SENSORS and TRANSDUCERS

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† INTRODUCTION TO MICROSENSORS

- Microsensors presentation
- Reasons for miniaturization
- History and technology of microsensors
- Scaling laws - numerical examples
- Application examples and markets

Reasons for miniaturization

The reasons for miniaturization of sensors are the same as for electronics:

- Cost
- Reliability
- Applicability
- Performance
- New functions

Transducer effects in silicon and other compatible materials

- *Transducer effects in silicon - electrons are the information carrier*

I/Out		Modulating			
Energy domain	**Self-generating**	**Resistor, inductance, capacitive**	**Diode**	**Transistor**	**Examples of smart transducers**
Radiation	Volta effect, solar cell	Photoconductor	Photodiode	Phototransistor	Photo-IC CCD
Mechanical	Not known	Piezoresistivity	Piezojunction	Piezotransistor	Accelerometer Piezo IC
Thermal	Seebeck effect, thermocouple	R = f(T)	Reverse biased I_{rev}= f(T)	Forward biased U_{BE}= f(T)	Temeperature IC
Electrical	Thermal energy, resistance	Electric field MOSFET	Electric field FET	Dual gate MOSFET	All types of IC
Magnetic	Maxwell diffused coil	Magnetoresistor	Magnetic diode	Hall effect	Hall IC
Chemical	Galvanic	Ion concentration	Not known	ISFET	Smart nose

Scaling Laws

With miniaturization will some effects be advantageous, some disadvantageous:

$$\text{acceleration} \quad a = \frac{F}{m} = \left[L^{F}\right] \bullet \left[L^{-3}\right]$$

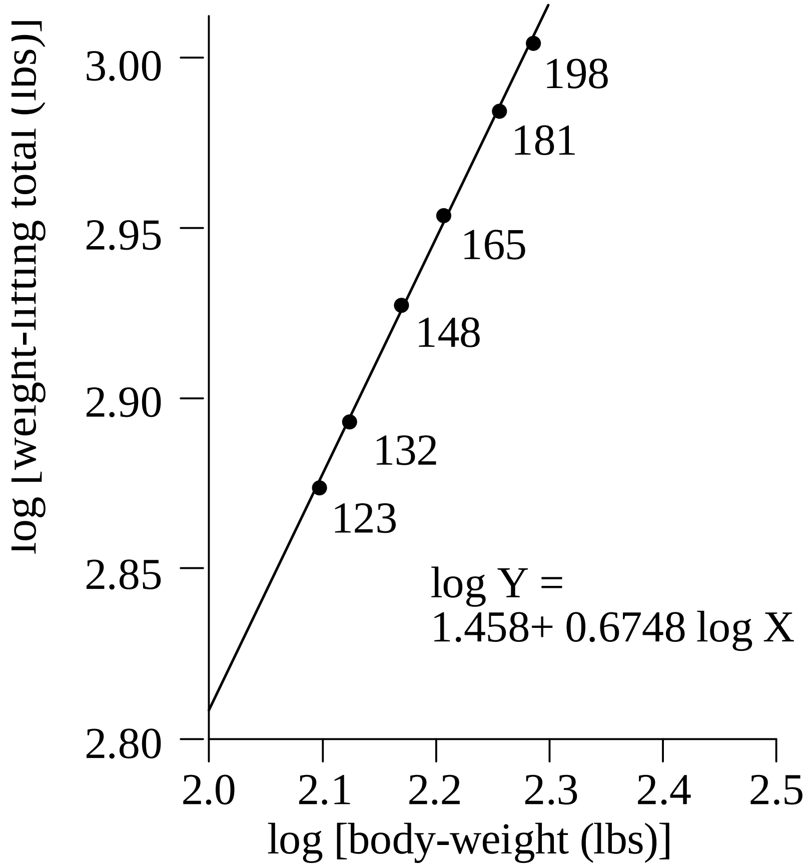
$$\text{response time} \quad t = \sqrt{\frac{2x}{a}} = \sqrt{\frac{2xm}{F}} = \left\{\left[L^{1}\right] \bullet \left[L^{3}\right] \bullet \left[L^{-F}\right]\right\}^{\frac{1}{2}}$$

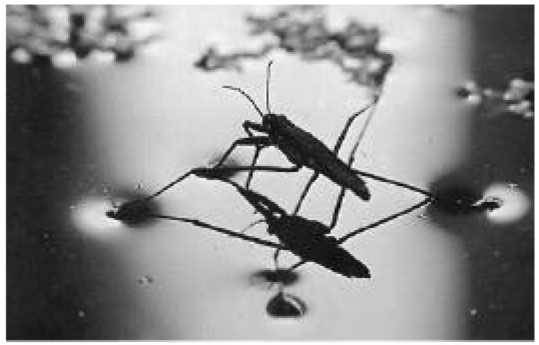
$$\text{power generation} \quad P = \frac{Fx}{t} \text{ and } \frac{P}{V} = \frac{Fx}{tV}$$

Scaling Laws

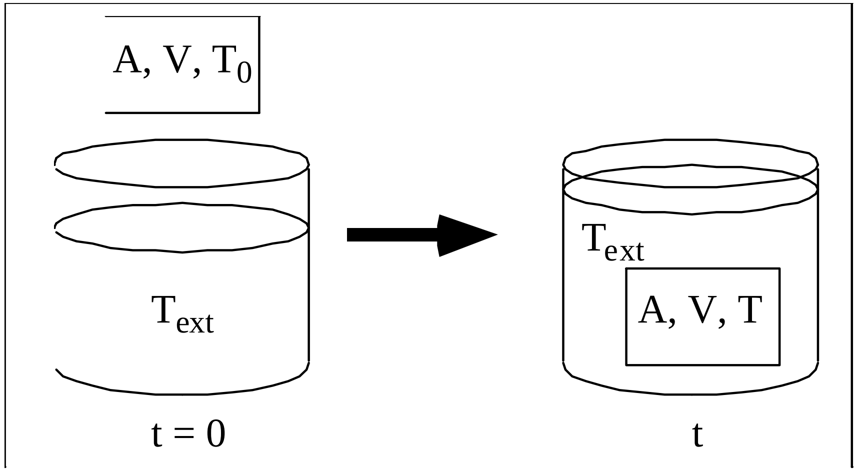
Condition	F	a	t	P/V
electrostatics with E prop. to $L^{-1/2}$, or surface tension	L^{1}	L^{-2}	$L^{3/2}$	$L^{-5/2}$
electrostatics with const. E, or pressure forces, muscles	L^{2}	L^{-1}	L^{1}	L^{-1}
magnetics (const. heat flow)	L^{3}	L^{0}	$L^{1/2}$	$L^{1/2}$
magnetics (const. current density)	L^{4}	L^{1}	L^{0}	L^{2}

Scaling Laws





Scaling Laws

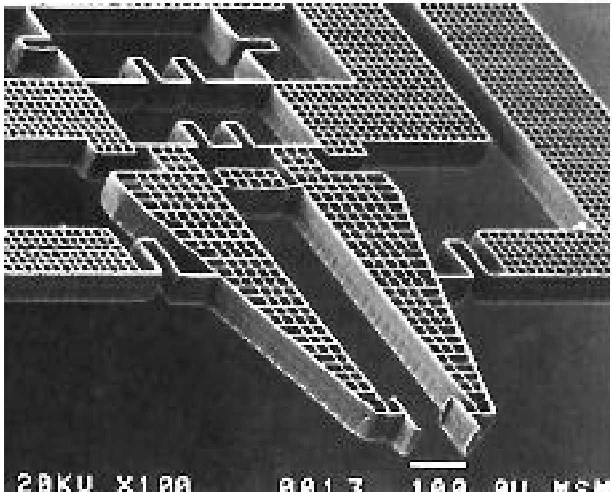


$$Q = -\lambda A(T_0 - T_{ext}) = \rho c_p V \frac{dT}{dt}$$

$$\frac{T - T_{ext}}{T_0 - T_{ext}} = e^{-\frac{\lambda A}{\rho c_p V} t}$$

1/time constant

Assuming equilibrium in
t = 4 time constants:
a Ø 50 µm Ni rod reaches
equilibrium
in 0.02 s and a Ø 2.5 mm rod in 5 s.



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Microsensor Technology

Developed from the technology of microelectronics:

- Photolithography
- Etching and thin film deposition
- Batch production
- Materials: mostly <u>silicon</u>, metals, quartz, glass, and polymers
- Specialized testing and packaging

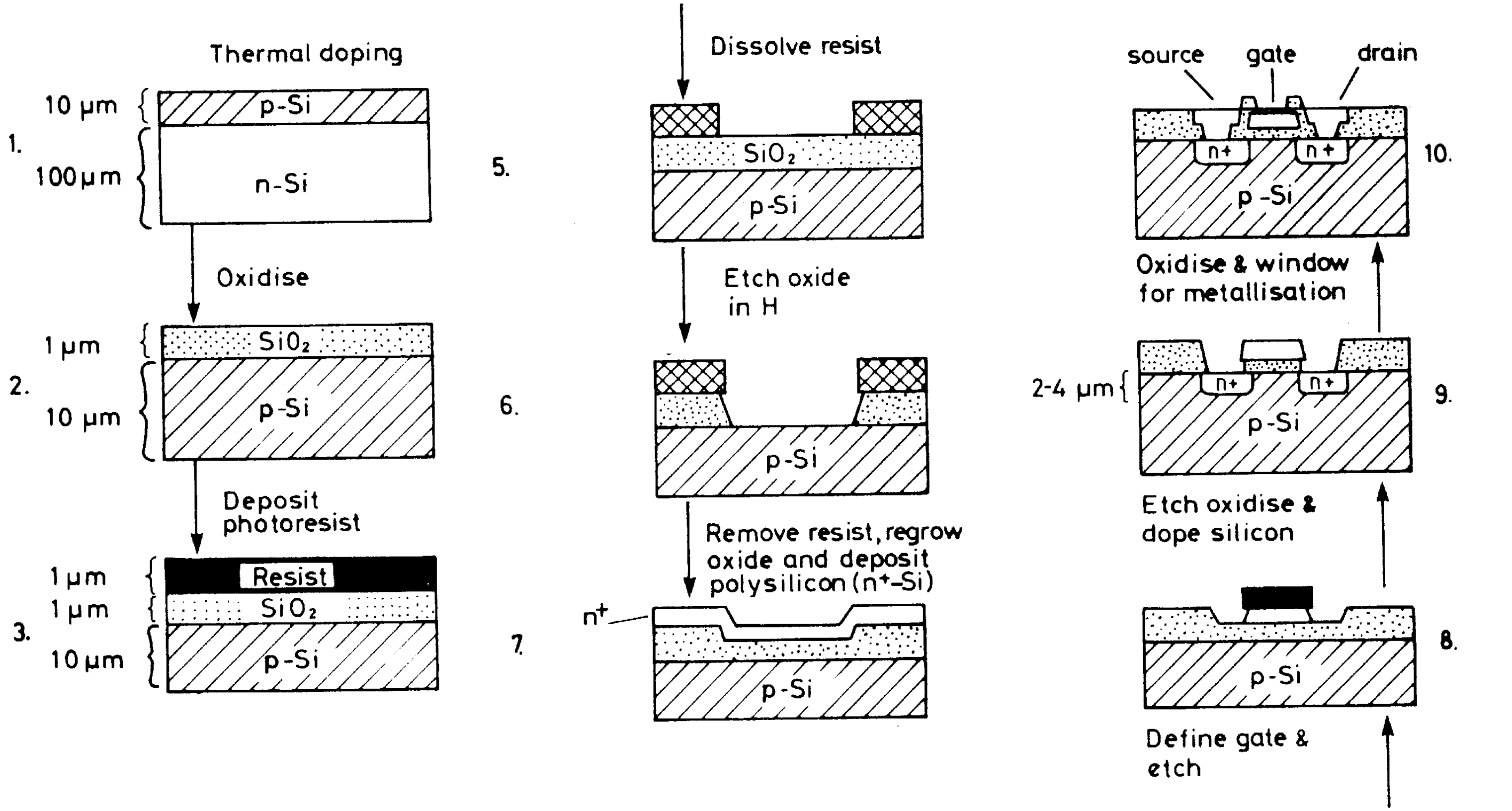
Microsensor Technology

masking and etching on armor
(fifteenth century)

first photolithography followed
by etching (Lemîtres, 1827)

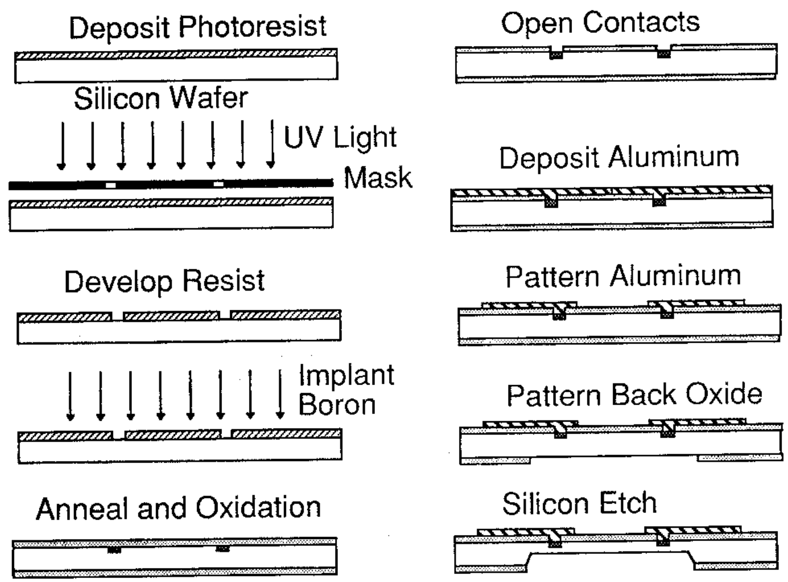
Microsensor Technology

MOSFET Process



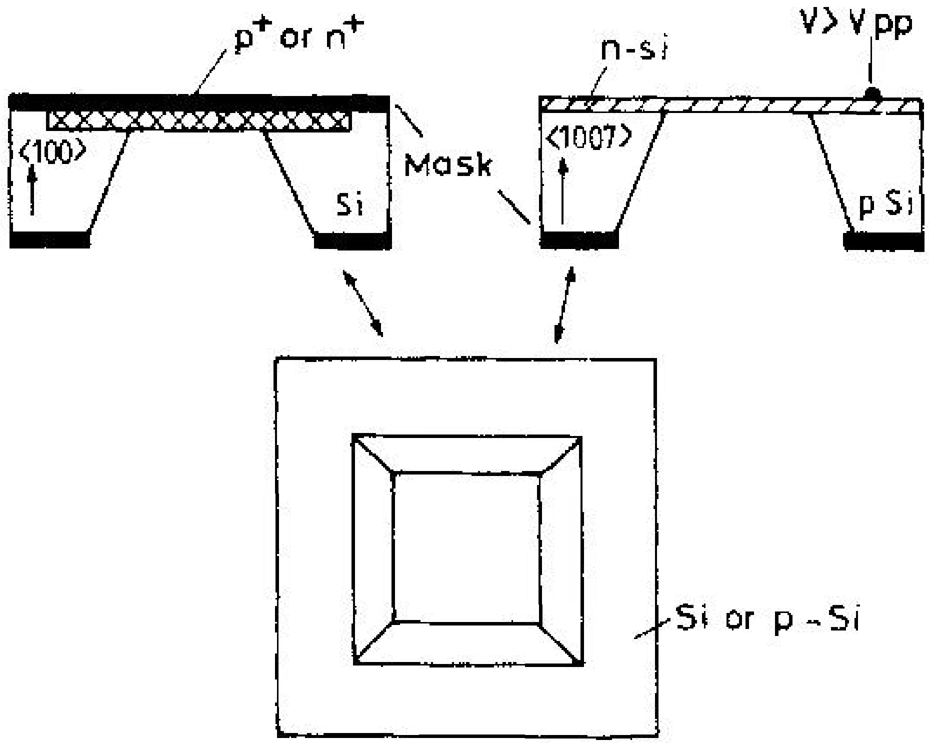
Microsensor Technology

Wet bulk micromachining



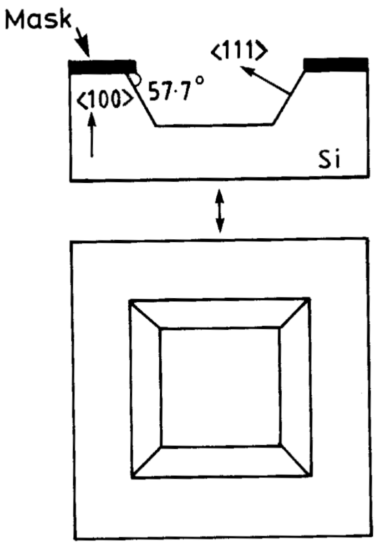
Microsensor Technology

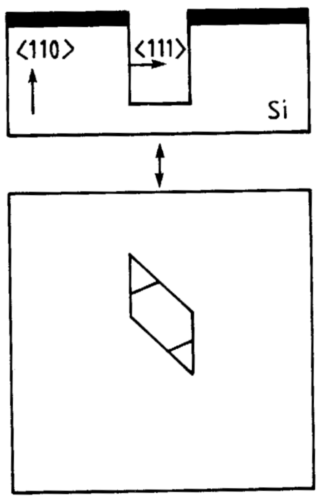
Selective anodic etching

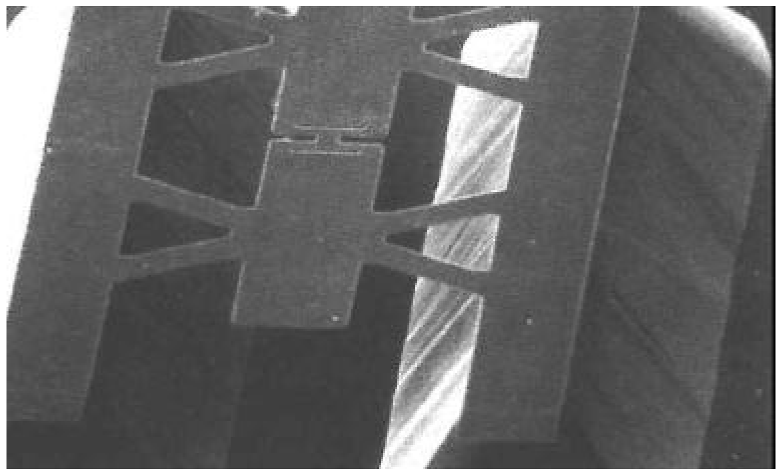


Microsensor Technology

Bulk wet etch micromachining

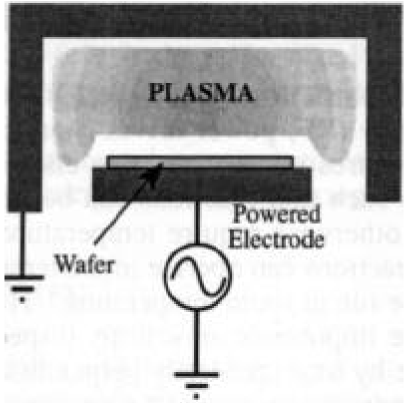


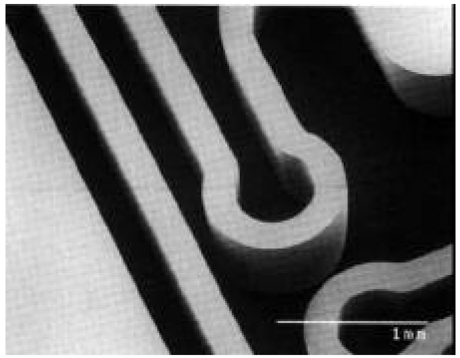




Microsensor Technology

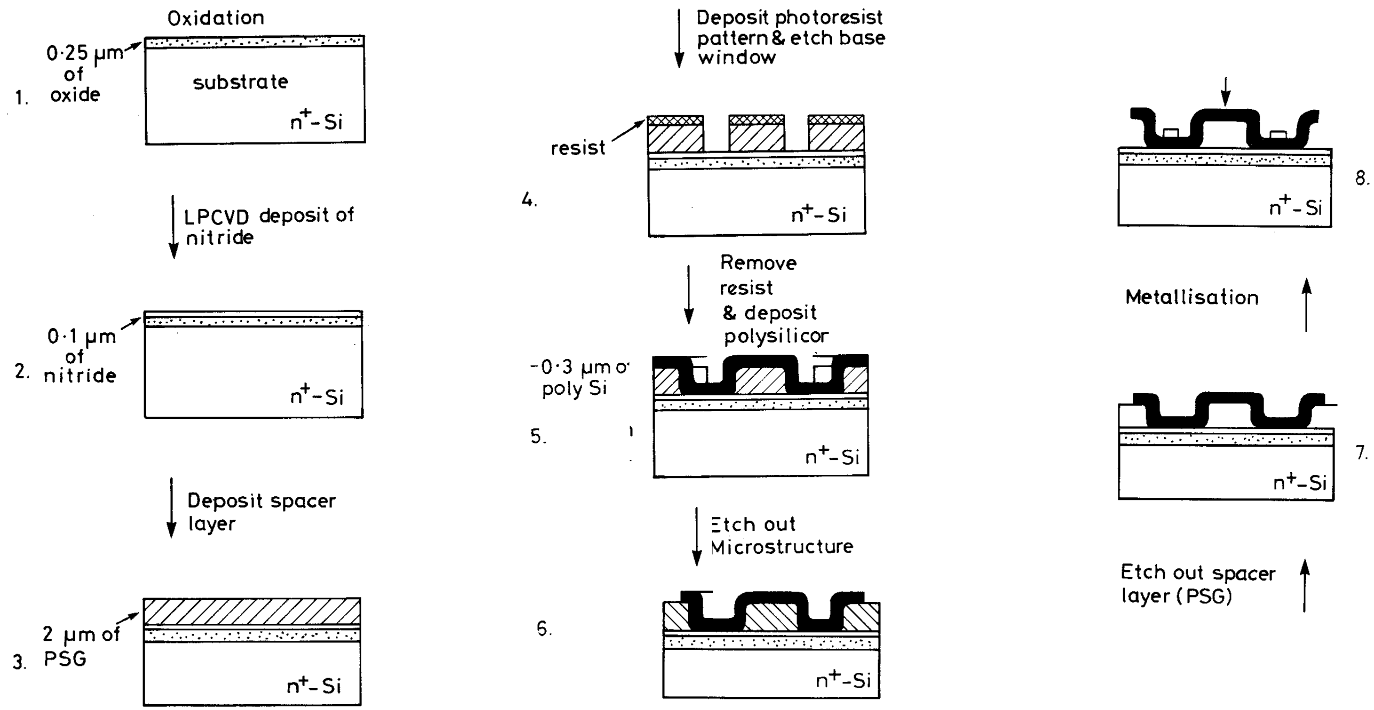
Deep reactive ion etching





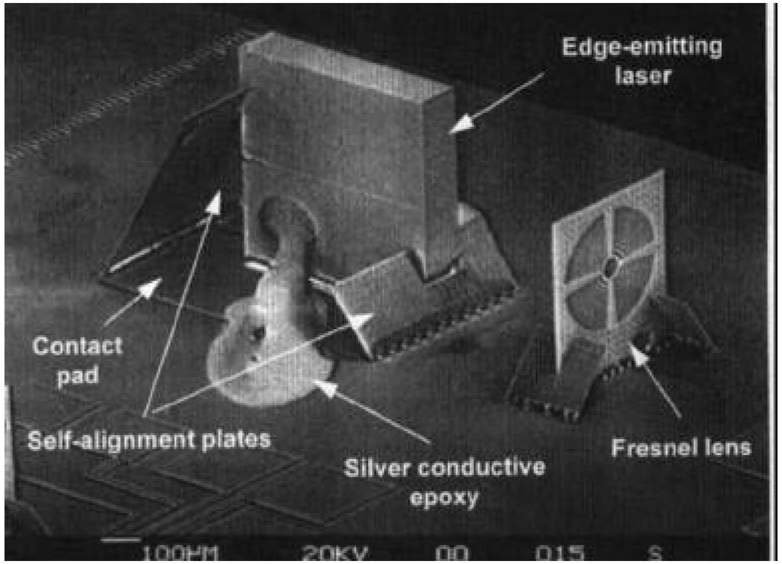
Microsensor Technology

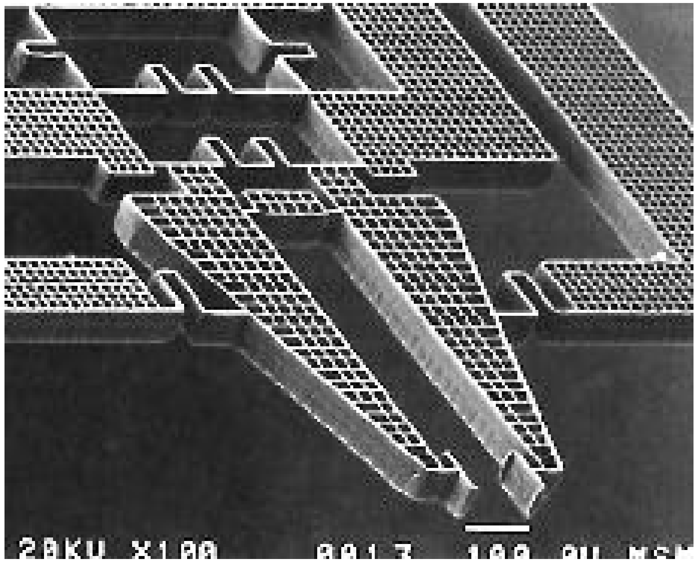
Surface micromachining



Microsensor Technology

Examples of surface micromachining





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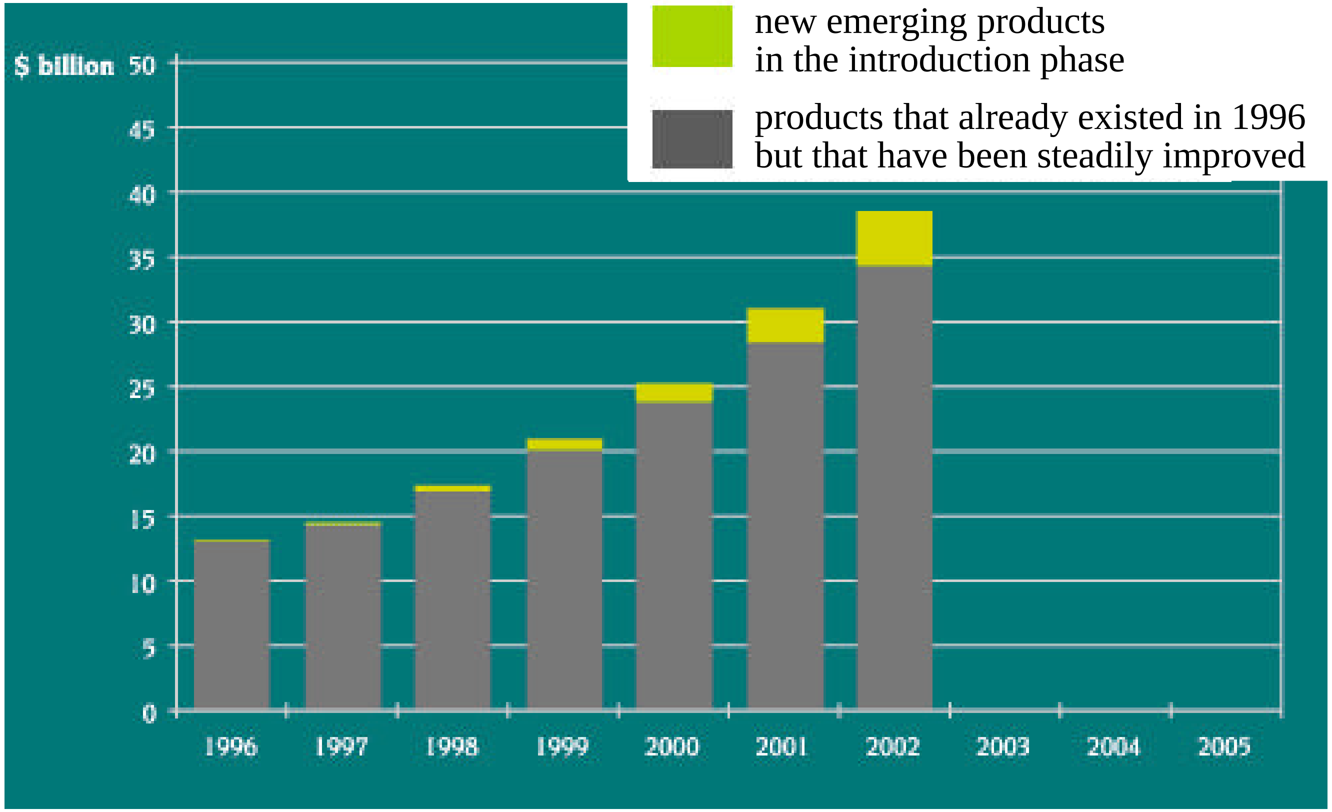
MST Transducer Market Projection



MST Sensor Market Projection