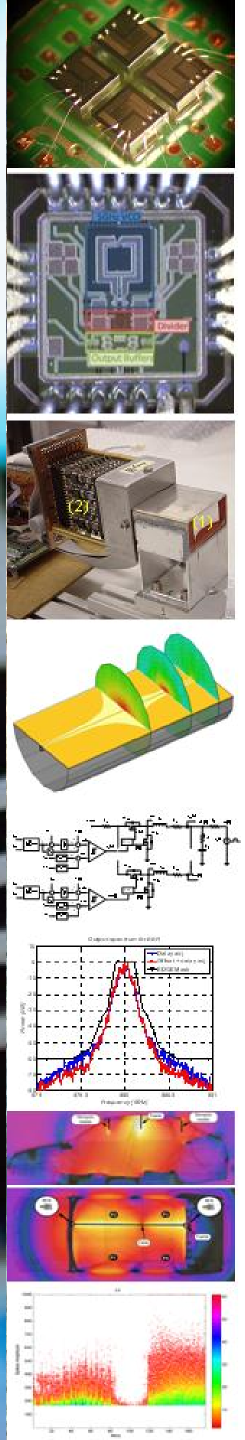

1st Barcelona Forum
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in Electronic Engineering
16th October 2009

Contribution to advanced hot wire wind sensing

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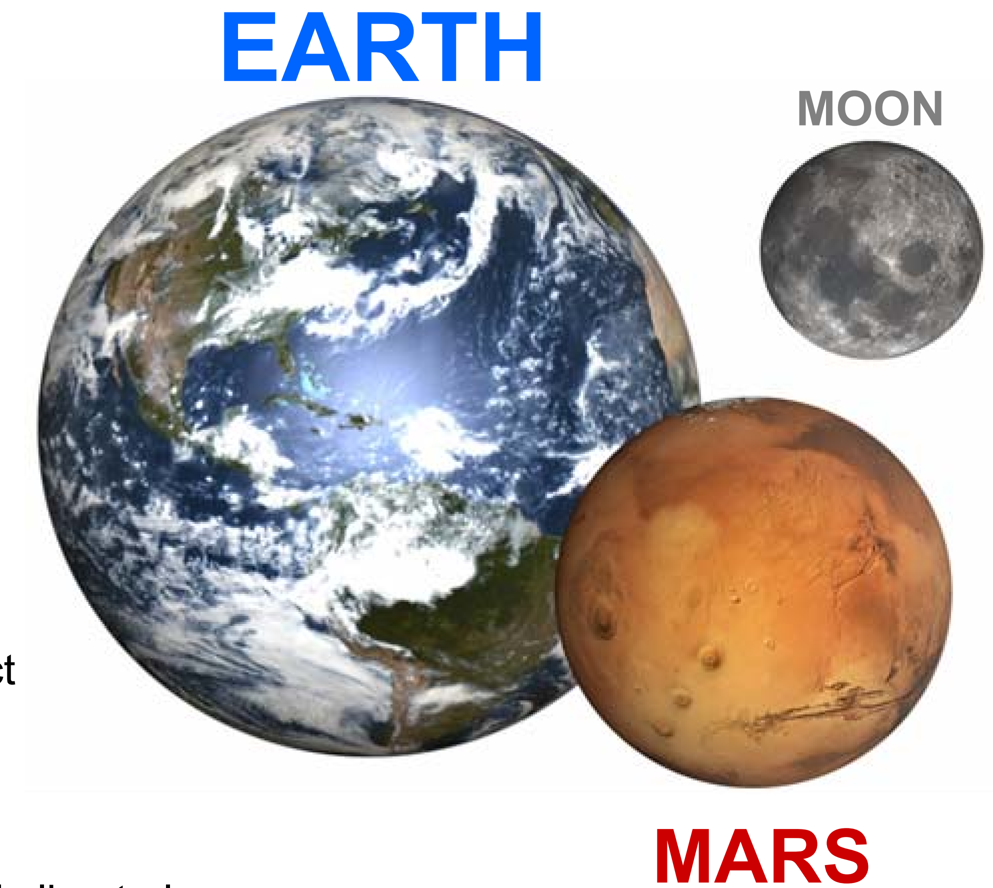
Introduction



Earth climate components:

- Mean flows
- Turbulences
- Huricanes
- Storms
- Greenhouse effect

1. Is it possible to scale all climate laws for MARS to behave like on EARTH?

No!

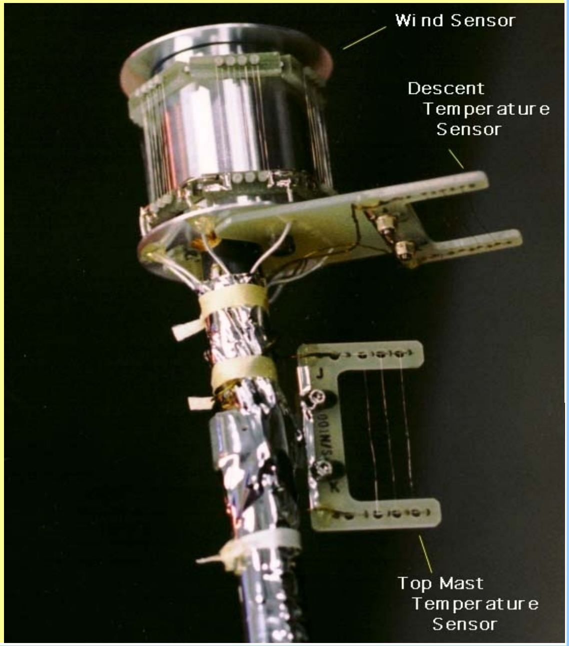
2. How to understand climate on MARS?

In-situ measurements on MARS surface are crucial!

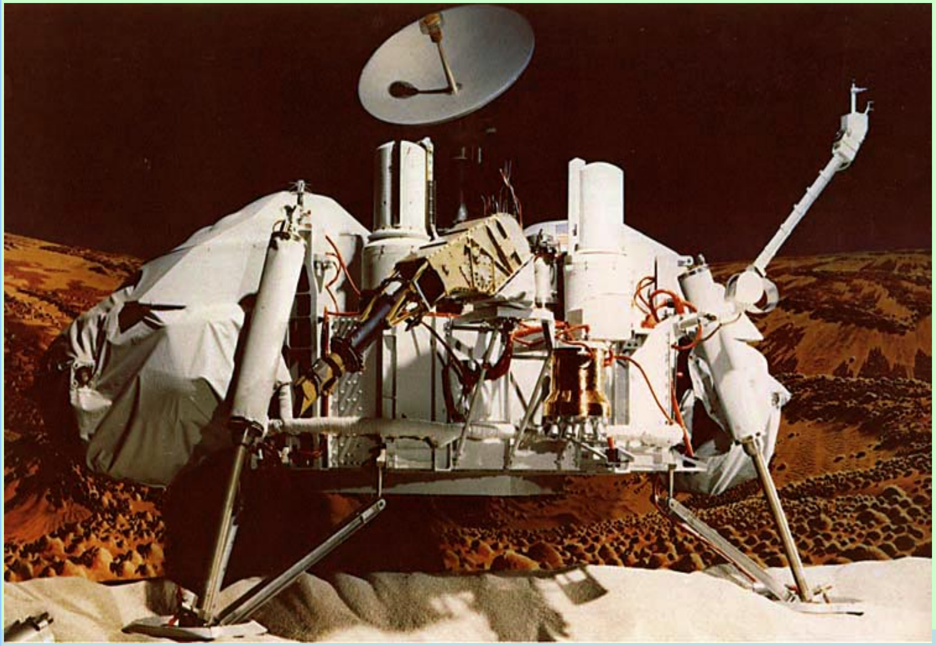
Mars regime comparing to the Earth

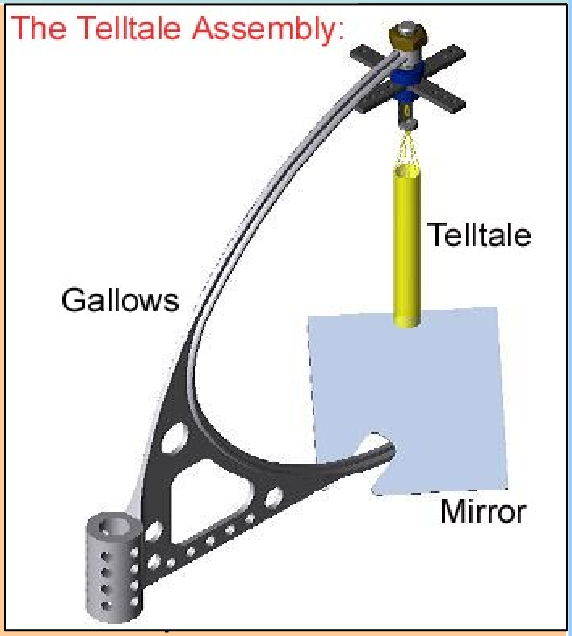
MARS	Planet	**EARTH**
	Photos done by the Hubble telescope.	
591	Solar constant [W/m^2]	1373
3,7	Gravity, g [m/s^2]	9,8
CO_2 95.32%, N_2 2.7%, Ar 1.6%, O_2 0.13%	Atmosphere air element composition [%]	N_2 78.08%, O_2 20.9%, Ar 0.93%
6-8 hPa (6-8mBar)	Surface pressure [hPa]	1013 hPa (1Bar)
0,0015	Surface density [kg/m^3]	1,2
0,01	Kinematic viscosity [m^2/s]	150000
220 (-73ºC)	Average temperature [K]	300 (27 º C)
from -125ºC to +25ºC	Temperature variation [K]	from -80ºC to +50ºC

Pathfinder

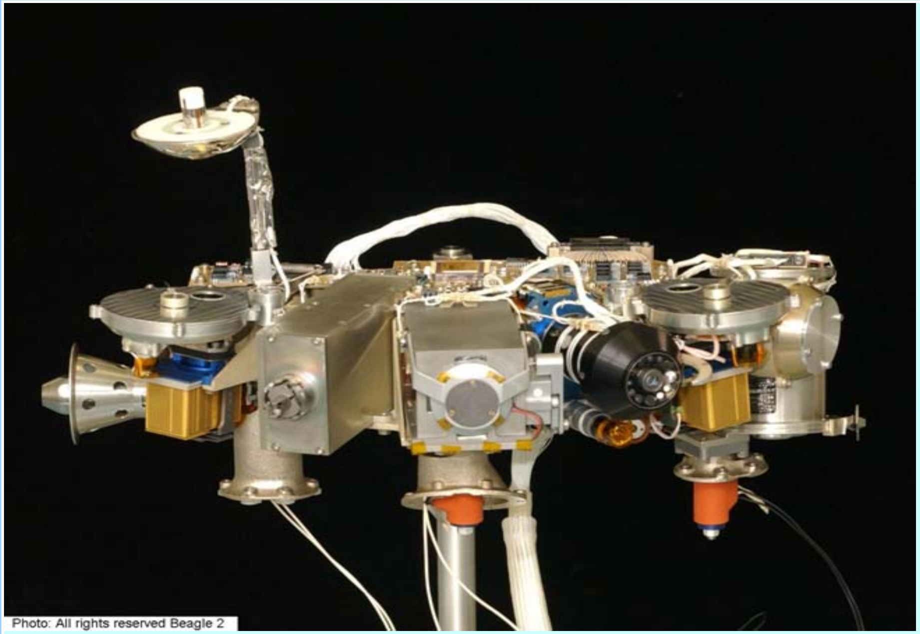


Viking





Pheonix



Beagle 2

Next opportunity

In fall of 2011, NASA launches Mars Science Laboratory as a part of Mars Exploration Program.

Main goal of MSL: study Mars' habitability looking for sygnature of life

Among instruments: **REMS** - Rover Environmental Monitoring Station for meteorological in-situ measurements

Cooperation

The **Finnish Meteorological Institute** works on pressure and humidity senosors

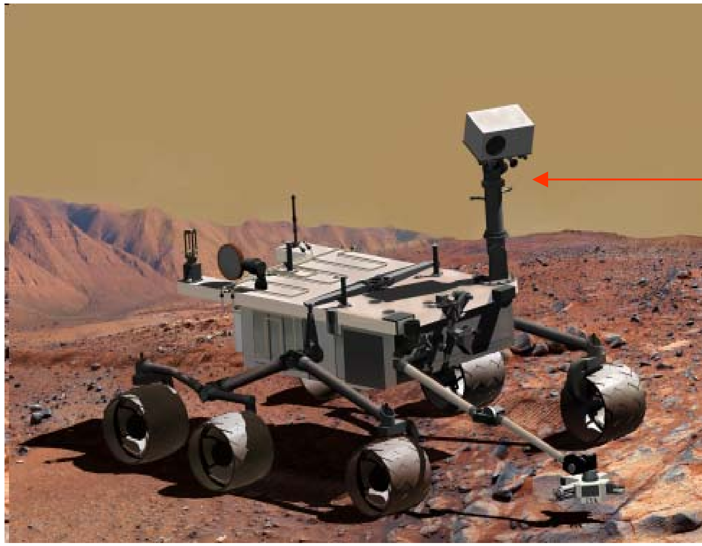
Univesidad Politecnica Catalunya development and technical research of 2D wind sensor for low density air Mars conditions

NASA - Jet Propulsion Laboratory control and integration with mission spacecraft

Redes e Ingeniería (CRISA) design and manufacture of ASIC for wind sensor and other instruments electronic interface

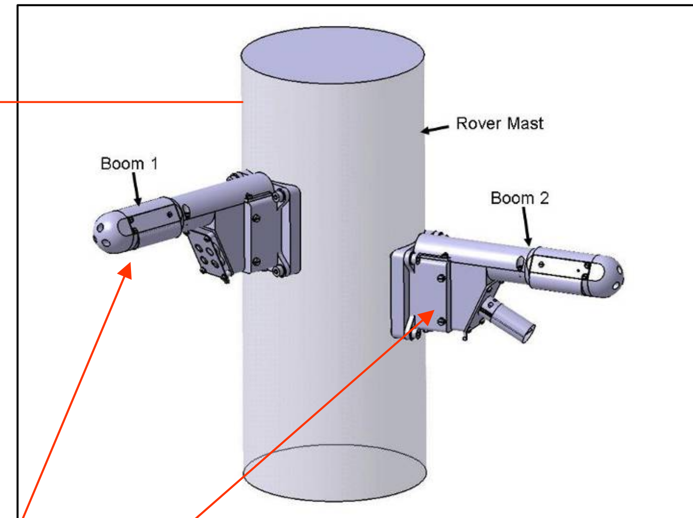
Centro de Astrobiolog’a (CAB) INTA-CSIC with government of Spain, aeronautical study for 3D wind concept inverse problem algorithm for MARS weather monitoring planetary station

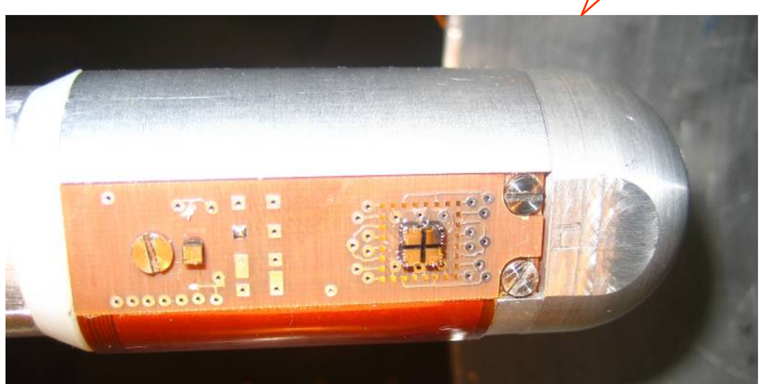
MSL Rover, 3D wind sensor, 2D wind transducer



MSL Rover with REMS instruments : pressure, humidity, air temperature, ground temperature around, and **3 dimensional wind sensor.**

Two small booms





Every boom has been equipped by three identical **2D wind transducers (WT)**. Each of WT board has to work independently as the hot mass anemometer for 2D wind flow measurements.

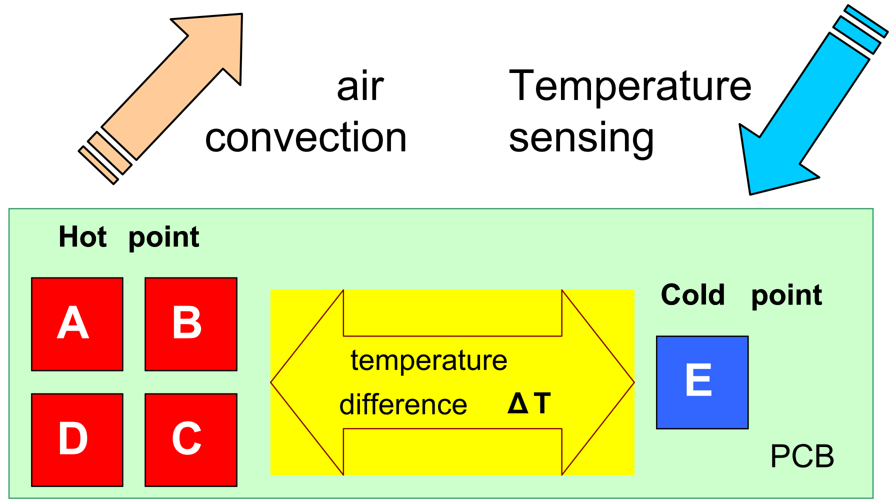
UPC 2D wind transducer

Hot terminals:

dice **A, B, C, D**

Cold terminal:

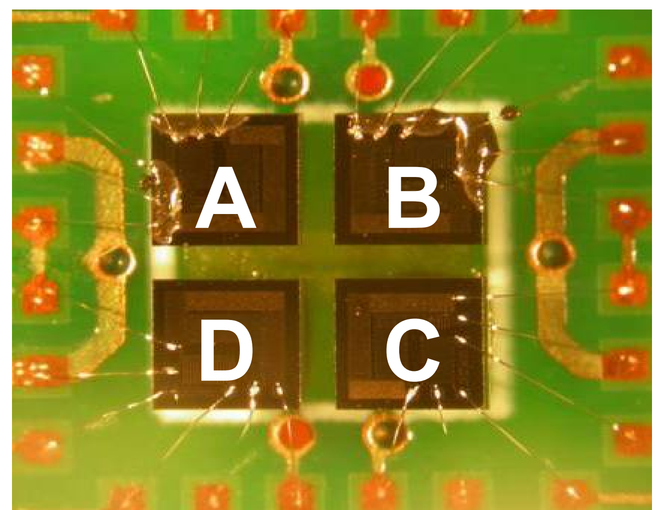
die **E**



How it works ?

Because of the dice are thermally coupled with surrounding gas due the natural and forced convection their thermal conductance is sensible for wind velocity and wind direction.

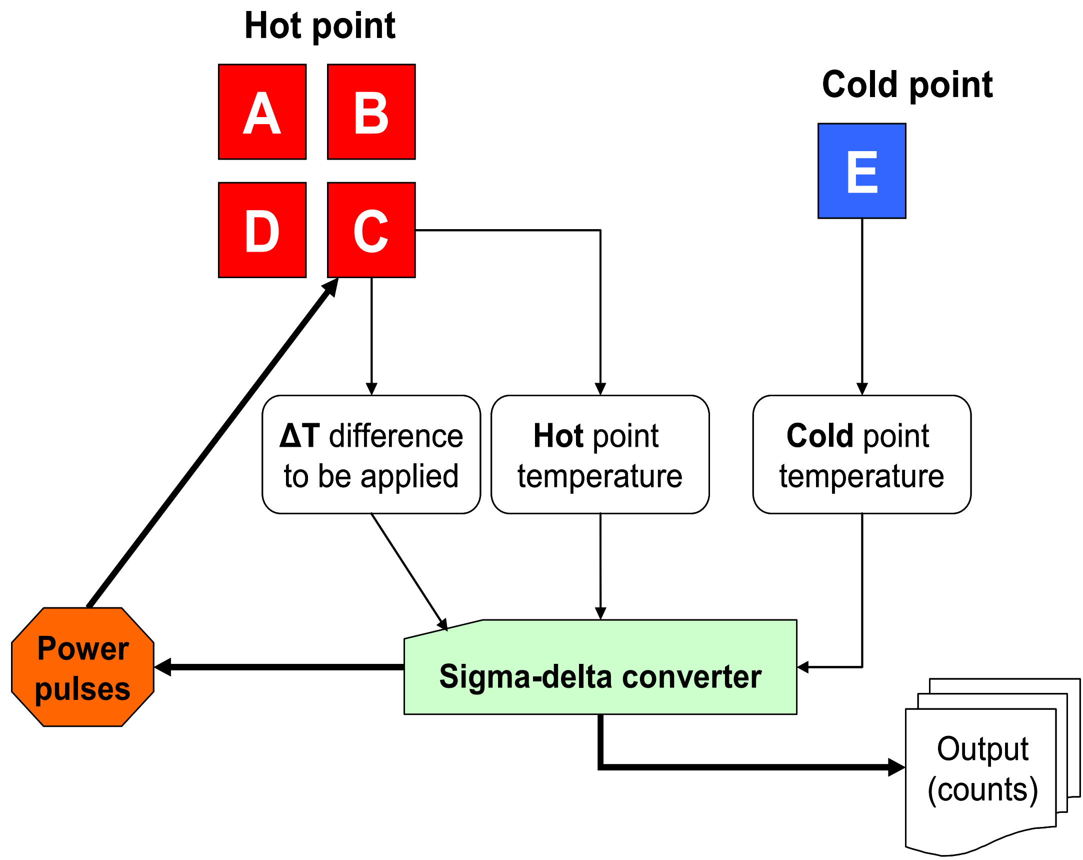
$Gth_{A,B,C,D}=f(Wind_{speed}, Wind_{direction})$



Concept diagram

Wind transducer system characteristic feature

- System works in close loop mode
- Hot die temperature is compared with cold die one plus applied temperature difference
- Power pulses are delivered selectively to maintain hot die temperature on demanded level
- Mean number of power pulses gives information about energy delivered to hot die



The idea for wind measurements!

Counts the power pulses (λ) which are necessary to provide constant temperature difference for hot point.

Silicon chip fabrication

a) Silicon wafer type n

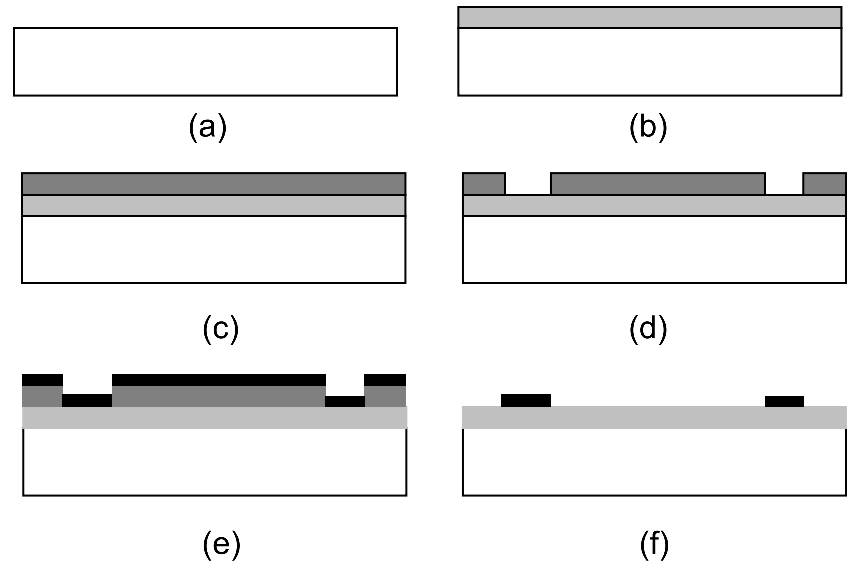
b) Dry oxidation

c) Fotoresist spin on

d) Metal mask photolitography

e) Titanium-**Platinum** sputtering deposition

f) Photoresist lift-off



Top view of silicon die

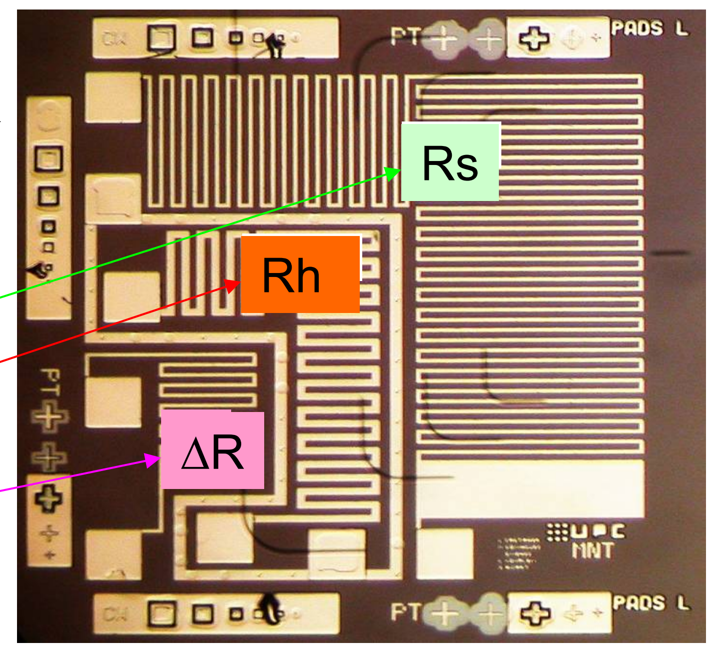
Size of 1.6mm x 1.6mm

Experimental batch have resistance paths value:

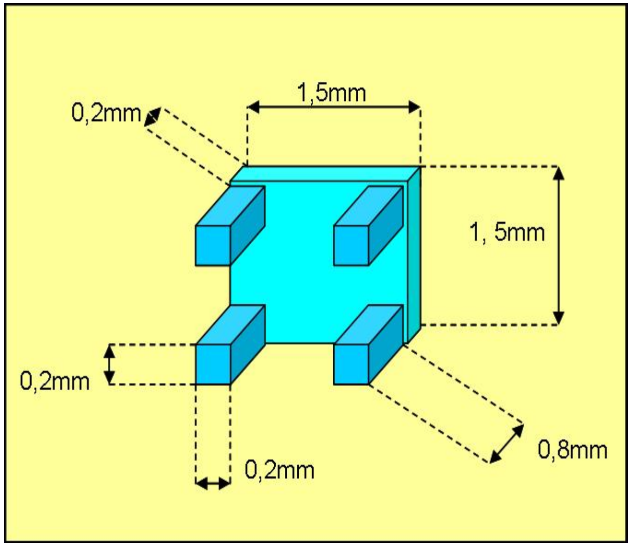
R_sens= 8k Ohm

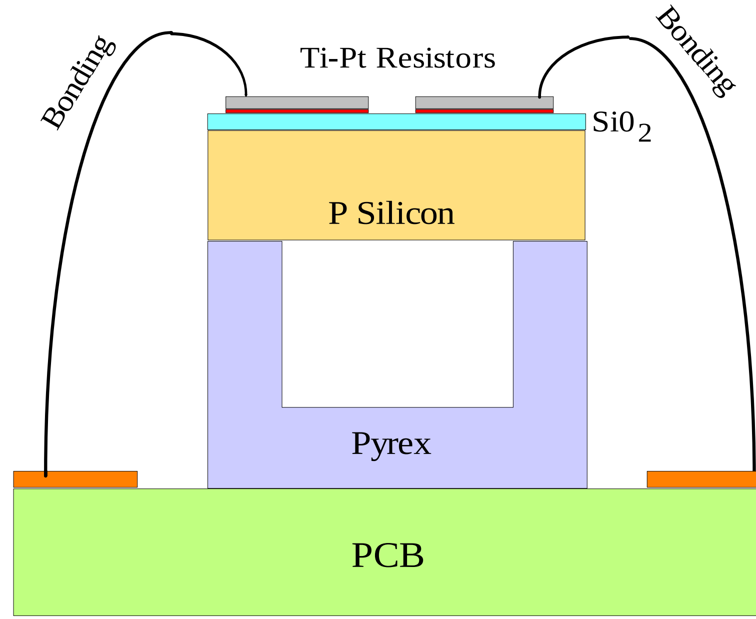
R_heat= 800 Ohm

Delta_R = 800 Ohm

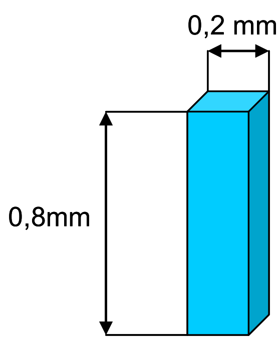


Structure assembling





PYREX support



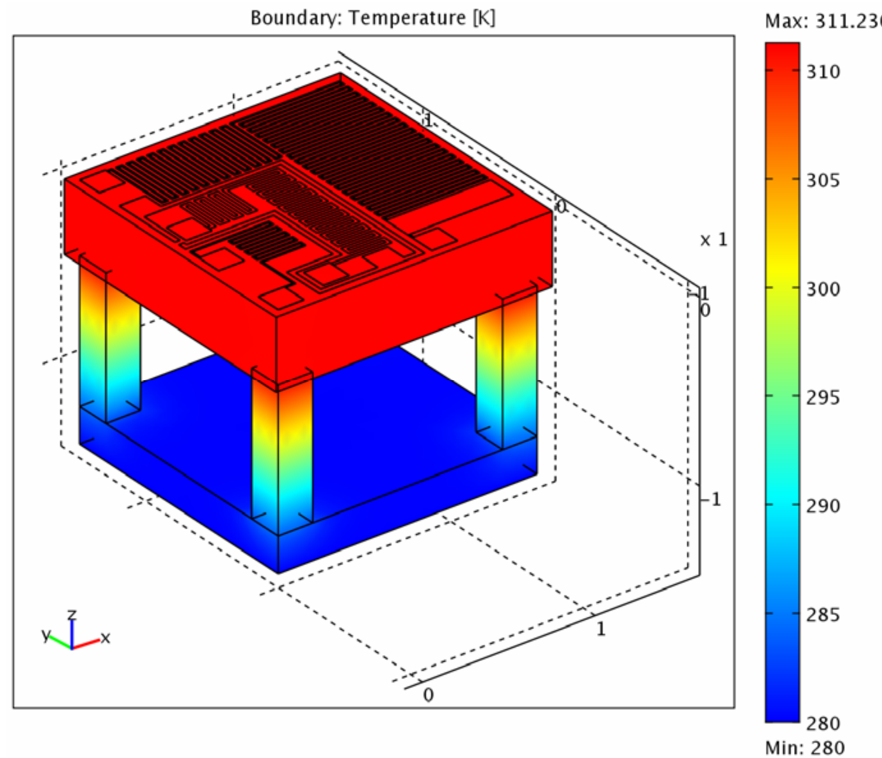
Thermal looses through substrate

$$Q = \frac{1{,}1W/m\cdot K\cdot\left(0{,}2\cdot 10^{-3}m\right)^2\cdot 1K}{0{,}8\cdot 10^{-3}m} = 0{,}055mW$$

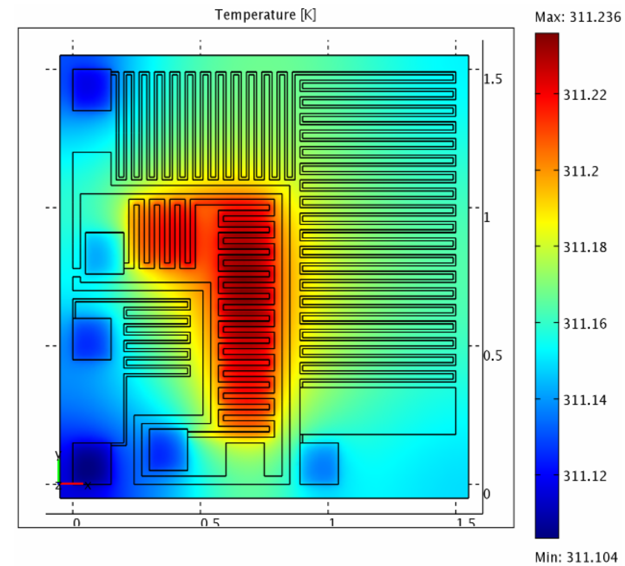
Q coefficient	0,055	mW / K	
delta T [K[or [C]	pillar [mW]	die [mW]	sensor [mW]
1	0,055	0,22	0,88
5	0,275	1,1	4,4
10	0,55	2,2	8,8
20	1,1	4,4	17,6
30	1,65	6,6	26,4
40	2,2	8,8	35,2
50	2,75	11	44
60	3,3	13,2	52,8
70	3,85	15,4	61,6
80	4,4	17,6	70,4
100	5,5	22	88

Thermal simulation (COMSOL)

average Overheat 30ºC



6mBar CO_2 atmosphere

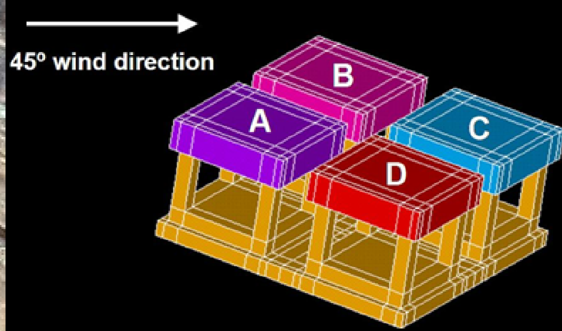


Heat Power ~17mW

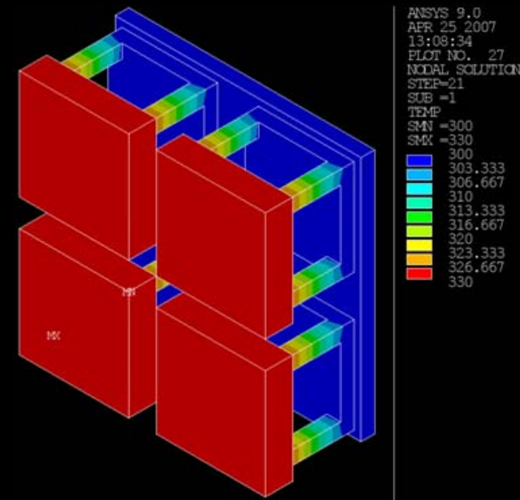
Silicon conductivity k_{SI}=149[W/mK] > Pyrex conductivity k_{PX}=1.1[W/mK]

FEM (CFD) simulations (ANSYS)

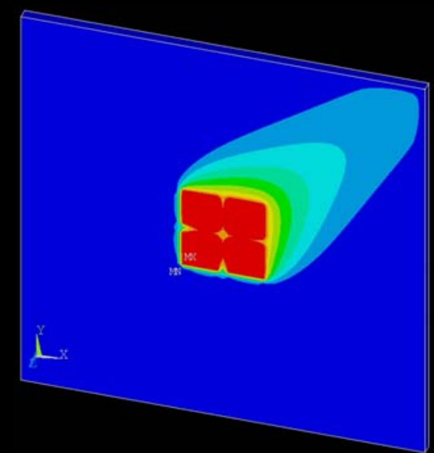
a) physical model and wind conditions



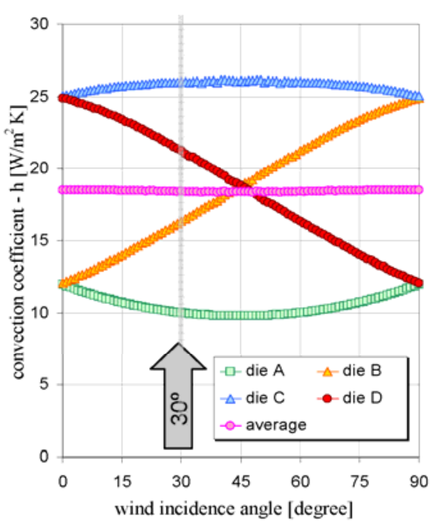
b) temperature constraints

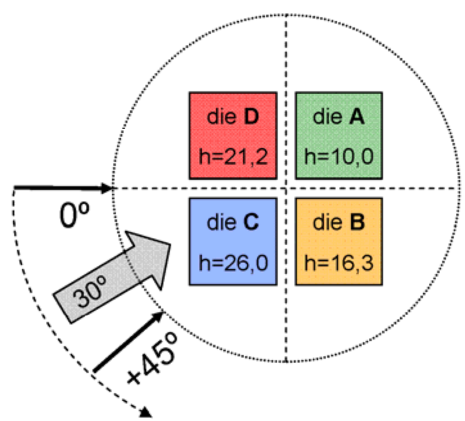


c) results plot



c) results of simulations

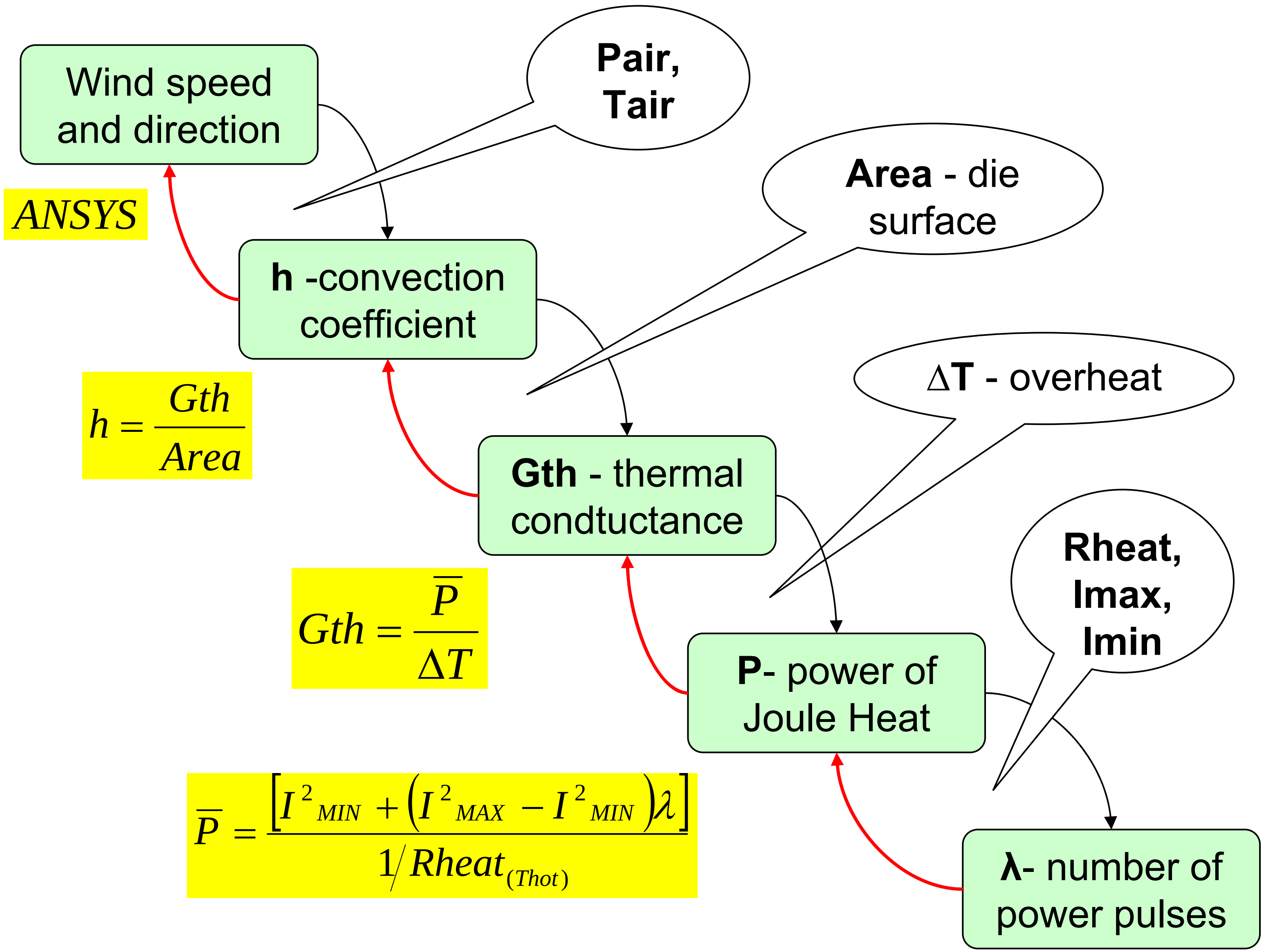




Conclusions

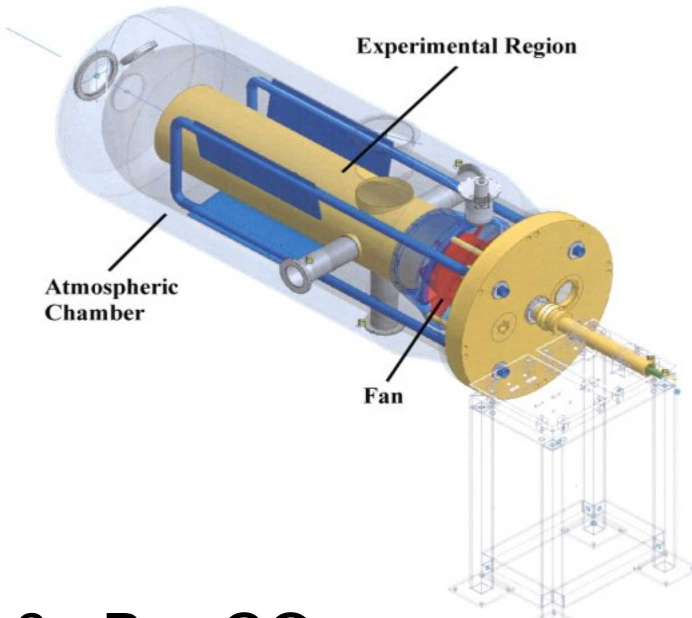
- average heat depends on wind speed
- Structure is sensible for wind horizontal angle
- Structure is equally sensibility for any measured angle

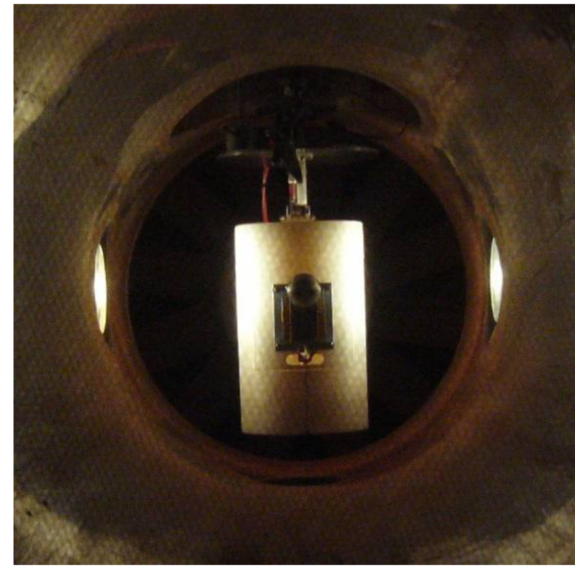
Thinking logic diagram



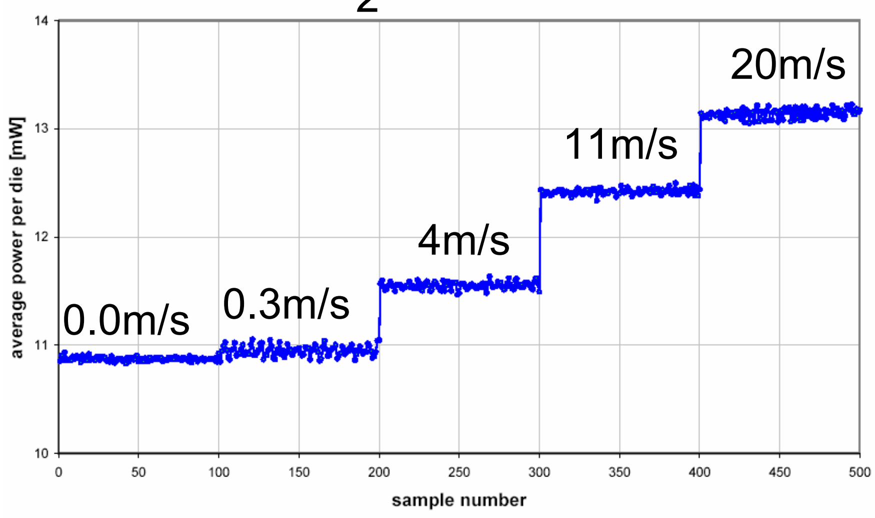
Sensor tests in Aarhus, Denmark

Re-circulating wind tunnel enclosed in a low pressure chamber





6mBar CO_2 measurement



Conclusion

Wind sensor shows ability to sense flow velocity and angle of flux incidence.

Patent and articles

Patent

Patent P200700259 submited to the spanish patent office on 25.I.2007.
"MÉTODO PARA LA MEDIDA DE LA VELOCIDAD DEL AIRE Y DE SU DIRECCION EN DOS DIMENSIONES PARA APLICACIONES AEROESPACIALES",
Authors: Manuel Domínguez Pumar, Vicente Jiménez Serres, Jordi Ricart, Lukasz Kowalski, Alberto Moreno, Luis Castañer Muñoz.

Articles:

[1] Dominguez M, Jimenez V, Ricart J, Kowalski L, Torres J, Navarro S, Romeral J, Castañer L, "**A hot Film anemometer for the Martian atmosphere**" Planetary and Space Science, vol. 56, pp. 1169-1179, February 2008

[2] Jimenez V, Dominguez M, Ricart J, Kowalski L, Navarro S, Torres J, Romeral J, Merrison J, Castañer L. "**Applications of hot film anemometry to space missions**" in Eurosensors XXII, September 2008, pp. 15-19

[3] Kowalski L, Ricart J, Jiménez V, Domínguez M, Castañer L, "**Sensitivity analysis of the chip for REMS wind sensor**", in 7th Spanish Conference on Electron Devices, February 2009, pp. 189-190

Questions?


UPC
MNT
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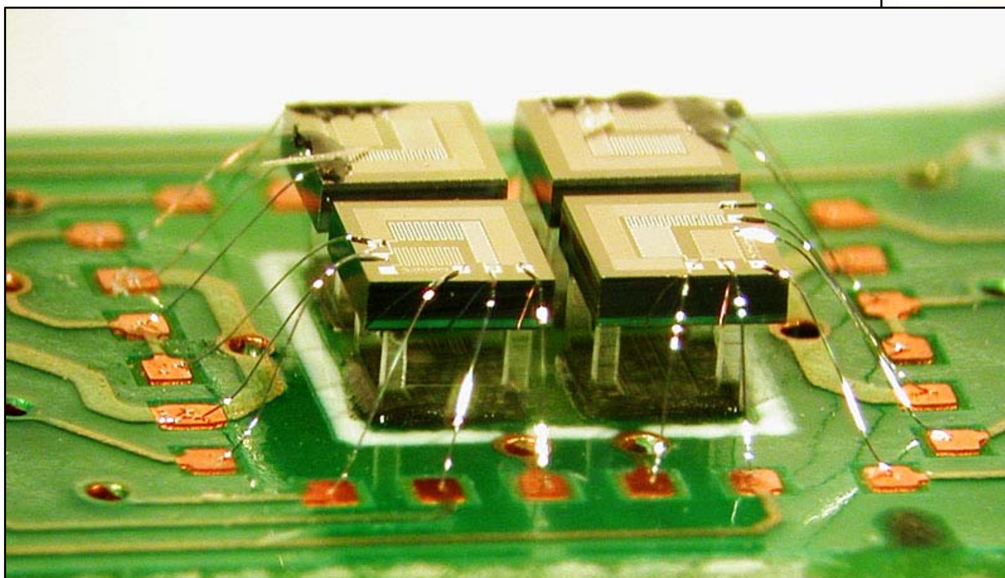
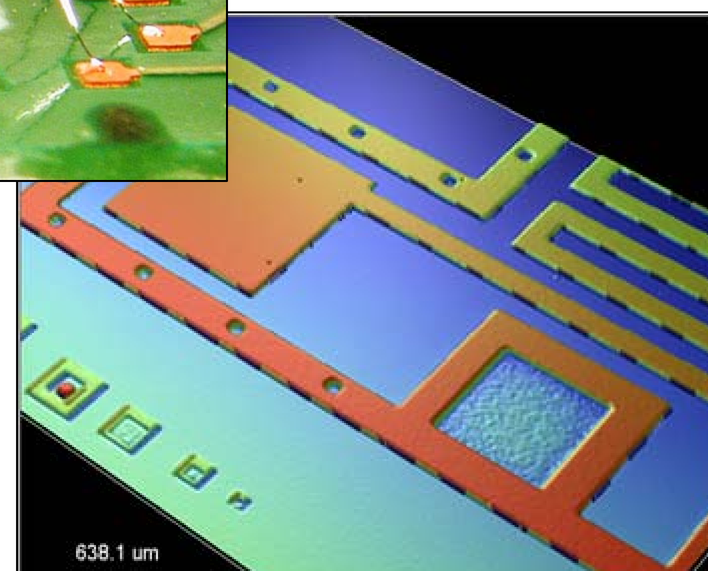
M. DOMINGUEZ
V. JIMENEZ
L. KOWALSKI
J. RICART

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