

# Multiphysics Simulation of REMS hot-film Anemometer Under Typical Martian Atmosphere Conditions

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COMSOL 3.5



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# Outline



- Rover Environmental Monitoring Station (**REMS**) hot-film anemometer
- Typical Martian atmosphere conditions vs. Earth atmosphere environment
- REMS wind sensor structure
- COMSOL model
- Conductive media DC simulation and boundary condition
- Thermal transfer by conduction simulation and boundary condition
- Solver parameters screenshots
- Coarse simulation results
- Specific simulation results and conclusions
- MarsLab-UPC wind sensor Team

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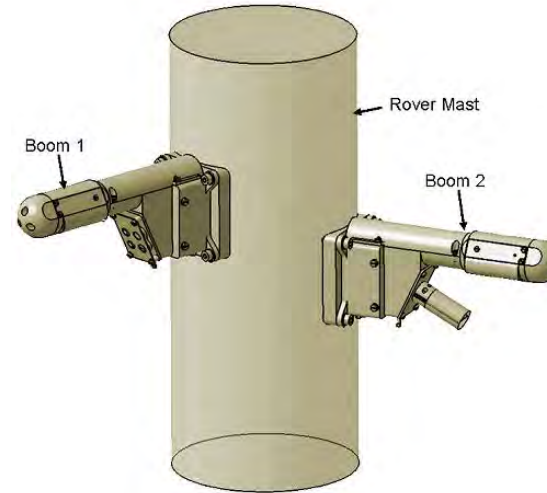


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# REMS hot-film anemometer



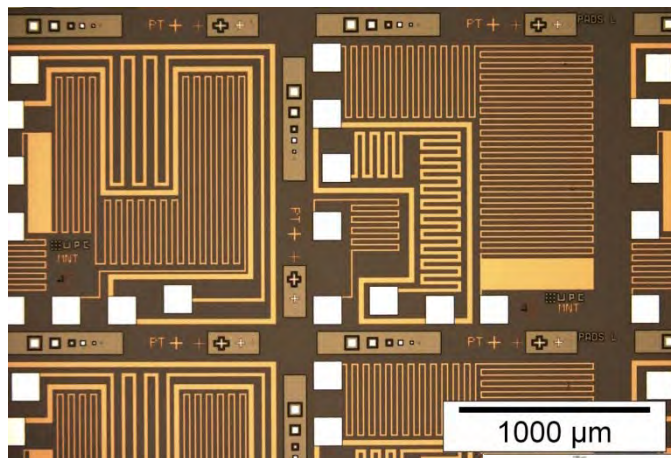
NASA JPL MSL robot mission, fall 2011



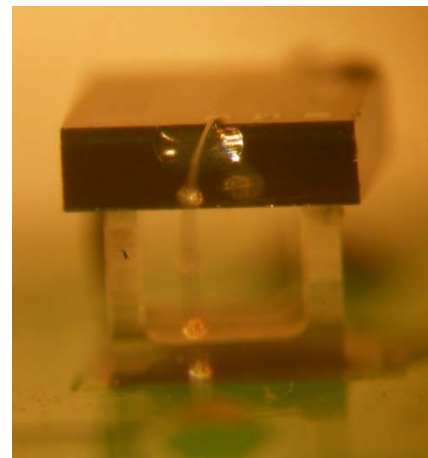
REMS mastil



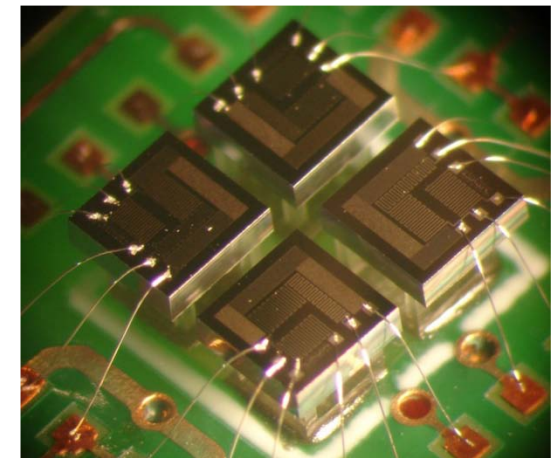
Boom head



wind sensor mask on wafer



wind sensor unit

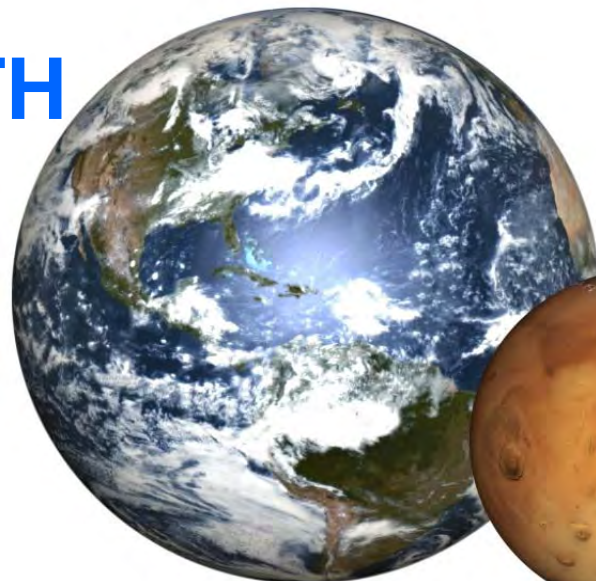


REMS wind sensor 2D

# Typical Martian atmosphere conditions vs. Earth atmosphere environment



**EARTH**



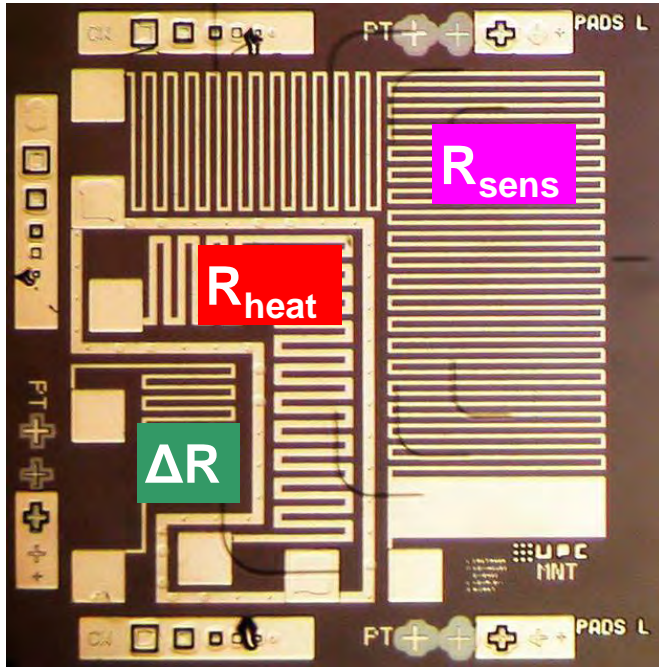
MOON



**MARS**

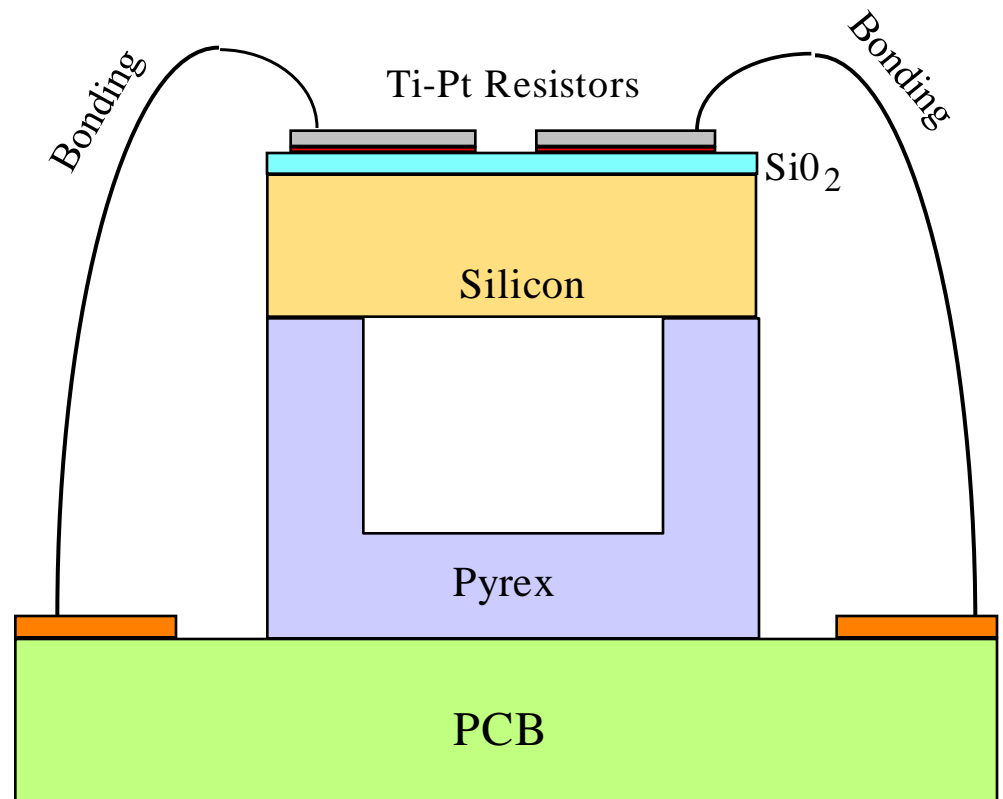
<b>EARTH</b>		<b>MARS</b>
1373	Solar constant [W/m <sup>2</sup> ]	591
9,8	Gravity, g [m/s <sup>2</sup> ]	3,7
N <sub>2</sub> 78.08%, O <sub>2</sub> 20.9%, Ar 0.93%	Atmosphere air element composition [%]	CO <sub>2</sub> 95.32%, N <sub>2</sub> 2.7%, Ar 1.6%, O <sub>2</sub> 0.13%
1013 hPa (1Bar)	Surface pressure [hPa]	6-8 hPa (6-8mBar)
1,2	Surface density [kg/m <sup>3</sup> ]	0,02
300 (27 ° C)	Average temperature [K]	220 (-73°C)
from -80°C to +50°C	Temperature variation [K]	from -125°C to +25°C

# REMS wind sensor structure

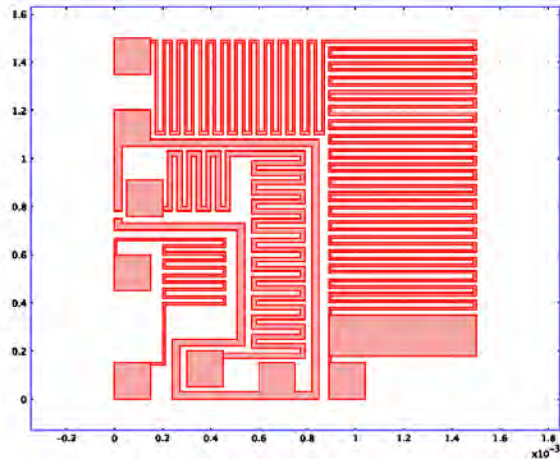


- Heating resistance is located in the center of the Silicon die

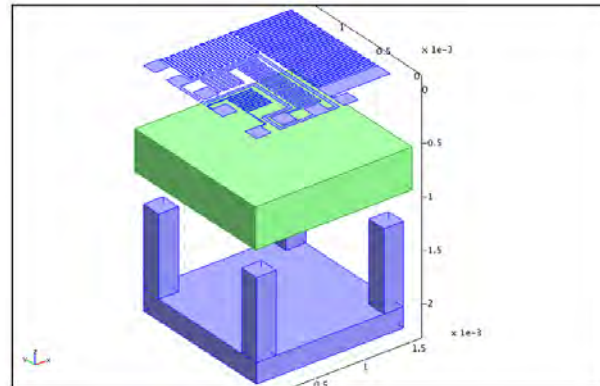
- Sputtering deposition of the thin layers: Titanium (20nm) and Platinum (60nm)



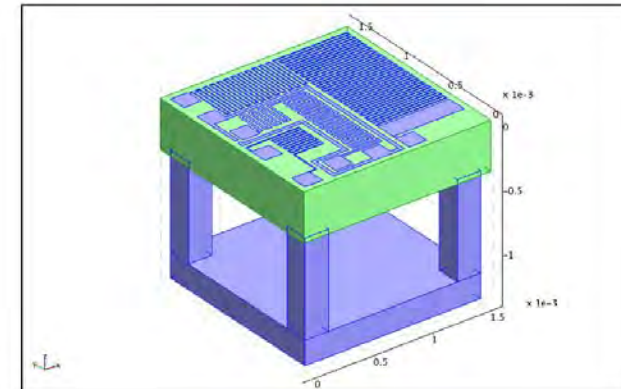
# COMSOL model



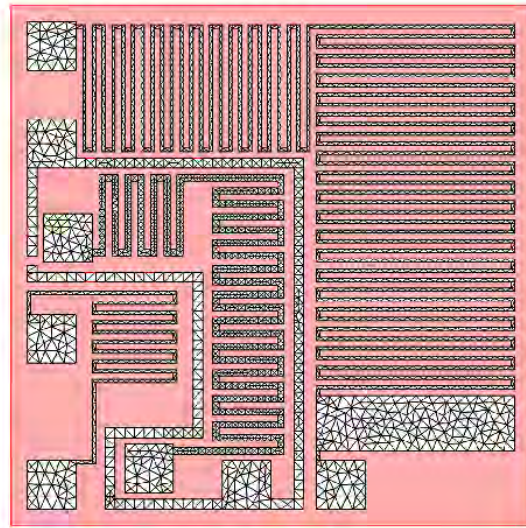
1. Plot 2D shape taken from photolithography mask
2. Extrude 80nm thick Platinum thin film geometry



3. Plot Silicon die of size 1,6mm·1,6mm·0,4mm
4. Plot Pyrex support of the inverted table, composed of: four pillars and base

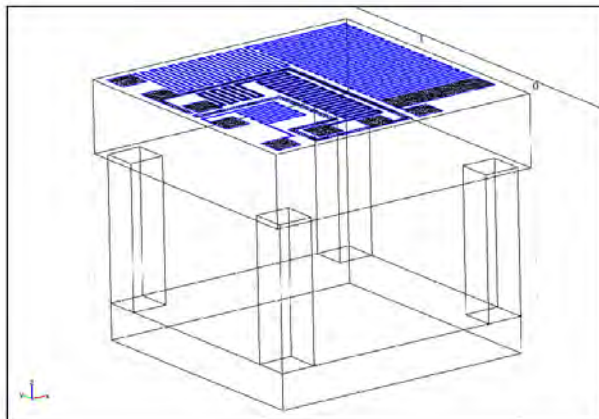


# Mesh structure

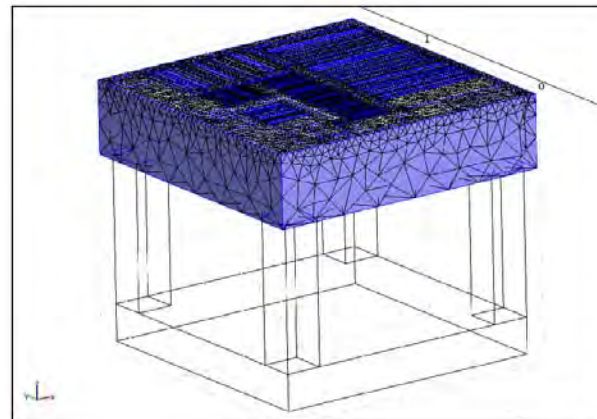


Platinum 2D mesh

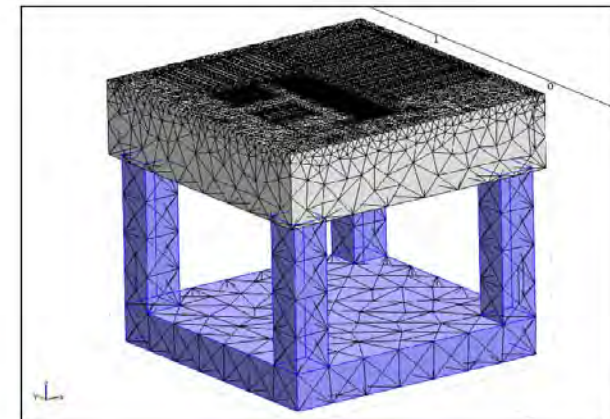
1. Triangular coarse mesh of up Platinum surface
2. Swept mesh of Platinum thin film by 3 layers
3. Triangular coarse mesh of Platinum 3D geometry
4. Triangular coarse mesh of Silicon die geometry
5. Triangular coarse mesh of Pyrex support geometry



Platinum 3D mesh



Silicon 3D mesh

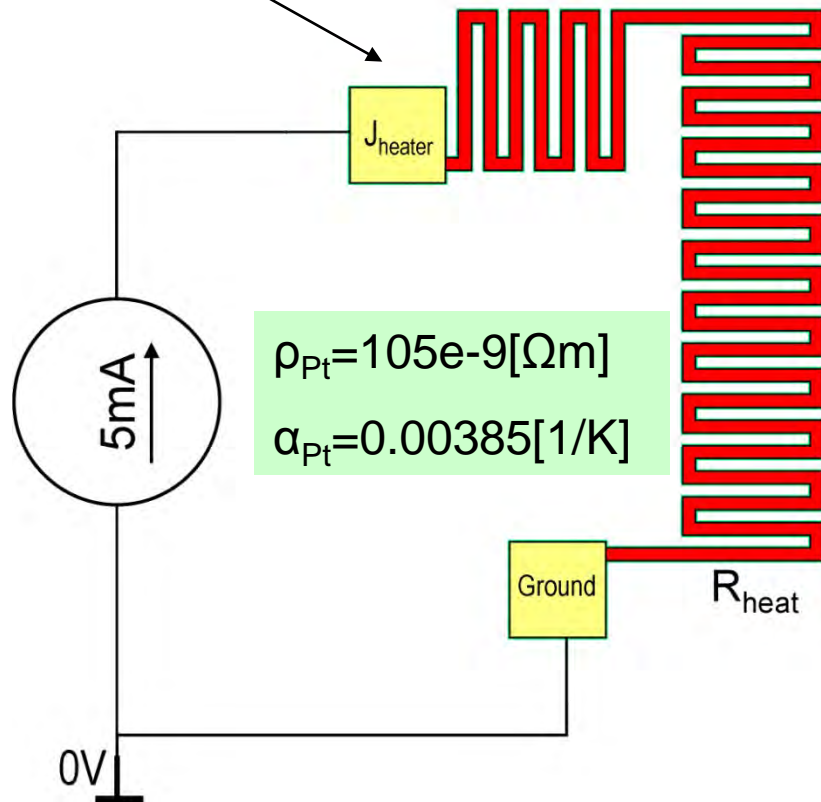


Pyrex 3D mesh

# Conductive media DC simulation and boundary condition



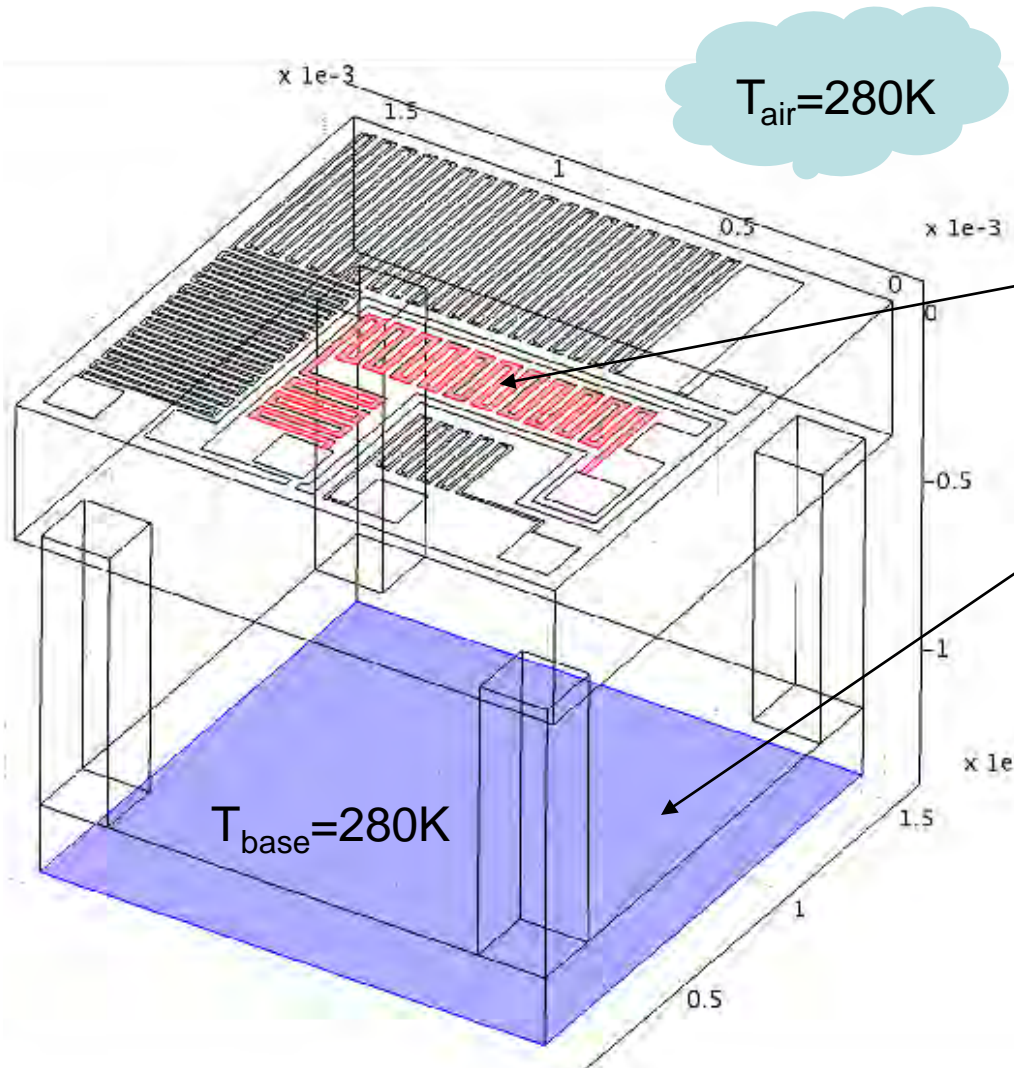
$$J_{heater} = \frac{I_{heater}}{S_{pad}} = \frac{5mA}{(150 \cdot \mu m)^2} = 222kA/m^2$$



- Only  $R_{heat}$  resistance with 2 pads has been used in simulation domain
- All external surfaces have been electrical isolated
- Ground potential of 0V has been assigned to the pad in the upper surface
- Typically the circuit works with heat current of 5mA. This allows to compute the current density for the other pad



# Thermal transfer by conduction simulation and boundary condition, part I

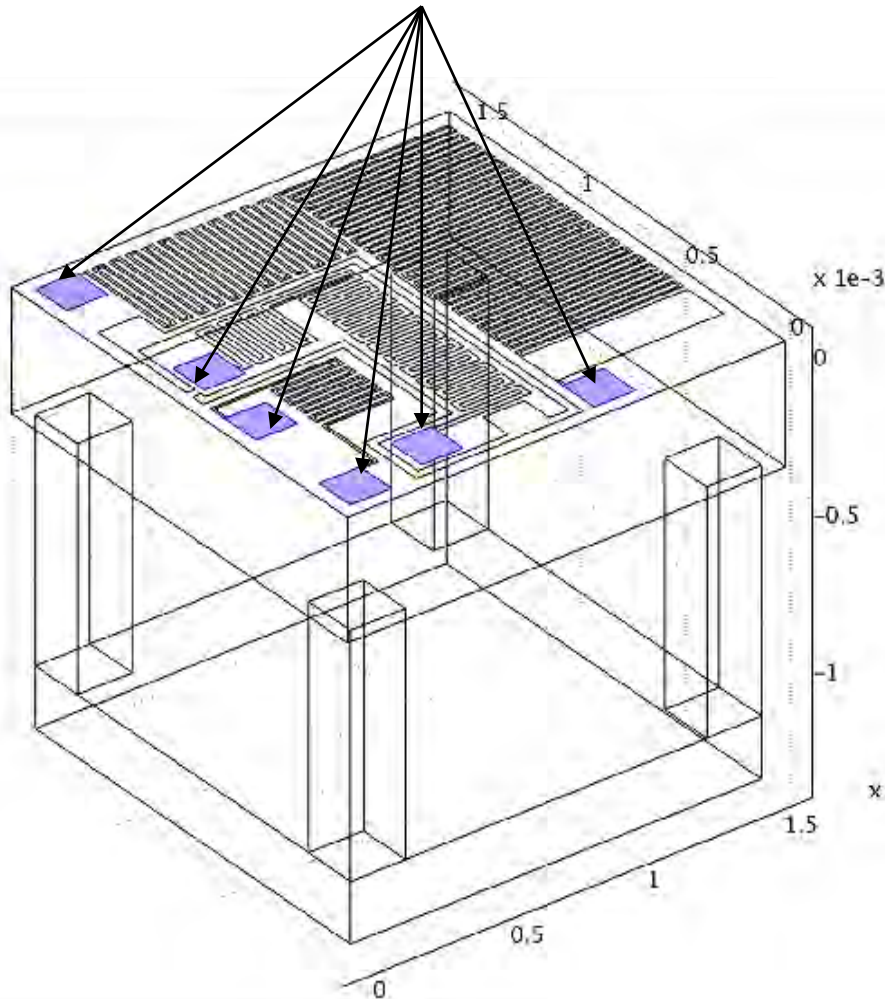


- The whole geometry was included into simulation domain
- The platinum heater resistance was defined as a heat source  $Q_d$  defined by electrical Joule effect
- The base temperature at the bottom of the Pyrex support structure has been set to 280K
- All external faces have been exposed to the wind convection coefficient  $h=5\text{W}/\text{m}^2$  assuming an atmosphere temperature 280K

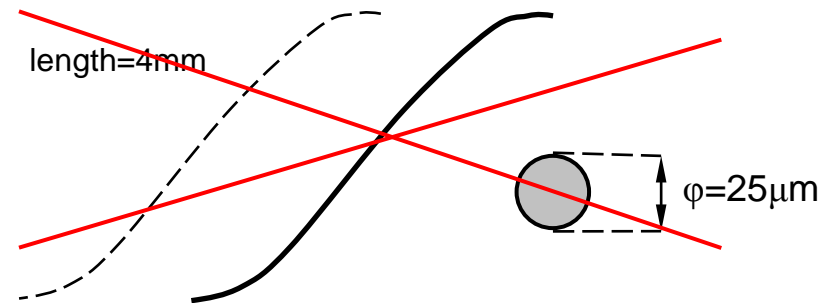
# Thermal transfer by conduction simulation and boundary conditions, part II pads



$$h_{PAD} = 5 \frac{W}{m^2 K} + h_{add}$$



- No wire-bonding in the model.



- But thermal conductivity heat losses has been estimated and incorporated into h coefficient!

$$-k_{pyrex} \cdot \frac{A_{cross.wire}}{L_{wire}} = -h_{add} \cdot A_{cross.pad}$$

$$h_{add} = \frac{k_{pyrex}}{L_{wire}} \cdot \frac{A_{cross.wire}}{A_{cross.pad}}$$

# Solver parameters screenshots



**Solver Parameters**

General Stationary Adaptive Optimization/Sensitivity Advanced

Linear system solver:

Linear system solver: GMRES

Preconditioner: Geometric multigrid

Settings...

Matrix symmetry: Automatic

**Solver Parameters**

General Stationary Adaptive Optimization/Sensitivity Advanced

Linearity: Automatic

Nonlinear settings:

Relative tolerance: 1.0E-4

Maximum number of iterations: 25

Damped Newton

Highly nonlinear problem

Manual tuning of damping parameters

Initial damping factor:

Minimum damping factor:

Restriction for step size update:

Augmented Lagrangian solver

Update augmentation components automatically

Augmentation components:

Tolerance: 0.0010

Maximum number of iterations: 25

Solver: PARDISO

**Solver Parameters**

General Stationary Adaptive Optimization/Sensitivity Advanced

Constraint handling method: Elimination

Null-space function: Automatic

Assembly block size:  Auto

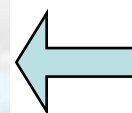
Use Hermitian transpose of constraint matrix and in symmetry detection

Use complex functions with real input

Stop if error due to undefined operation

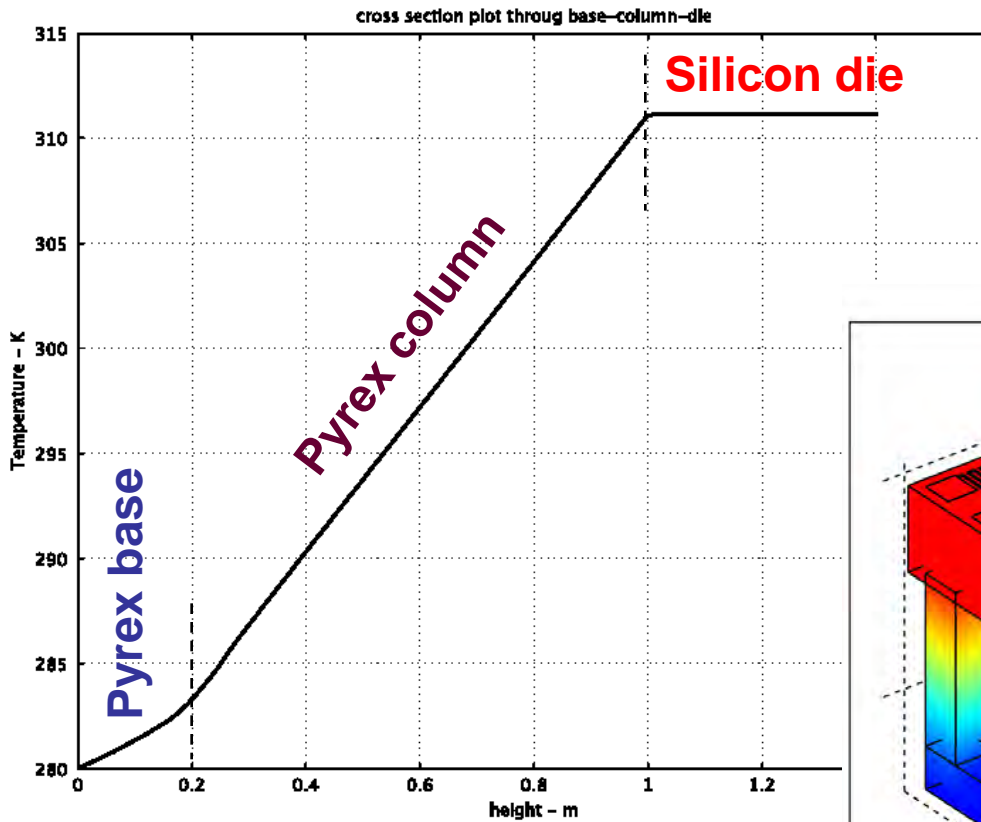
Store solution on file

Solution form: Automatic



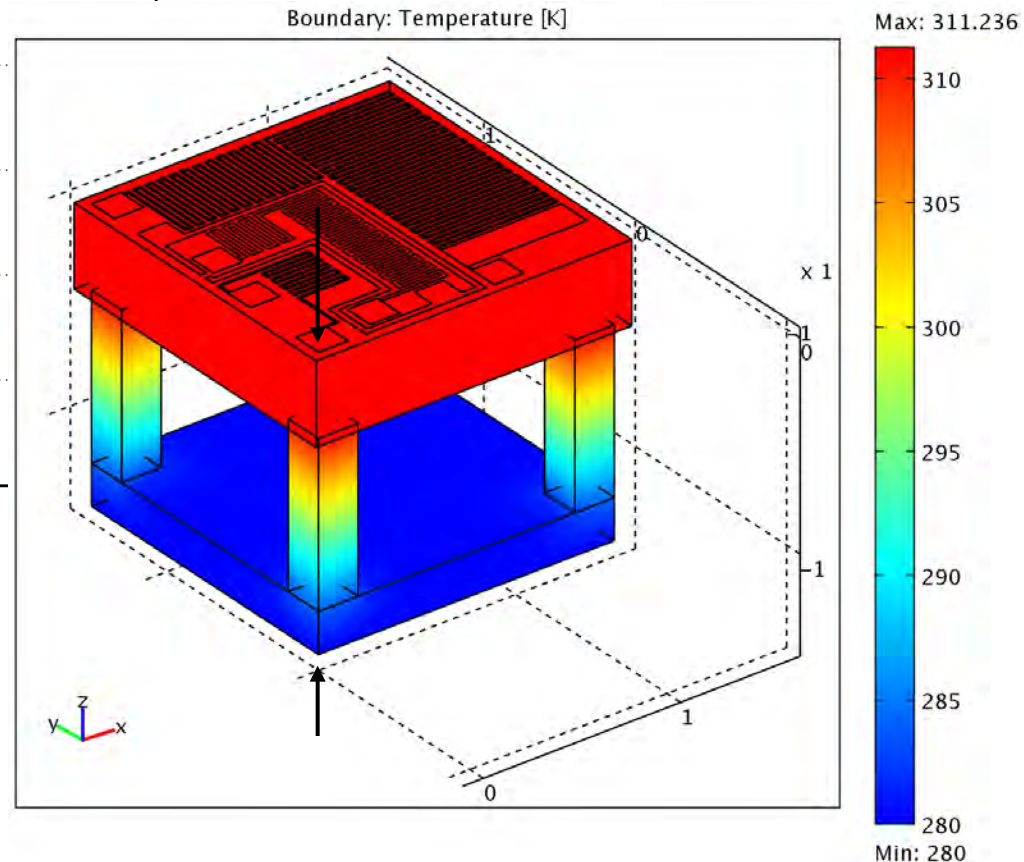
We did not change advanced part of the Solver Parameters

# Coarse simulation results



Die average overheat  $\geq 30^{\circ}\text{C}$   
by Joule Heat Power  $\approx 17\text{mW}$

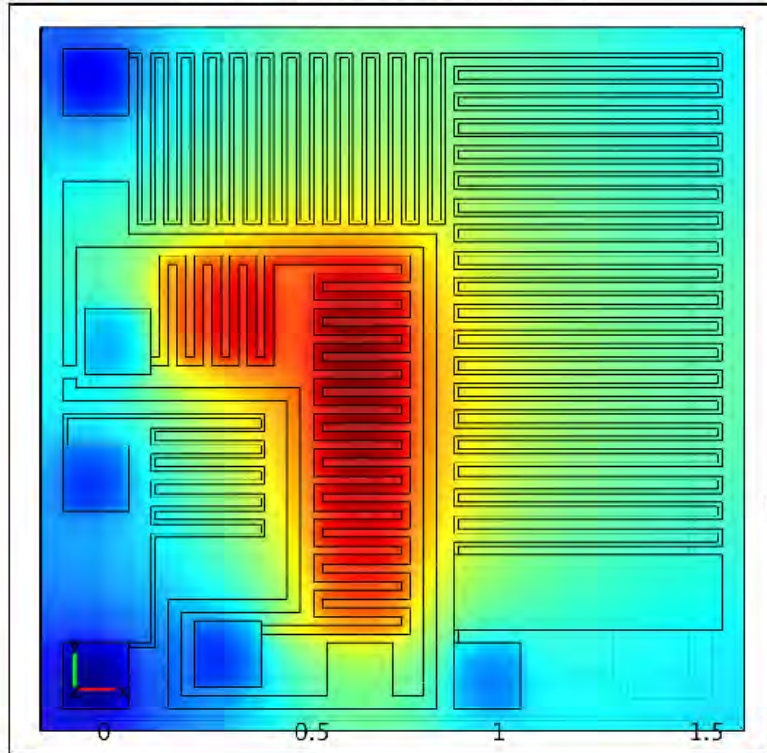
Moving along the pyrex column  
which uphold the die we find  
constant temperature gradient



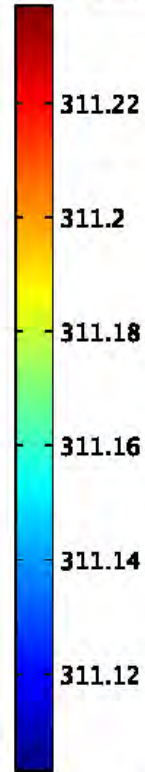
# Specific simulation results and conclusions



Silicon die top view - Temperature [K]

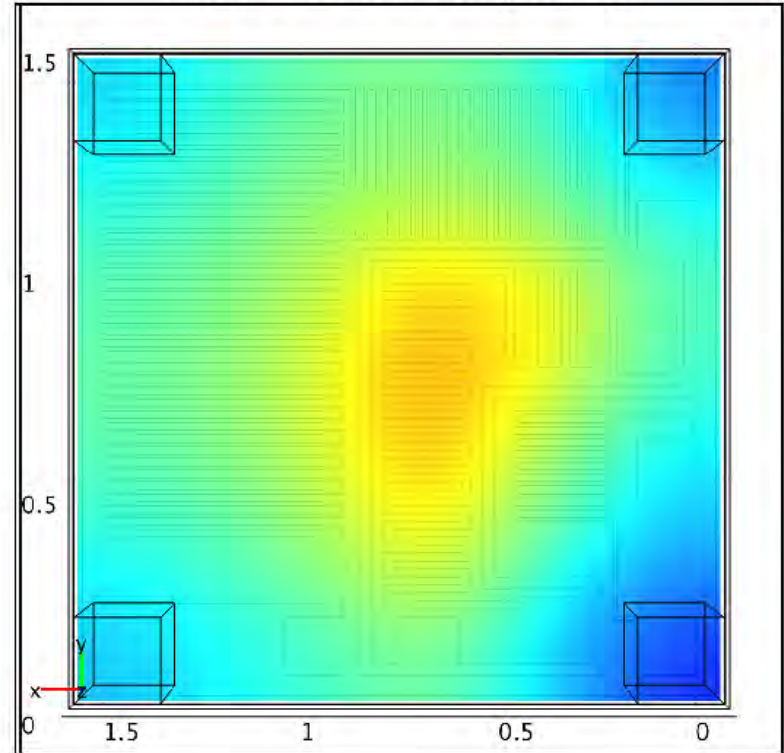


Max: 311.237



Min: 311.103

Silicon die bottom view - Temperature [K]



- Maximum temperature is within the core of heater resistance location
- Minimum temperature spots are due to the wire-bonding pads position
- Silicon high conductivity provides uniform die temperature distribution

# MarsLab-UPC wind sensor team, Thank You for Your attention!



**UPC**  
**MNT**

L. CASTAÑER  
M. DOMINGUEZ  
V. JIMENEZ  
L. KOJALSKI  
J. RICART

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