Desarrollo de sensores basados en MEMS

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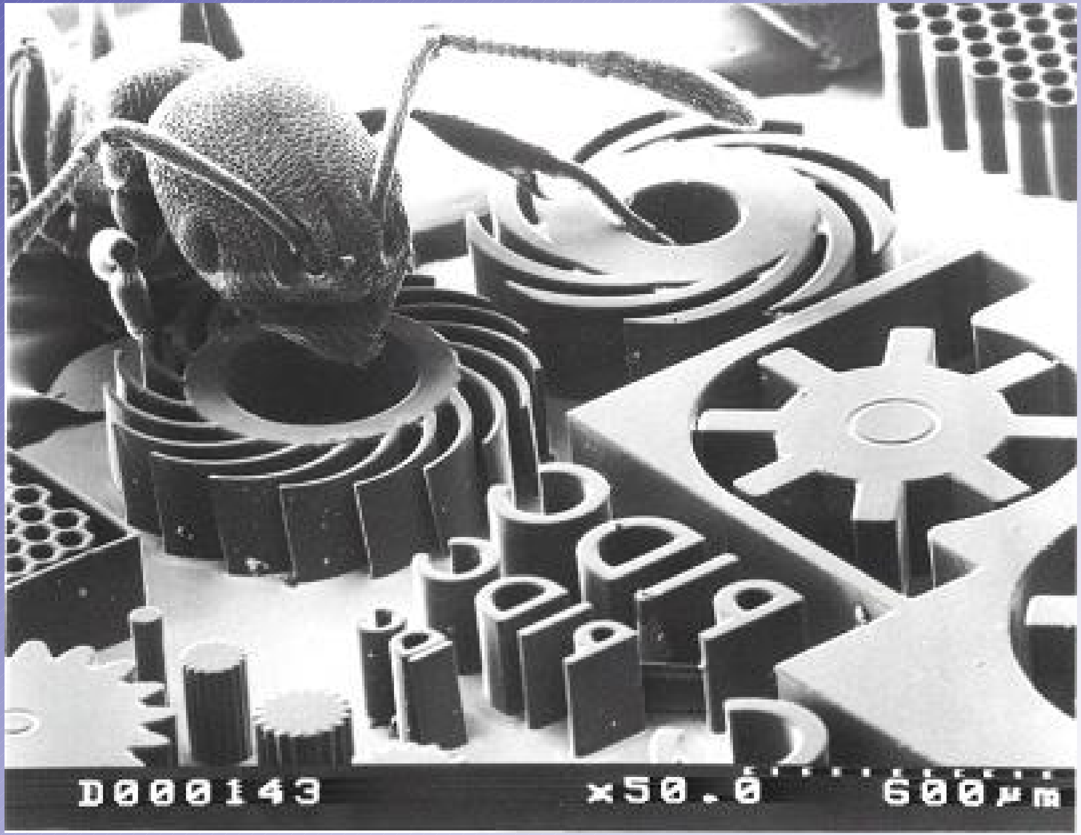
¿A qué nos referimos cuando hablamos de MEMS?

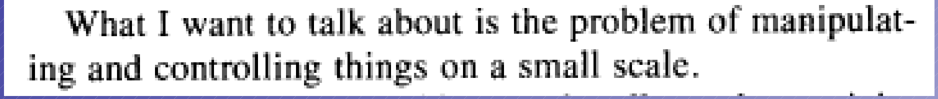
- Sistemas mecánicos de dimensiones micrométricas
- En general estructuras maquinadas con técnicas litográficas


D000143
x50.0
600μm

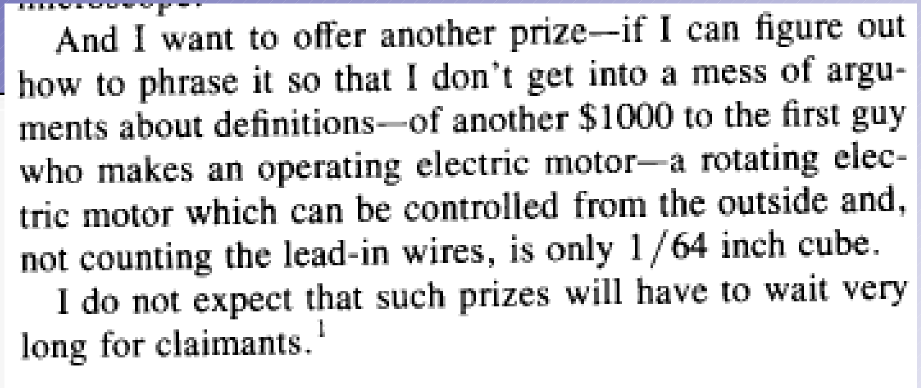
There's Plenty of Room at the Bottom

Richard P. Feynman

Caltech, APS Meeting
26 de Diciembre de 1959

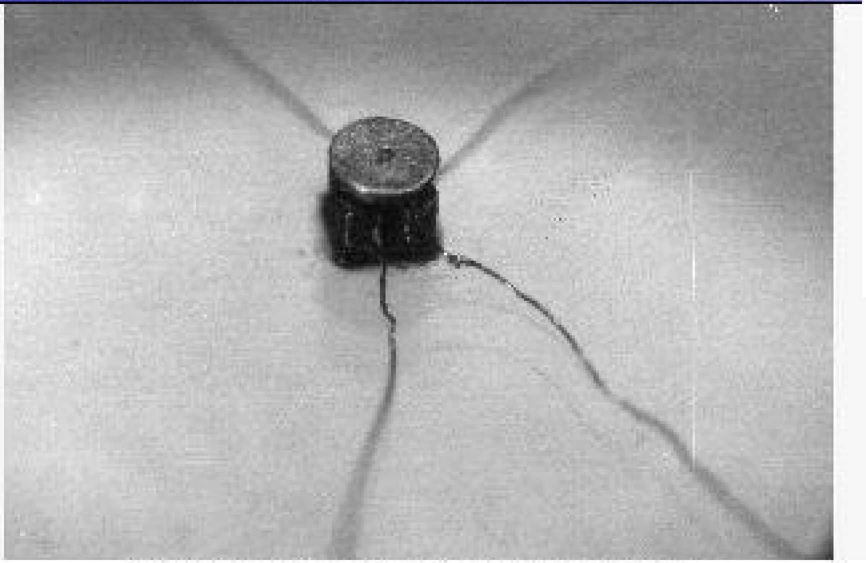


What I want to talk about is the problem of manipulating and controlling things on a small scale.



And I want to offer another prize—if I can figure out how to phrase it so that I don't get into a mess of arguments about definitions—of another $1000 to the first guy who makes an operating electric motor—a rotating electric motor which can be controlled from the outside and, not counting the lead-in wires, is only 1/64 inch cube.

I do not expect that such prizes will have to wait very long for claimants.[1]



Caltech Archives. For reference only.
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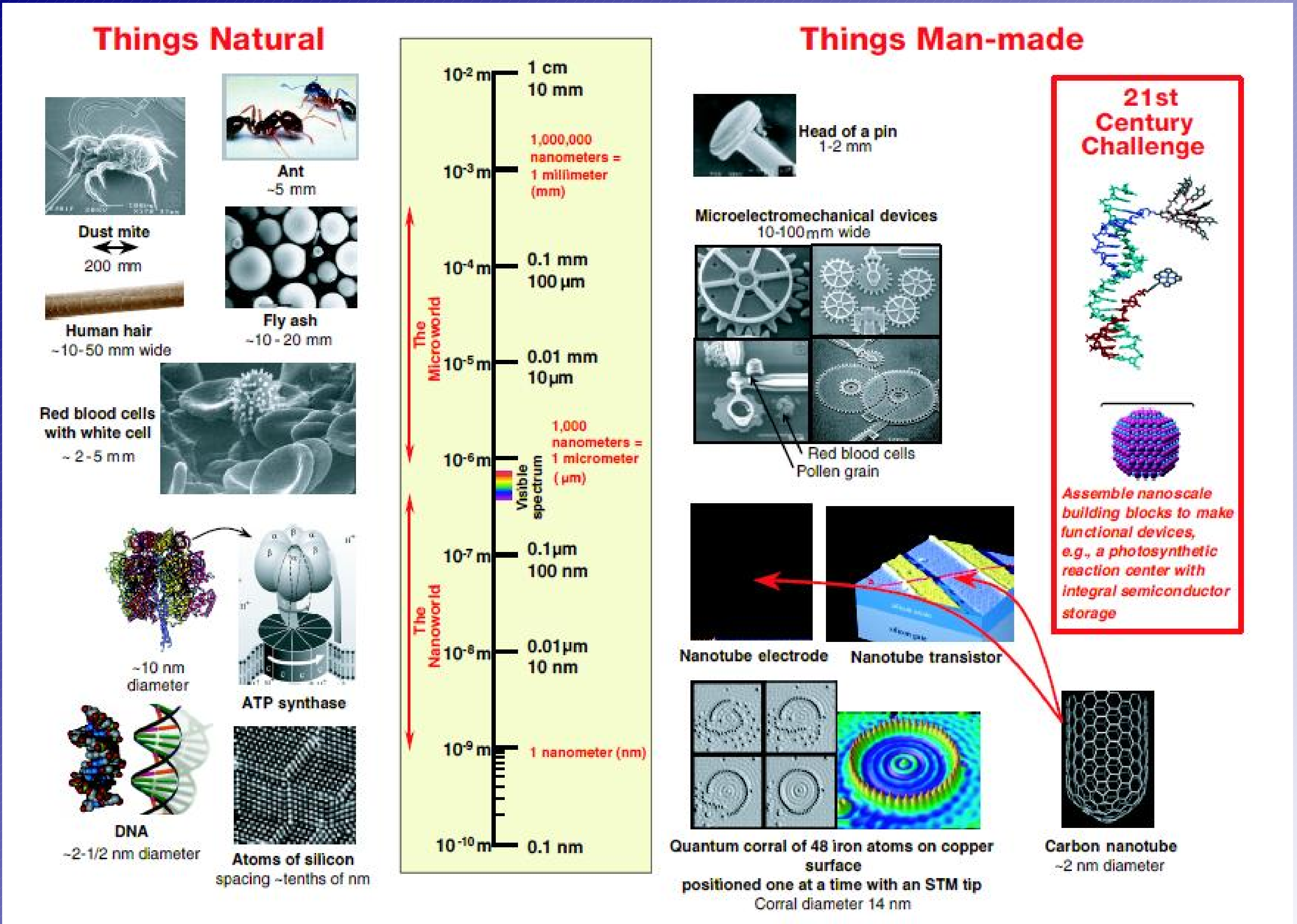


Things Natural

Dust mite
200 mm

Ant
~5 mm

Human hair
~10-50 mm wide

Fly ash
~10 - 20 mm

Red blood cells with white cell
~ 2-5 mm

~10 nm diameter

ATP synthase

DNA
~2-1/2 nm diameter

Atoms of silicon
spacing ~tenths of nm

10^{-2} m — 1 cm, 10 mm

1,000,000 nanometers = 1 millimeter (mm)

10^{-3} m

10^{-4} m — 0.1 mm, 100 µm

10^{-5} m — 0.01 mm, 10µm

1,000 nanometers = 1 micrometer (µm)

10^{-6} m

Visible spectrum

10^{-7} m — 0.1µm, 100 nm

10^{-8} m — 0.01µm, 10 nm

10^{-9} m — 1 nanometer (nm)

10^{-10} m — 0.1 nm

The Microworld

The Nanoworld

Things Man-made

Head of a pin
1-2 mm

Microelectromechanical devices
10-100mm wide

Red blood cells
Pollen grain

Nanotube electrode

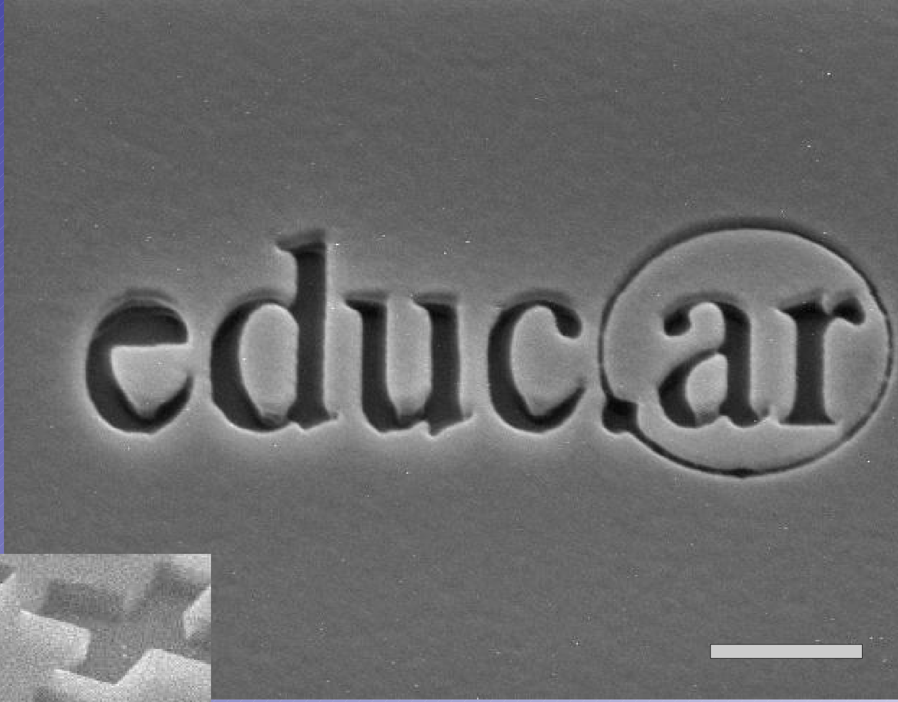
Nanotube transistor

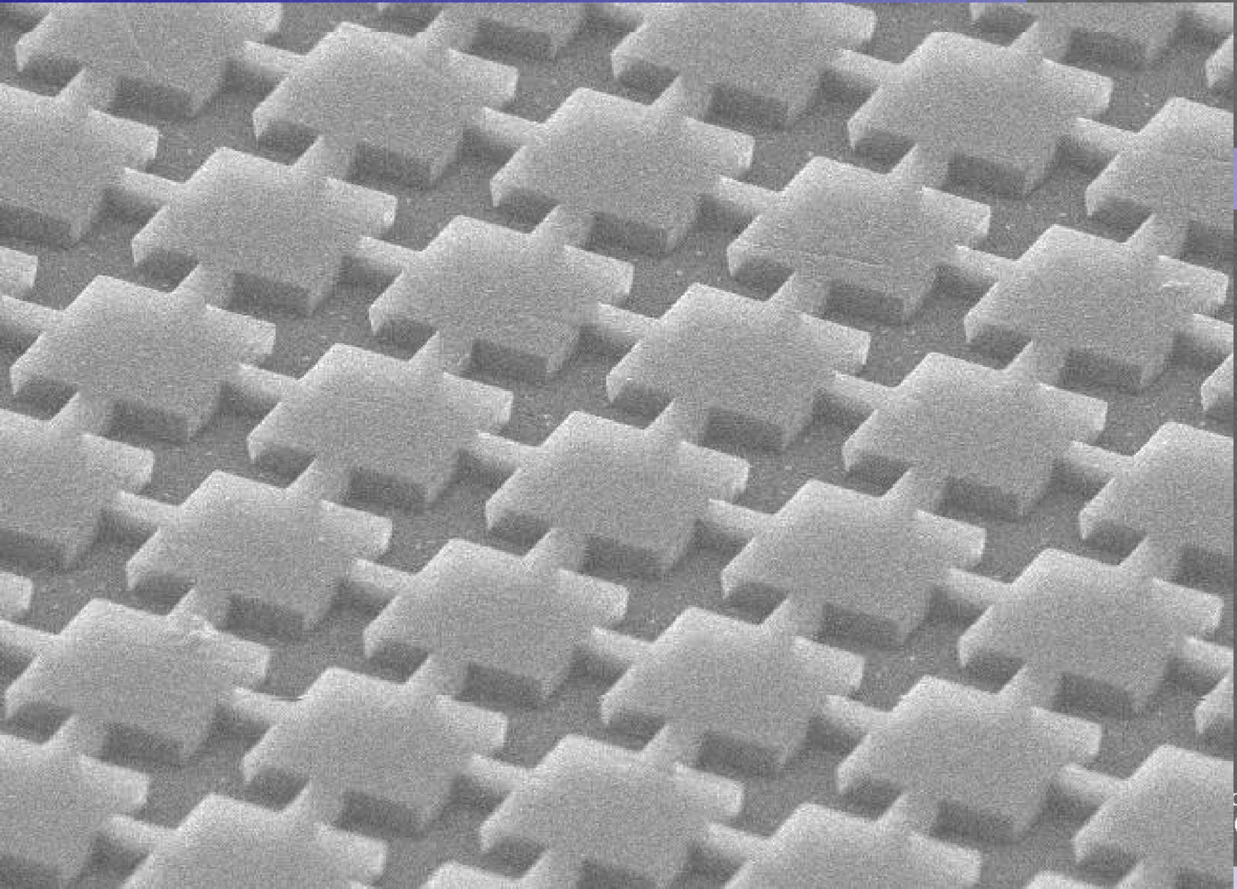
Quantum corral of 48 iron atoms on copper surface
positioned one at a time with an STM tip
Corral diameter 14 nm

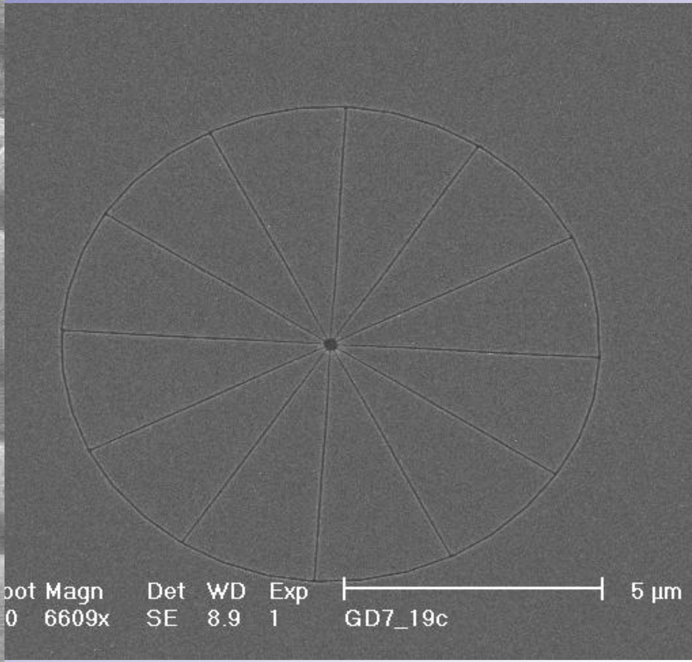
Carbon nanotube
~2 nm diameter

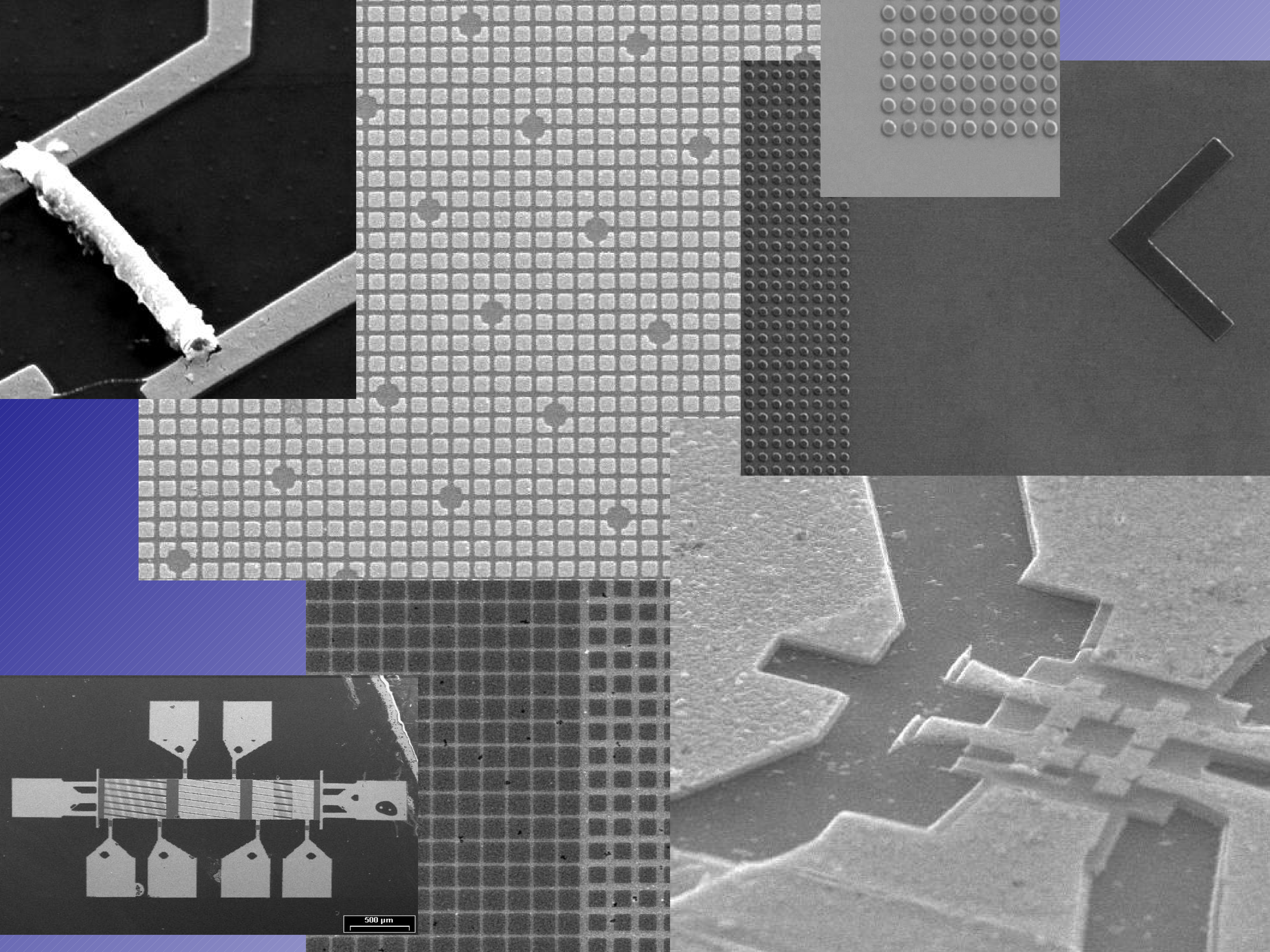
21st Century Challenge

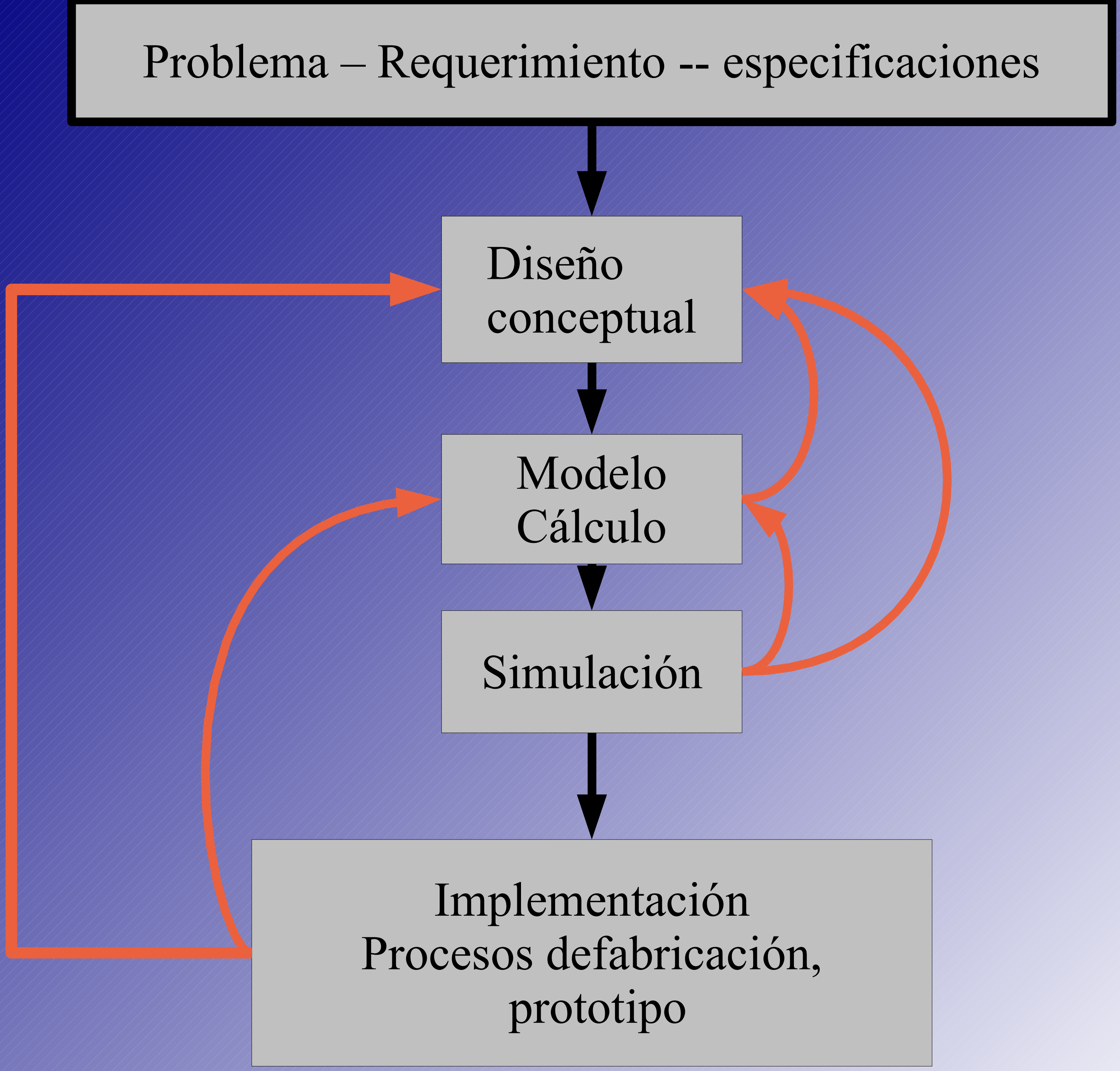
Assemble nanoscale building blocks to make functional devices, e.g., a photosynthetic reaction center with integral semiconductor storage


educ.ar




ot Magn
Det
WD
Exp
5 µm
0
6609x
SE
8.9
1
GD7_19c


500 µm



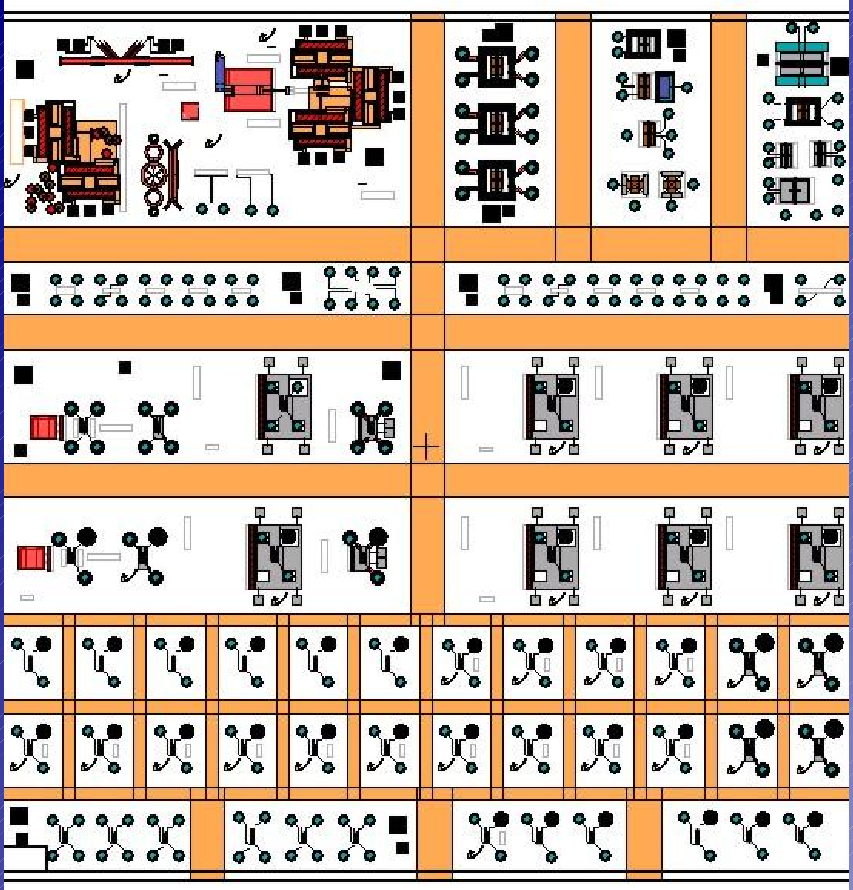
Problema – Requerimiento -- especificaciones

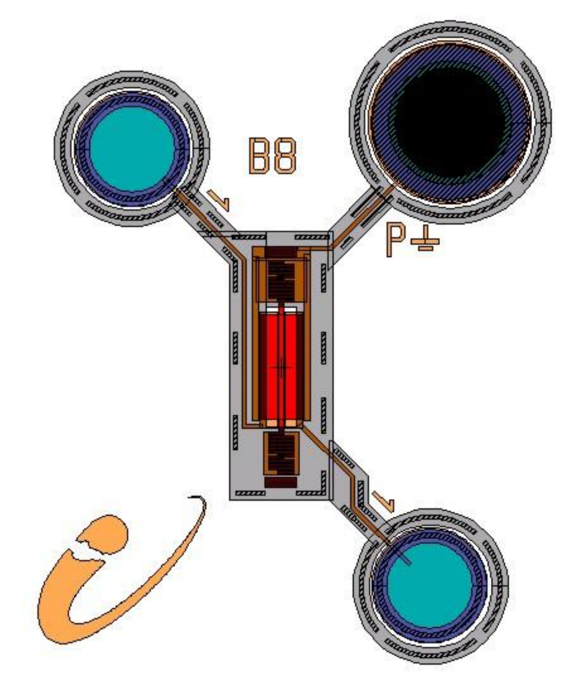
Diseño conceptual

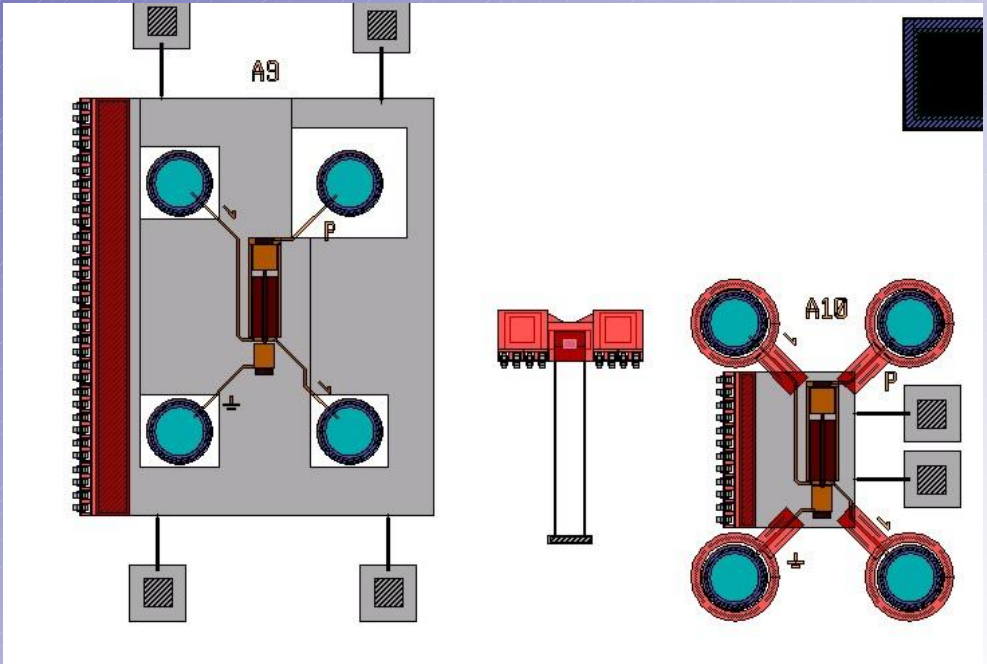
Modelo
Cálculo

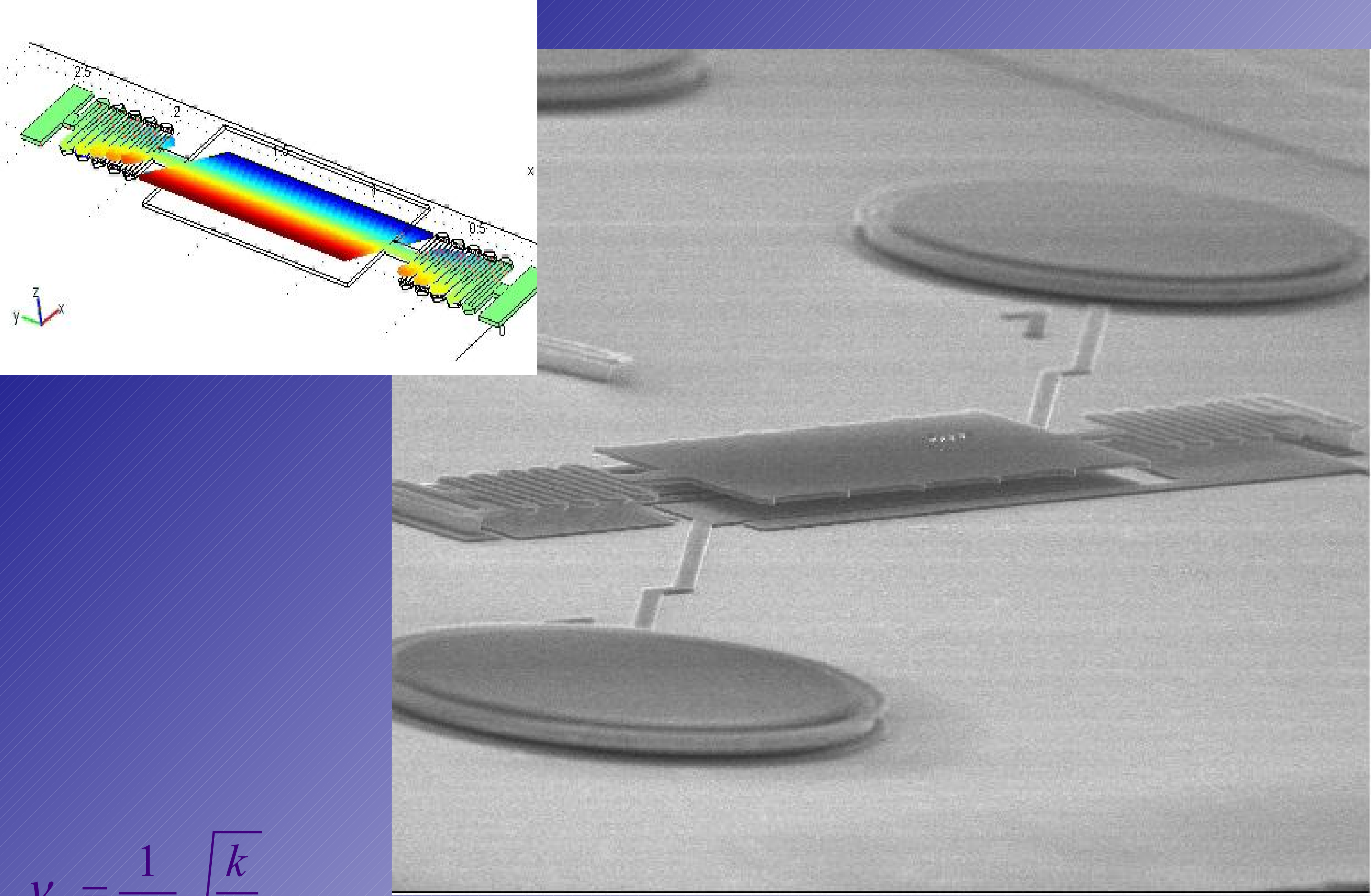
Simulación

Implementación
Procesos defabricación,
prototipo



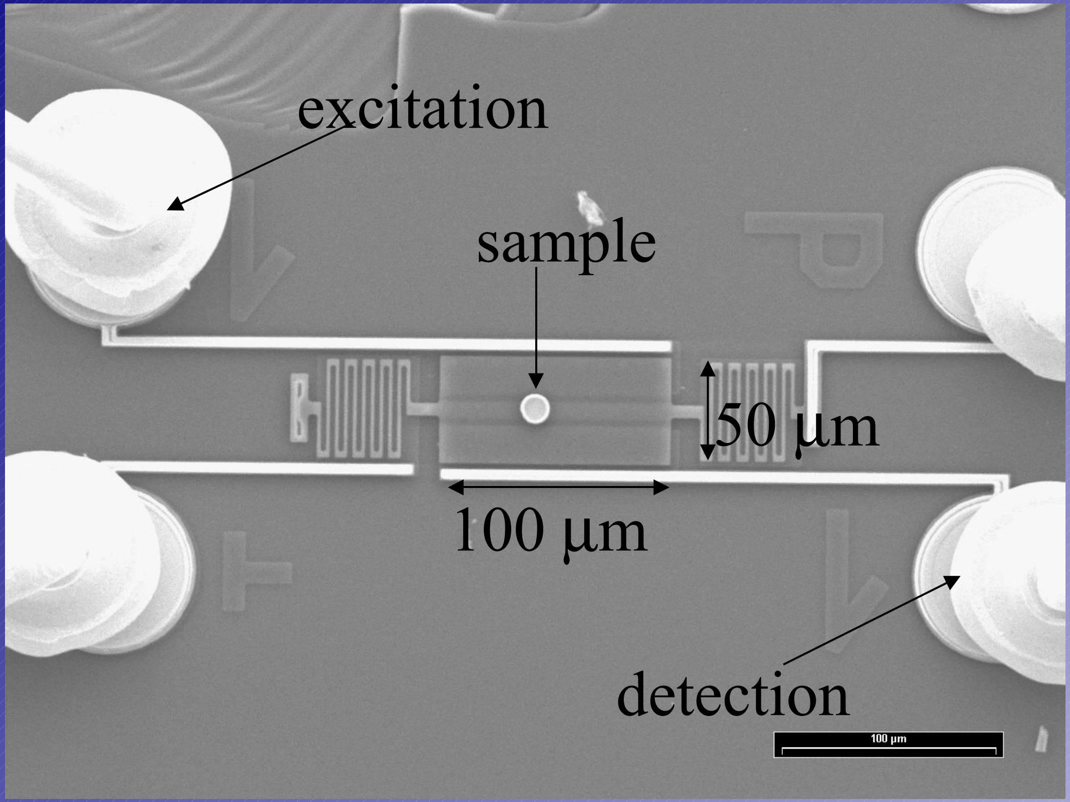

B8
P

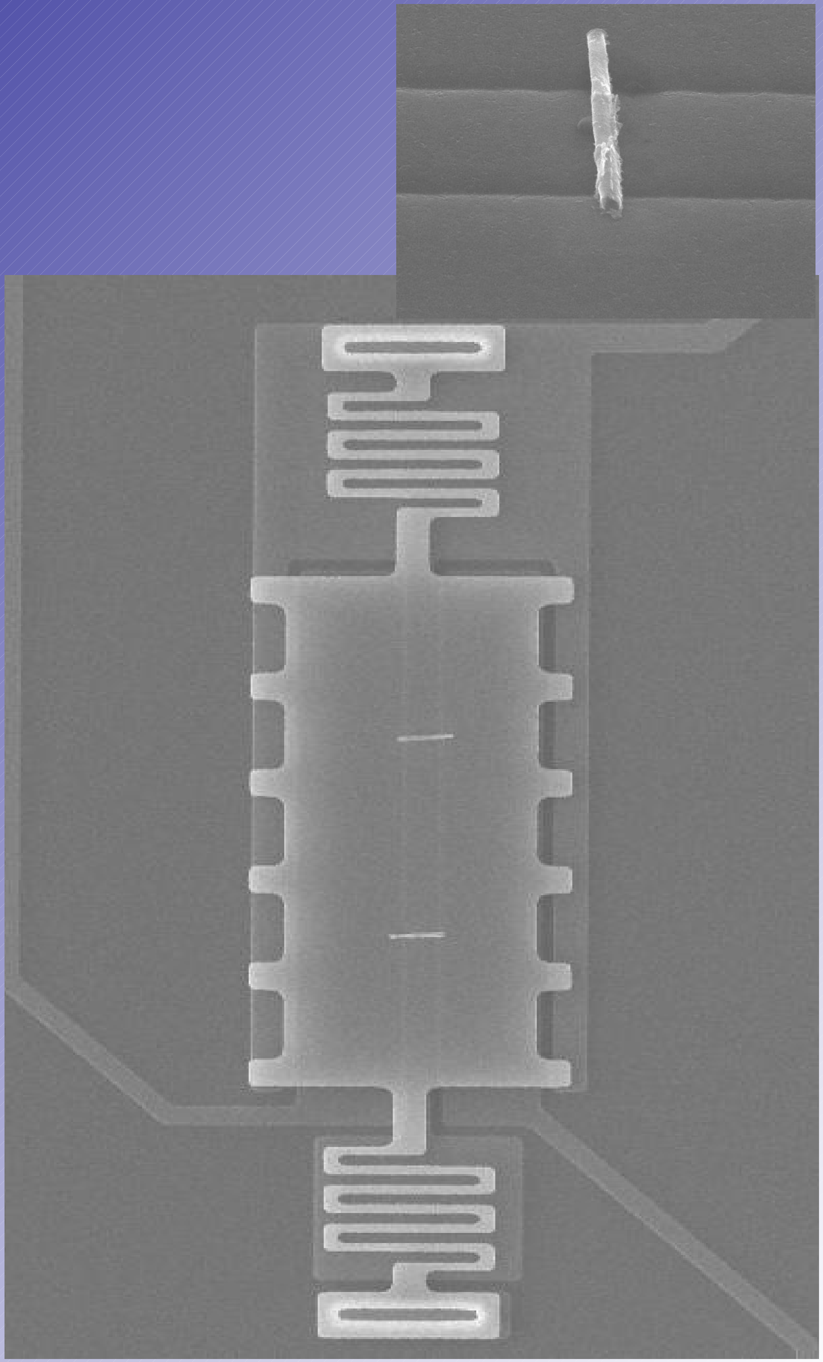

A9
P
A10
P

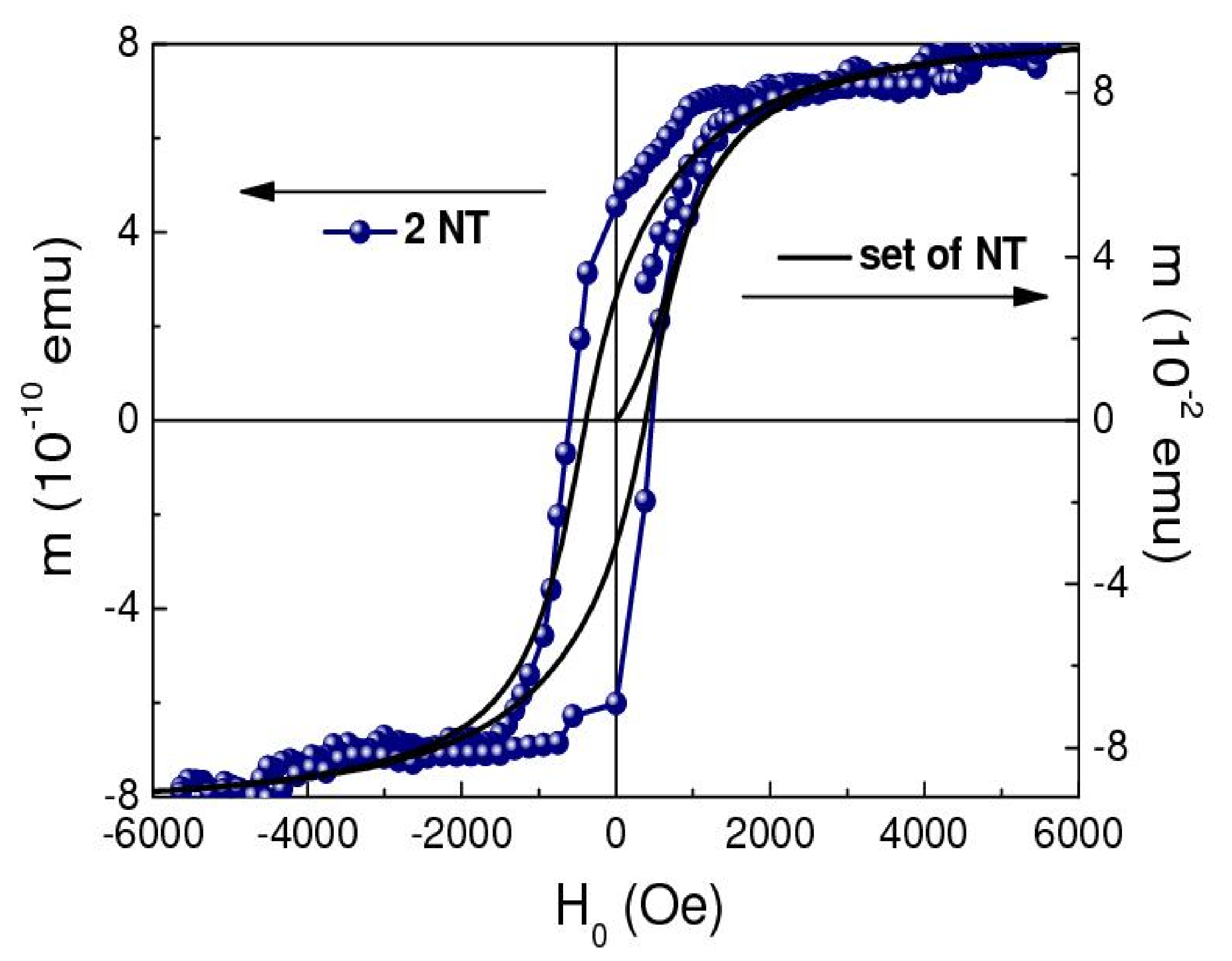

2.5
2
1.5
1
0.5
0
x
z
y
x

$$\nu_0 = \frac{1}{2\pi}\sqrt{\frac{k}{I_0}}$$

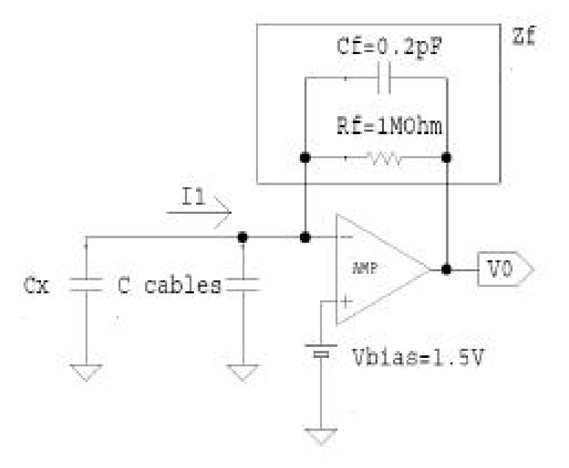
$Q > 10^5$

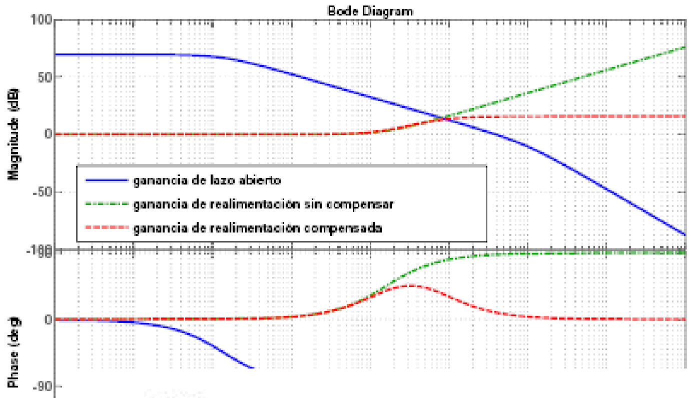

excitation
sample
50 µm
100 µm
detection
100 µm

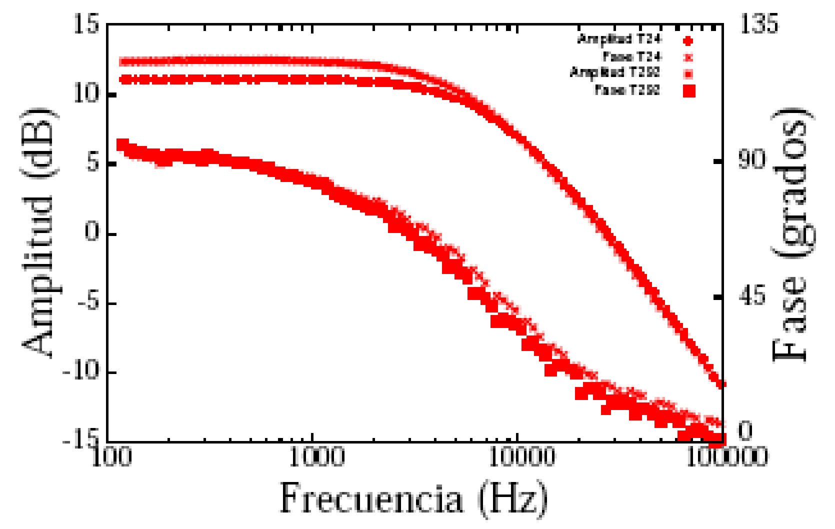


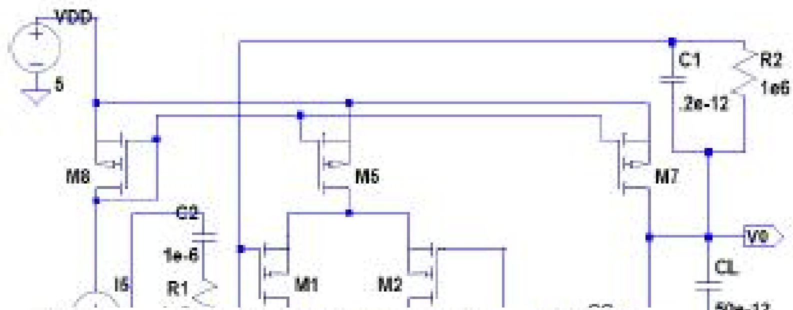


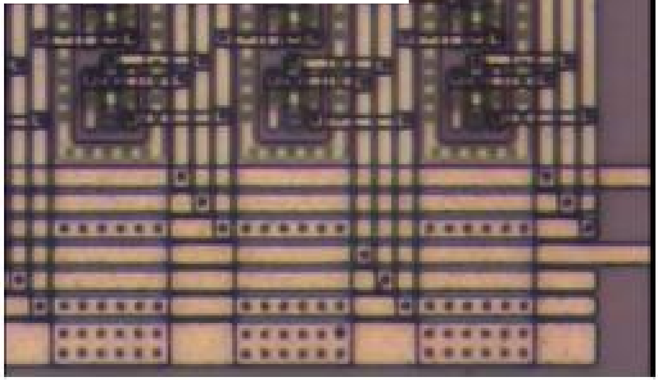
8
4
0
-4
-8
m (10^-10 emu)
2 NT
set of NT
8
4
0
-4
-8
m (10^-2 emu)
-6000
-4000
-2000
0
2000
4000
6000
H_0 (Oe)

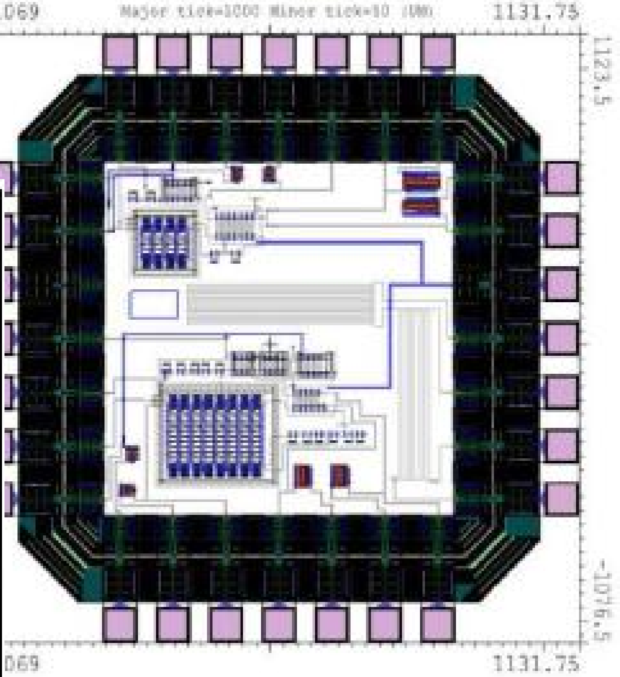

Cf=0.2pF
Zf
Rf=1MOhm
I1
Cx
C cables
AMP
V0
Vbias=1.5V


Bode Diagram
Magnitude (dB)
Phase (deg)
100
50
0
-50
-100
180
0
-90
-180
10
ganancia de lazo abierto
ganancia de realimentación sin compensar
ganancia de realimentación compensada


Amplitud (dB)
Fase (grados)
Frecuencia (Hz)
15
10
5
0
-5
-10
-15
135
90
45
0
100
1000
10000
100000
Amplitud T24
Fase T24
Amplitud T292
Fase T292


VDD
5
M8
M5
M7
C1
.2e-12
R2
1e6
C2
1e-6
R1
I6
M1
M2
V0
CL
50e-12




-1069
Major tick=1000 Minor tick=10 (UM)
1131.75
1123.5
-1076.5
069

Un ejemplo de desarrollo: Sensores infrarrojos

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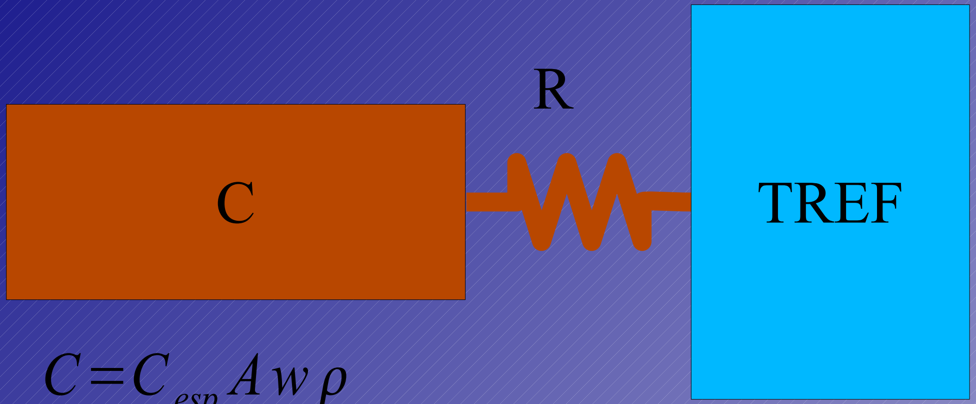
Algunos requerimientos:

Pixel Size: 25 - 40 µm
Response Time: 15 -20 mseg
Resolución: $5x10^{-2}$ W/m^2


R

C

TREF

$$C = C_{esp}\, A\, w\, \rho$$

$$R = \frac{l}{A}\frac{1}{\kappa}$$

$$\tau = R\, C$$

$$T - T_{REF} = R\frac{dQ}{dt}$$

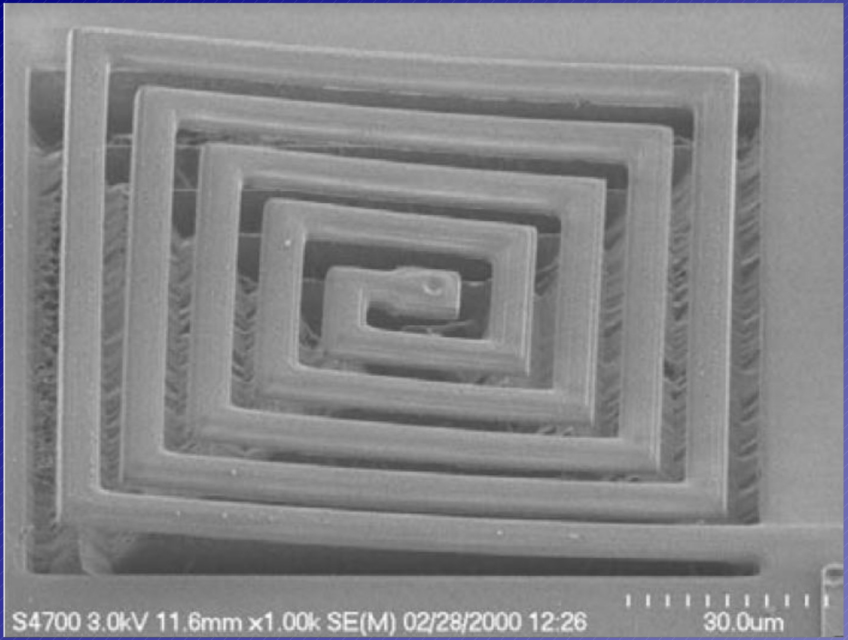
$$\tau \approx 27\, ms$$

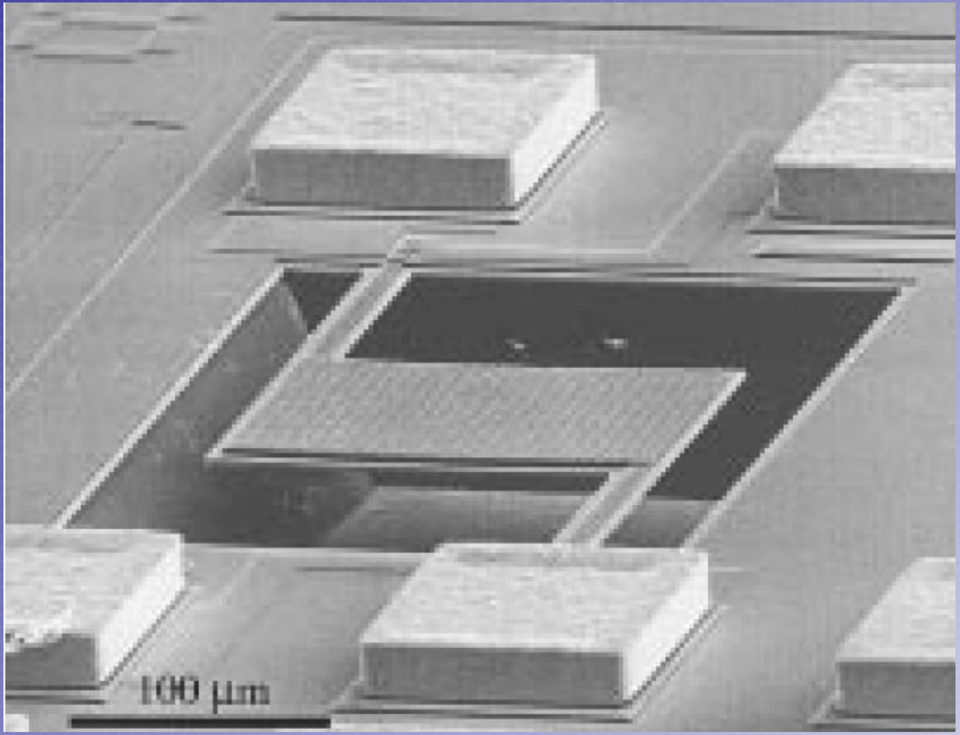
$$\Delta T \approx 5\, mK$$

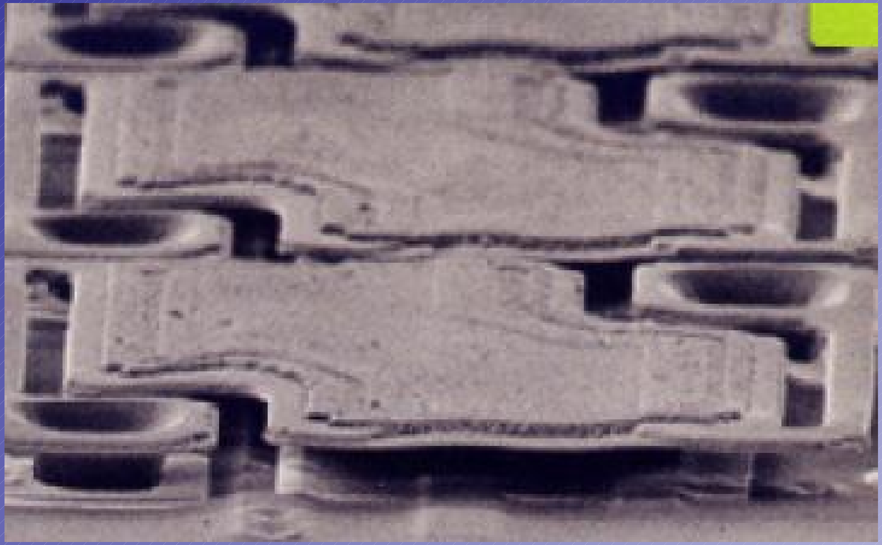
$$C_{esp} = 678\frac{J}{K\, kg}$$

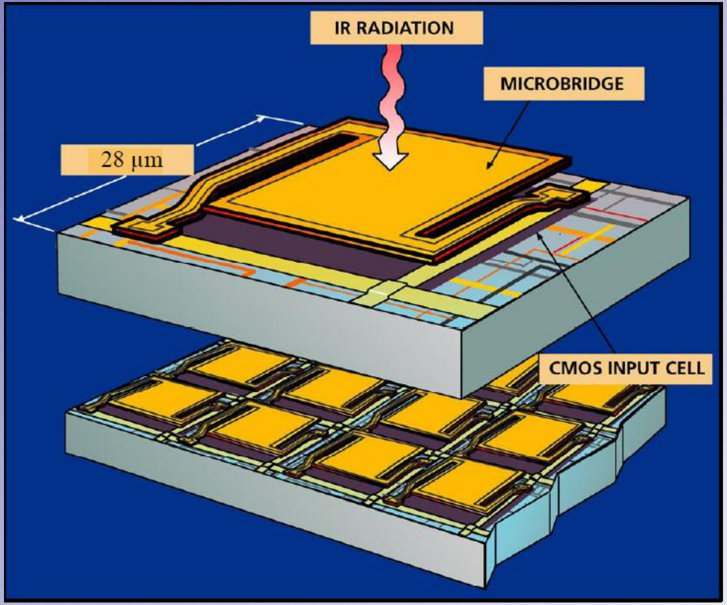
$$\rho = 2320\frac{kg}{m^3}$$

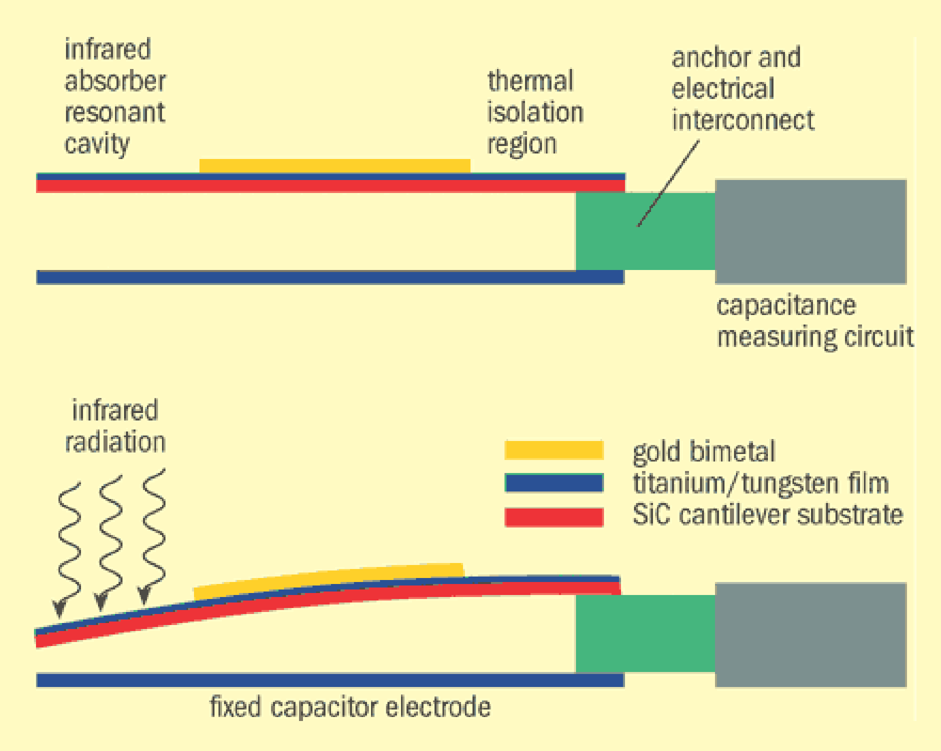
$$\kappa = 34\frac{W}{K\,.\,m}$$

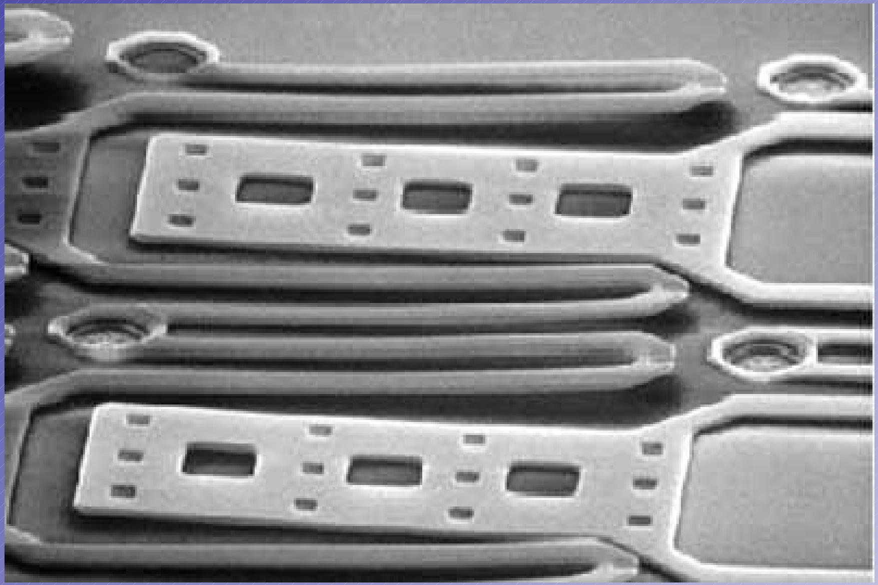

S4700 3.0kV 11.6mm x1.00k SE(M) 02/28/2000 12:26
30.0um

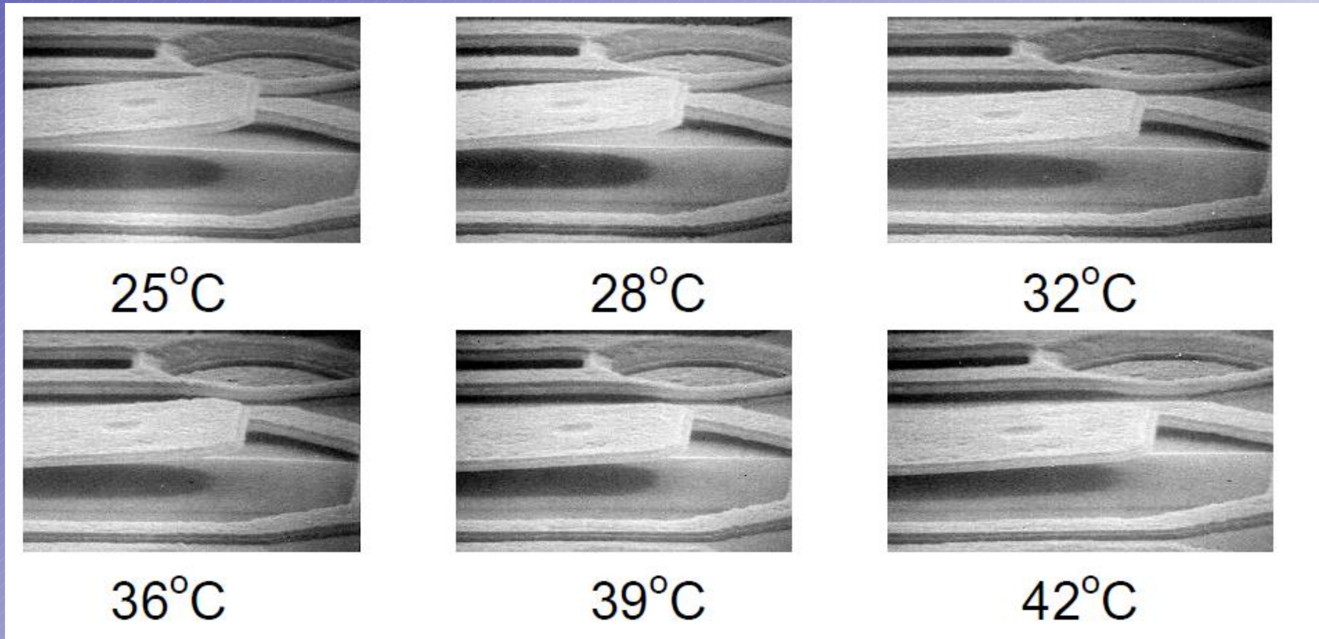

100 µm




IR RADIATION
MICROBRIDGE
28 µm
CMOS INPUT CELL


infrared absorber resonant cavity
thermal isolation region
anchor and electrical interconnect
capacitance measuring circuit
infrared radiation
gold bimetal
titanium/tungsten film
SiC cantilever substrate
fixed capacitor electrode

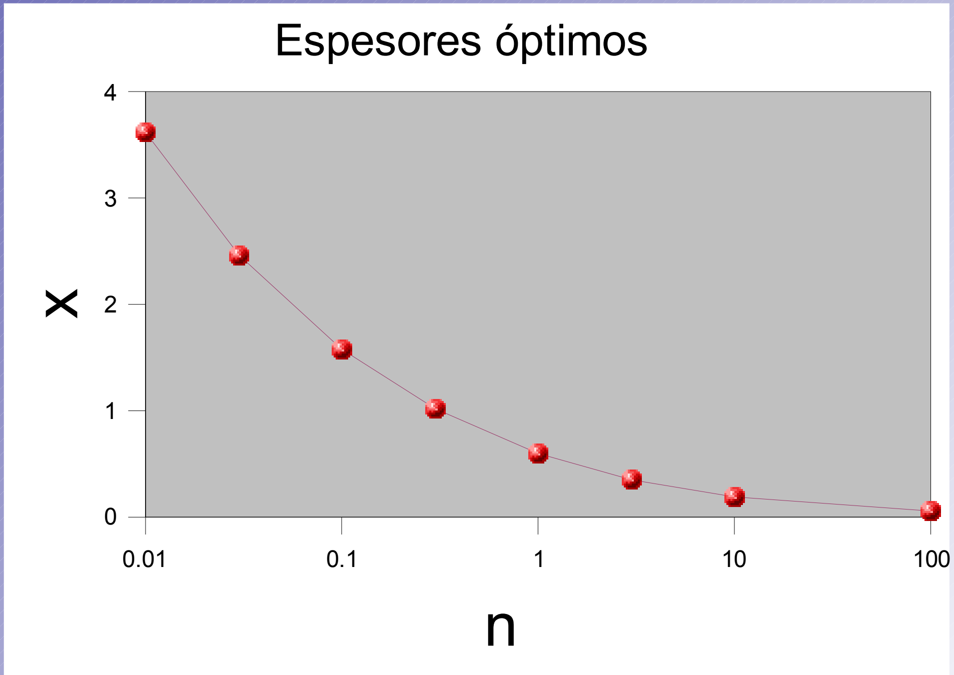



25°C
28°C
32°C
36°C
39°C
42°C

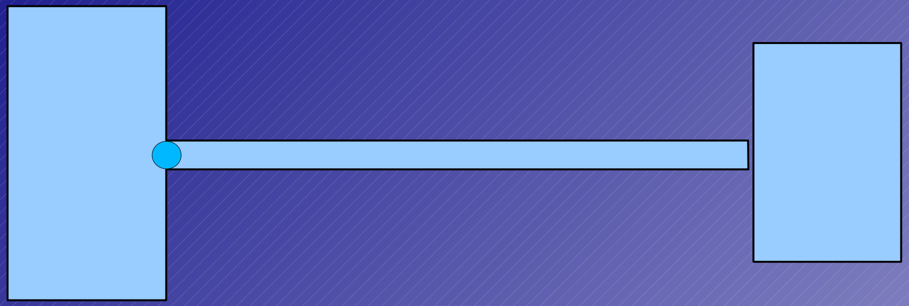
¿Cuánto se desplaza un bimorfo?

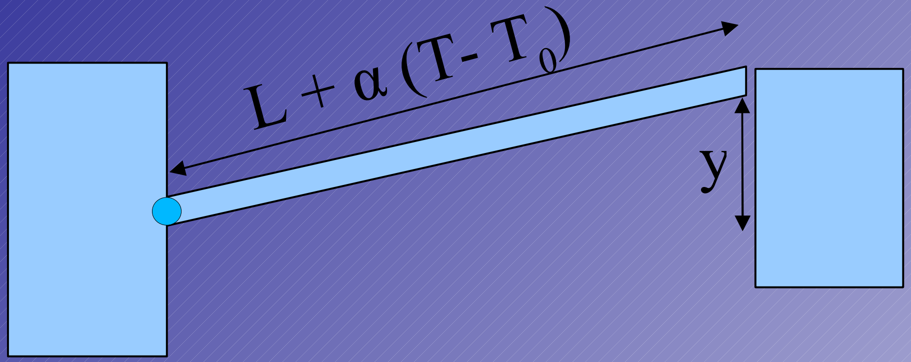
$$\Delta y = \frac{3L^2}{8t_{bi}} \frac{8(1+x)}{(1/x+4+6x+4x^2+nx^3)} (\alpha_{bi} - \alpha_{subs})(T - T_0)$$

$$x = \frac{t_{subs}}{t_{bi}} ; n = \frac{E_{subs}}{E_{bi}}$$


Espesores óptimos

Una estructura más simple:

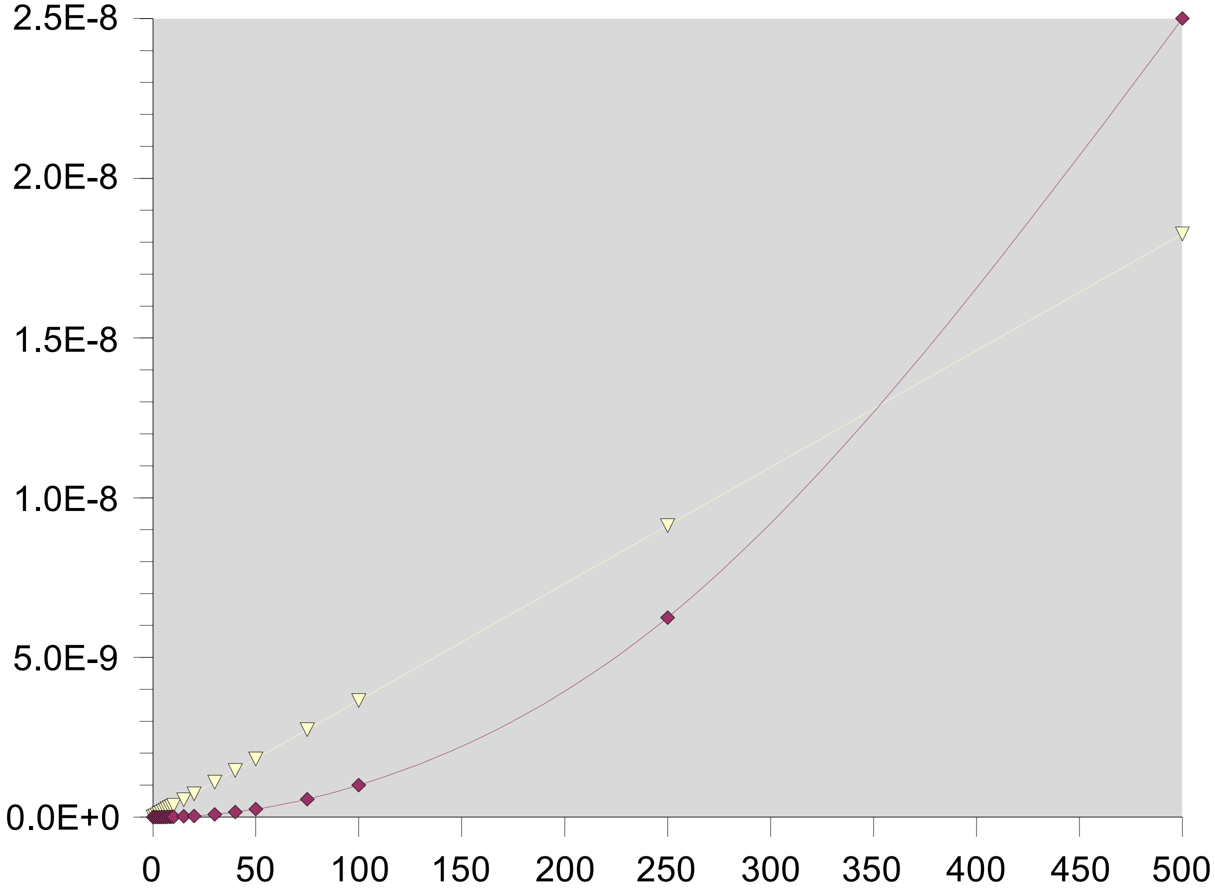


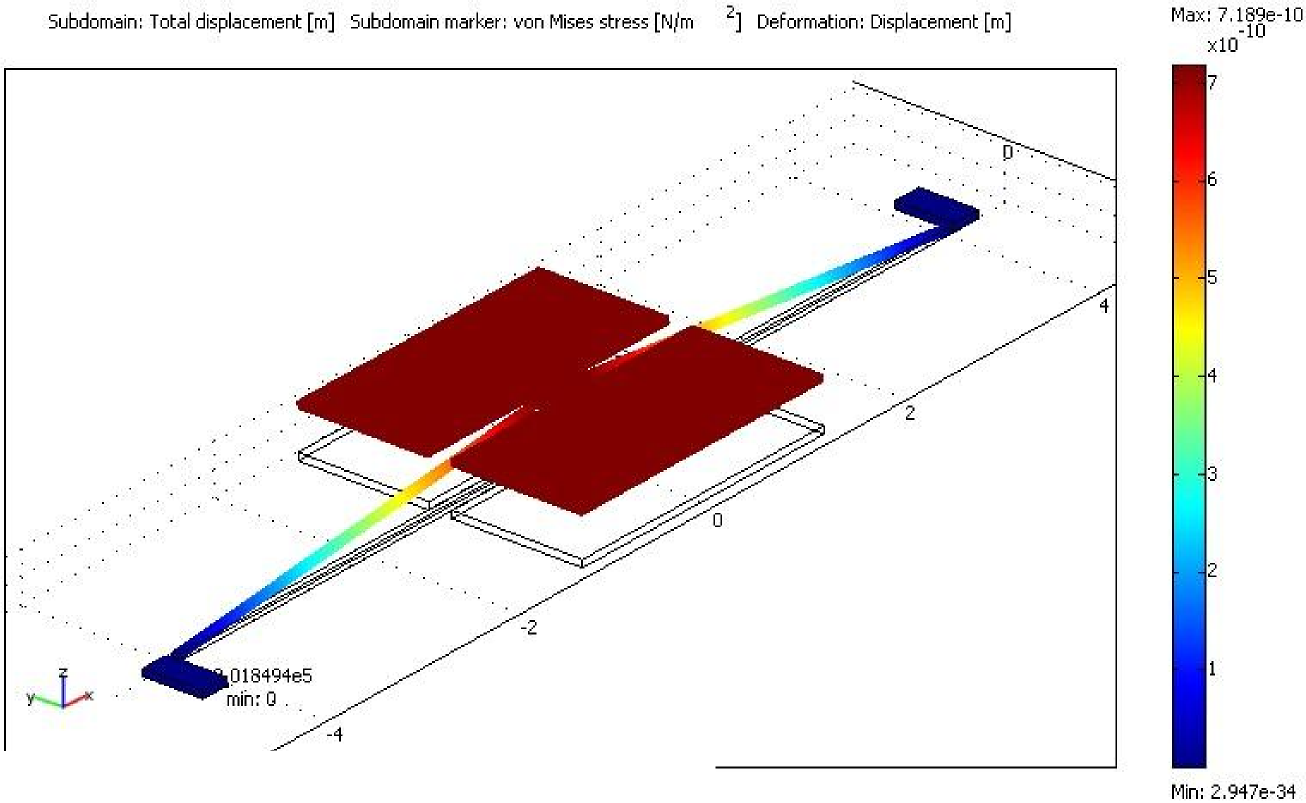


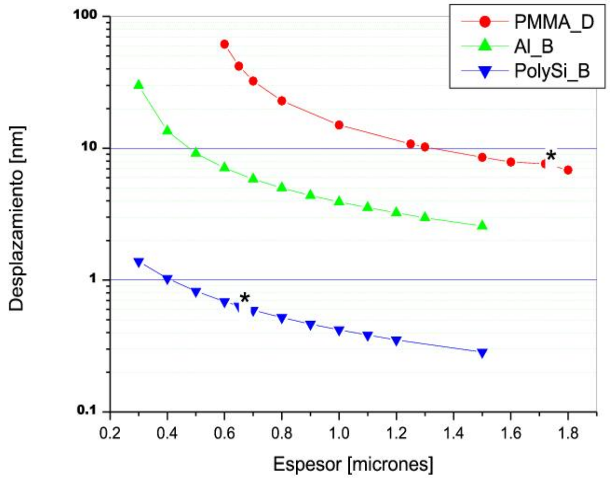
$$y = L\sqrt{(\alpha(T-T_0)[1+\alpha\frac{(T-T_0)}{4}])} \qquad \alpha \simeq 10^{-6}K^{-1}$$

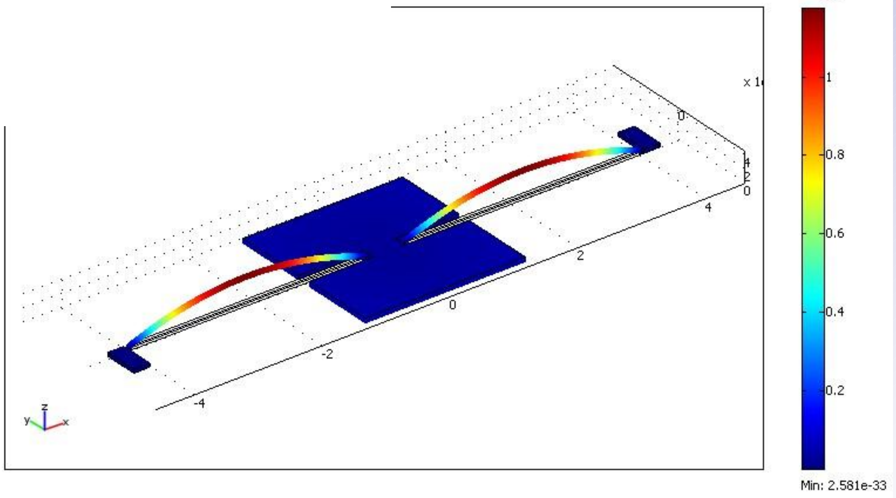
$$y \simeq L\sqrt{\alpha(T-T_0)}$$

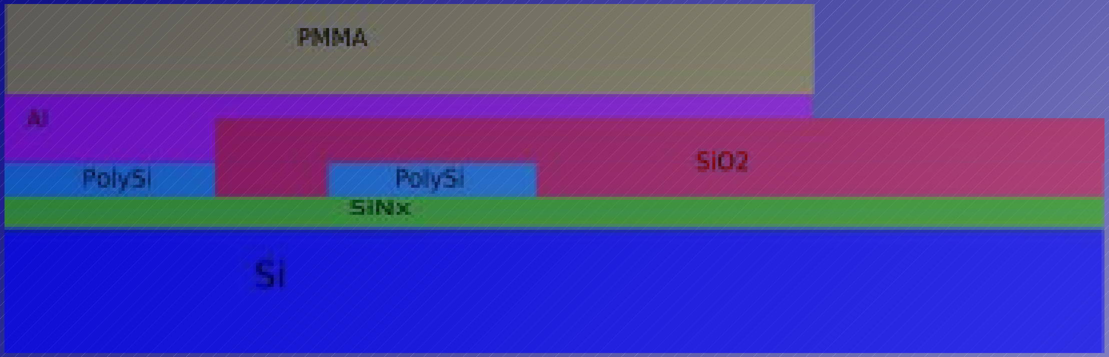
Desplazamientos

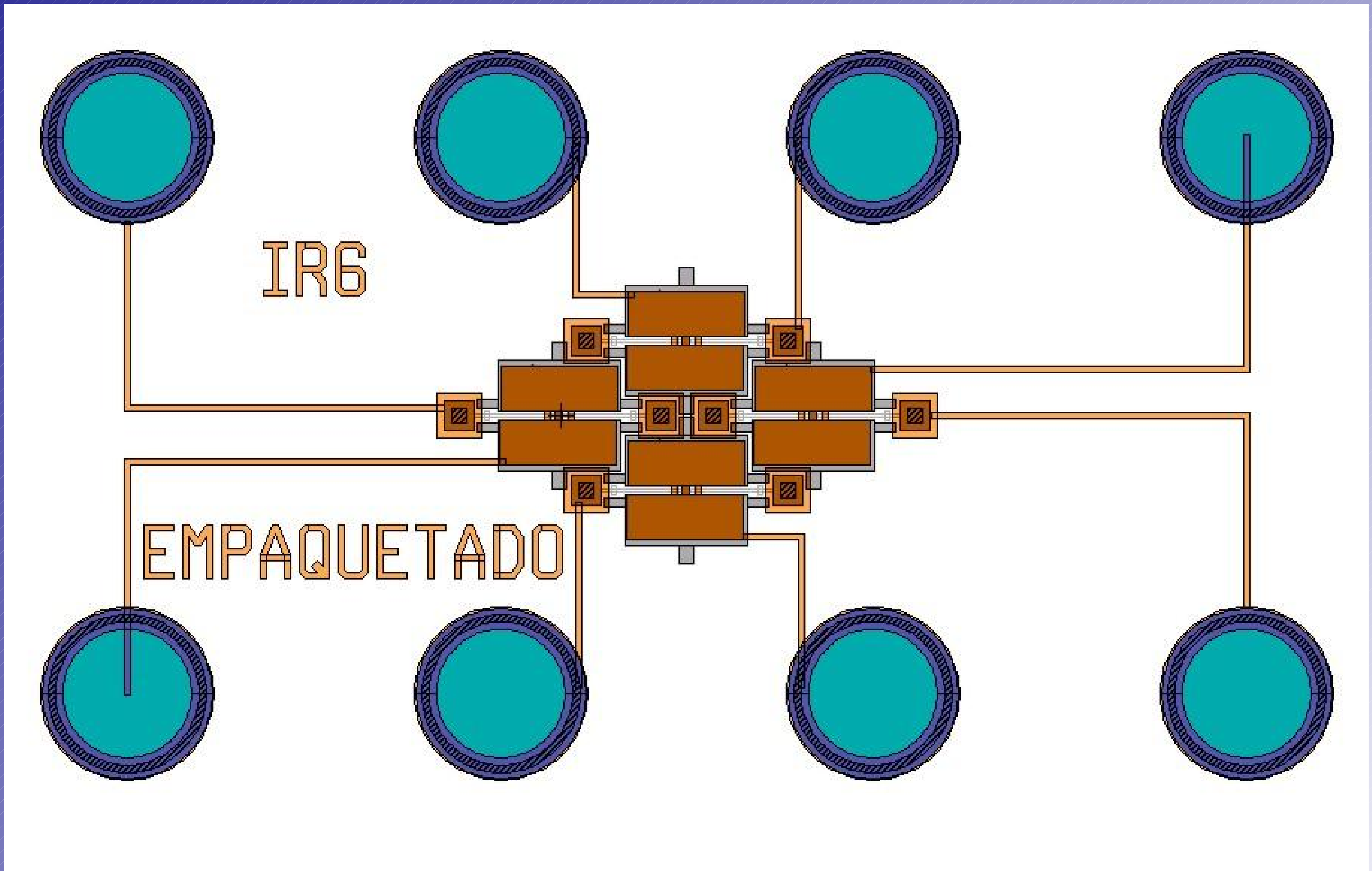



Subdomain: Total displacement [m] Subdomain marker: von Mises stress [N/m^2] Deformation: Displacement [m]
Max: 7.189e-10
x10^-10
7
6
5
4
3
2
1
Min: 2.947e-34
0
4
2
0
-2
-4
.018494e5
min: 0
z
y
x


PMMA_D
Al_B
PolySi_B
Desplazamiento [nm]
Espesor [micrones]
100
10
1
0.1
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
*
*


Max: 1.176e-10
x10^-10
1
0.8
0.6
0.4
0.2
Min: 2.581e-33
0
4
2
0
-2
-4
z
y
x


PMMA
Al
SiO2
PolySi
PolySi
SiNx
Si


IR6
EMPAQUETADO

Ultimos 7 años nanoestructuración y MEMS:

- ✓12 trabajos científicos en revistas internacionales con referato
- ✓presentaciones en congresos científicos nacionales
- ✓ 1 patente de invención en trámite
-
- Formación de recursos:
-
- ✓4 Maestrías en Física (Mat Cond. y Tecnológica)
- ✓2 tesis doctorales en curso
- ✓1 tesis doctoral finalizada (premio AFA)
- ✓Escuelas-pasantias