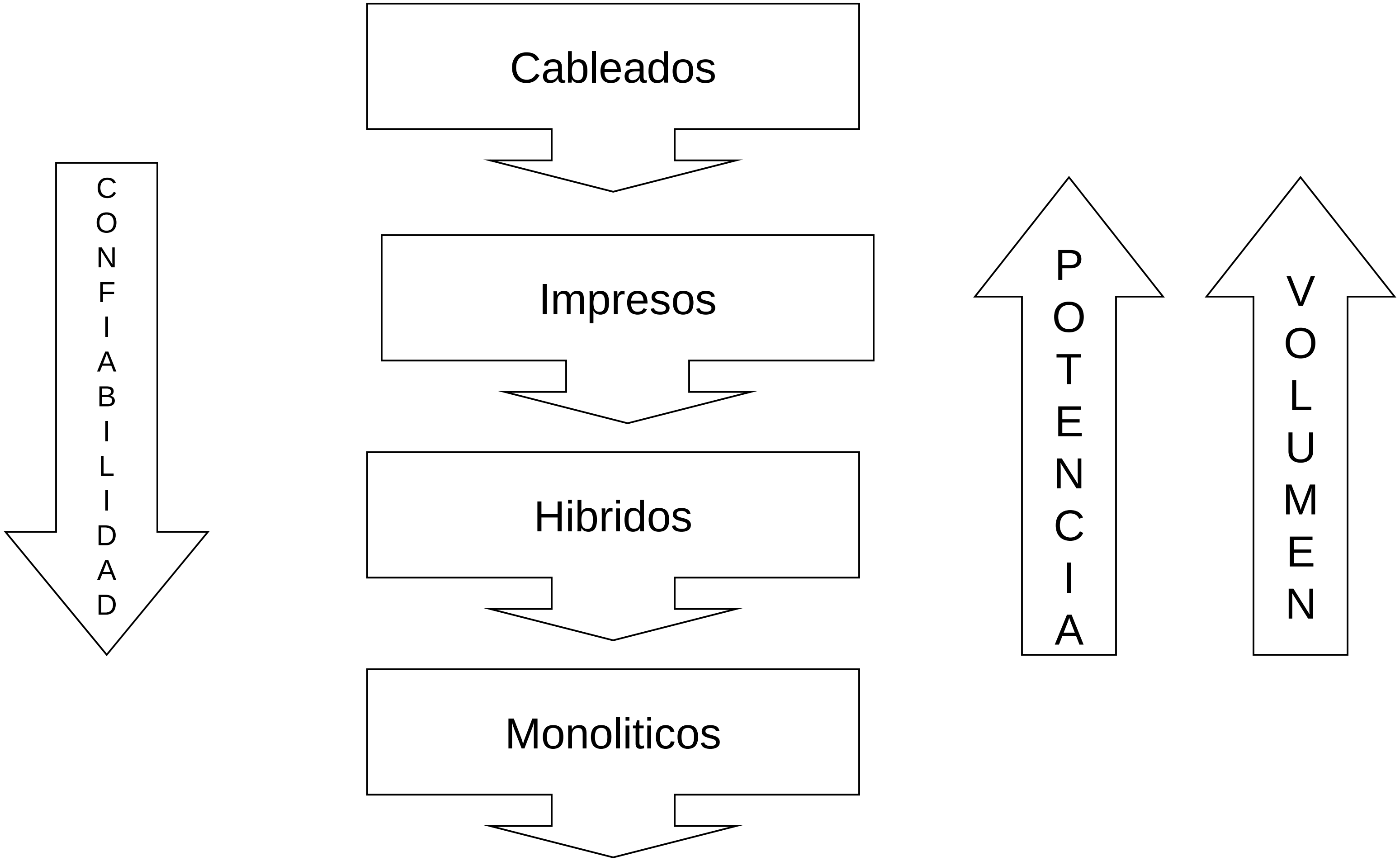
CIRCUITOS INTEGRADOS MONOLITICOS

Evolucion de los Circuitos Electronicos



CONFIABILIDAD

Cableados

Impresos

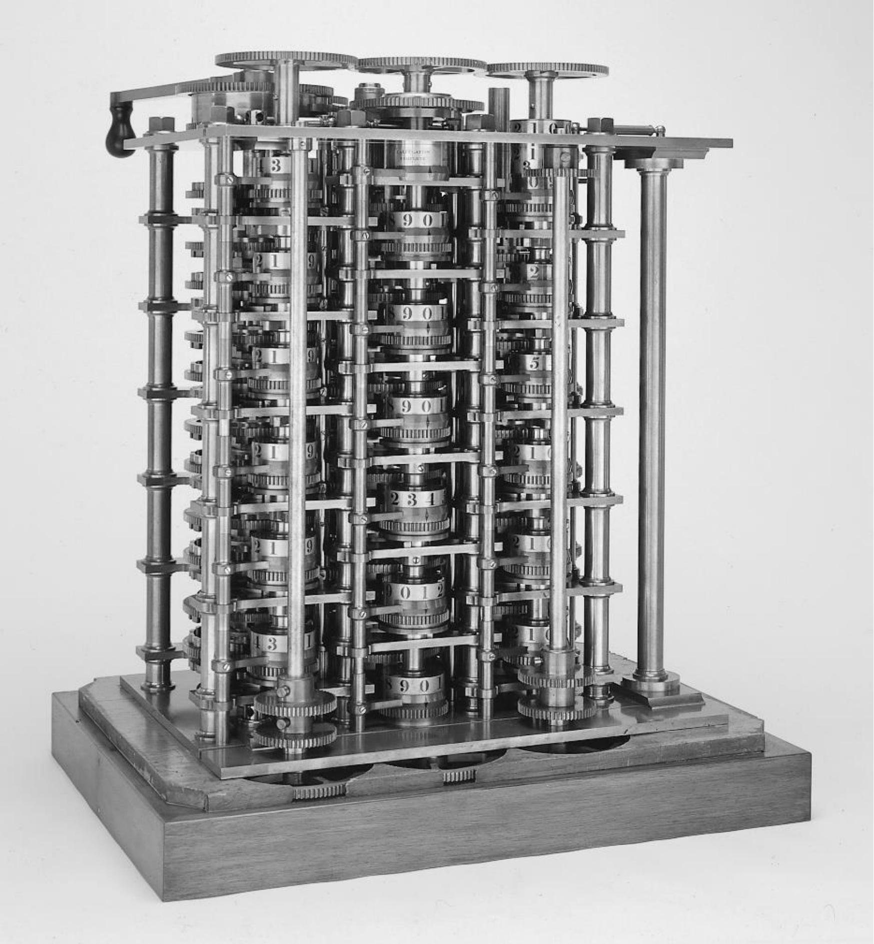
Hibridos

Monoliticos

POTENCIA

VOLUMEN

El primer Computador

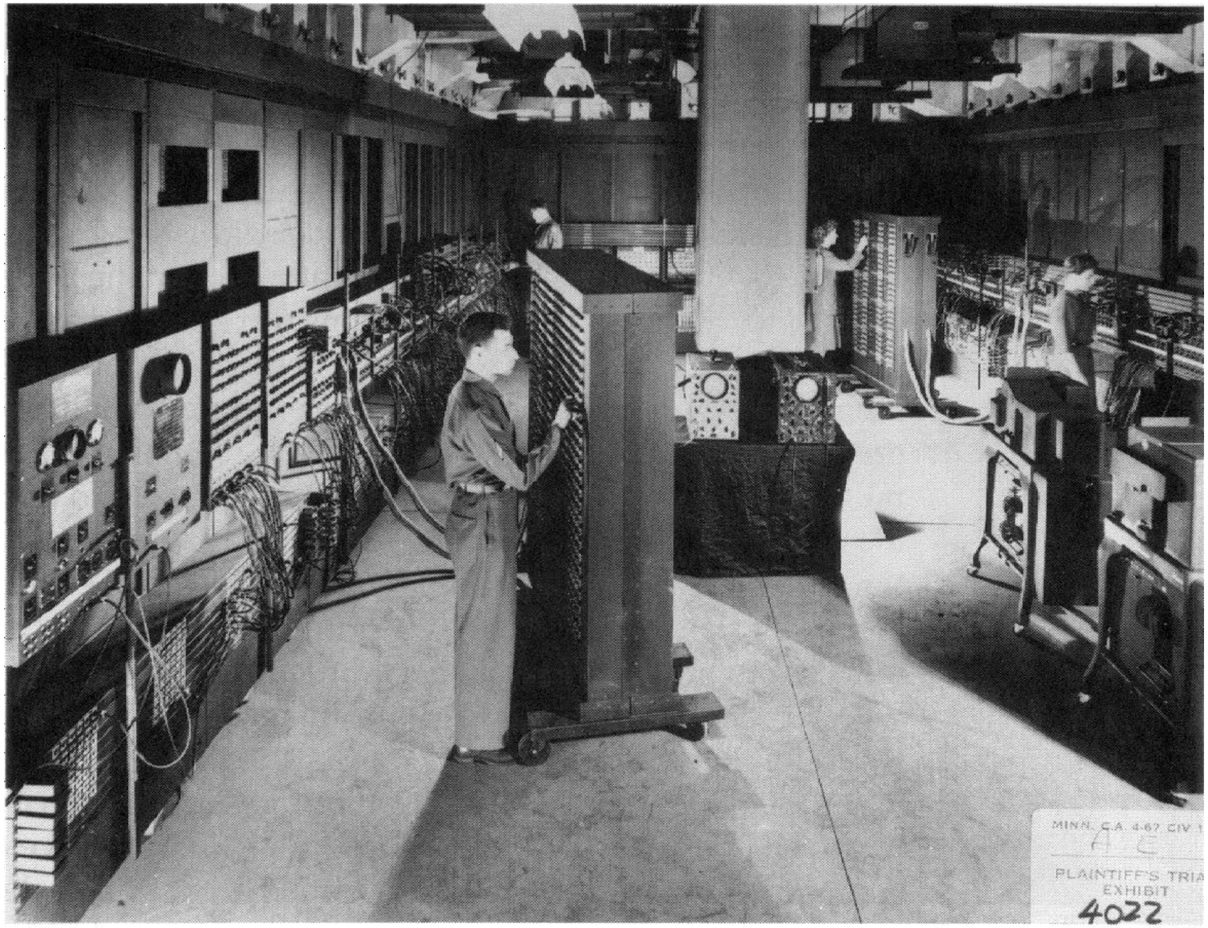


The Babbage Difference Engine (1832)

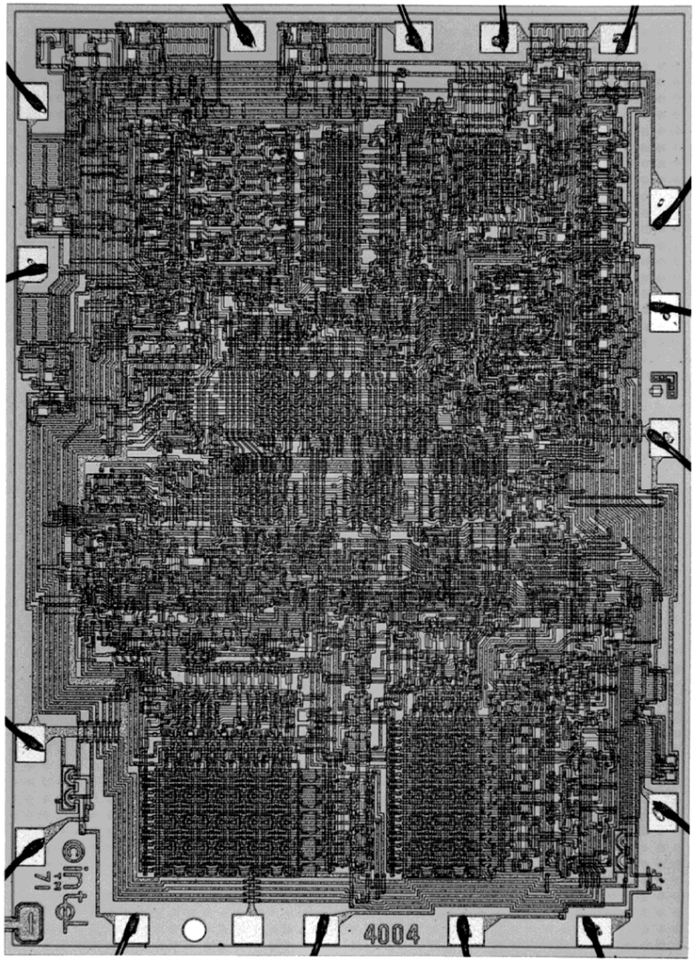
25,000 parts

cost: £17,470

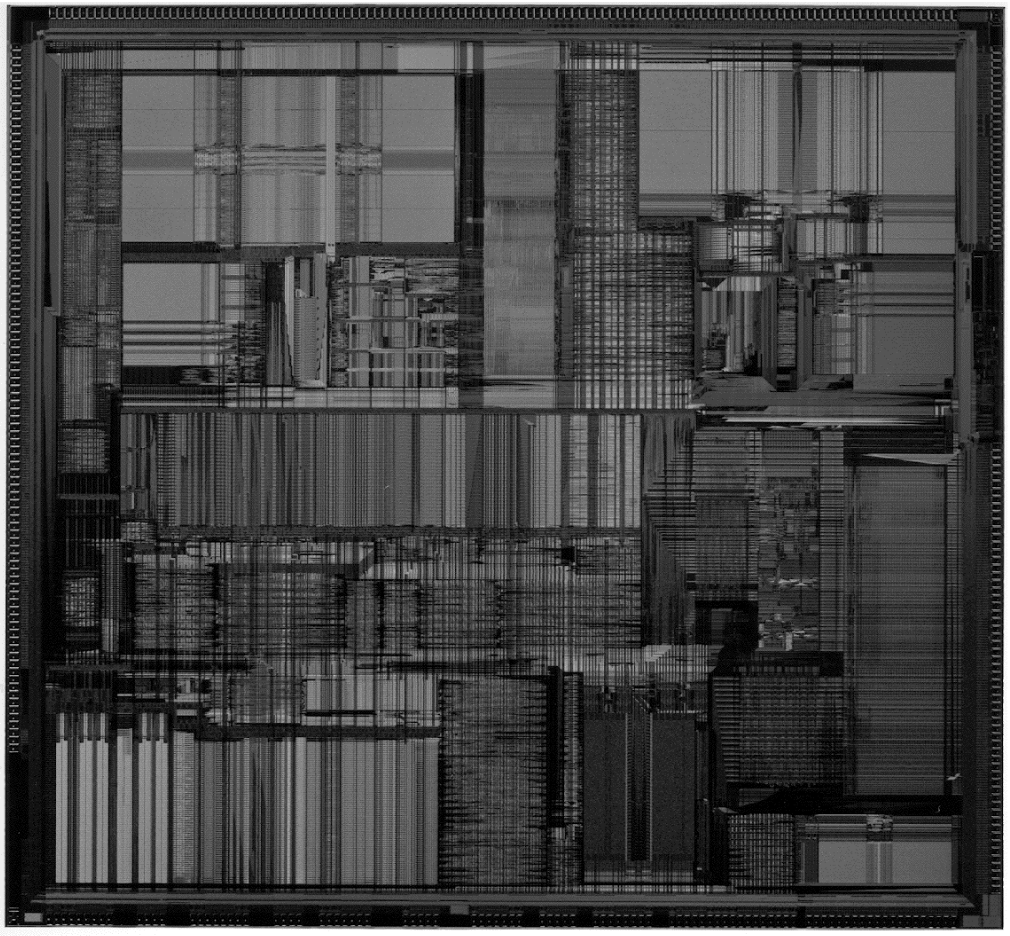
ENIAC – La primera computadora electrónica (1946)



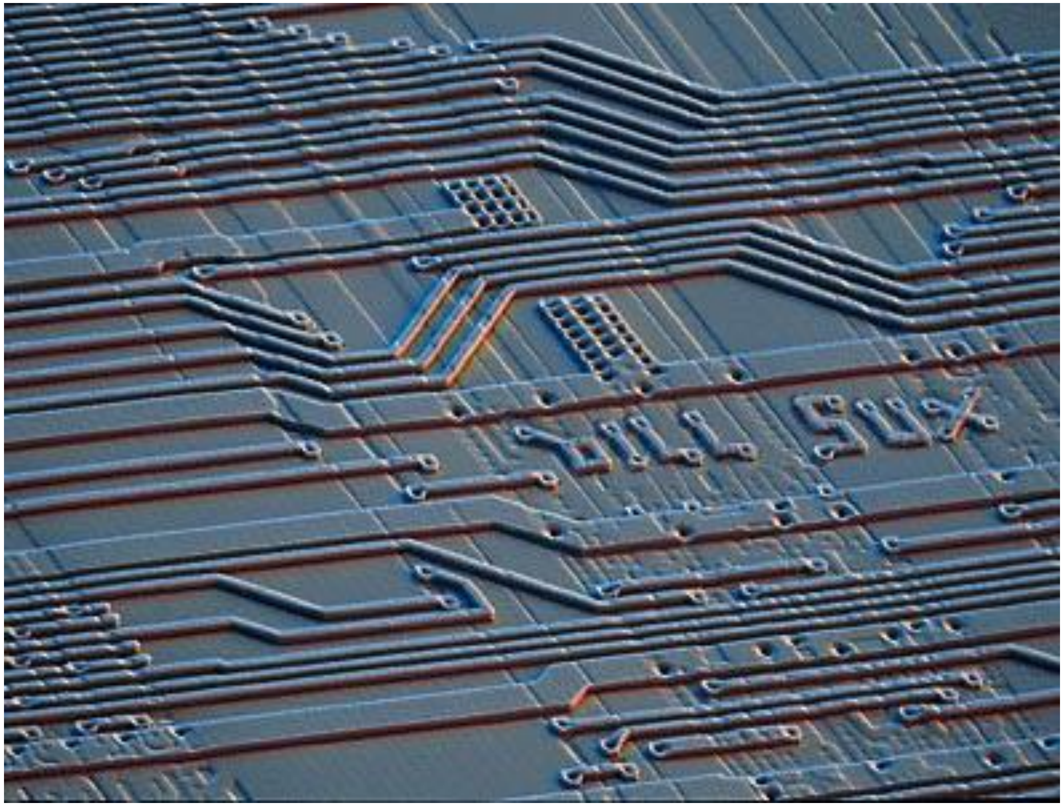
Intel 4004 Micro-Processor



Intel Pentium (II) microprocessor

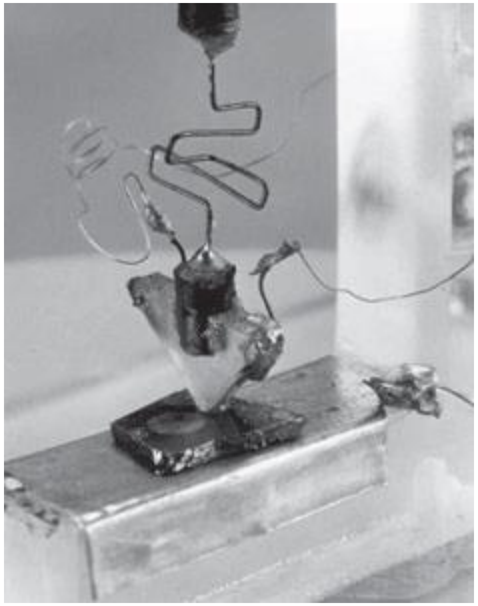


Vista de un Chip Intel?

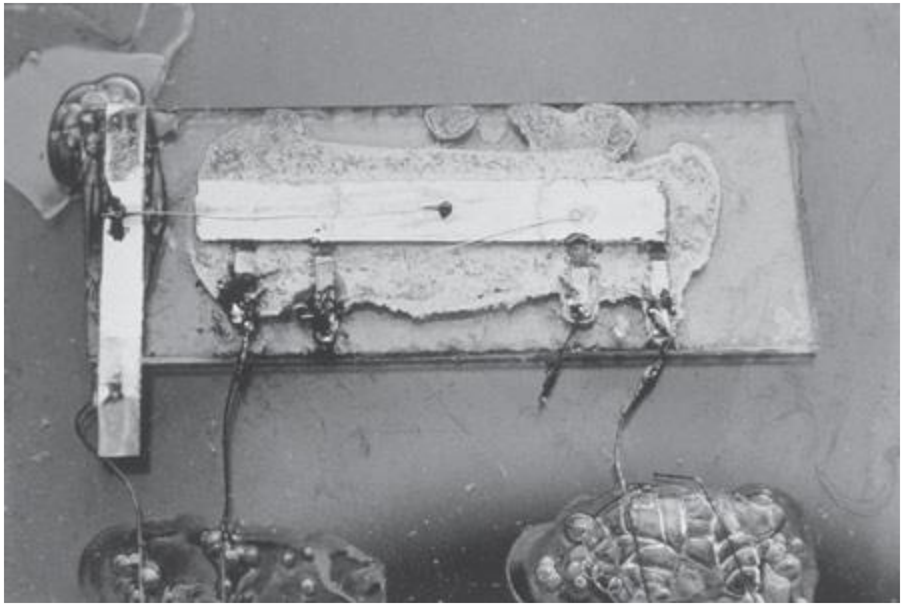


Time Magazine, July 1998

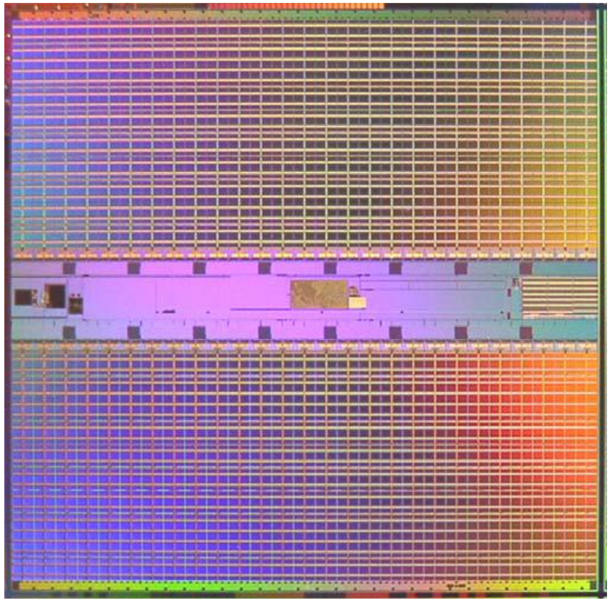
EVOLUCION DE LOS CI.PDF



1° TBJ 1947



1° CI 1957



SRAM 70 Mbit 65 nm

1947 – When it comes to helping jumpstart innovation and technology, no invention is more important than the transistor created 60 years ago at Bell Labs.

1953 – The first commercial device to make use of the transistor is put on the market – the Sonotone 1010 hearing aid.

1954 – The first transistor radio, the Regency TR-1, goes on the market for just $49.99. The radio contains just four transistors.

1947

1950

1960 – Sony introduces the first portable, transistorized TV, the TV8-301. It has a modest 5-inch screen and uses 23 silicon and germanium transistors.

1965 – Moore's Law, which states that the number of transistors on a chip doubles about every two years, is born when Intel's Gordon Moore made a prediction about the semiconductor business that still holds true today.

1971 – Intel launches its first microprocessor, the 4004, containing just over 2,000 transistors.

1971 – Busicom introduces the first single-chip, pocket-size calculator, the LE-120A "HANDY," which uses a MOSTEK MK6010 integrated circuit.

1950

1960

1976 – An operator in an early bunnysuit shows how a 4-inch wafer is prepared for a positive acid spin.

1972 – Intel's first microprocessor, powered the Busicom calculator and paved the way for the personal computer.

1975 – The Altair 8800 microcomputer, based on the Intel® 8080 microprocessor, was the first successful home or personal computer.

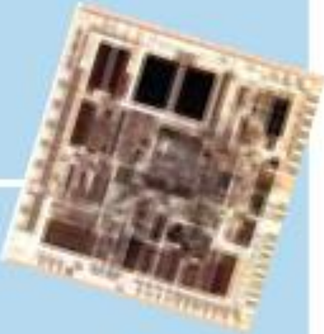
1960

1970

1981 – The Intel® 8088 microprocessor was selected to power the IBM PC.

1981 – IBM introduces the first personal computer with an Intel 8088 processor serving as the "brains" behind the computer.

1982 – Intel launches their new high performance, 16-bit 80286 microprocessor featuring 134,000 transistors.



1970

1980

1982 – Within six years of its release, an estimated 15 million 286-based personal computers were installed around the world.

1983 – Mobile communication changes forever when Motorola introduces the first commercial mobile phone – the DynaTAC 800X – powered by transistors and costing a mere $3,995.

1993 – With the creation of the World Wide Web in 1990, the need for transistor speed becomes greater than ever.

1993 – The World Wide Web debuts and Intel responds with its Pentium® processor, boasting speeds of 66 and 60 MHz 3.1 million transistors.

1980

1990

2000 – The 42-million transistor debuts. If automobile speed increased similarly over that same period, you could drive from New York City to San Francisco in 13 seconds.

2000 – Silicon Valley based company develops TiVo - a device that records TV programs on an internal hard drive.

2003 – Intel® Centrino® mobile technology brought high performance, enhanced battery life, and integrated WLAN capability to thinner, lighter PCs.

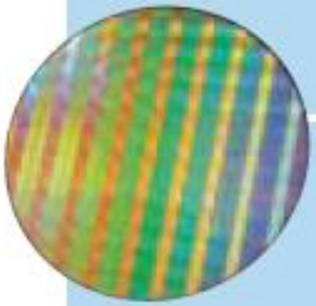
1990

2000

2005 – Dual-core technology was introduced.

2006 – The dual core Intel® Itanium® 2 processor launches with the world's most intricate product design to date, utilizing more than 1.72 billion transistors.

2007 – 45nm Intel debuts the Penryn chip – the biggest change to transistors (all 820 million of them in our quad-core processors) in 40 years based on the company's 45 nanometer transistor technology. More than 2,000 45nm transistors fit across the width of a human hair.

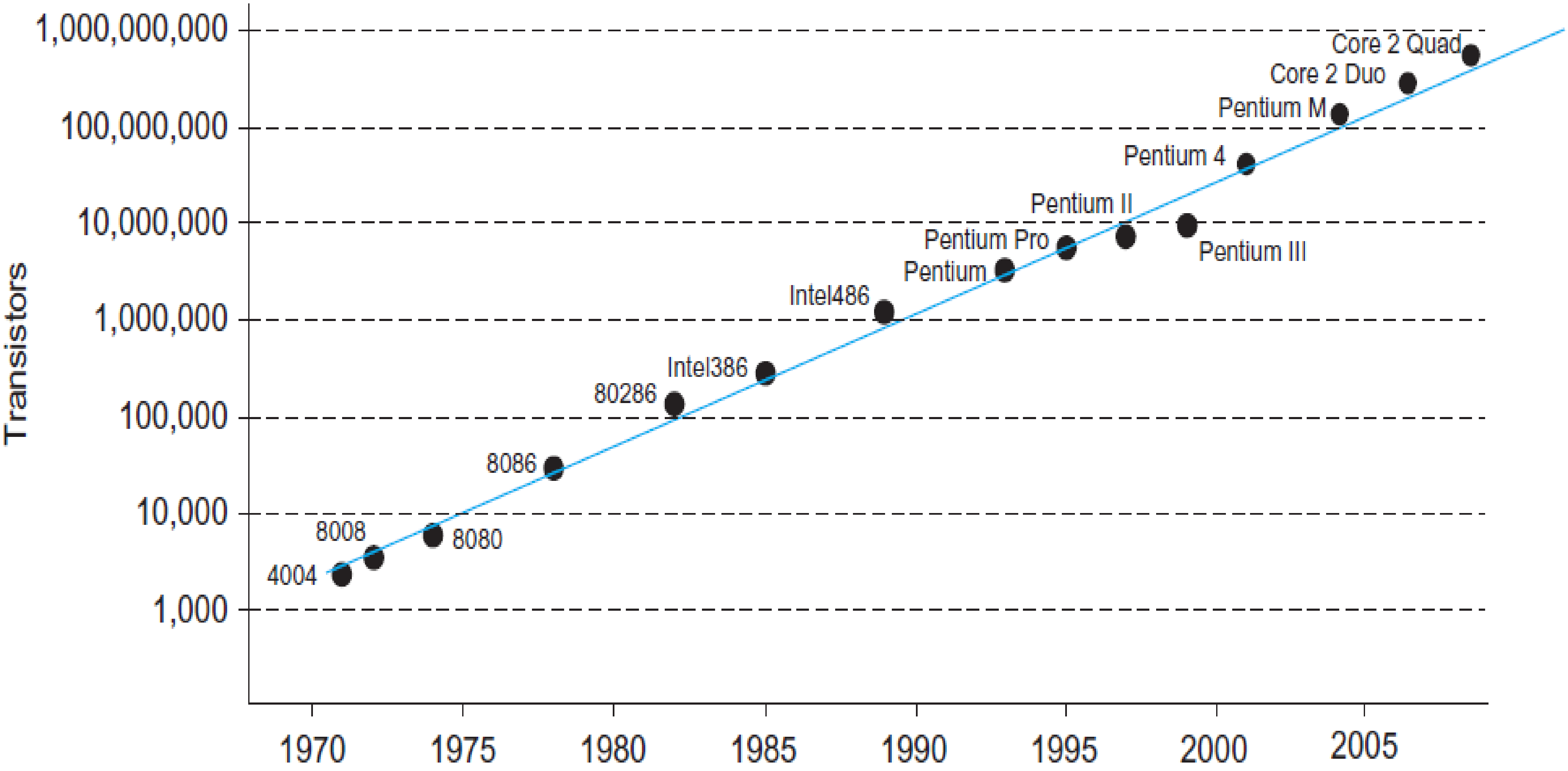


2007 – In the second half of 2007, Intel began production of the next generation Intel® Core™2 and Xeon processor families based on 45-nanometer (nm) Hi-k metal gate silicon technology.

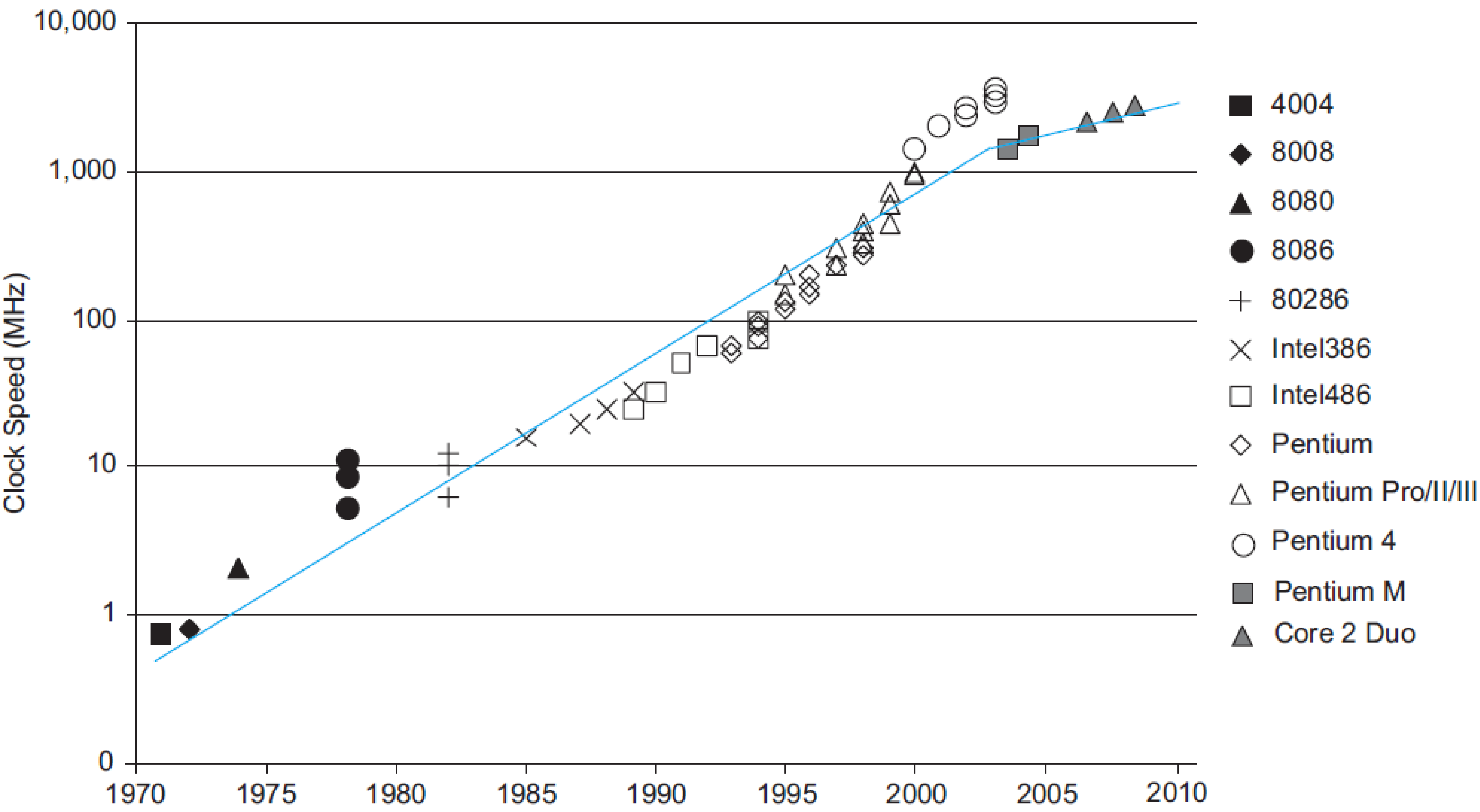
2000

2007

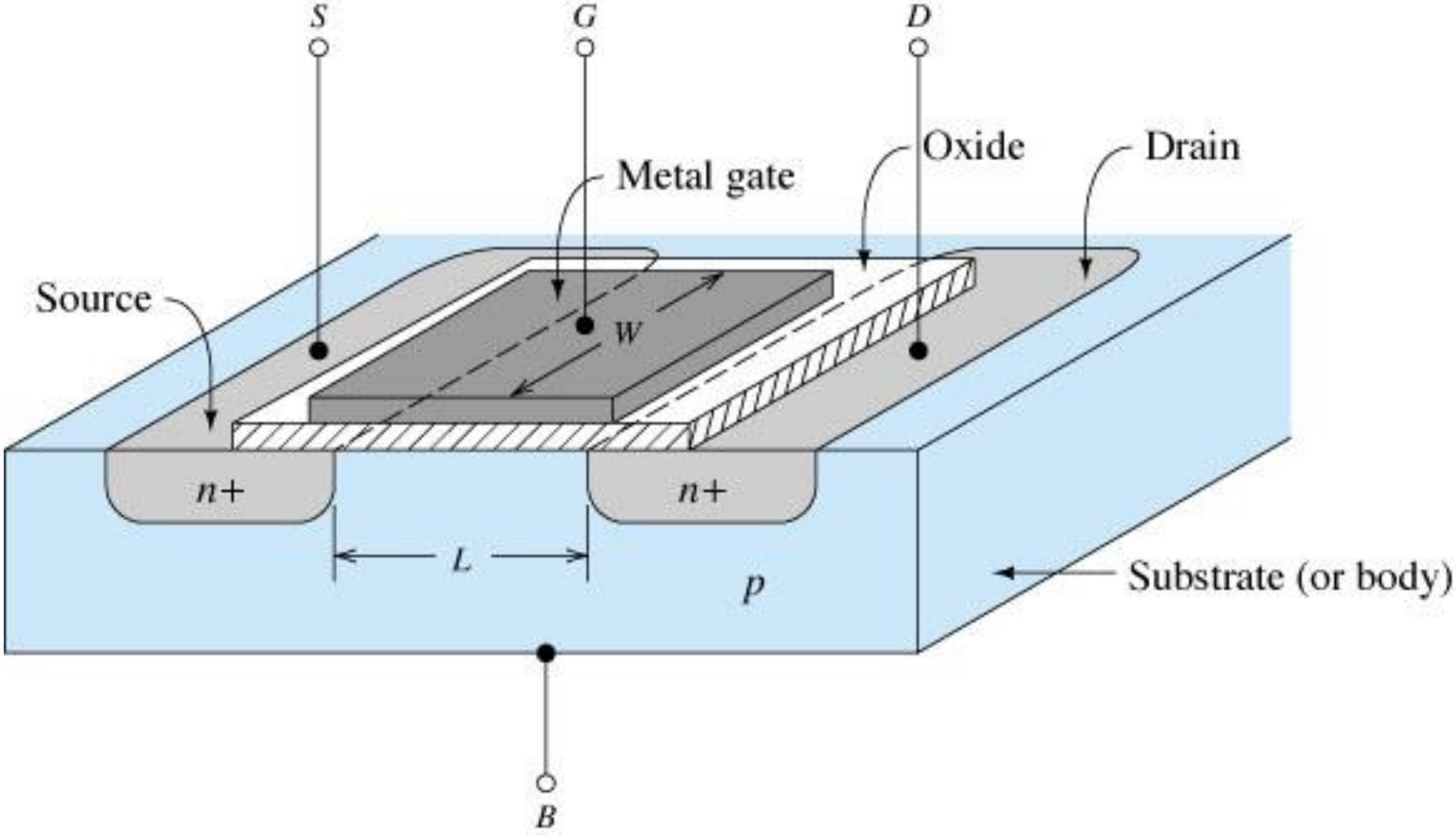
Cantidad de transistores

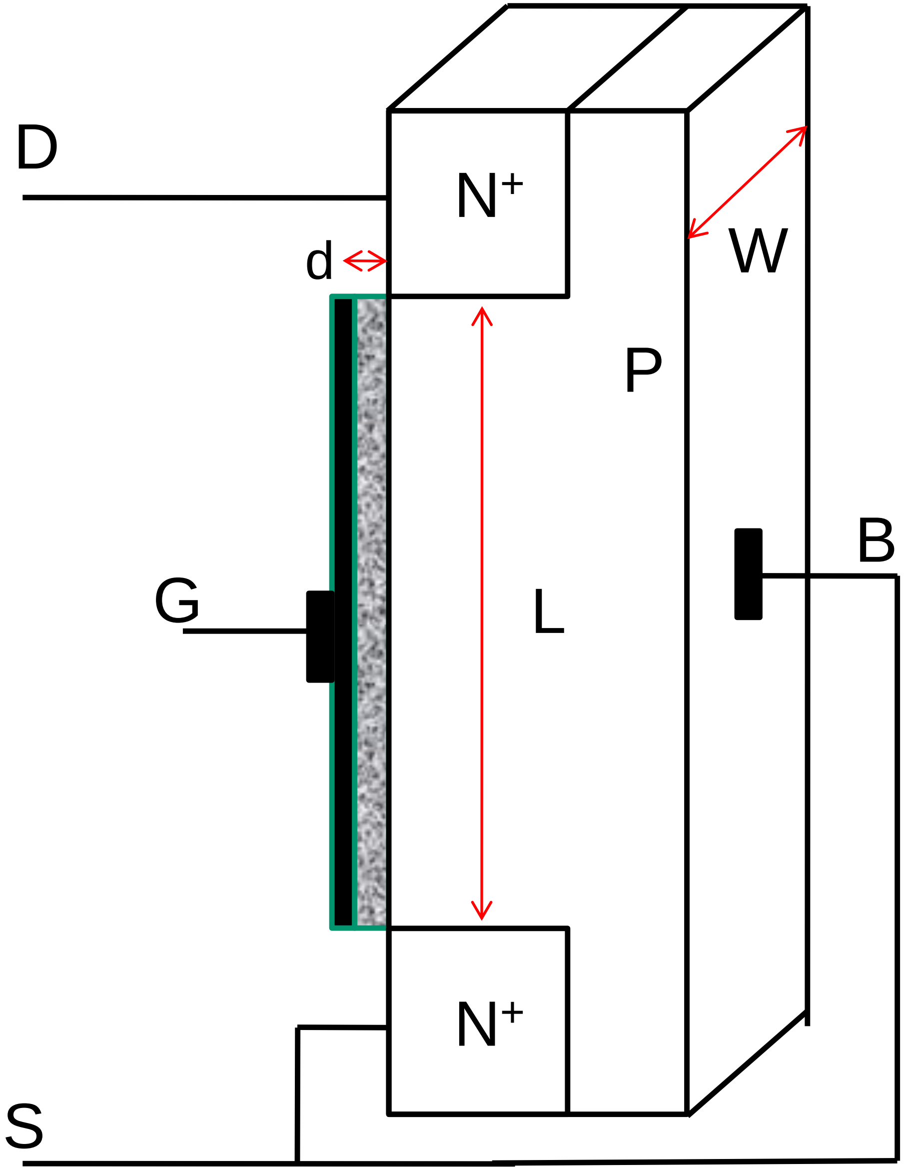


Frecuencia de operación

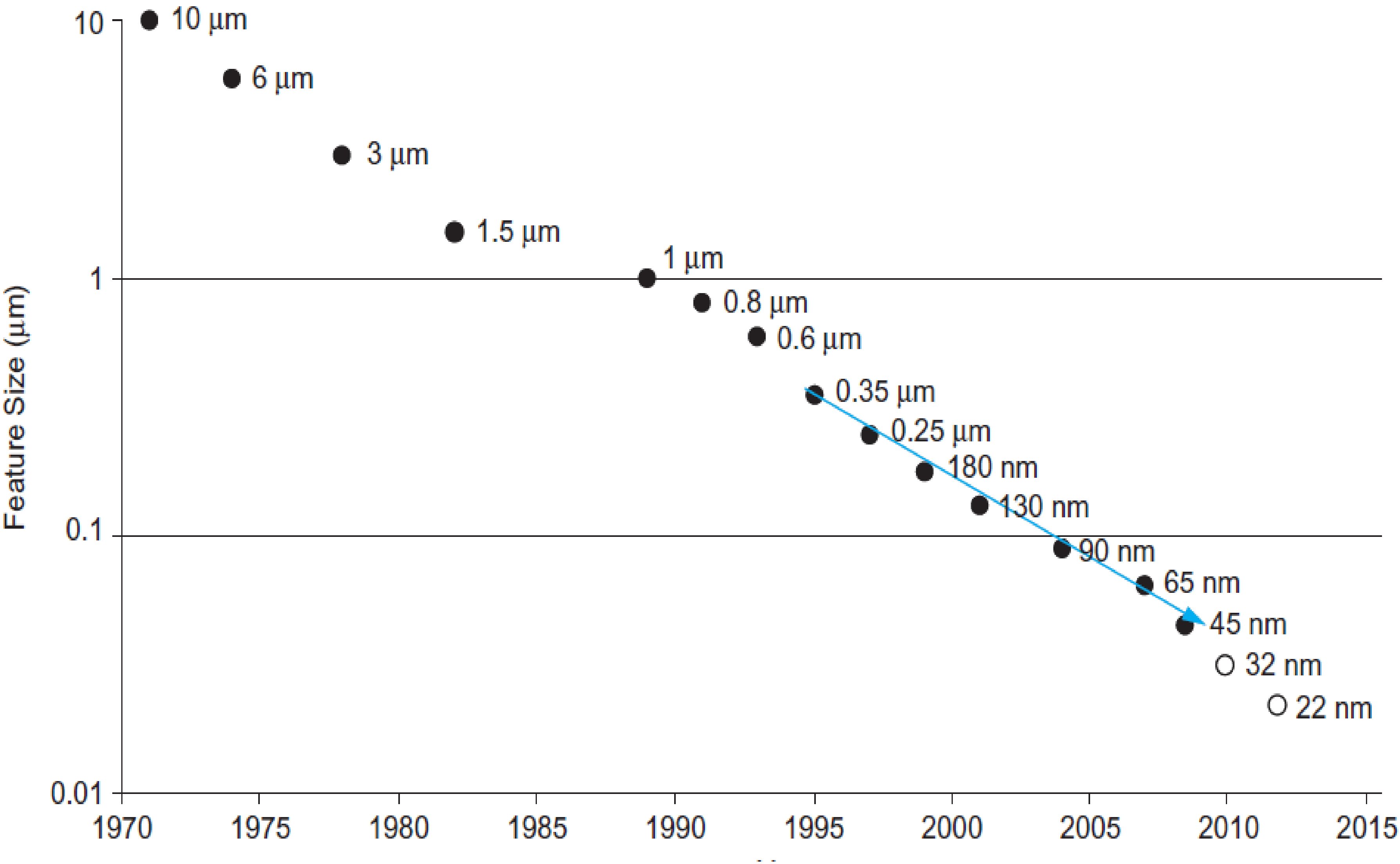


TECNOLOGIA de FABRICACION

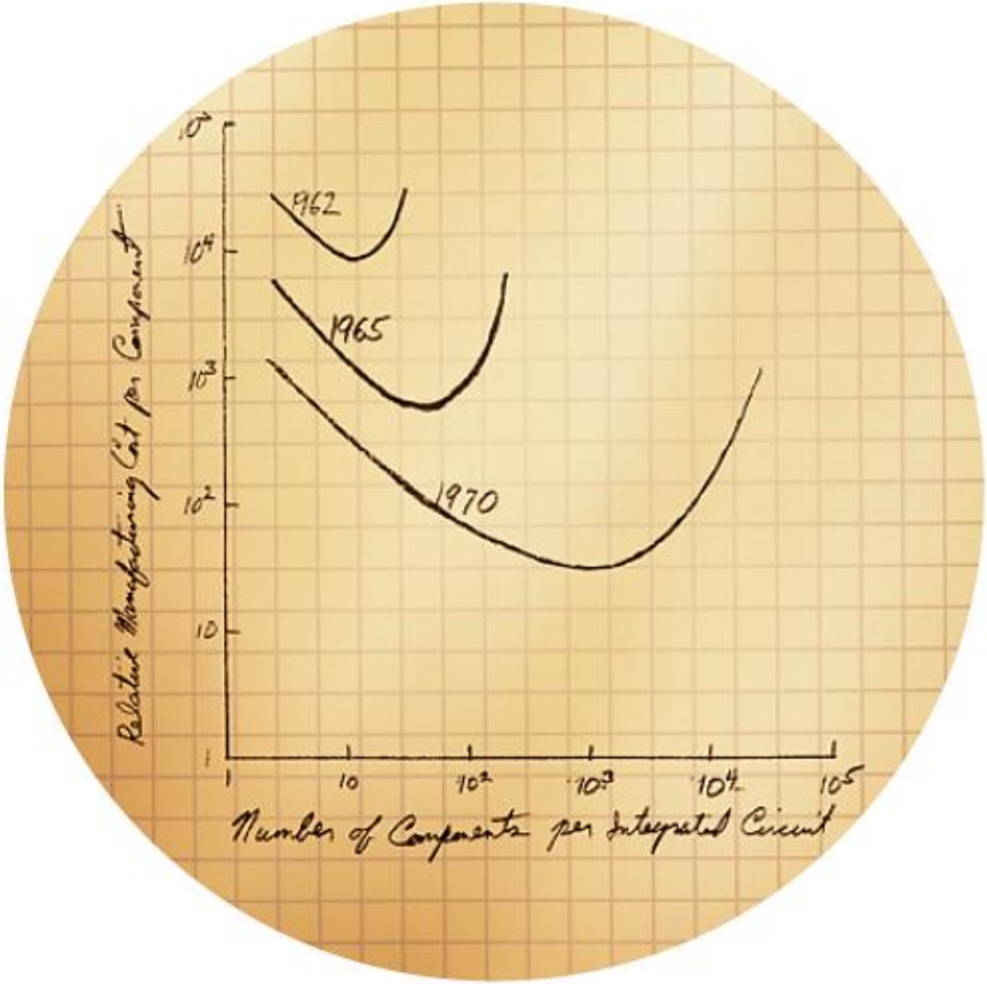



D
N+
d
W
P
B
G
L
N+
S

Tecnología


10 µm
6 µm
3 µm
1.5 µm
1 µm
0.8 µm
0.6 µm
0.35 µm
0.25 µm
180 nm
130 nm
90 nm
65 nm
45 nm
32 nm
22 nm
Feature Size (µm)
10
1
0.1
0.01
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

Moore's Law

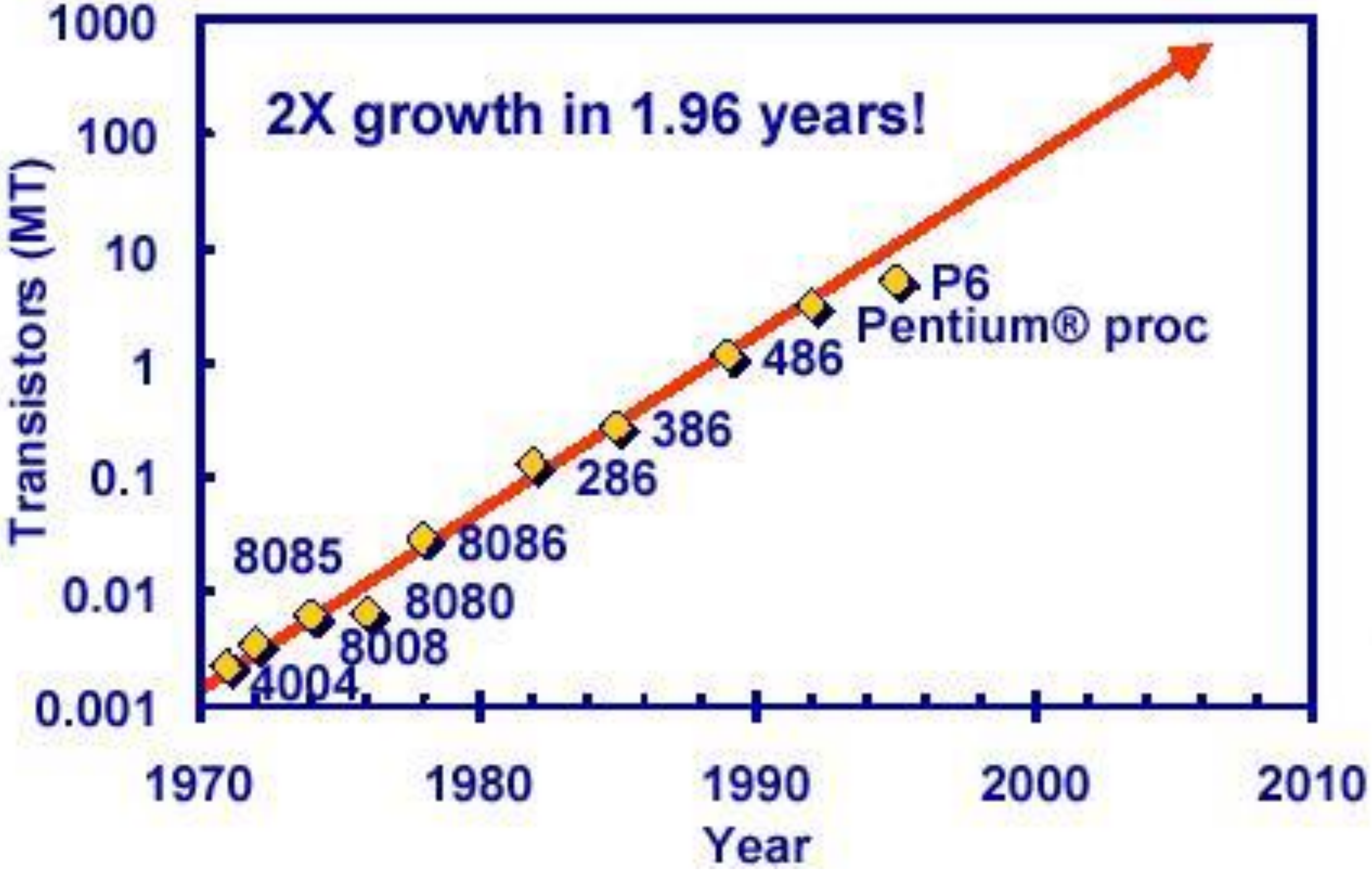


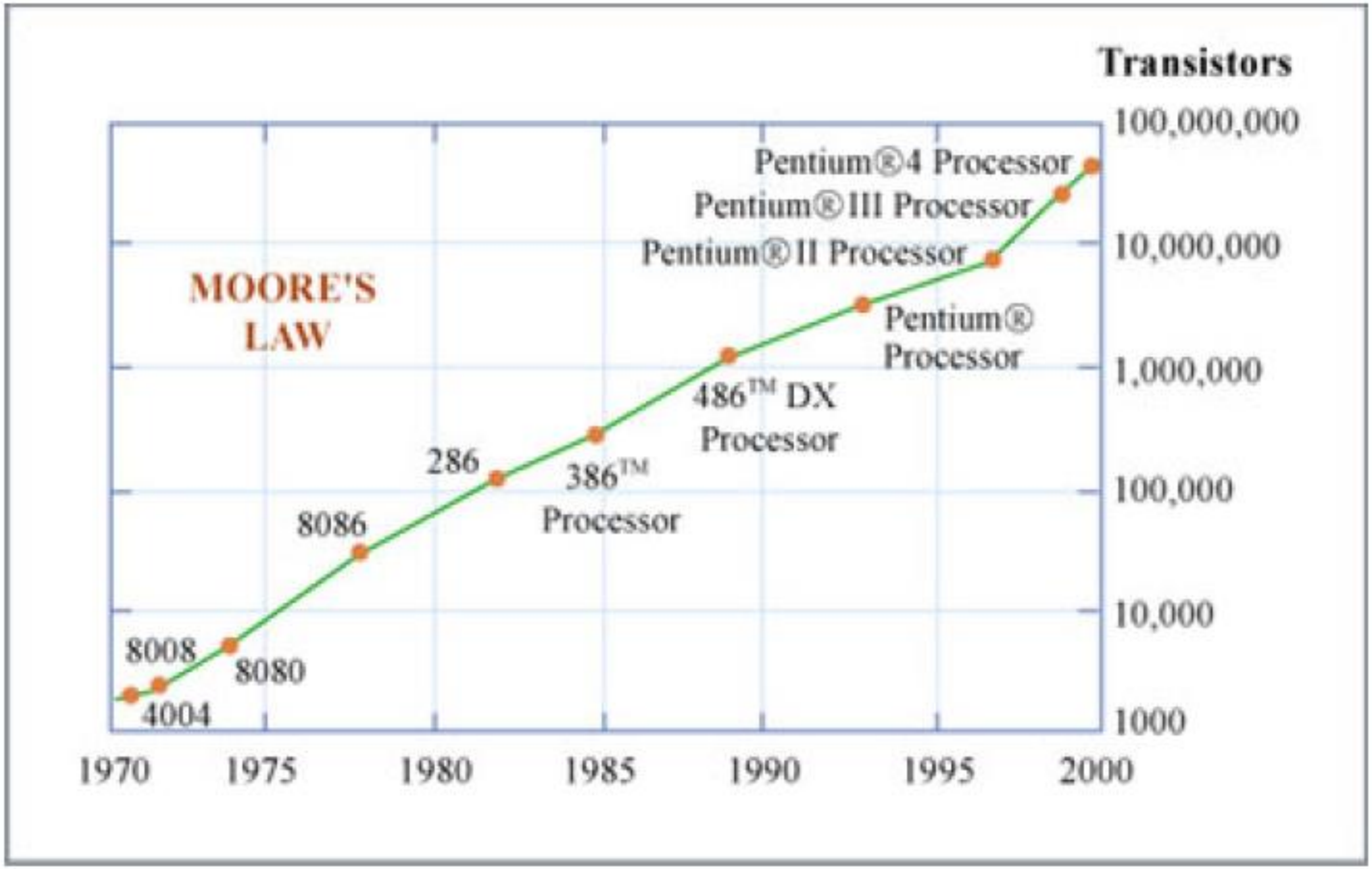
10⁵
10⁴
10³
10²
10
1
1962
1965
1970
1
10
10²
10³
10⁴
10⁵
Relative Manufacturing Cost per Component
Number of Components per Integrated Circuit

Numero de transistores en un CHIP

Microprocessor	Year of Introduction	Transistors
4004	1971	2,300
8008	1972	2,500
8080	1974	4,500
8086	1978	29,000
Intel286	1982	134,000
Intel386™ processor	1985	275,000
Intel486™ processor	1989	1,200,000
Intel® Pentium® processor	1993	3,100,000
Intel® Pentium® II processor	1997	7,500,000
Intel® Pentium® III processor	1999	9,500,000
Intel® Pentium® 4 processor	2000	42,000,000
Intel® Itanium® processor	2001	25,000,000
Intel® Itanium® 2 processor	2003	220,000,000
Intel® Itanium® 2 processor (9MB cache)	2004	592,000,000

Moore's law in Microprocessors




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

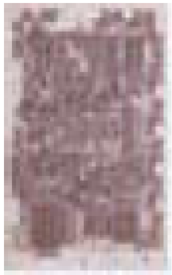
Moore's Law

In 1965, Intel co-founder Gordon Moore predicted that the number of transistors on a chip would double about every two years. Since then, Moore's Law has fueled a technology revolution as Intel has exponentially increased the number of transistors integrated into its processors for greater performance and energy efficiency.

Note: Number of transistors is an approximate number.

Intel® 4004 processor
Introduced 1971
Initial clock speed
108 KHz
Number of transistors
2,300
Manufacturing technology
10µ

The groundbreaking Intel® 4004 processor was introduced with the same computing power as ENIAC.



Intel® 8008 processor
Introduced 1972
Initial clock speed
500-800 KHz
Number of transistors
3,500
Manufacturing technology
10µ

The Intel® 8008 processor was twice as powerful as the Intel® 4004 processor.

Intel® 8080 processor
Introduced 1974
Initial clock speed

2 MHz

Number of transistors

4,500

Manufacturing technology

6µ

The Intel® 8080 processor made video games and home computers possible.

Intel® 8086 processor
Introduced 1978
Initial clock speed

5 MHz

Number of transistors

29,000

Manufacturing technology

3µ

The Intel® 8086 processor was the first 16 bit processor and delivered about ten times the performance of its predecessors.

Intel® 8088 processor
Introduced 1979
Initial clock speed

5 MHz

Number of transistors

29,000

Manufacturing technology

3µ

A pivotal sale to IBM's new personal computer division made the Intel® 8088 processor the brains of IBM's new hit product--the IBM PC.

Intel® 286 processor
Introduced 1982
Initial clock speed

6 MHz

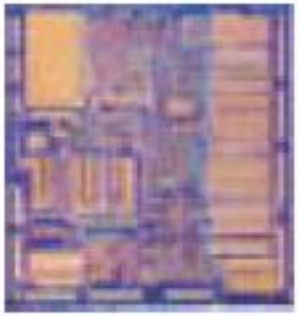
Number of transistors

134,000

Manufacturing technology

1.5µ

The Intel® 286 was the first Intel processor that could run all the software written for its predecessor.



Intel386™ processor
Introduced 1985
Initial clock speed

16 MHz

Number of transistors

275,000

Manufacturing technology

1.5µ

The Intel386™ processor could run multiple software programs at once and featured 275,000 transistors—more than 100 times as many as the original Intel® 4004.

Intel486™ processor
Introduced 1989
Initial clock speed

25 MHz

Number of transistors

1,200,000

Manufacturing technology

1µ

The Intel486™ introduced the integrated floating point unit. This generation of computers really allowed users to go from a command level computer into point and click computing.

Intel® Pentium® processor
Introduced 1993
Initial clock speed

66 MHz

Number of transistors

3,100,000

Manufacturing technology

0.8μ

The Intel® Pentium® processor, executing 112 million commands per second, allowed computers to more easily incorporate "real world" data such as speech, sound, handwriting and photographic images.

Intel® Pentium® Pro processor
Introduced 1995
Initial clock speed

200 MHz

Number of transistors

5,500,000

Manufacturing technology

0.6μ

The Pentium® Pro processor delivered more performance than previous generation processors through an innovation called Dynamic Execution. This made possible the advanced 3D visualization and interactive capabilities.

Intel® Pentium® II processor
Intel® Pentium II Xeon® processor
Introduced 1997
Initial clock speed

300 MHz

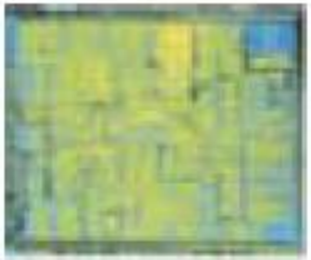
Number of transistors

7,500,000

Manufacturing technology

0.25μ

The Intel® Pentium® II processor's significant performance improvement over previous Intel-Architecture processors was based on the seamless combination of the P6 microarchitecture and Intel MMX media enhancement technology.



Intel® Pentium® III processor
Intel® Pentium® III Xeon® processor
Introduced 1999
Initial clock speed

500 MHz

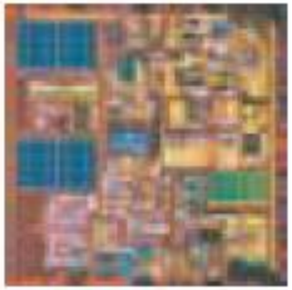
Number of transistors

9,500,000

Manufacturing technology

0.18µ

The Intel® Pentium® III processor executed Internet Streaming SIMD Extensions, extended the concept of processor identification and utilized multiple low-power states to conserve power during idle times.



Intel® Pentium® 4 processor
Introduced 2000
Intel® Xeon® processor
Introduced 2001
Initial clock speed

1.5 GHz

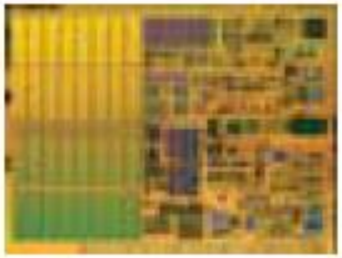
Number of transistors

42,000,000

Manufacturing technology

0.18µ

The Intel® Pentium® 4 processor ushers in the advent of the nanotechnology age.



Intel® Pentium® M processor
Introduced - 2002
Initial Clock Speed

1.7 GHz

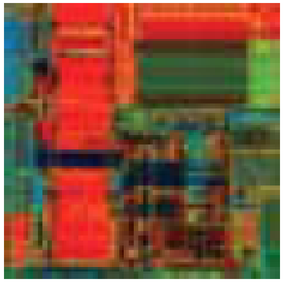
Number of transistors

55,000,000

Manufacturing technology

90nm

The Intel® Pentium® M processor, the Intel® 855 chipset family, and the Intel® PRO/Wireless 2100 network connection are the three components of Intel® Centrino® processor technology. Intel® Centrino® processor technology was designed specifically for portable computing.



Intel® Itanium® 2 processor
Introduced 2002
Initial clock speed

1 GHz

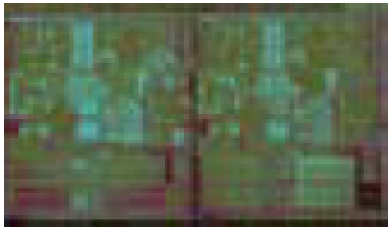
Number of transistors

220,000,000

Manufacturing technology

0.13µ

The Intel® Itanium® 2 processor is the successor of the first Itanium processor.
The architecture is based on Explicitly Parallel Instruction Computing (EPIC). It is theoretically capable of performing roughly eight times more work per clock cycle than other CISC and RISC architectures.



Intel® Pentium® D processor
Introduced 2005
Initial clock speed

3.2 GHz

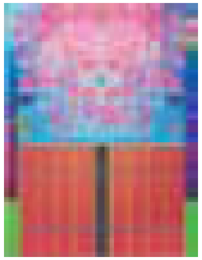
Number of transistors

291,000,000

Manufacturing technology

65nm

The Intel® Pentium® D processor features the first desktop duel-core design with two complete processor cores, that each run at the same speed, in one physical package.



Intel® Core™ 2 Duo processor
Intel® Core™2 Extreme processor
Dual-Core Intel® Xeon® processor
Introduced 2006
Initial clock speed

2.93 GHz

Number of transistors

291,000,000

Manufacturing technology

65nm

Intel® Core™2 Duo processor optimizes mobile microarchitecture of the Intel® Pentium® M processor and enhanced it with many microarchitecture innovations. Intel® Centrino® Pro and Intel® vPro™ processor technology provide excellent performance from the Dual-Core Intel® Core™2 Duo processor.

Dual-Core Intel® Itanium® 2 processor 9000 series
Introduced 2006
Initial clock speed

1.66 GHz

Number of transistors

1,720,000,000

Manufacturing technology

90nm

Dual-Core Intel® Itanium® 2 processor 9000 series outperforms the earlier, single-core version of the Itanium 2 processors. With more than 1.7 billion transistors and with two execution cores, these processors double the performance of previous Itanium processors while reducing average power consumption.

Quad-Core Intel® Xeon® processor
Quad-Core Intel® Core™2 Extreme processor
Introduced 2006
Intel® Core™2 Quad processors
Introduced 2007
Initial clock speed

2.66 GHz

Number of transistors

582,000,000

Manufacturing technology

65nm

The unprecedented performance of the Intel® Core™2 Quad processor is made possible by each of the four complete execution cores delivering the full power of Intel Core microarchitecture. The Quad-Core Intel® Xeon® processor provides 50 percent greater performance than industry-leading Dual-Core Intel® Xeon® processor in the same power envelope. The quad-core-based servers enable more applications to run with a smaller footprint.

Quad-Core Intel® Xeon® processor (Penryn)
Dual-Core Intel® Xeon® processor (Penryn)
Quad-Core Intel® Core™2 Extreme processor (Penryn)
Introduced 2007
Initial clock speed

> 3 GHz

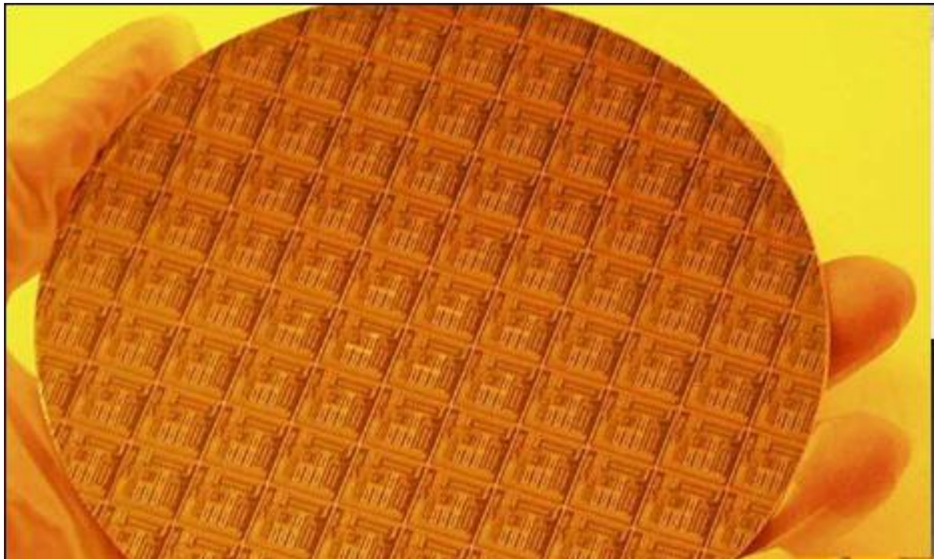
Number of transistors

820,000,000

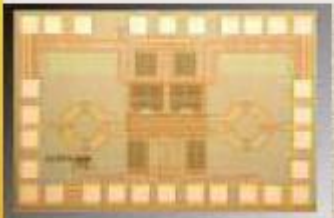
Manufacturing technology

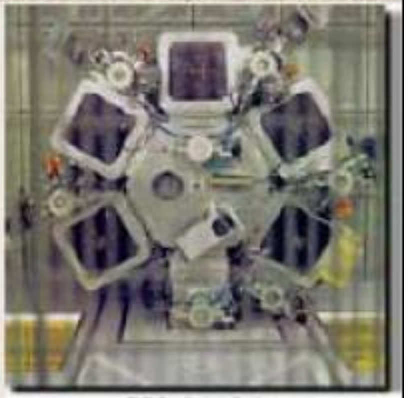
45nm

Intel's next generation Intel® Core™2 processor family, codenamed "Penryn", contains industry-leading microarchitecture enhancements. Further, new SSE4 instructions for improved video, imaging, and 3D content performance and new power management features will extend "Penryn" processor family leadership in performance and energy efficiency.



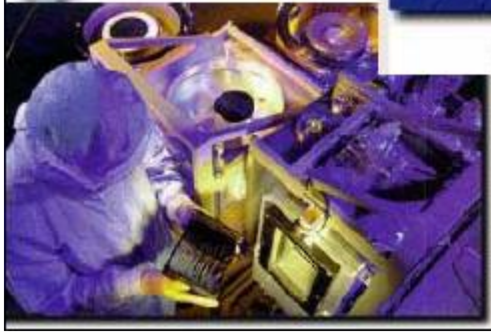
Polysilicon Ingots





PVD Sputtering Tool
(Sputtered Films Corporation)

Ion Implanter
(Varian Associates)



El Proceso Tecnológico

OBTENCION POLICRISTALINO

OBTENCION MONOCRISTALINO

OBTENCION OBLEAS

CRECIMIENTO EPITAXIAL

ELIMINACION DE METAL SOBRANTE

ELIMINACION DE FOTORRESINA Y OXIDO

OXIDACION Y FOTORRESINA

PREPARACION DE LA MASCARA Y EXPOSICION A RADIACION

METALIZACION

CVD

CREACION DE ZONAS CON IMPUREZAS CONTROLADAS

IMPLANTACION DE ION

REVELADO Y GRABADO

EMPAQUETADO

UNION DE ALAMBRES

TESTEO Y CORTE

MANIPULACION Y LIMPIEZA

Fabricación de C.I.M.(Monoliticos.pdf pag 5)

Obtención de polisilicio en bruto

Obtención de silicio monocristalino

Corte en obleas

Oxidación

Crecimiento epitaxial

Pulido

Recubrimiento con foto-resina

Generación de máscaras

Revenido

Exposición

Ataque del metal

Revelado

Deposición de metal

Ataque ácido

Deposición química por vapor

Implante iónico

Enjuague y secado

Encapsulado

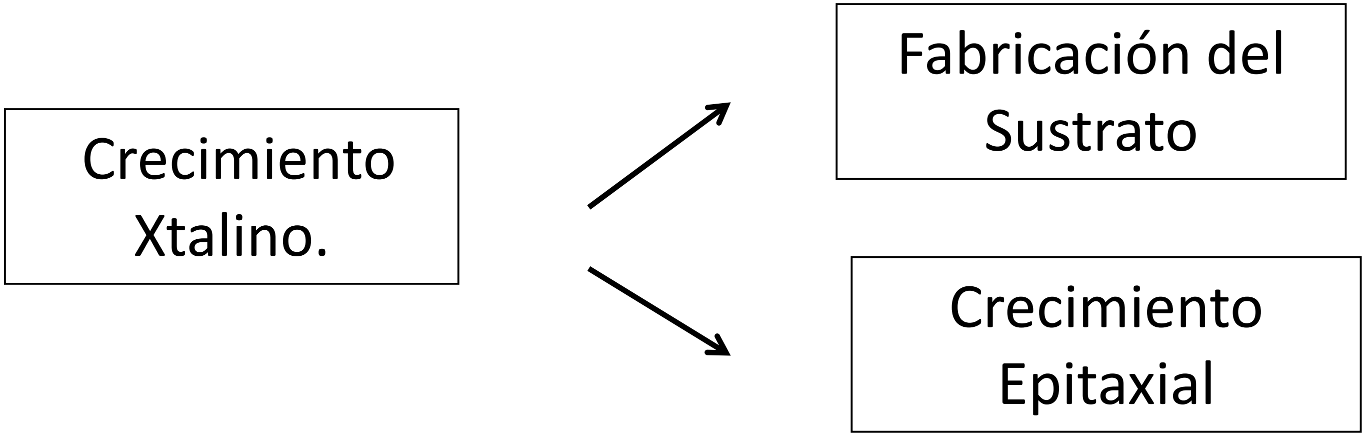
Conexionado

Test y corte de dados

Procesos para la Fabricacion de C.I.M.

- Fabricación del Sustrato
- Crecimiento Epitaxial
- Fotolitografia
- Colocación de impurezas
- Metalización
- Pasivación
- Encapsulado

Procesos para la Fabricación de C.I.M.



Crecimiento Xtalino.

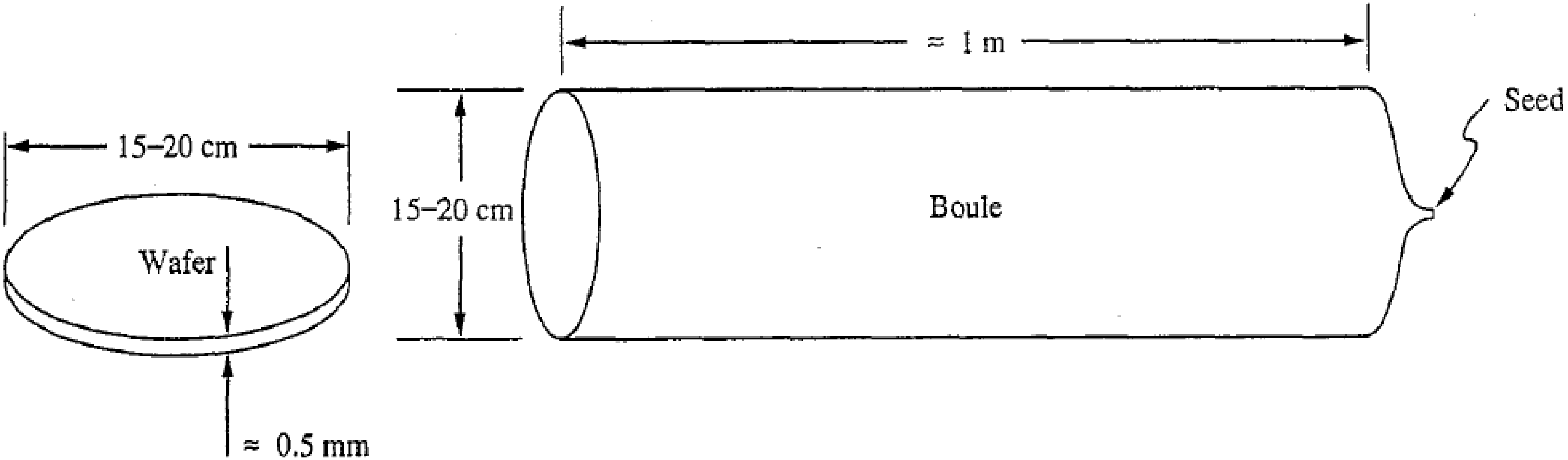
Fabricación del Sustrato

Crecimiento Epitaxial

Crecimiento Xtalino.

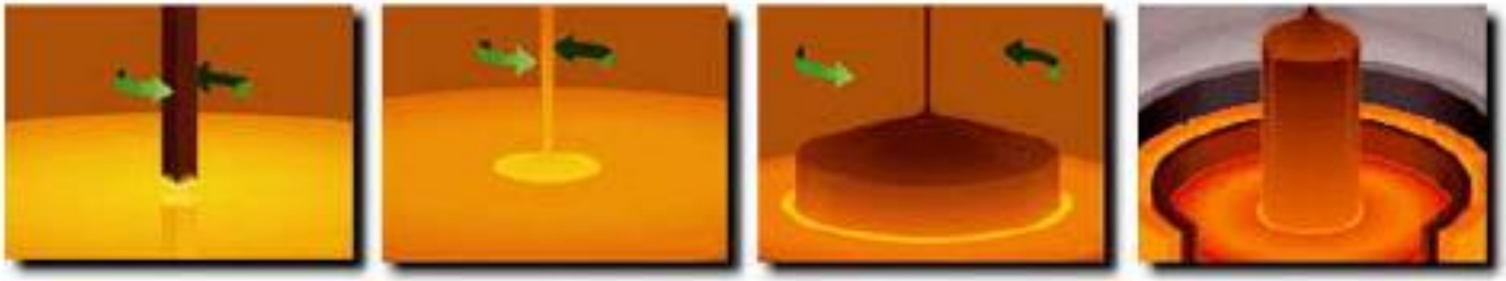
Fabricación del sustrato

1. Silicio poli cristalino
2. Refinado del silicio poli cristalino (Silicio de grado electrónico)
3. Fabricación de barras de silicio mono cristalino (1 mt. de largo x 30 cm de diámetro)
4. Obtención de las obleas (Corte de discos de silicio)
    a) Espesor 400 µm a 600 µm
    b) 10 defectos por cm^2 en cualquier sección transversal



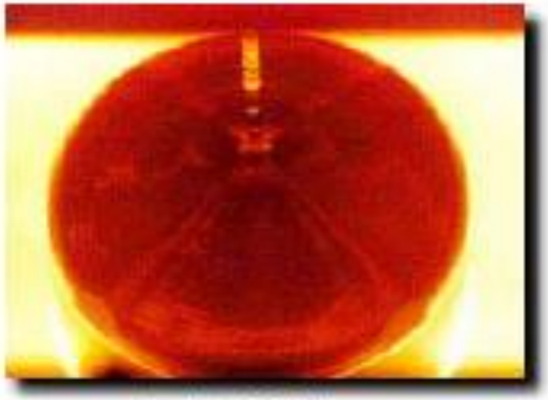
Obtención de lingotes de Silicio Monocristalino

Los lingotes se obtienen por el método de Czochralski



El silicio policristalino es molido e impurificado con elementos del tipo As, B, P o Sb y fundido a 1400ºC en un crisol de cuarzo en atmósfera de gas inerte (Ar) de alta pureza.

El diámetro del lingote se controla con la temperatura del baño y la velocidad de extracción.



Inside CZ Puller
(MEMC)

Obtención de lingotes de Silicio Monocristalino

CZ Crystal Pullers
(Mitsubishi Materials Silicon)

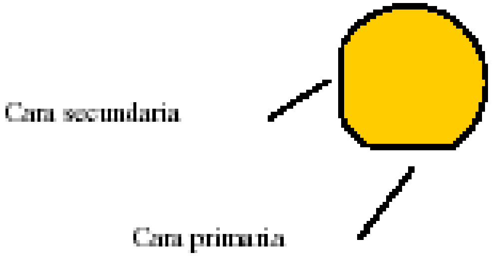
Los mayoría de los lingotes son de 150 mm (6") y 200 mm (8"), pero también pueden ser de 300 mm (12") y 400 mm (16")

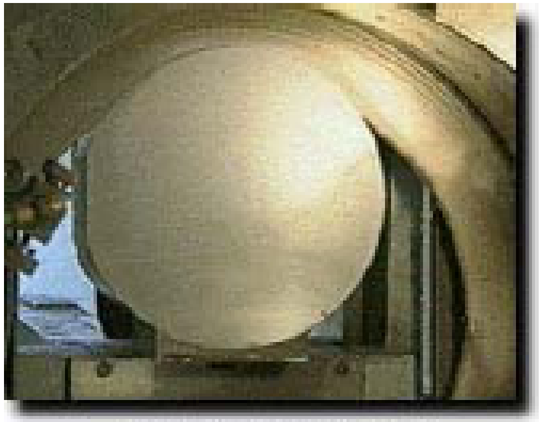
Silicon Ingots
(Mitsubishi Materials Silicon)

Los equipos de estiramiento se instalan sobre fundamentos de hormigón de gran profundidad para prevenir la vibración

Corte de Obleas

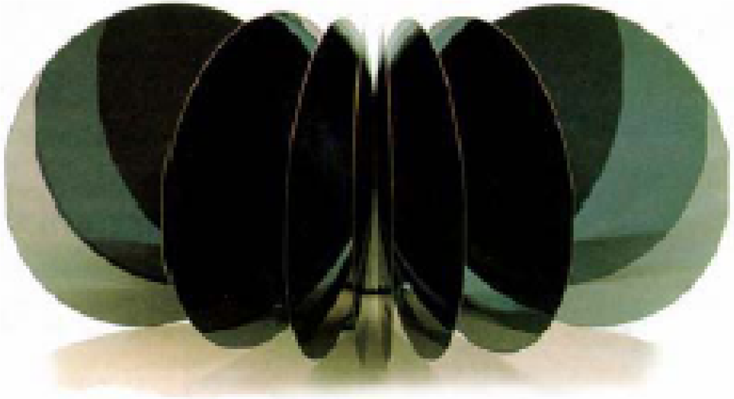
Antes de proceder a cortar los lingotes en finas obleas se hacen unas marcas para especificar la orientación cristalina



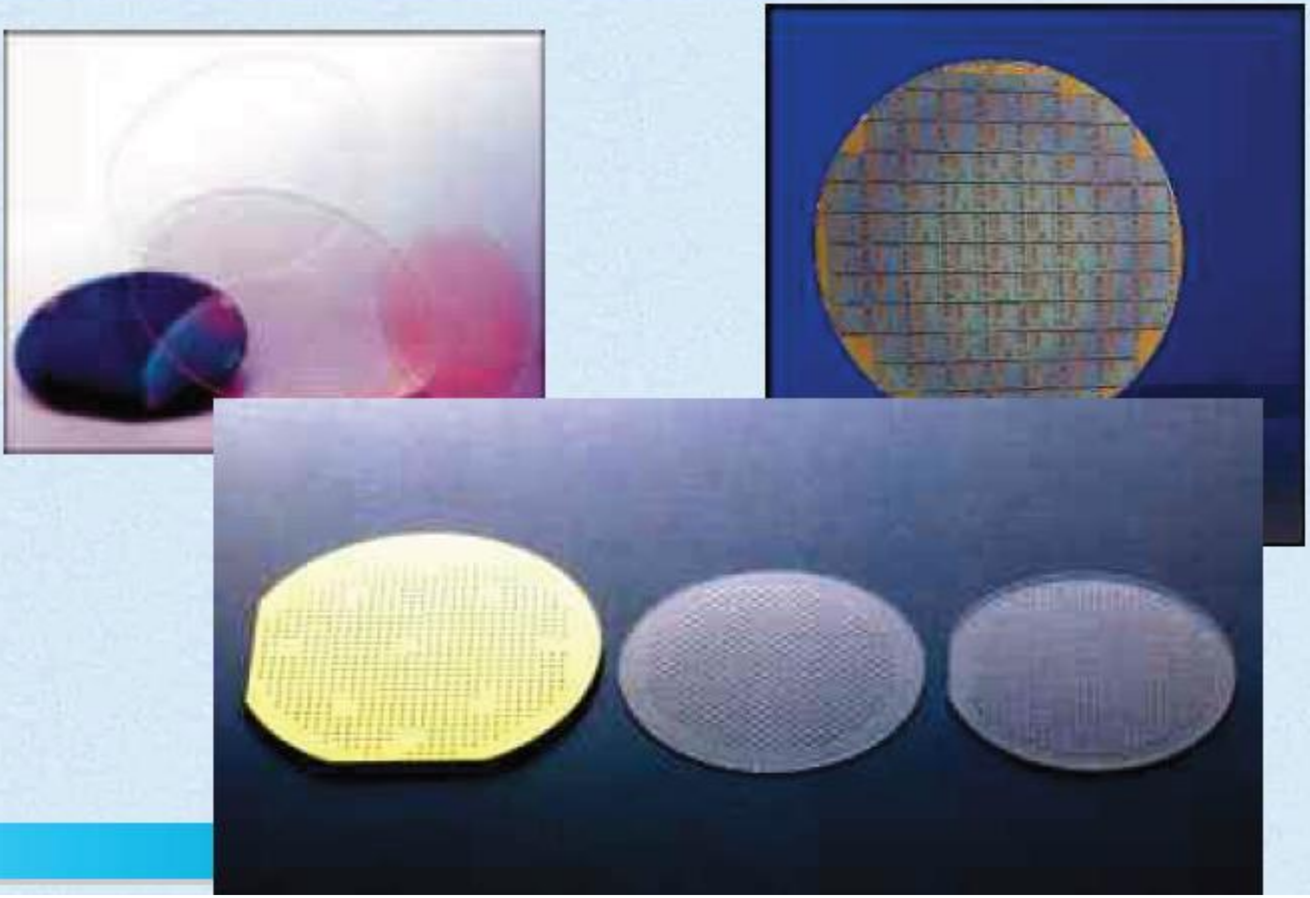


ID Wafer Slicing Saw

Las obleas se cortan en una sierra circular cuyo borde de corte es el interno para asegurar una mayor precisión y finura



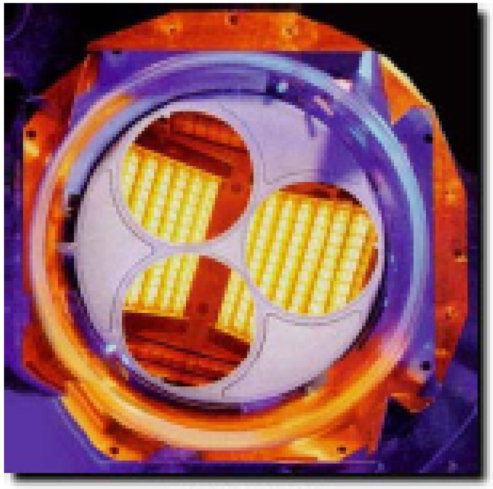
Obleas de silicio y de vidrio



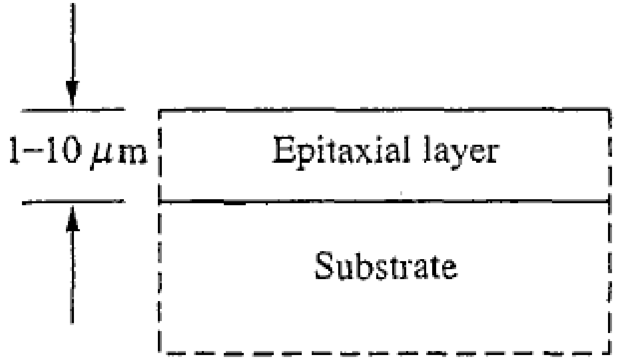
Crecimiento Epitaxial

Este proceso se utiliza para hacer crecer una capa de silicio con una concentración diferente, generalmente menor, de dopantes en el seno del sustrato.

El triclorosilano ($SiHCl_3$) o el tetracloruro de silicio ($SiCl_4$) y el hidrógeno se combinan con gas de diborano ($B2H_6$) o fosfina (PH_3) para actuar como dopante.



Epitaxial Reactor
(Moore Epitaxial ®)



Crecimiento Epitaxial

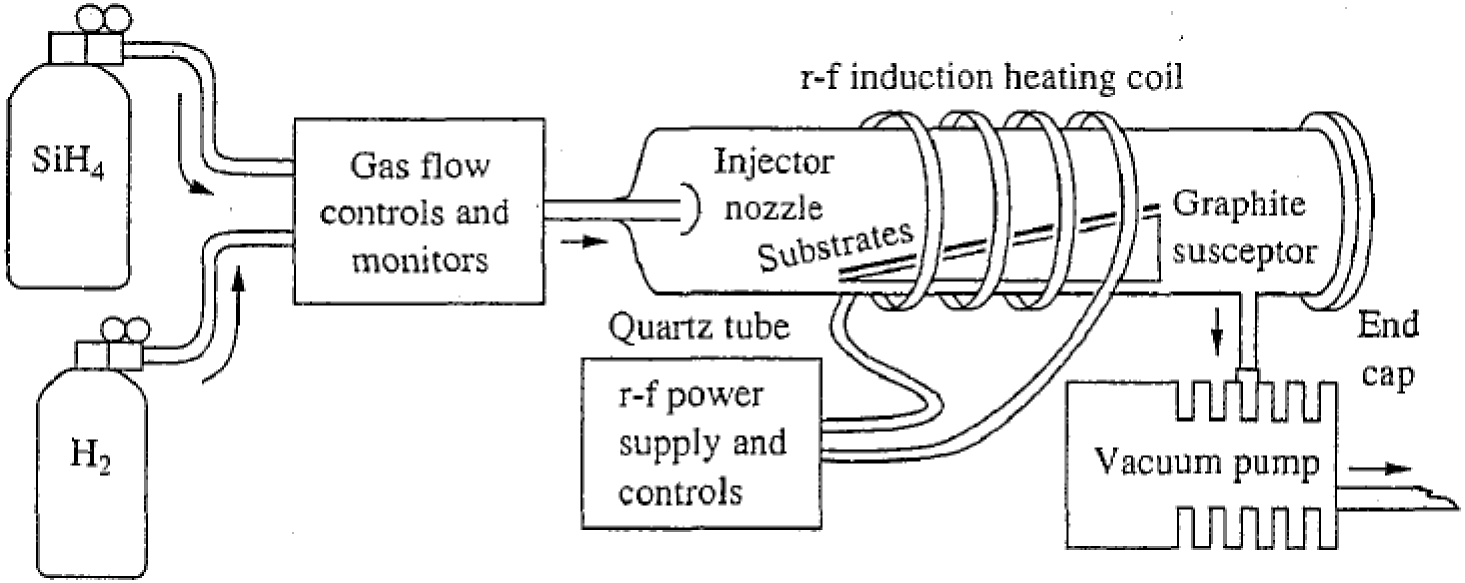


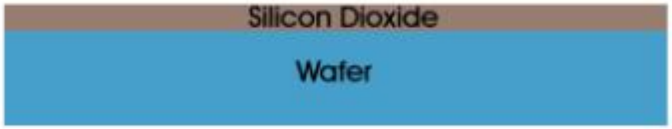
FIGURE G.2
Representative chemical vapor deposition system for epitaxial growth of silicon.

Fotolitografía

- Oxidación
- Aplicación de Fotoresist
- Enmascarado
- Revelado
- Etching (Remoción del oxido)

Oxidación

Se crea una fina capa de SiO_2 sobre la superficie por exposición a una mezcla de O_2 e H_2 de alta pureza a 1000 ºC



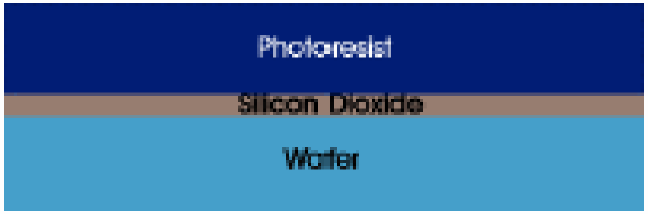
Oxidation Layering

Oxidation Furnace
(Silicon Valley Group - Thermco Systems)

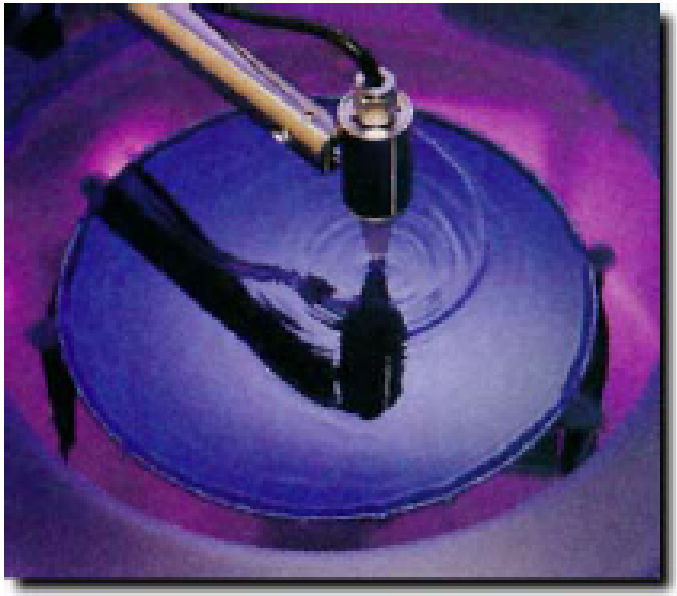
El óxido se utiliza como aislante (en torno a 1500 Å) y como óxido de puerta (entre 200 y 500 Å)

Recubrimiento con fotoresina

La fotoresina es un material fotosensible que se aplica sobre la oblea en estado líquido en pequeñas cantidades



Photoresist Coating

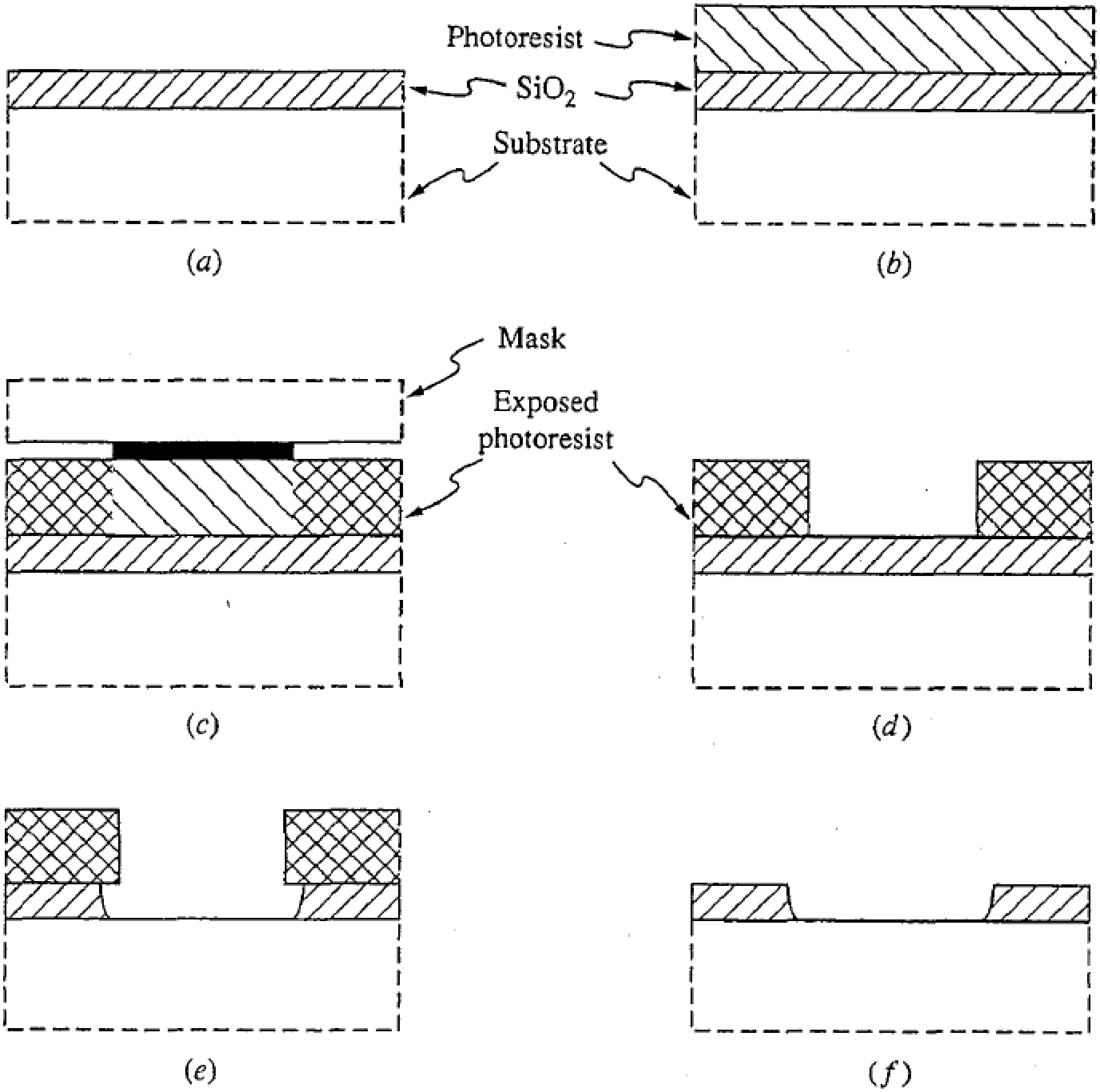


Photoresist Application
(Ontrak)

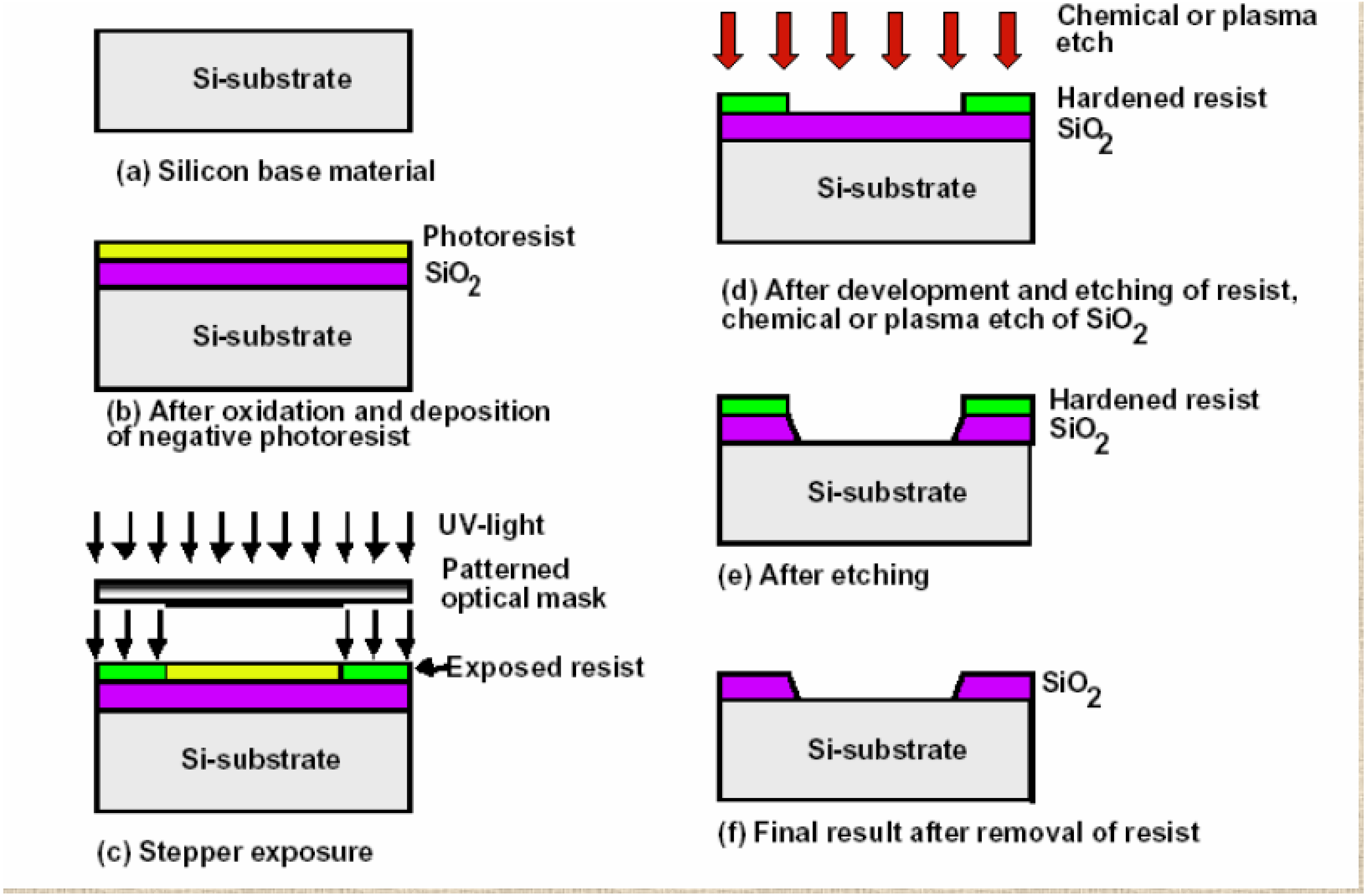
La oblea se hace girar a 3000 r.p.m. extendiendo el material en forma de una capa uniforme de entre 2 y 200 μm de espesor.

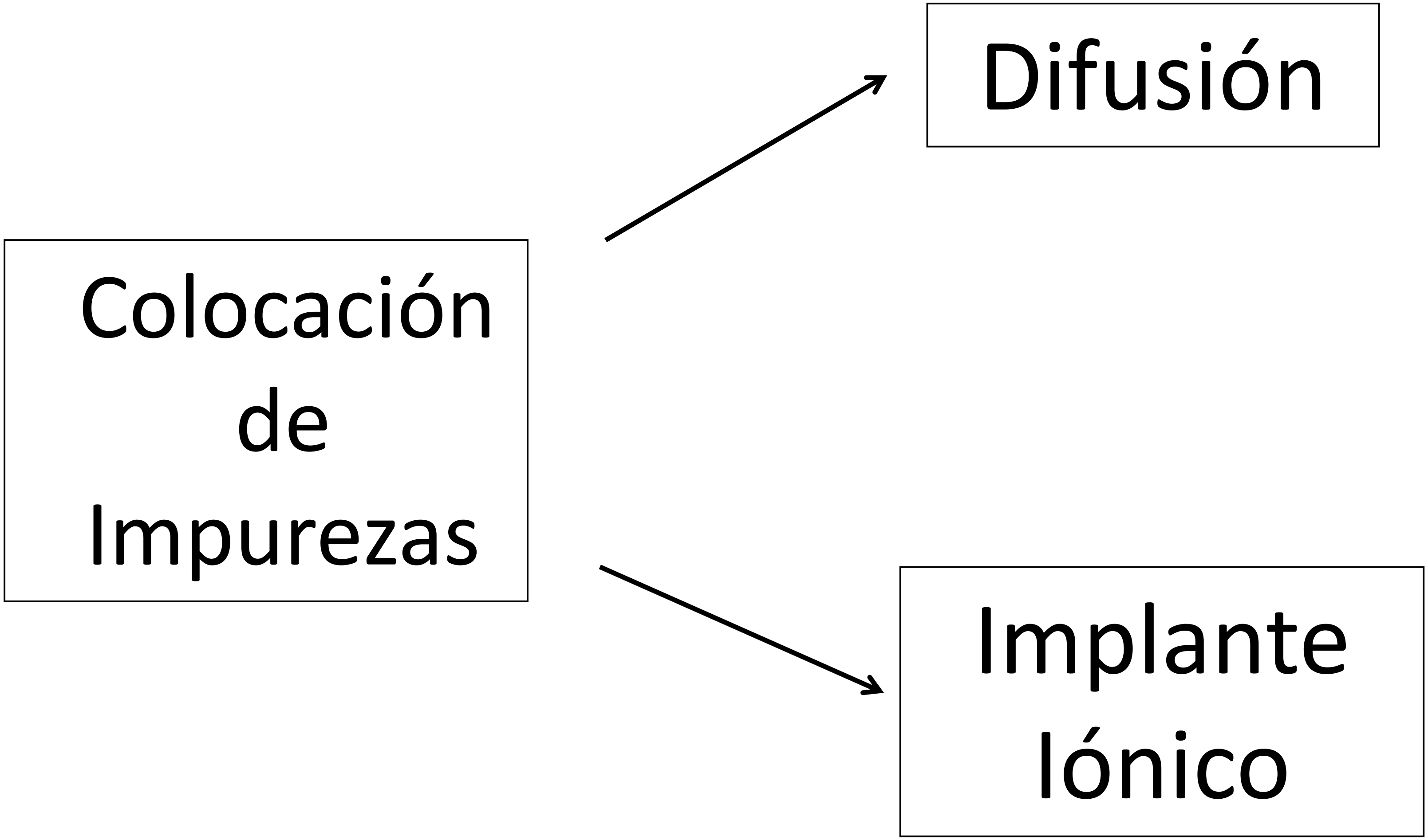
Hay dos tipos de fotoresinas: negativa y positiva

La fotoresina positiva se adapta mejor a las exigencias de la tecnología moderna en cuanto a alcanzar menores dimensiones, las cuales se encuentran por debajo de 1,0 μm y puede llegar a 0,15 μm.


Photoresist
SiO_2
Substrate
Mask
Exposed photoresist
(a)
(b)
(c)
(d)
(e)
(f)

FOTOLITOGRAFIA



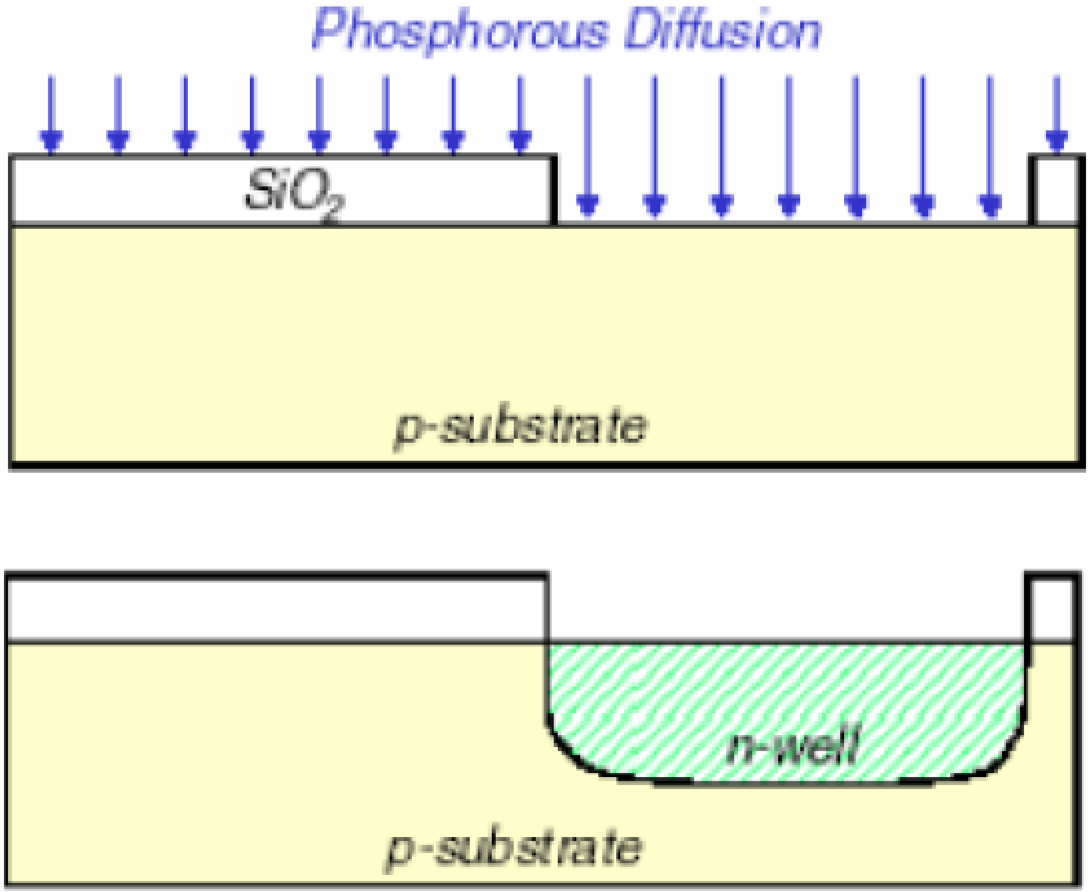


Colocación de Impurezas

Difusión

Implante Iónico

DIFUSION DE IMPUREZAS



DIFUSION DE IMPUREZAS

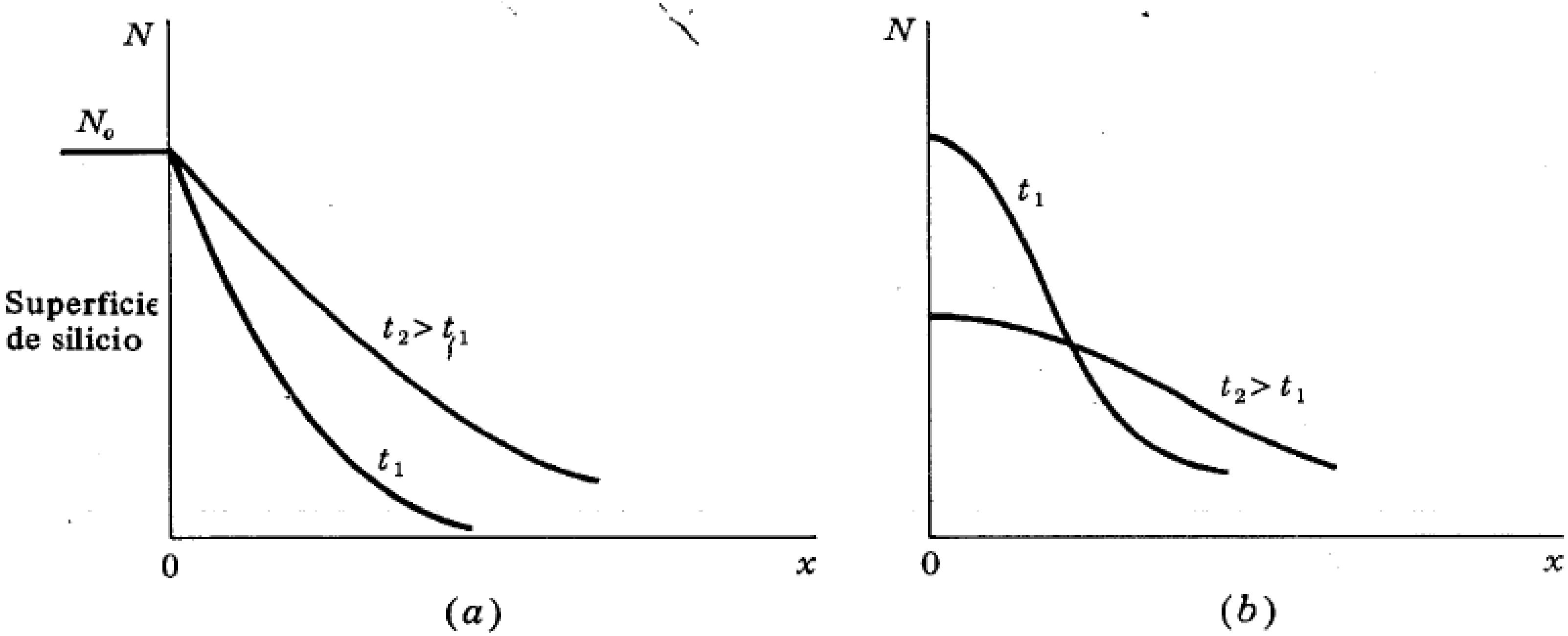
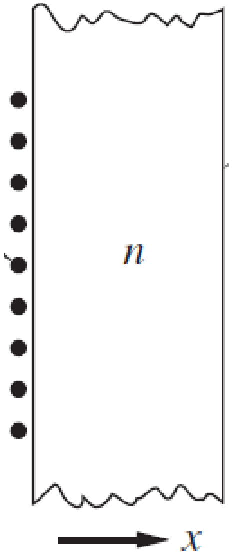
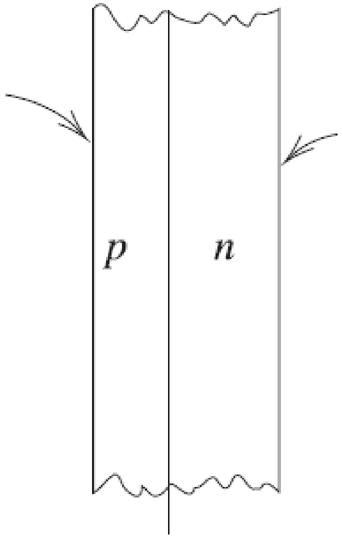
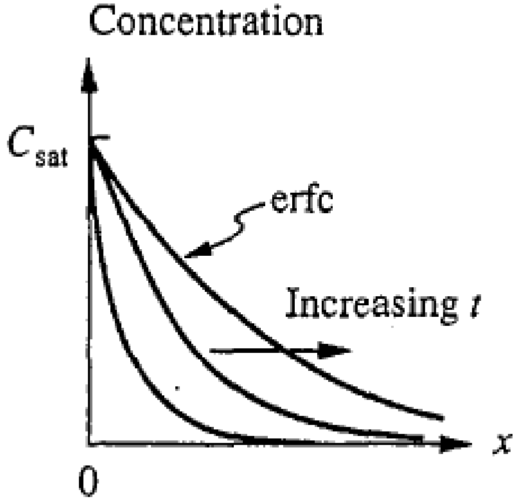


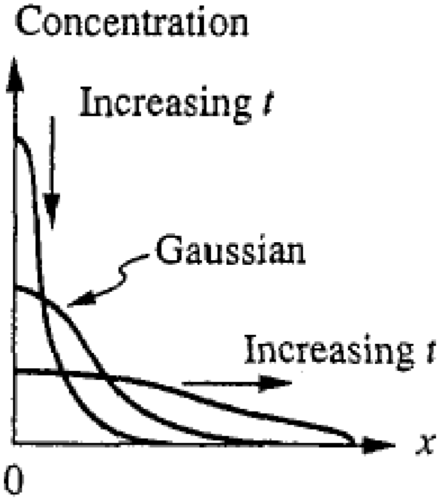
Fig. 7-6. Concentración N en función de la distancia x dentro del chip de silicio para dos valores t_1 y t_2 del tiempo de difusión. (*a*) La concentración en la superficie constante es igual a N_o por unidad de volumen. (*b*) El número total de átomos en la superficie es constantemente igual a Q por unidad de superficie



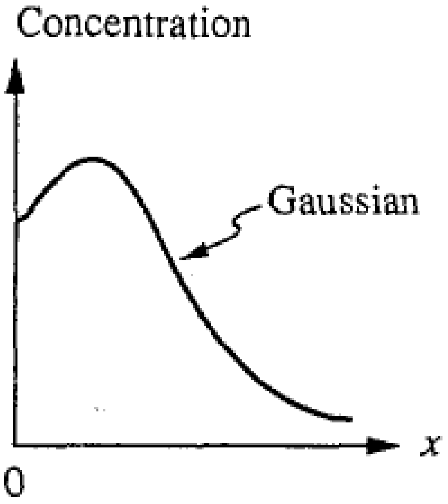




Concentración de impurezas constante en la superficie



Cantidad de impurezas fija en la superficie



Implante IONICO

DIFUSION DE IMPUREZAS

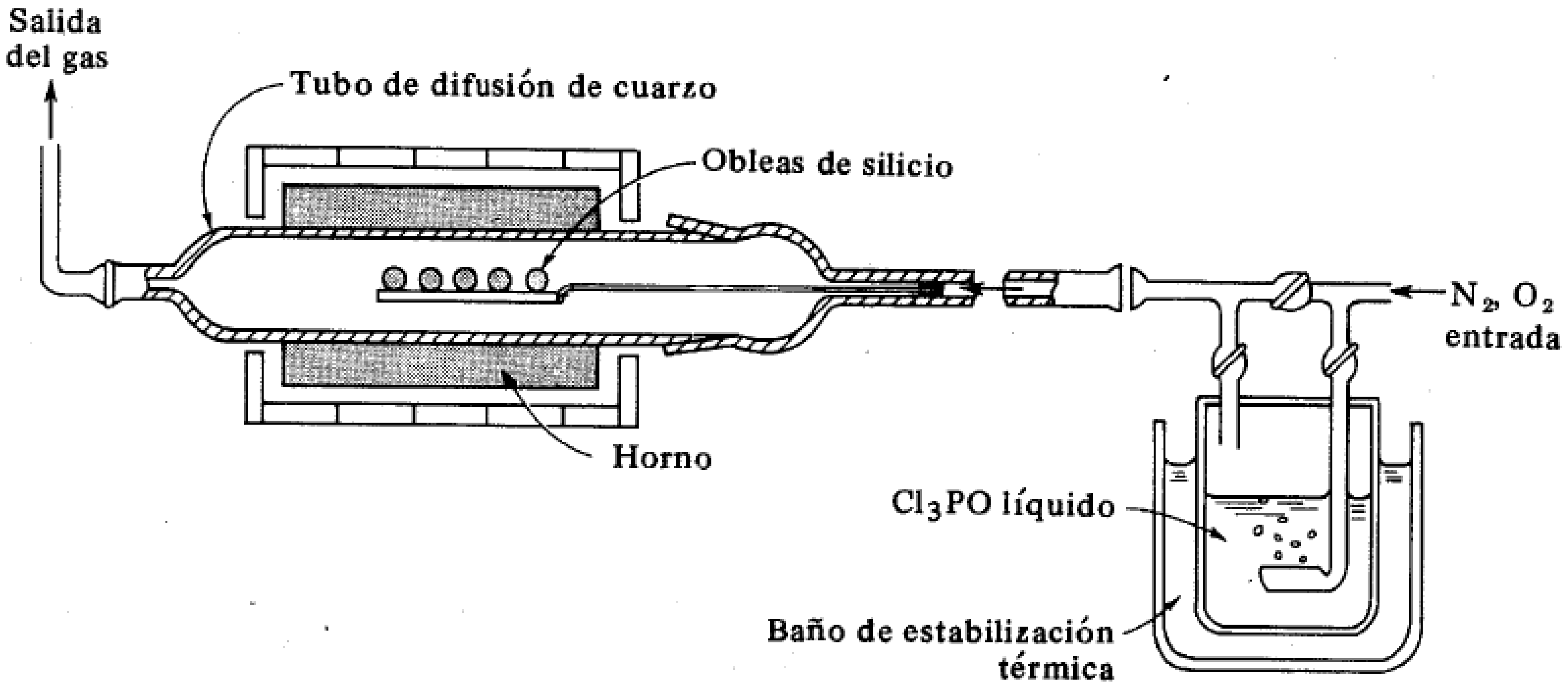
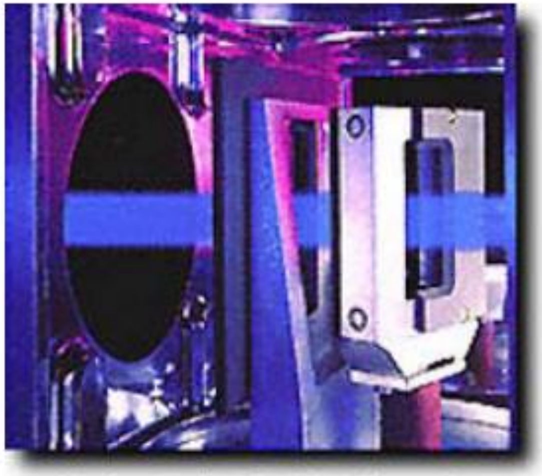


Fig. 7-10. Representación esquemática de un aparato típico para la difusión de Cl_3 PO. (Cortesía de Motorola, Inc.[1])

Implante iónico

El implantador iónico utiliza un tubo acelerador de alta corriente e imanes de dirección focalizadores para bombardear la superficie de la oblea con iones de un dopante específico. Estos iones dopantes son implantados en la capa superior de la oblea, justo debajo de la superficie, modificando la conductividad de una región específica.

Ion Implanter
(Varian Associates)



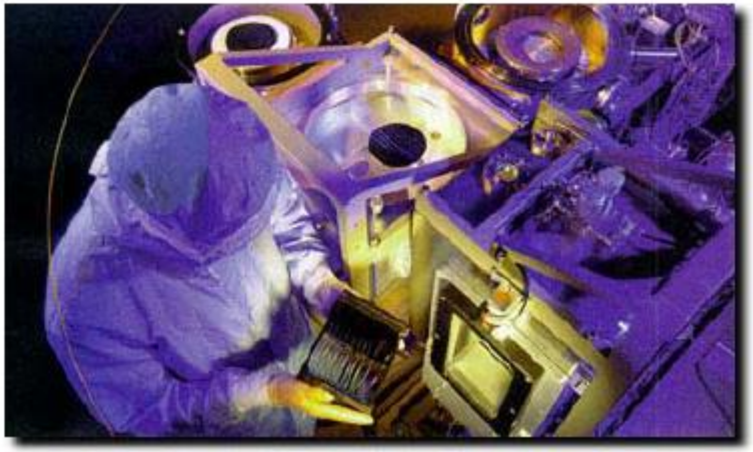
Ion Implanter Steering Magnets
(Varian Associates)

Los equipos de implante se clasifican en los de alta corriente (corriente mayor de 3 mA) o de corriente media (menores de 3 mA)

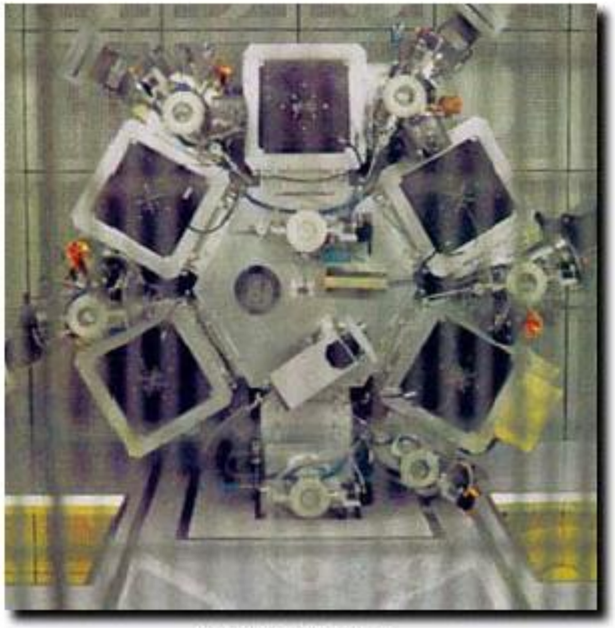
Metalización (deposición de metal)

La evaporación utiliza el calor de un filamento eléctrico o de un haz de electrones y un fuerte vacio para vaporizar la fuente de metal. El material vaporizado se condensa sobre la superficie de las obleas.

El chisporreteo utiliza plasma de argón que bombardea el metal fuente. Las moléculas de metal desprendidas son focalizadas por una "lente", llamada colimador; y se depositan en una fina película sobre la superficie de la oblea.



Thin Film Deposition
(Alcatel High Vacuum Technology)

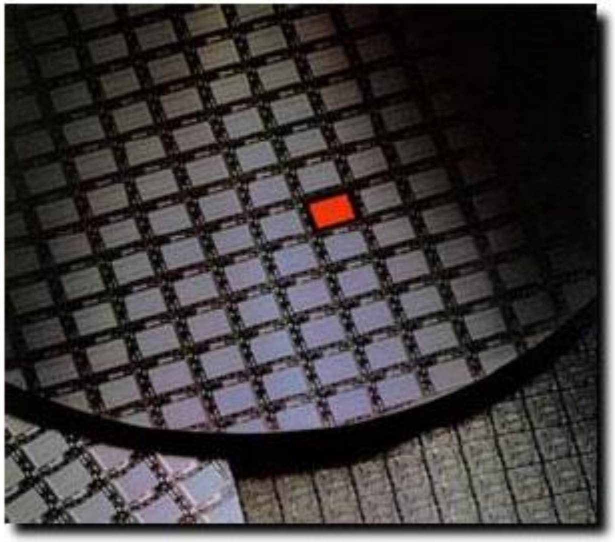


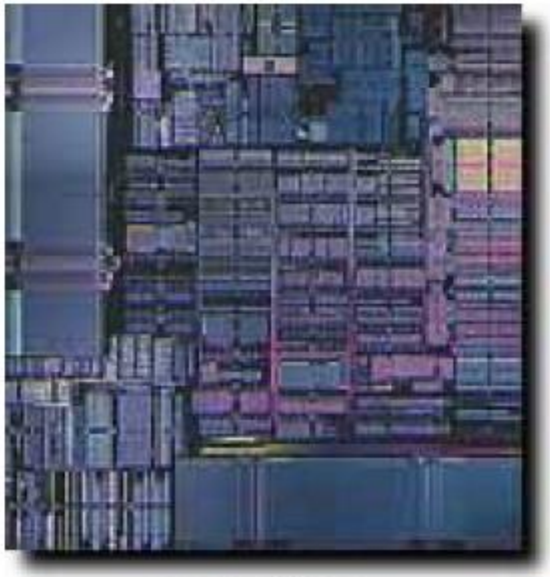
PVD Sputtering Tool
(Sputtered Films Corporation)

Testeo y Corte en dados

Cada oblea terminada puede contener algunos cientos de dispositivos del mismo tipo contenidos en pequeños dados. Todos los dados son testeados de forma automática antes de proceder a cortarlos.

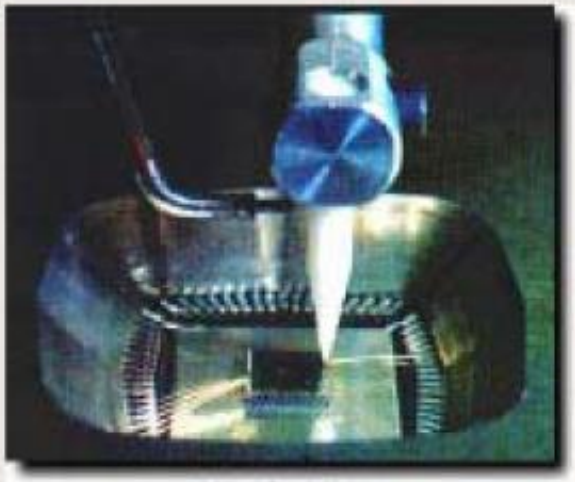
El equipo de testeo utiliza unas sondas tipo agujas para hacer contacto en los *pads* de soldadura (puntos de conexión del circuito) de cada dispositivo y verificar su funcionamiento.





64-Bit RISC
Microprocessor Die
(Motorola)

CONEXIONADO

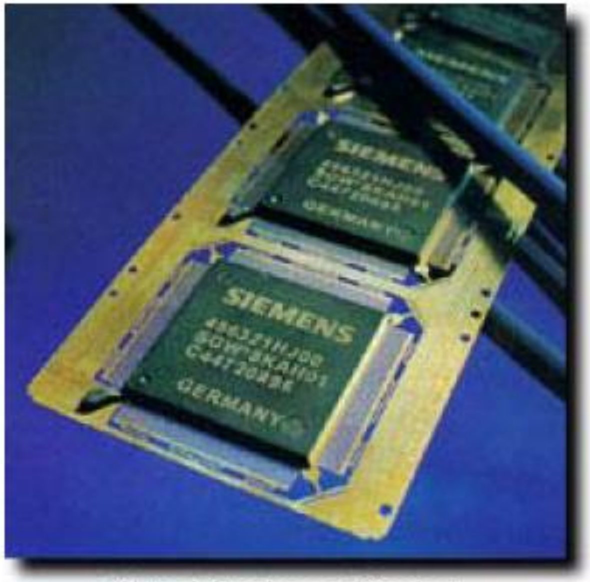


Wire Bonding
(Kulicke & Soffa Industries, Inc.)

Encapsulado

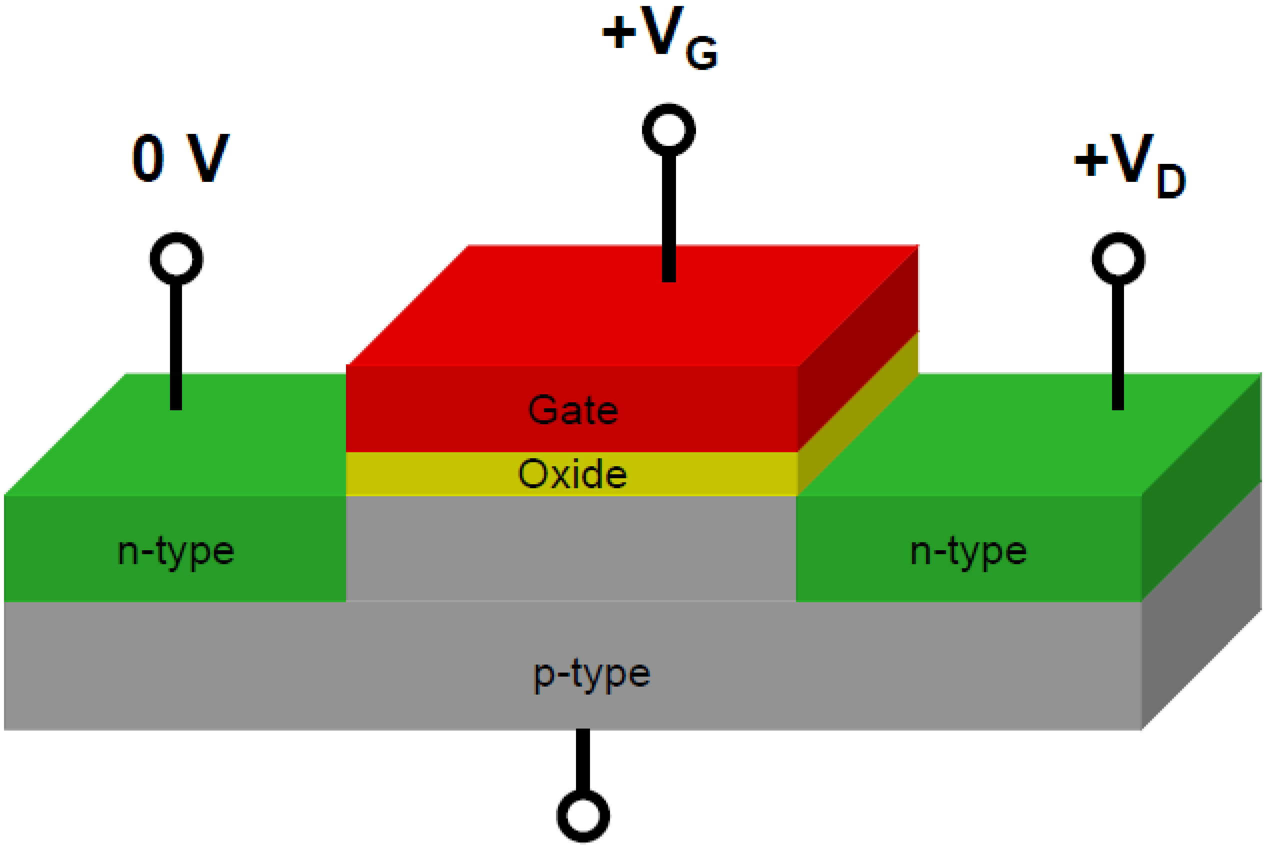
Después de terminada la soldadura de los cables se procede al sellado del dispositivo en un envoltorio cerámico o de plástico.

DIP (Dual Inline Package) Device
(AMD Corporation)

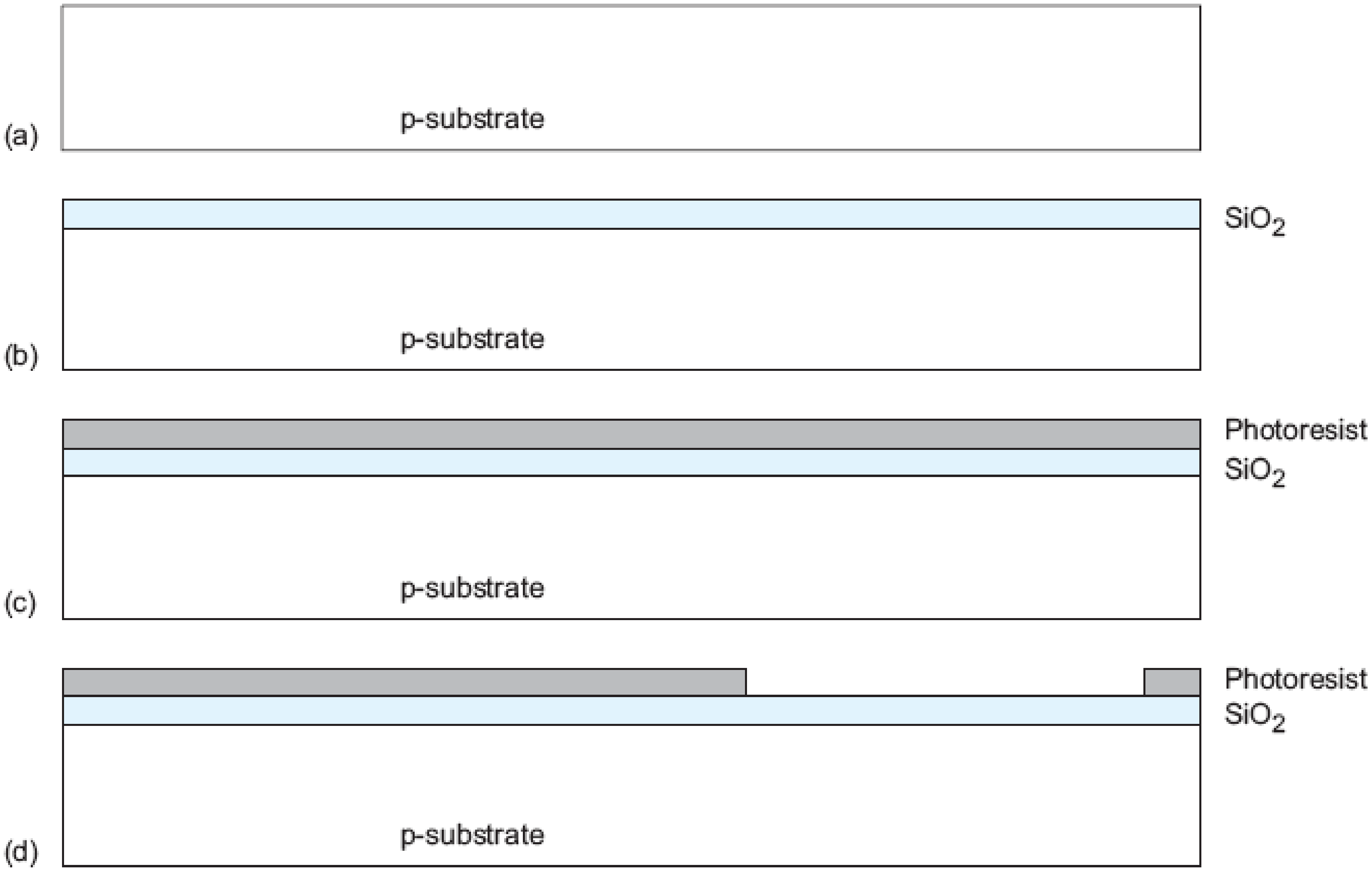


Quad Package Device
(Siemens AmG)

TRANSISTOR MOS

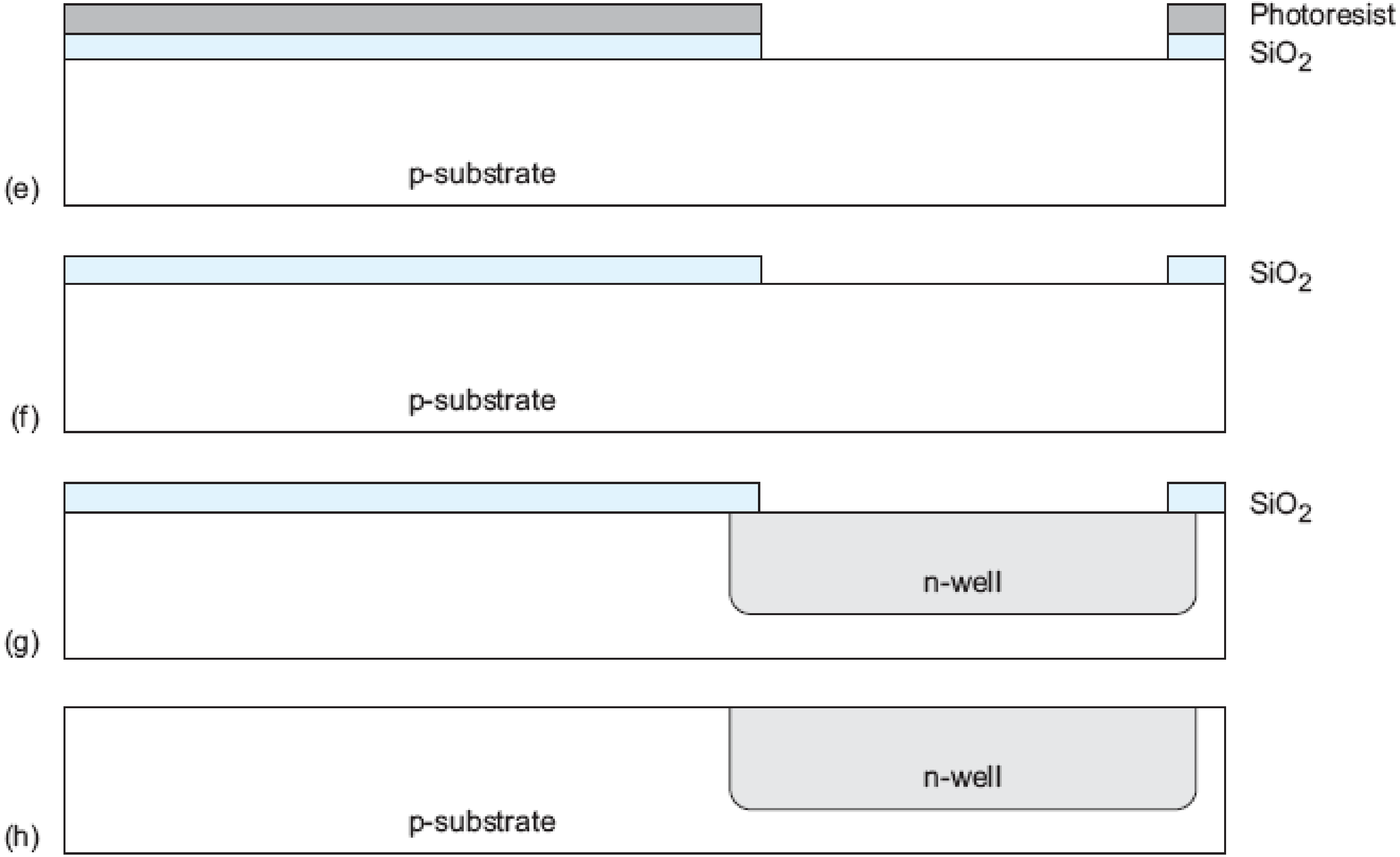


Fabricación de un inversor CMOS I

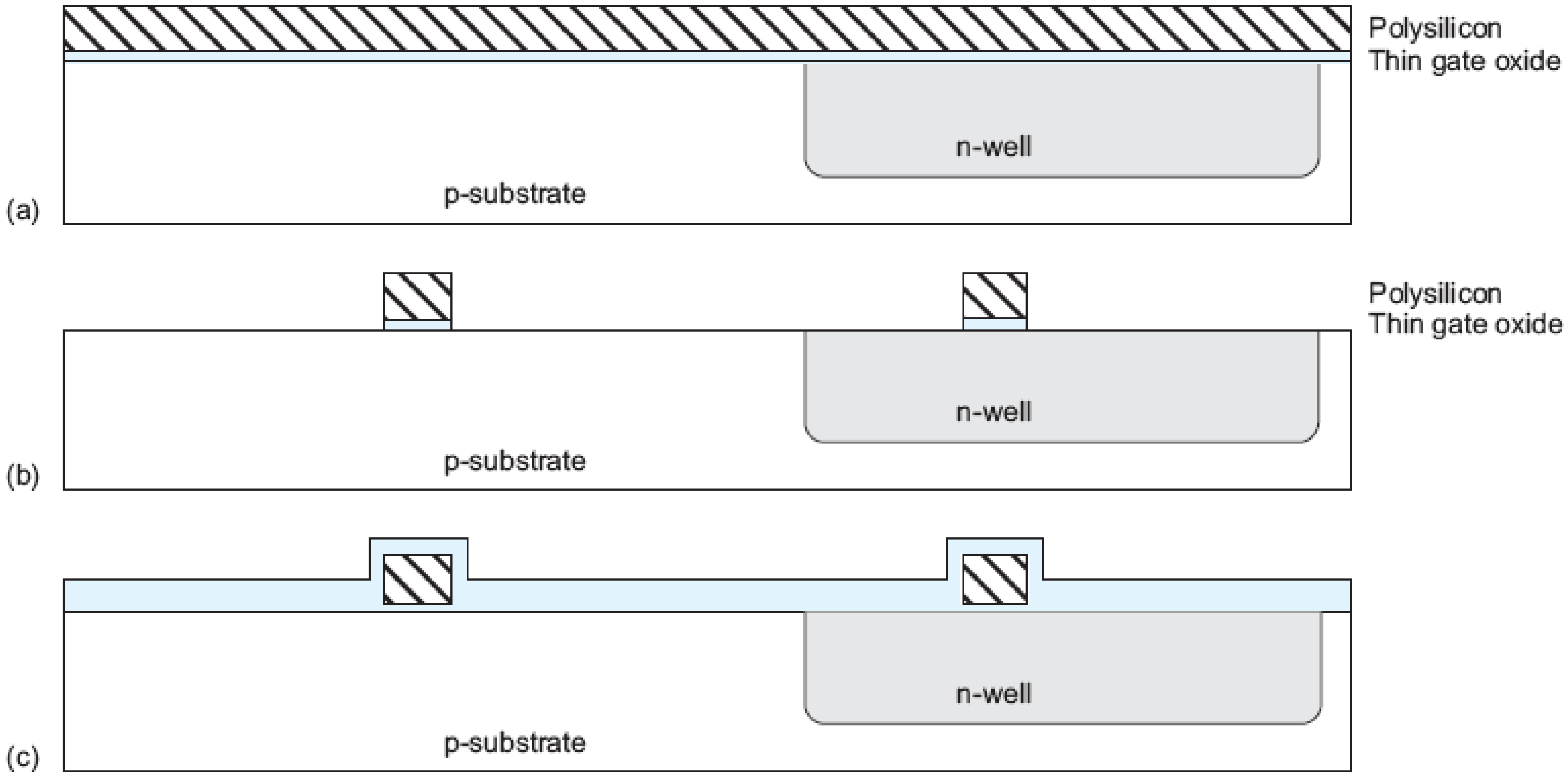


Fabricación de un inversor CMOS

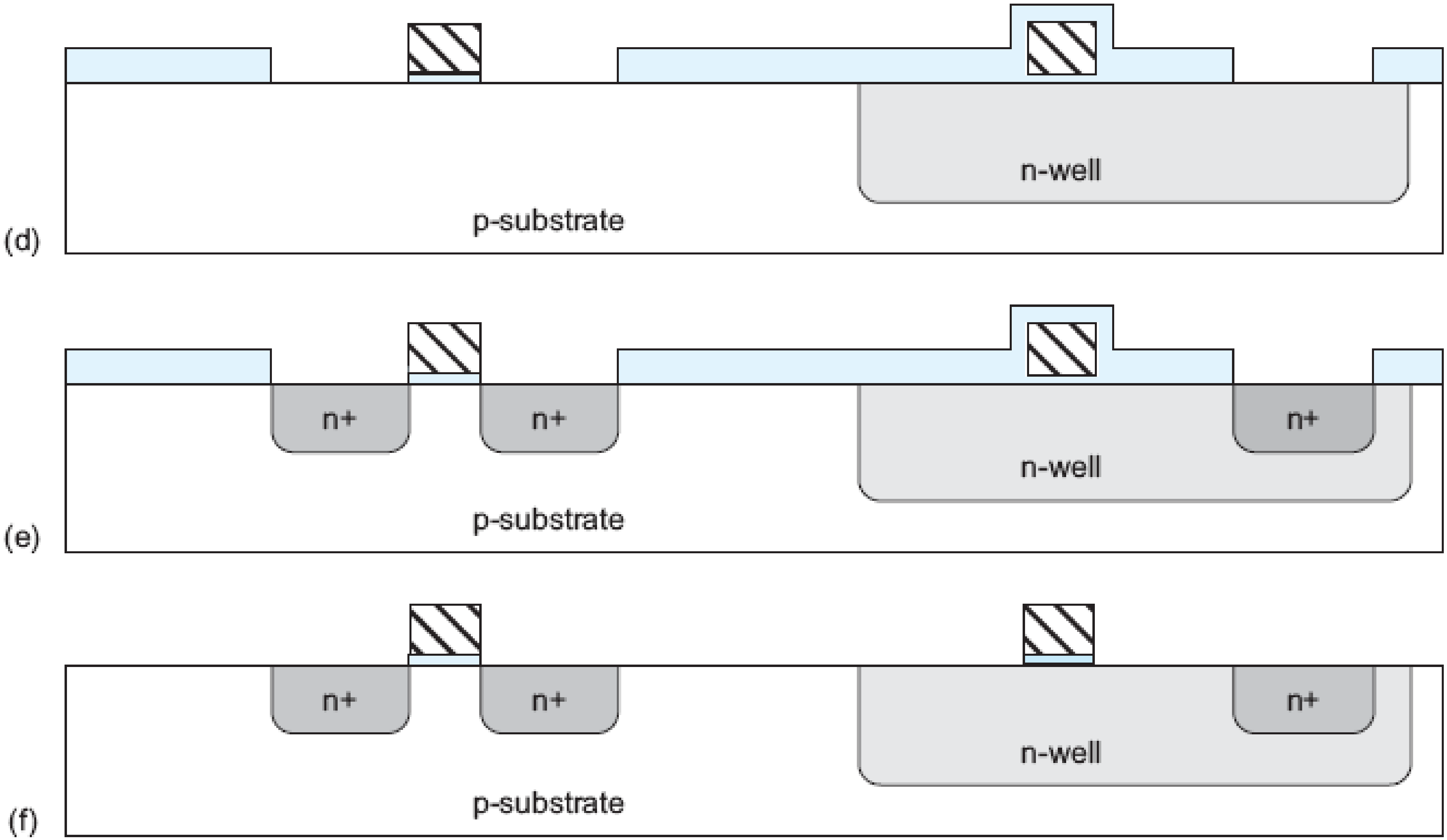
II



Fabricación de un inversor CMOS III

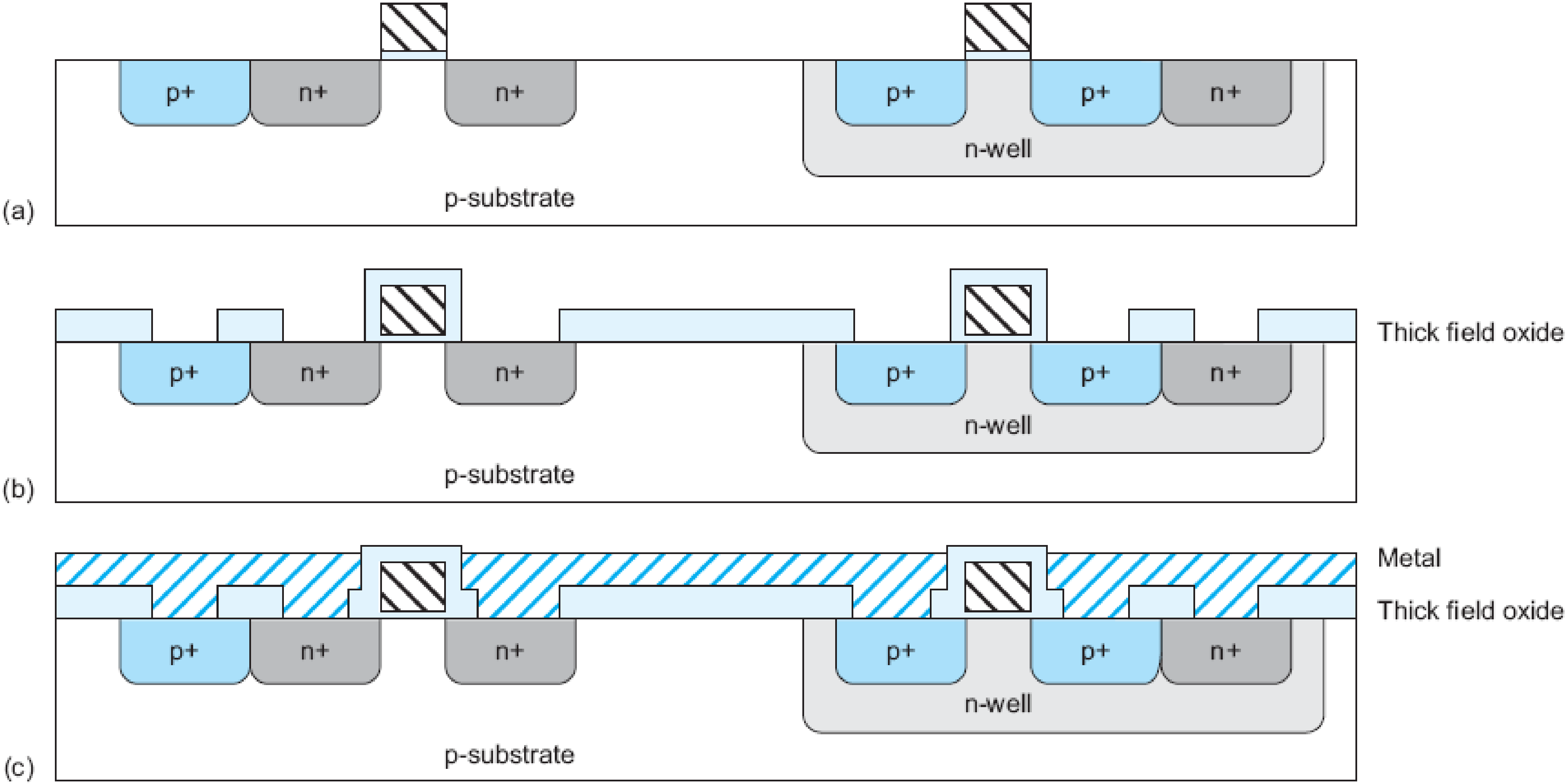


Fabricación de un inversor CMOS

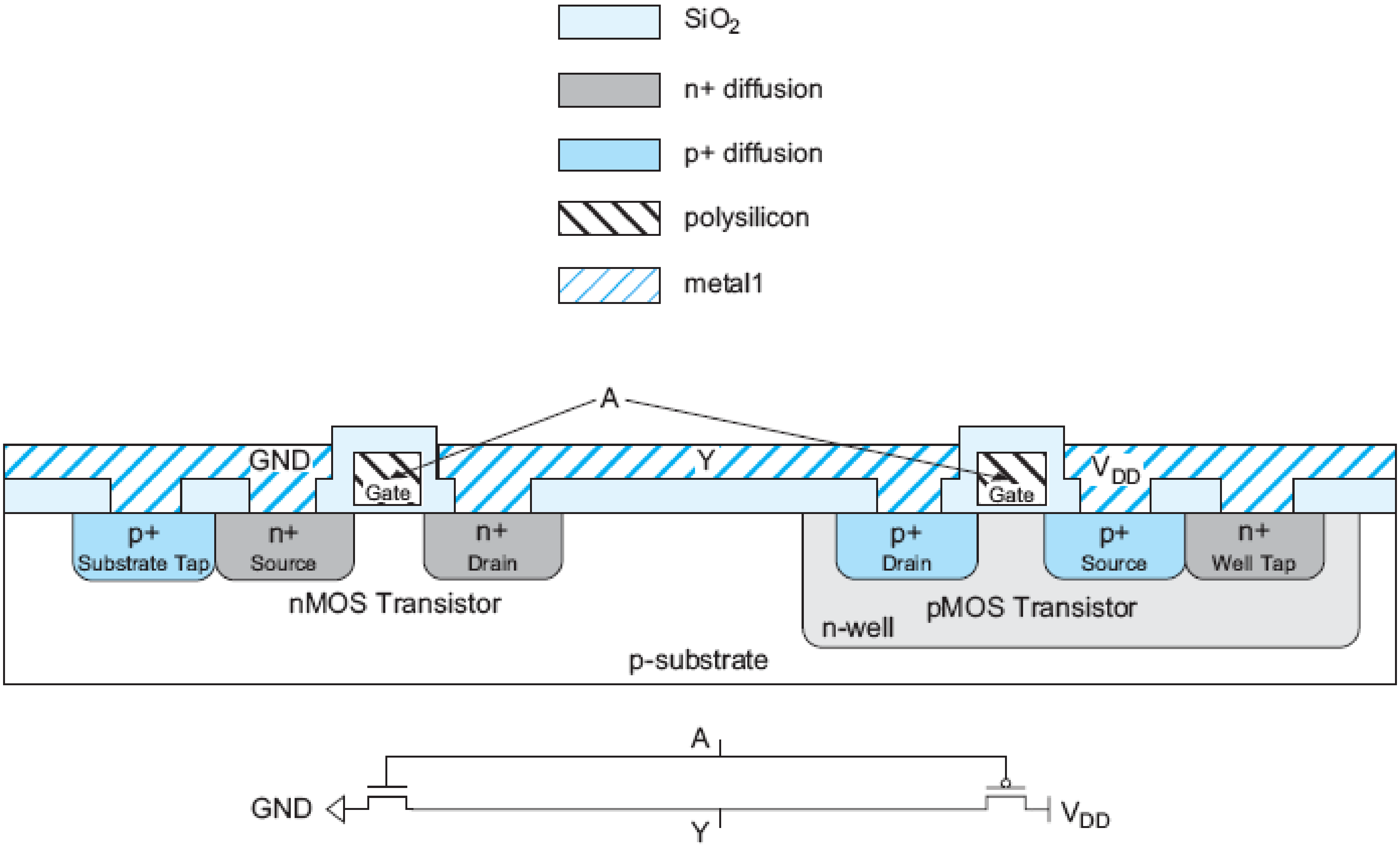


Fabricación de un inversor CMOS

IV

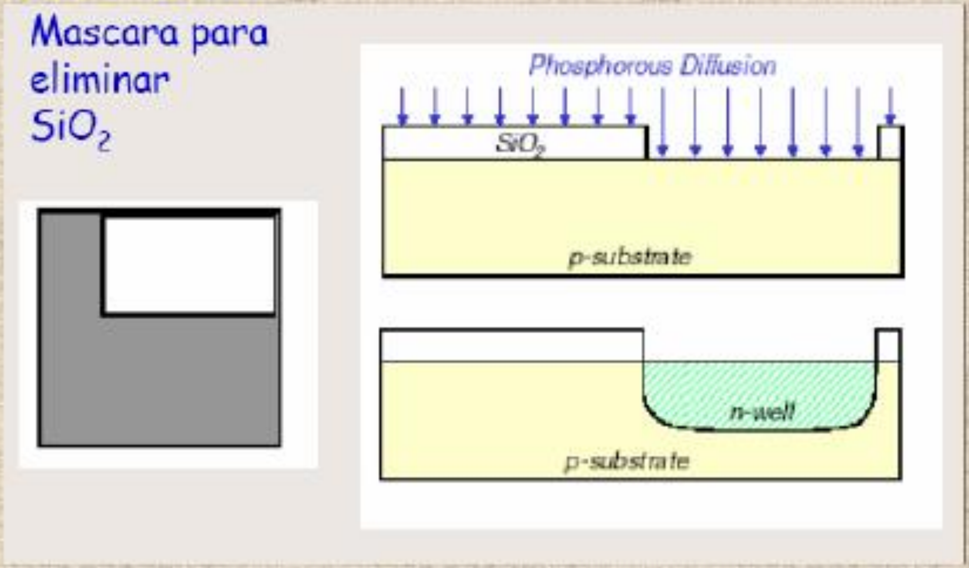


Corte transversal de un inversor CMOS

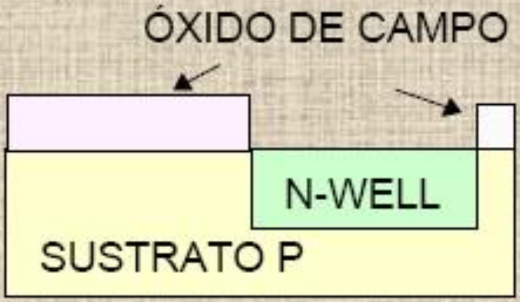


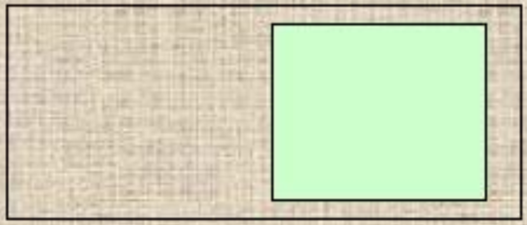
Máscara 1

Difusión de pozo


Mascara para eliminar SiO_2

Pozo

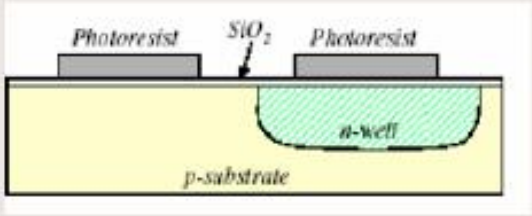


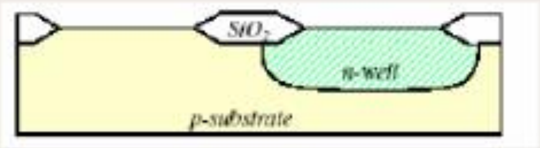


Máscara 2

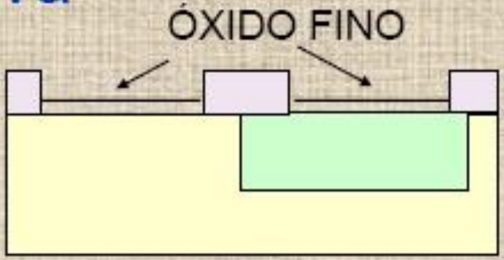
Definición de áreas activas

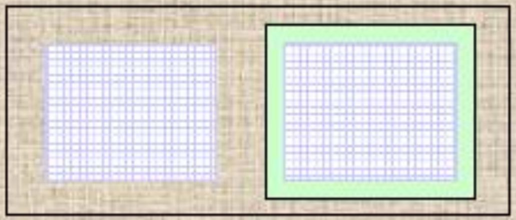
Define las regiones activas donde se van a colocar los dispositivos





Área activa

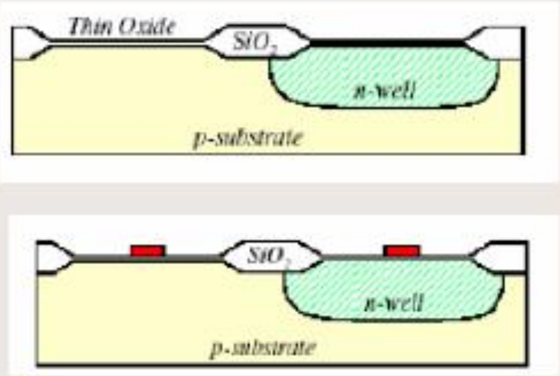




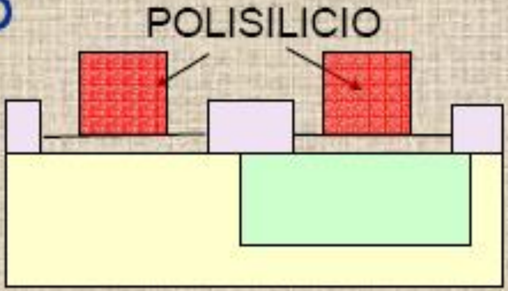
Máscara 3

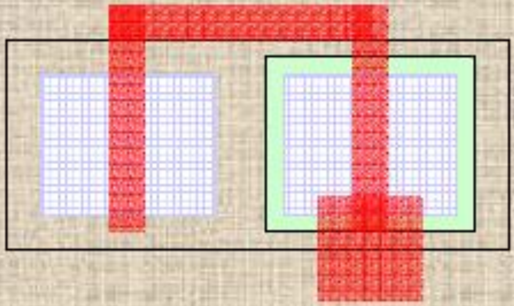
Definición de las puertas

Se deposita el polisilicio de puerta



Polisilicio

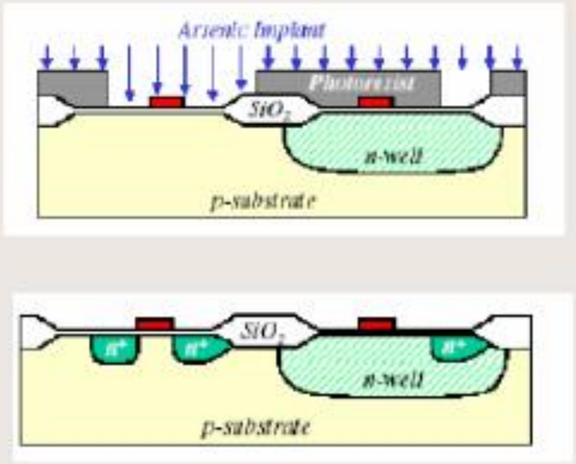


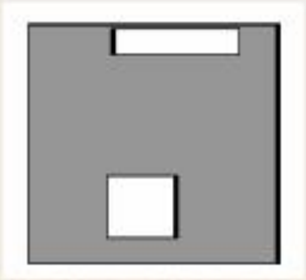


Máscara 4

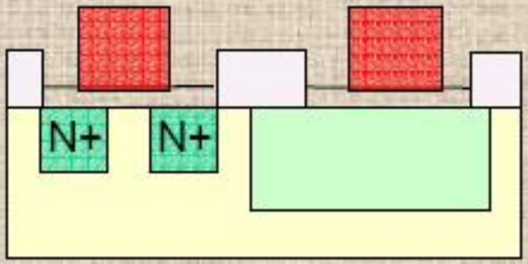
Difusión n+
MOS canal N

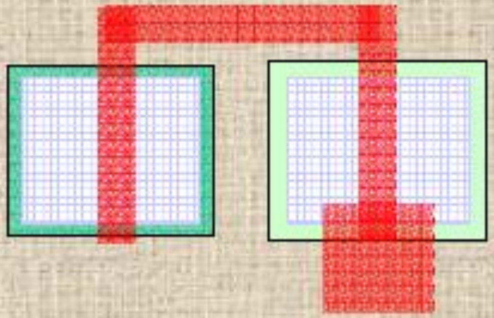
Se crea la fuente y el drenador de los dispositivos n





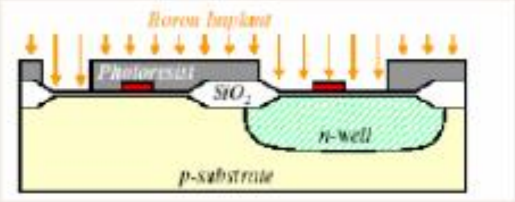
Implante N+

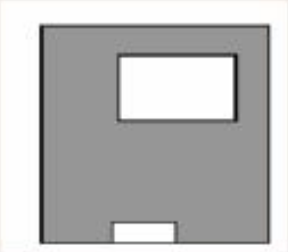


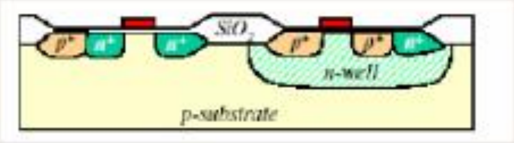


Máscara 5

Se crea la fuente y el drenador de los dispositivos p

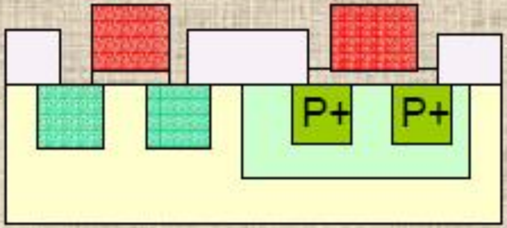


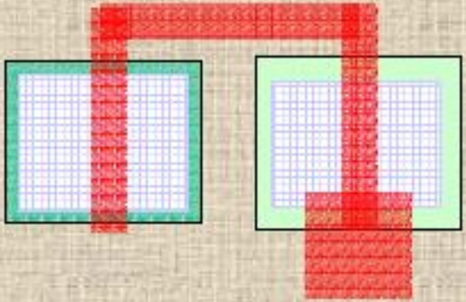




Difusión p+
MOS canal P

Implante P+

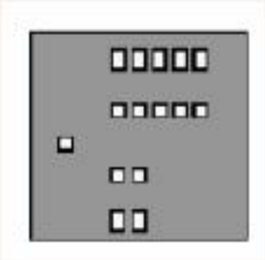


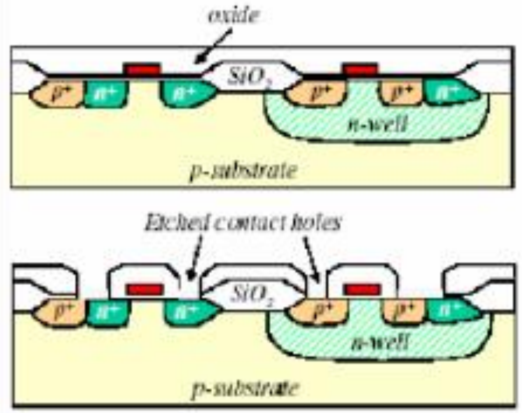


Máscara 6

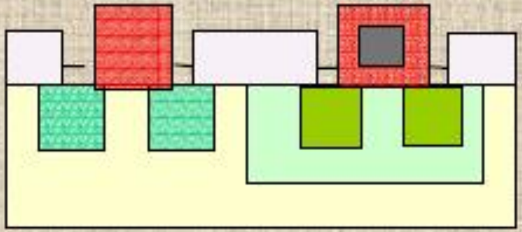
Perforaciones de contacto

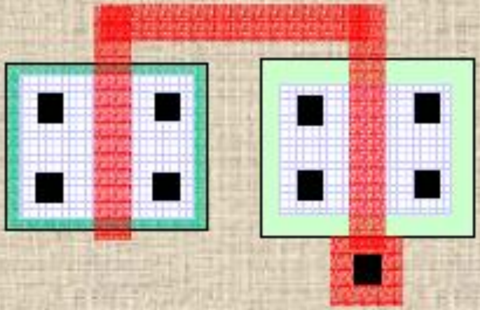
Determina las posiciones donde van los contactos





Contactos

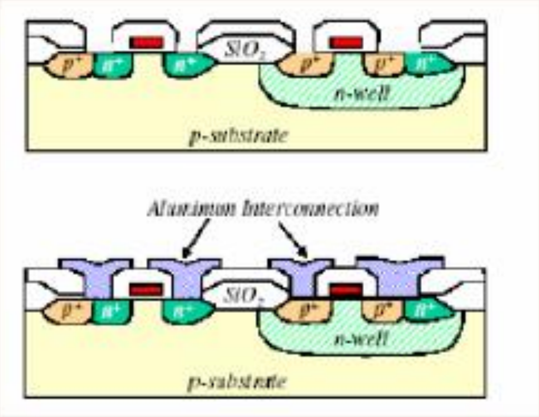


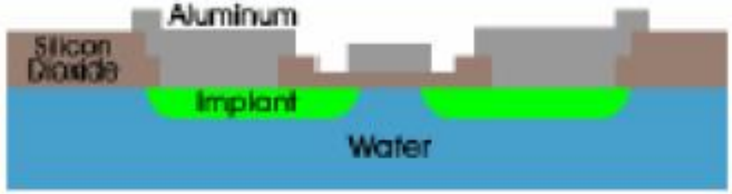


Máscara 7

Metalización

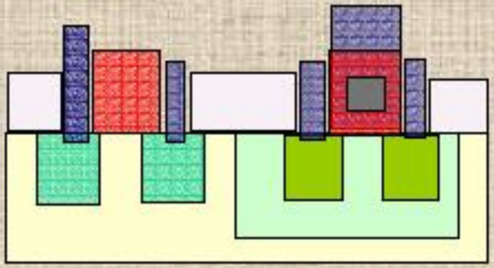
Determina las posiciones donde van las interconexiones

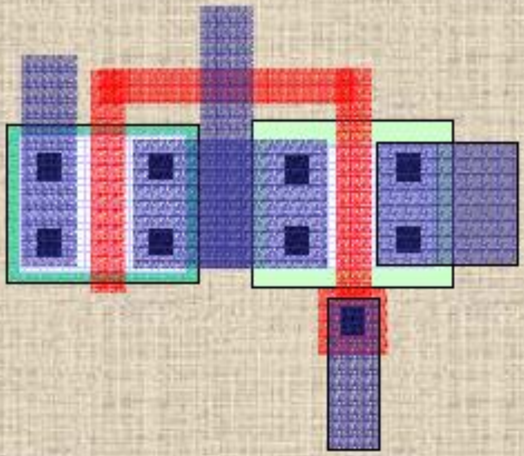




Metal Deposition

Metal



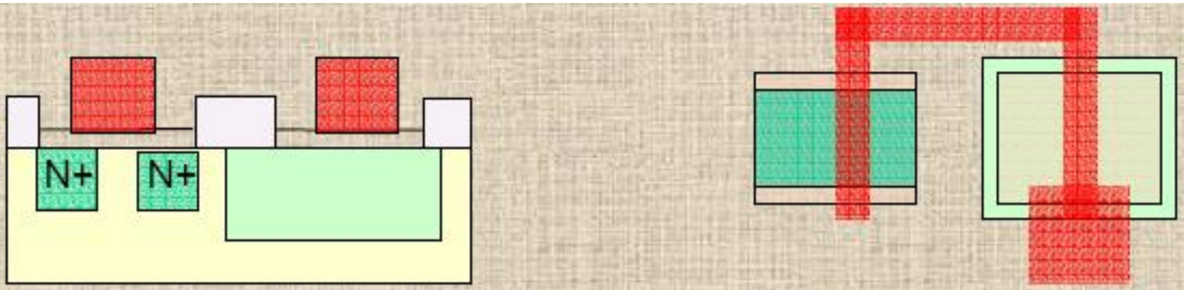


Pozo

Área activa

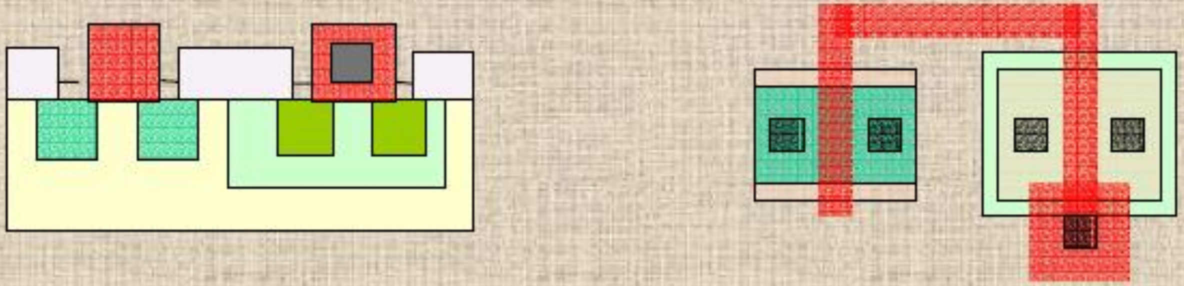
Polisilicio

Implante N+

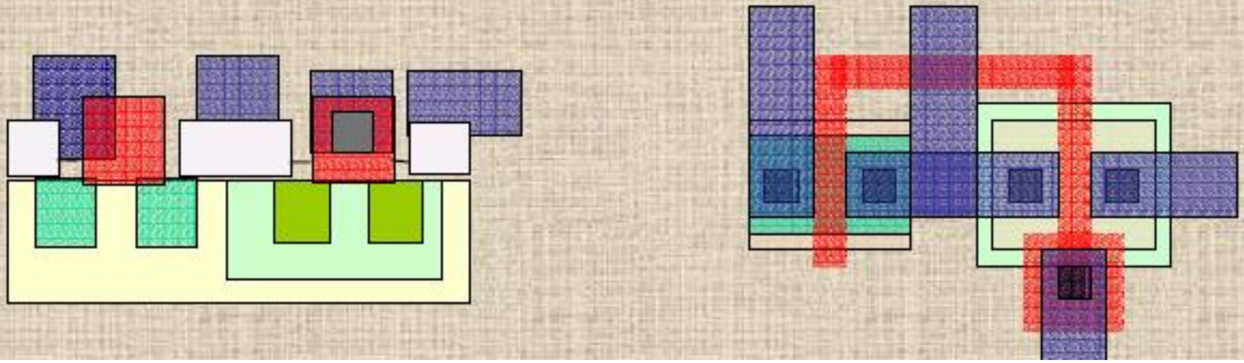


Implante P+

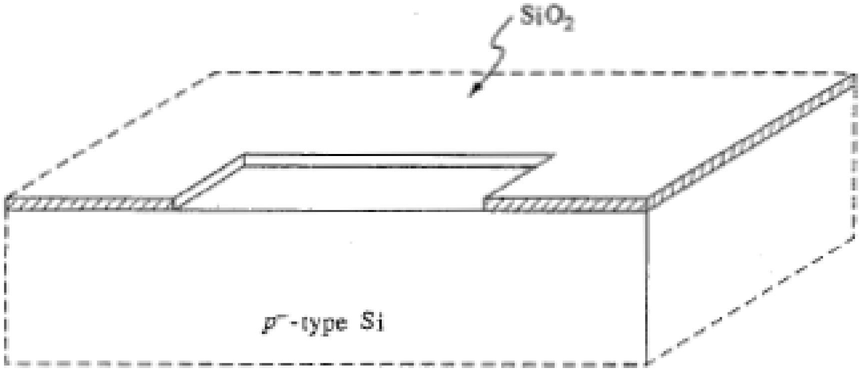
Contactos



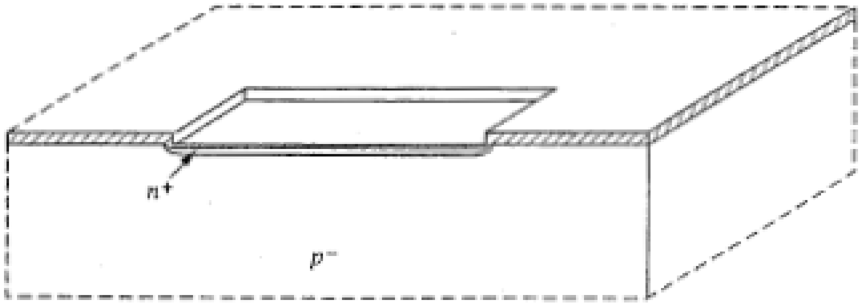
Metal



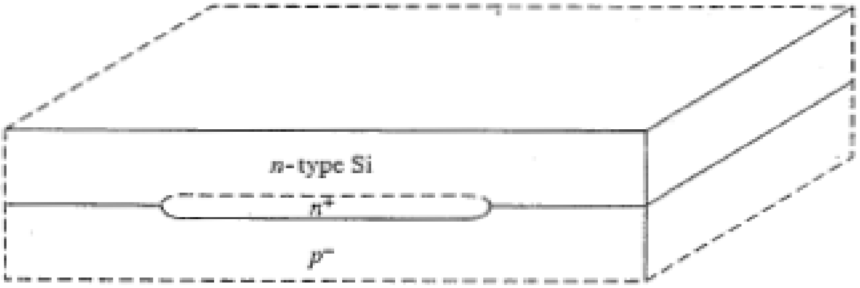
PASOS DE FABRICACION DE UN TBJ NPN



(a)



(b)



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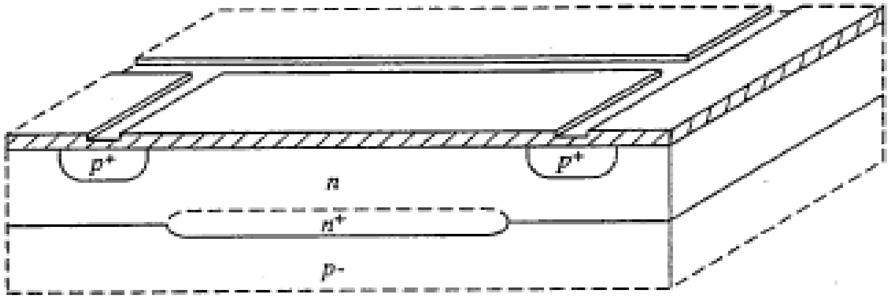
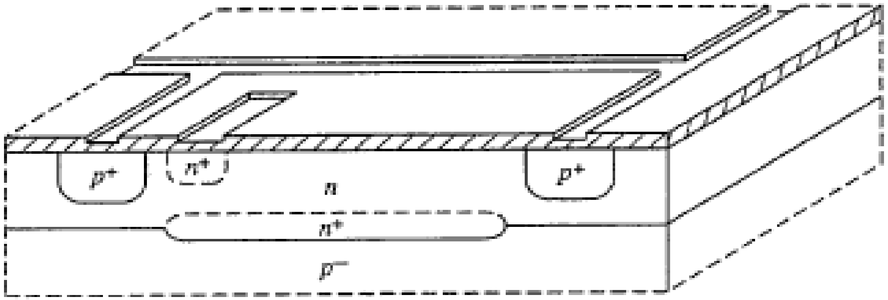


(d)



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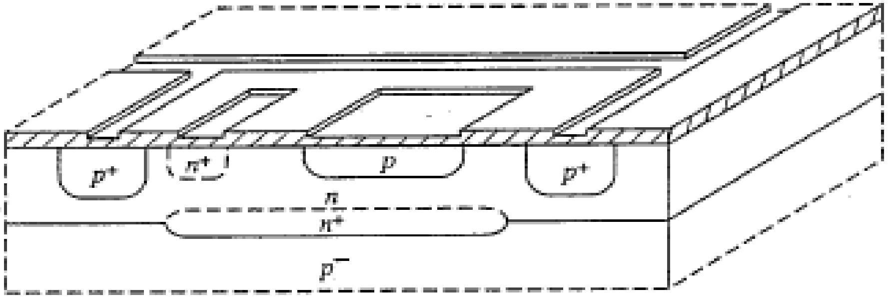

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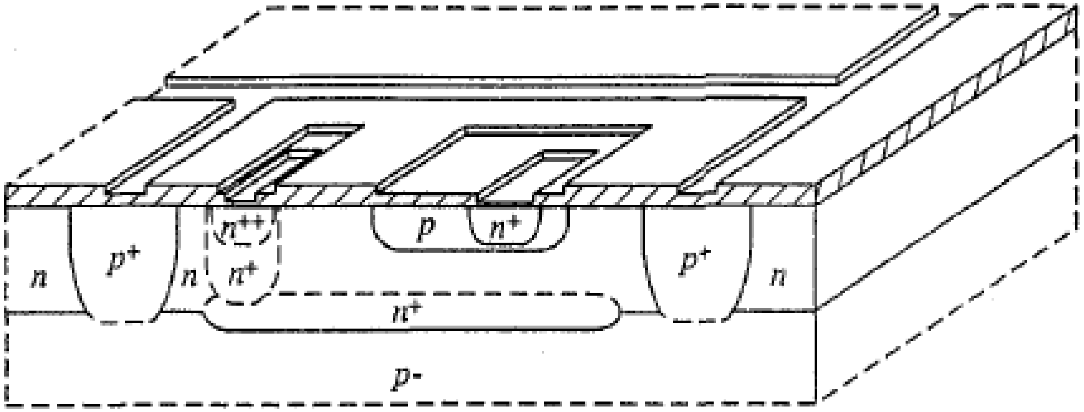

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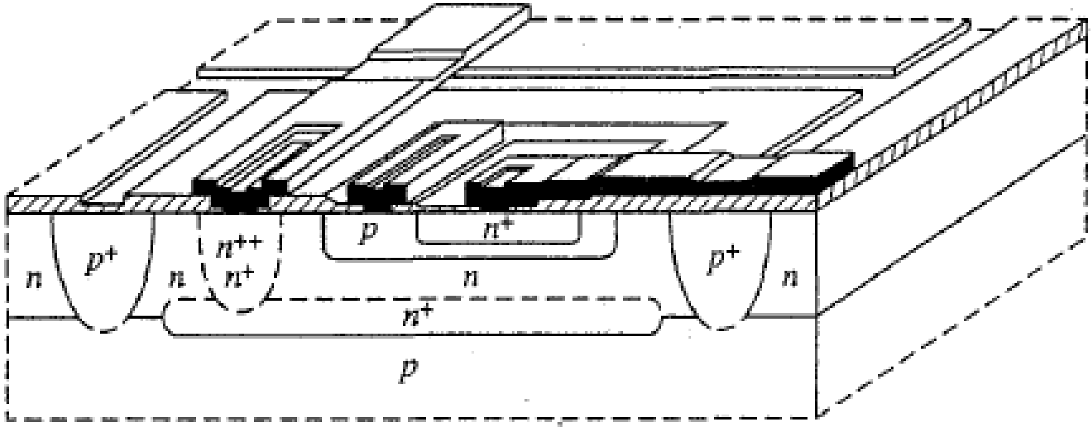


(h)

TBJ de Crecimiento Epitaxial (1)

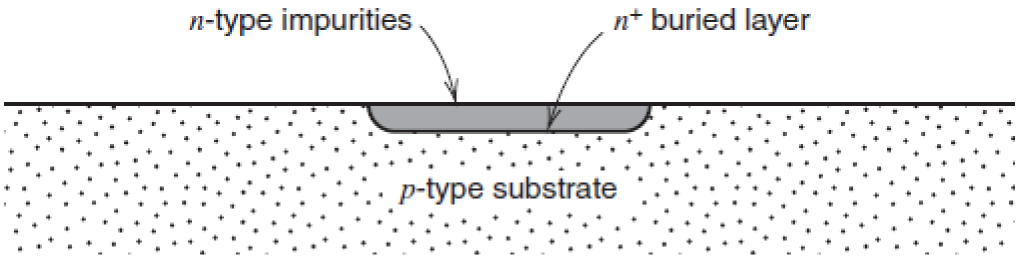


Figure 2.10 Buried-layer diffusion.

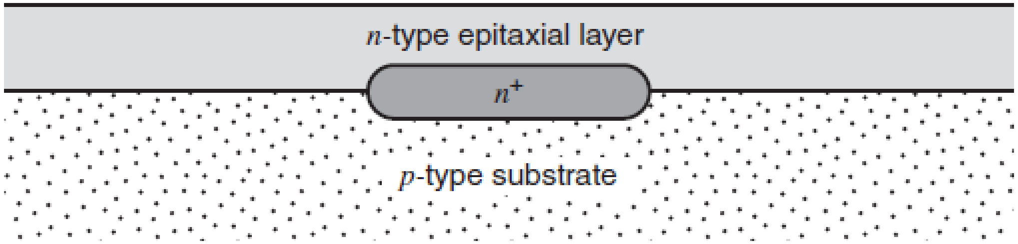


Figure 2.11 Bipolar integrated-circuit wafer following epitaxial growth.

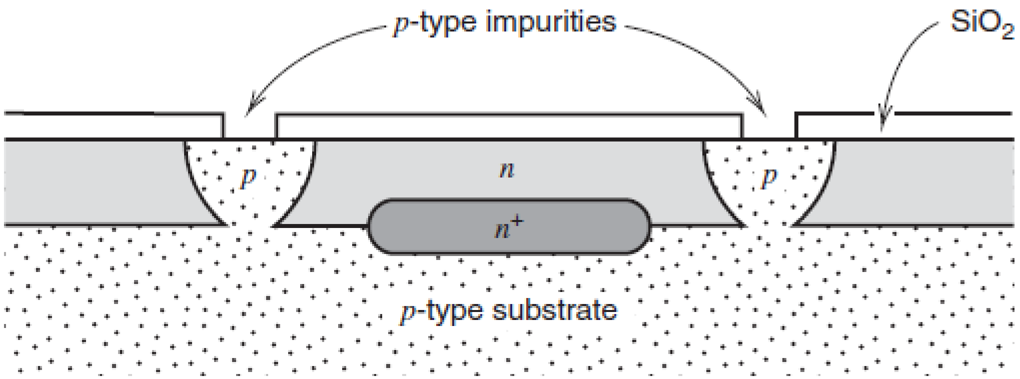


Figure 2.12 Structure following isolation diffusion.

TBJ de Crecimiento Epitaxial (2)

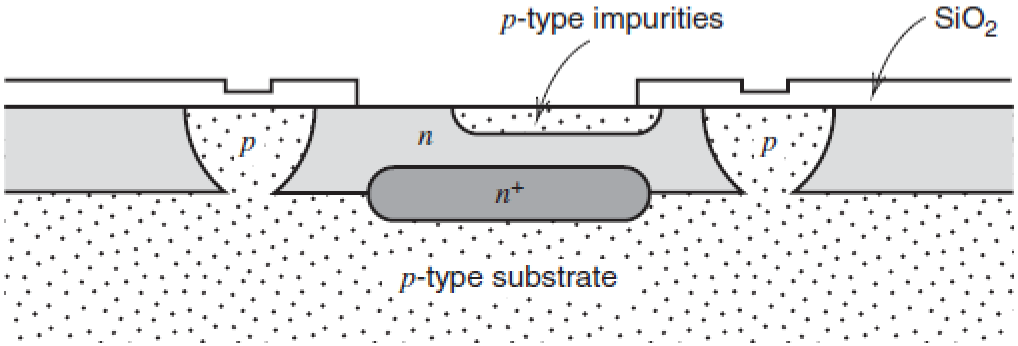


Figure 2.13 Structure following base diffusion.

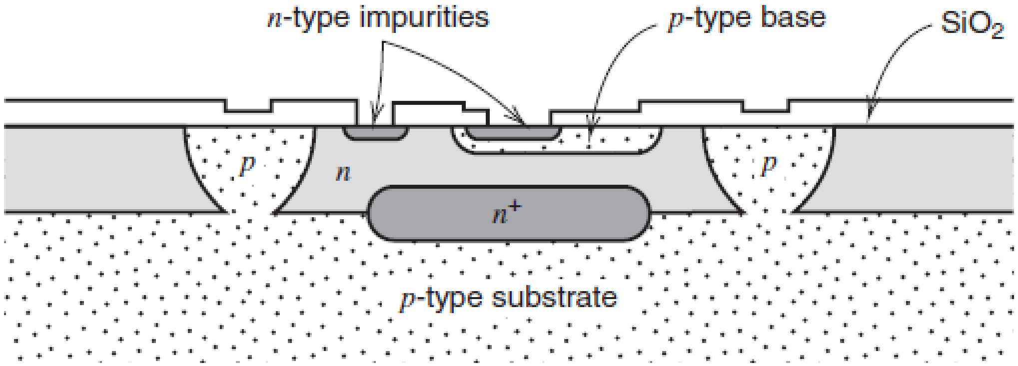


Figure 2.14 Structure following emitter diffusion.

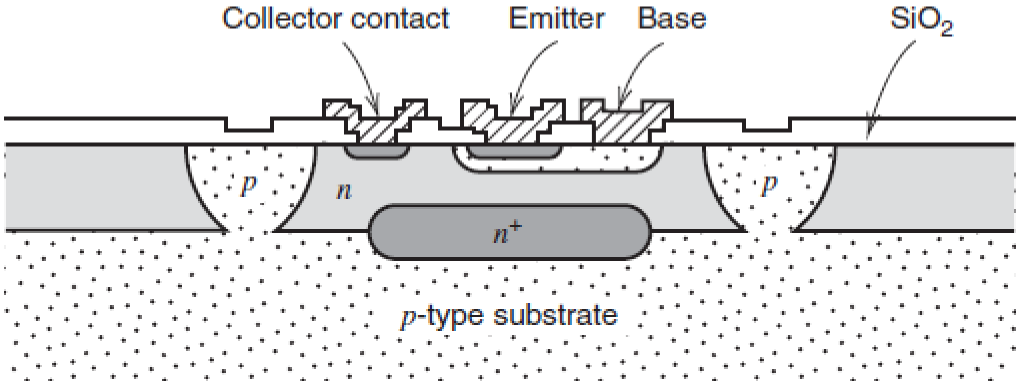
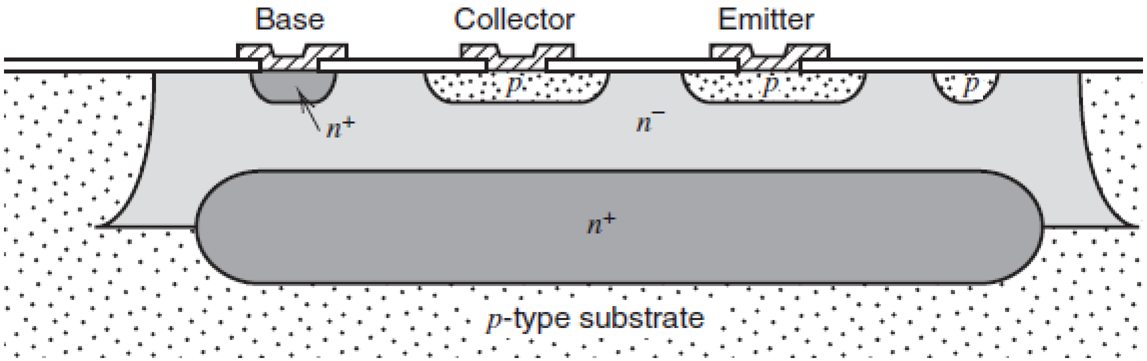


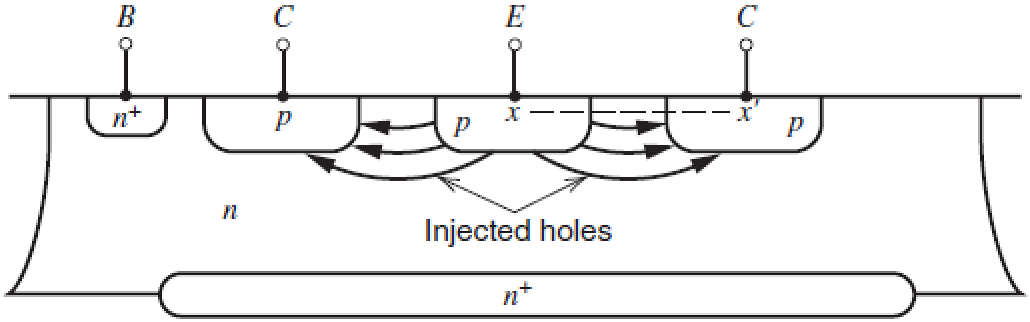
Figure 2.15 Final structure following contact mask and metallization.

TBJ PNP lateral



(a)

Figure 2.33 (a) Lateral *pnp* structure fabricated in a high-voltage process.



(b)

Figure 2.33 (b) Minority-carrier flow in the lateral *pnp* transistor.

Parametros de Fabricacion TBJ´

Parametro	**Valor Tipico**	**Tolerancia**	**Coef.Termico**
β (NPN)	30 a 100	+50% a -30%	0.5%/°C
Apar. β (NPN)	_	± 10%	10% /°C
VBE (NPN)	0.7 V	± 3%	-2mV/°C
Apar. VBE (NPN)	_	± 2mV	± 10 uV/°C
VBE (BR)	6 a 8 V	± 5%	3 mV/°C
VCB (BR)	mas de 45 V	± 30%	_
VCSust (BR)	Mas de 60 V	_	_
β (PNP) lateral	0.5 a 20	+ 200% a –50%	± 0.5%

Resistores Integrados

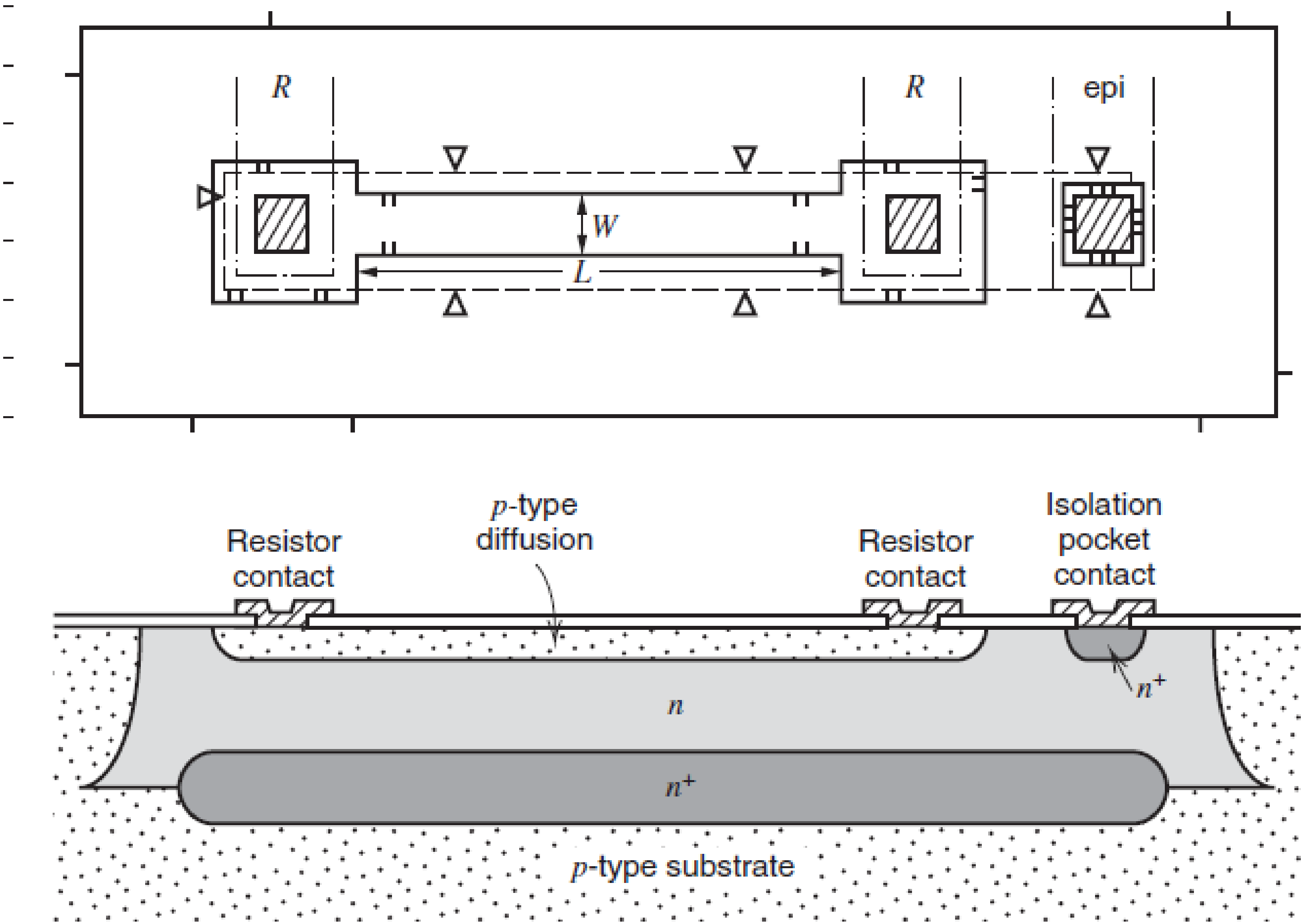


Figure 2.39 Base-diffused resistor structure.

Resistores Integrados

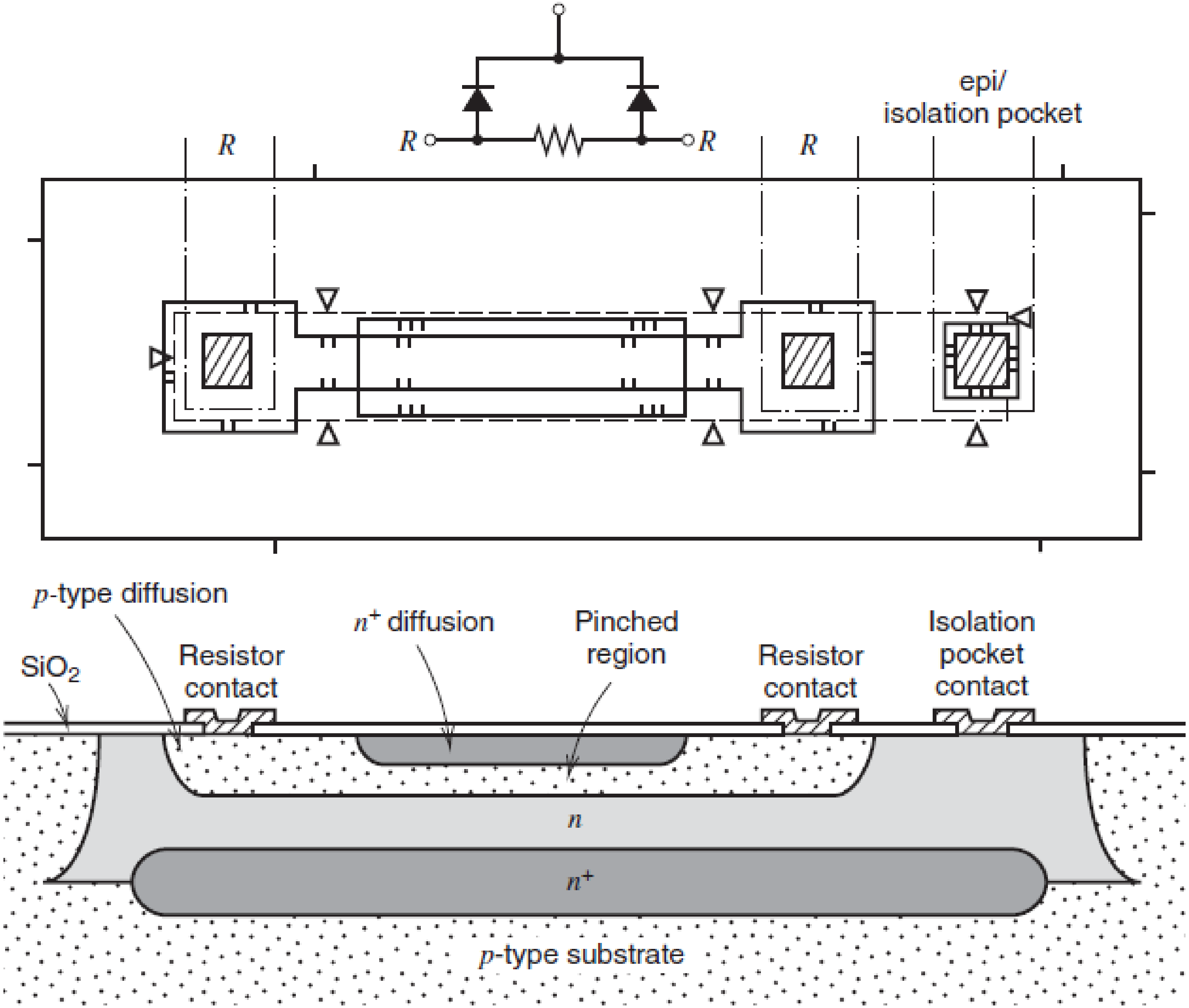


Figure 2.41 Pinch resistor structure.

Resistores Integrados

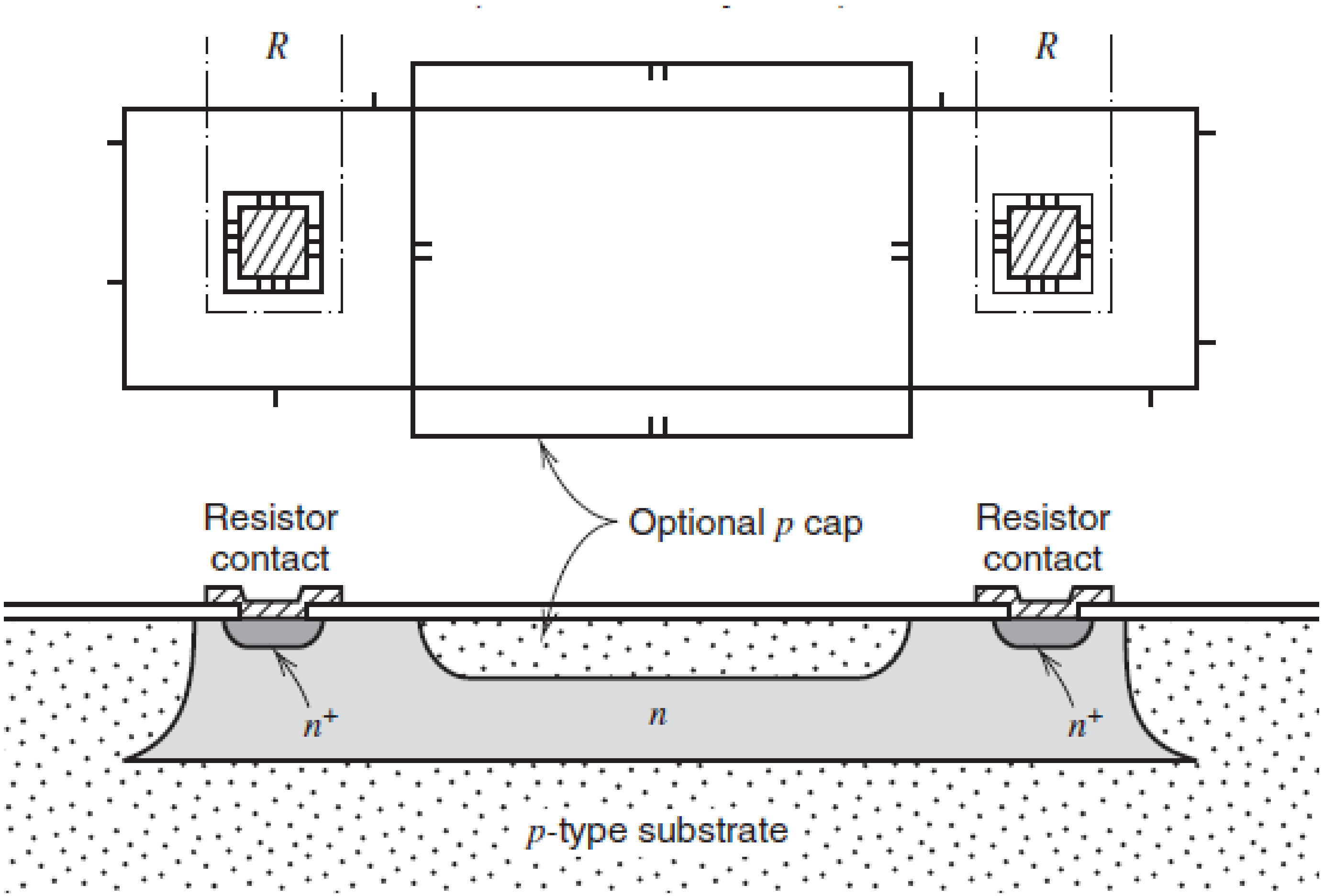
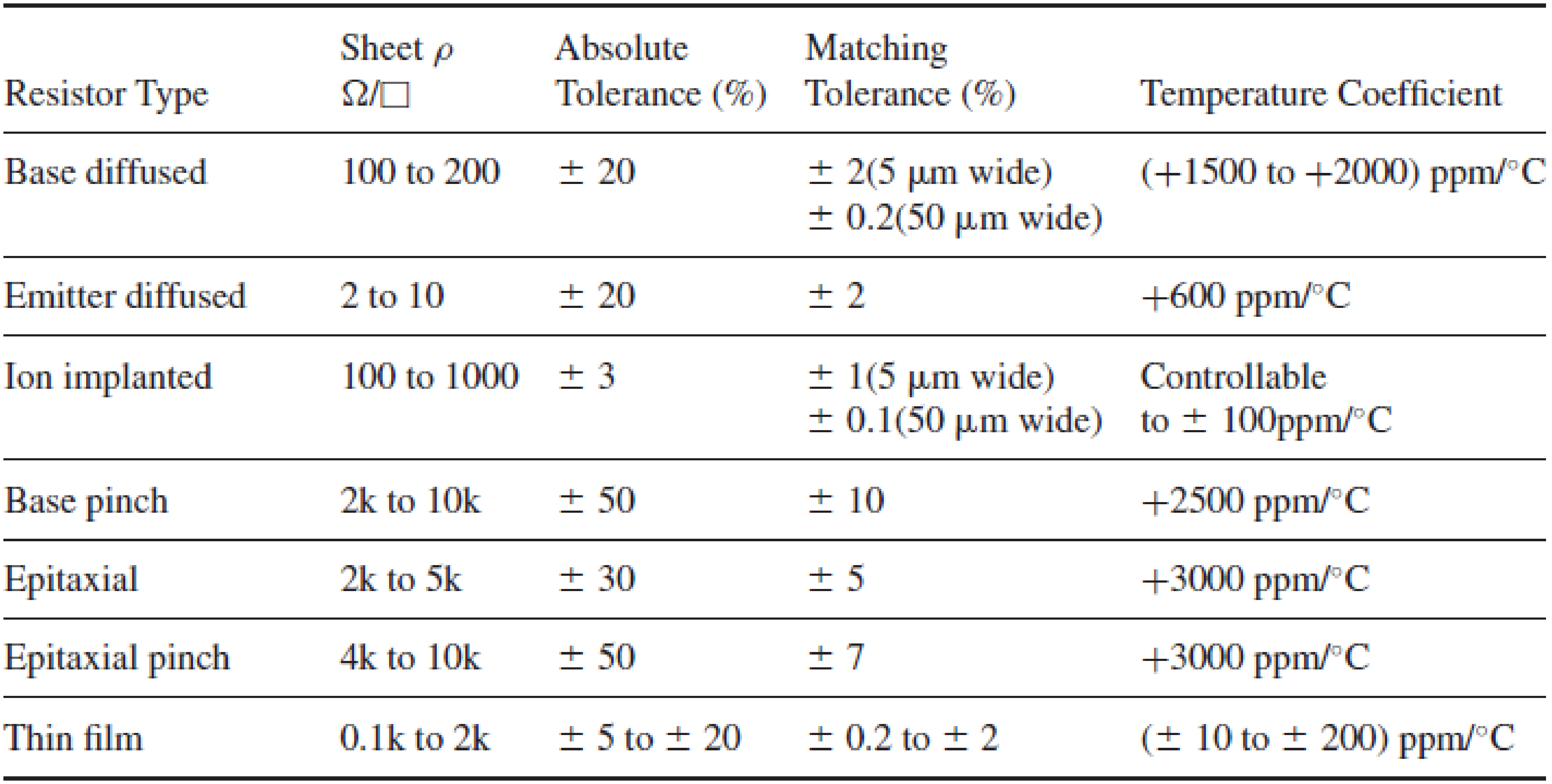


Figure 2.42 Epitaxial resistor structure. The *p*-cap diffusion is optional and forms an epitaxial pinch resistor.

Parametros de Resistores



Resistor Type	Sheet ρ $\Omega/\square$	Absolute Tolerance (%)	Matching Tolerance (%)	Temperature Coefficient
Base diffused	100 to 200	± 20	± 2(5 µm wide) ± 0.2(50 µm wide)	(+1500 to +2000) ppm/°C
Emitter diffused	2 to 10	± 20	± 2	+600 ppm/°C
Ion implanted	100 to 1000	± 3	± 1(5 µm wide) ± 0.1(50 µm wide)	Controllable to ± 100ppm/°C
Base pinch	2k to 10k	± 50	± 10	+2500 ppm/°C
Epitaxial	2k to 5k	± 30	± 5	+3000 ppm/°C
Epitaxial pinch	4k to 10k	± 50	± 7	+3000 ppm/°C
Thin film	0.1k to 2k	± 5 to ± 20	± 0.2 to ± 2	(± 10 to ± 200) ppm/°C

Circuitos Integrados Monolíticos

Ventajas

- Disminuye el Nº de interconexiones
- Apareamiento de las características de los componentes
- Bajo gradiente térmico

Limitaciones

- NPN o PNP óptimos
- R con altos Coeficientes térmicos
- Alta dispersión en el valor de los parámetros
- Resistencias de bajo valor (50 Kohms o menos)
- Capacitores de bajo valor (50 pF o menos)
- Elementos parásitos
- Baja disipación de potencia
- No inductores

Nueva Electrónica

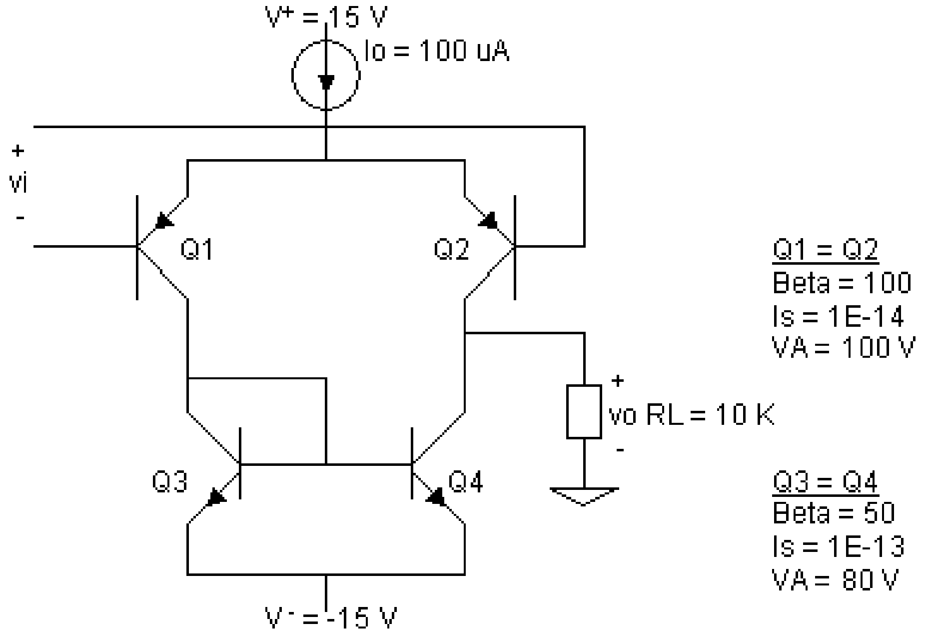
1 – Circuitos sin Resistores

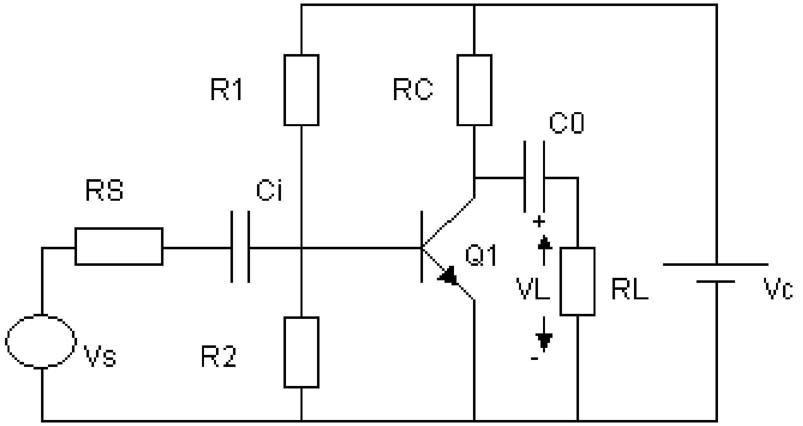
2 – Circuitos sin Capacitores

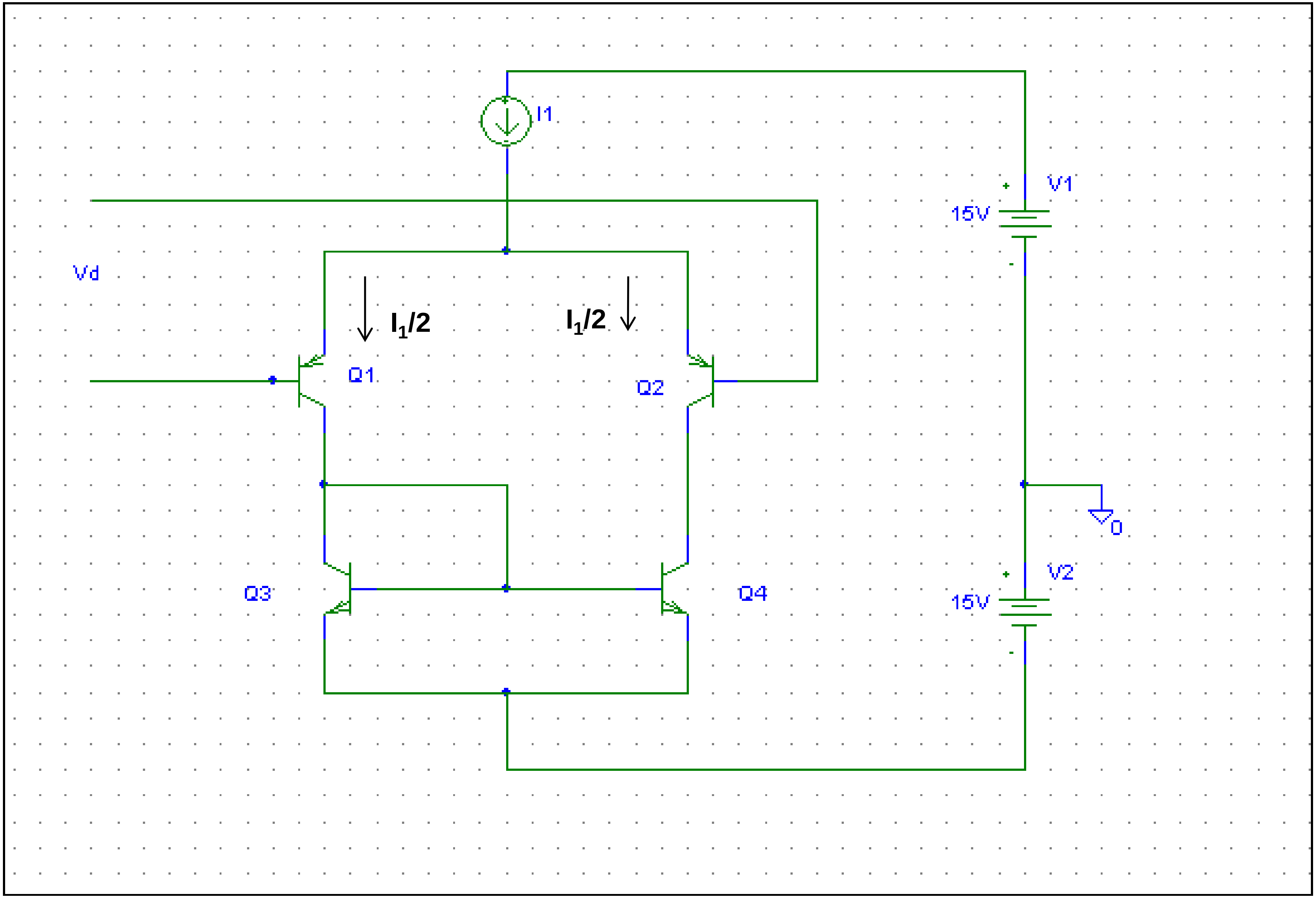
3 – Circuitos sin Inductores

4 – Características del circuito (Ej. Ganancia) función del cociente de parámetros

Amplificador típico = AMPLIFICADOR DIFERENCIAL






I1
V1
15V
+
-
Vd
$I_1/2$
$I_1/2$
Q1
Q2
0
Q3
Q4
V2
15V
+
-