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

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COMSOL 3.5

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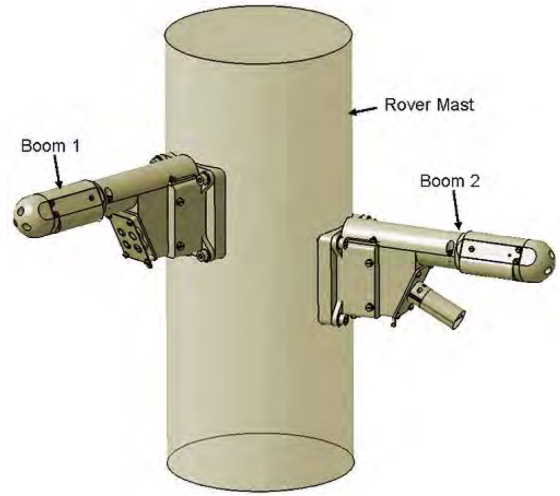
Outline

- 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

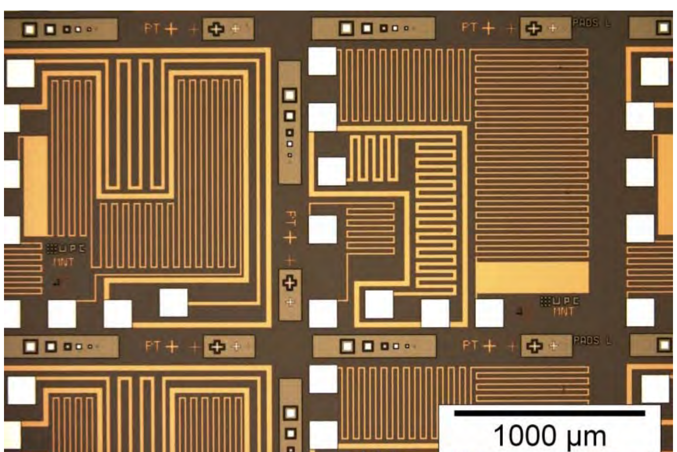
REMS hot-film anemometer

NASA JPL MSL robot mission, fall 2011

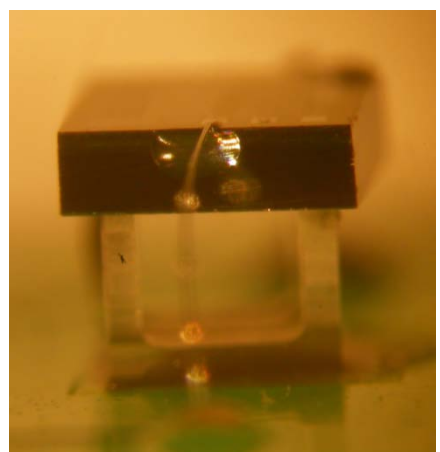


REMS mastil

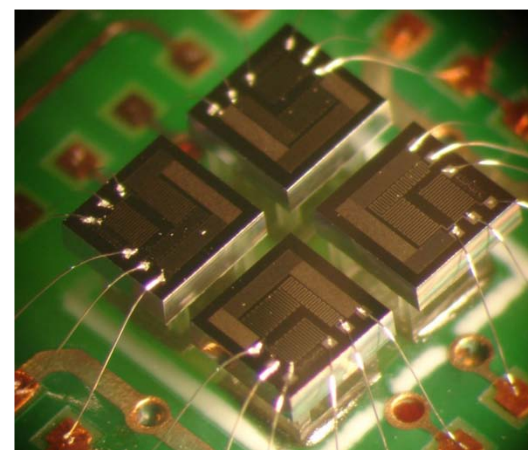
Boom head



wind sensor mask on wafer

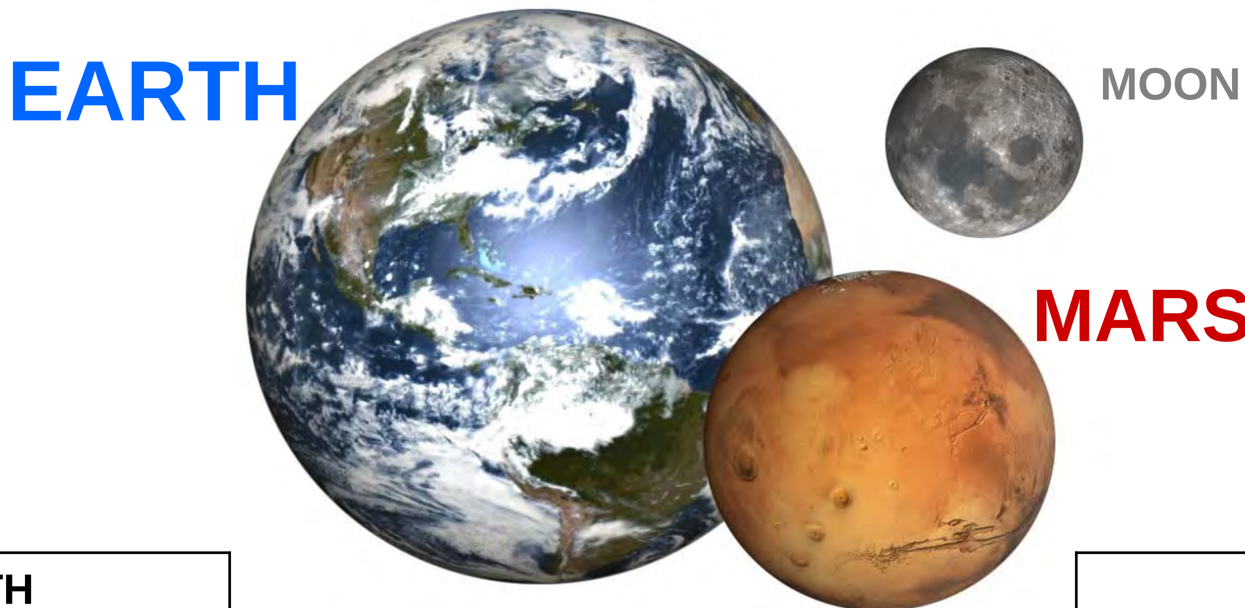


wind sensor unit



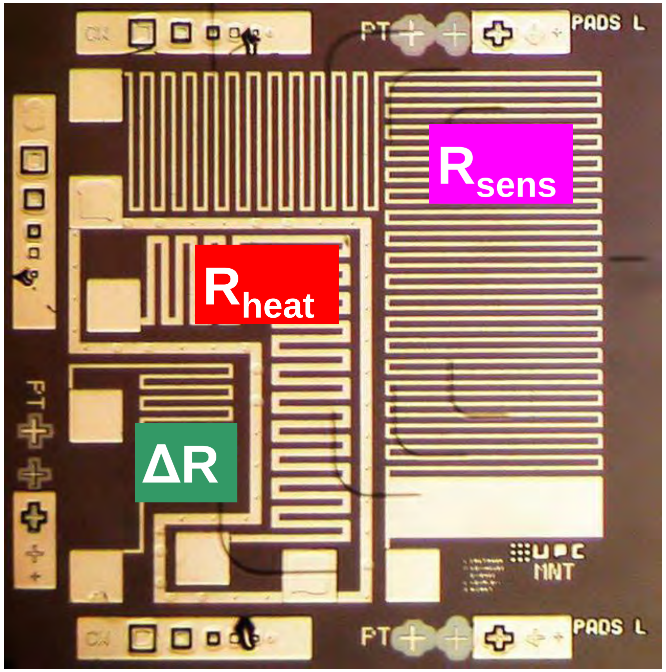
REMS wind sensor 2D

Typical Martian atmosphere conditions vs. Earth atmosphere environment



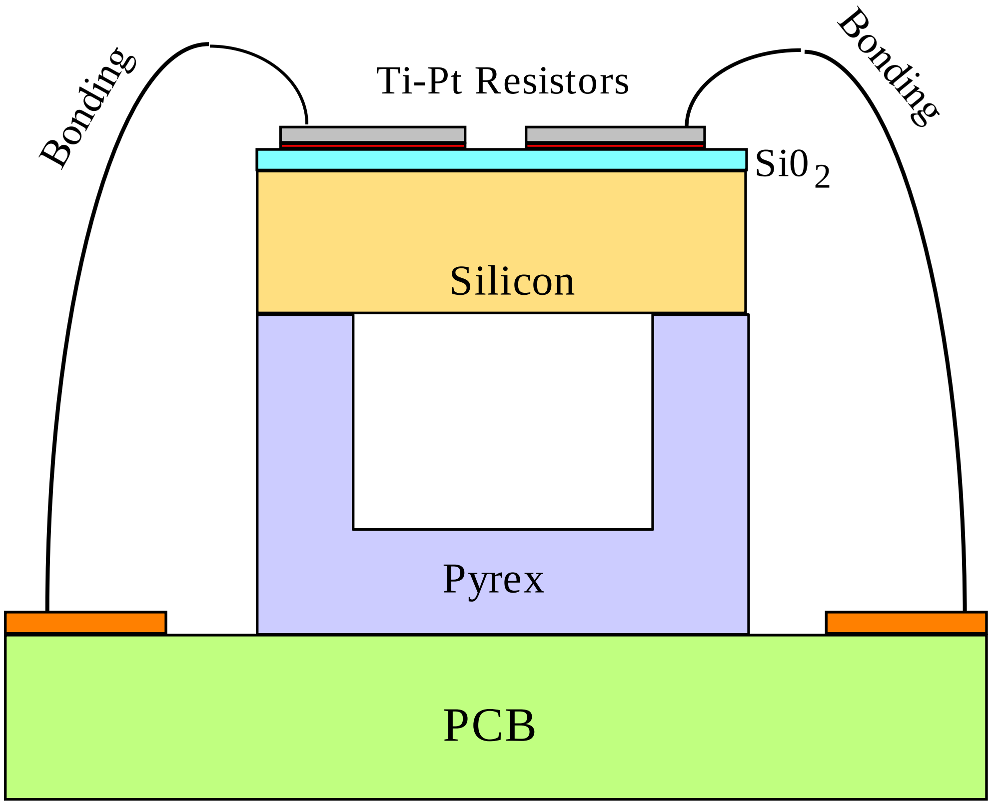
EARTH		MARS
1373	Solar constant [W/m^2]	591
9,8	Gravity, g [m/s^2]	3,7
N_2 78.08%, O_2 20.9%, Ar 0.93%	Atmosphere air element composition [%]	CO_2 95.32%, N_2 2.7%, Ar 1.6%, O_2 0.13%
1013 hPa (1Bar)	Surface pressure [hPa]	6-8 hPa (6-8mBar)
1,2	Surface density [kg/m^3]	0,02
300 (27 º C)	Average temperature [K]	220 (-73ºC)
from -80ºC to +50ºC	Temperature variation [K]	from -125ºC to +25ºC

REMS wind sensor structure

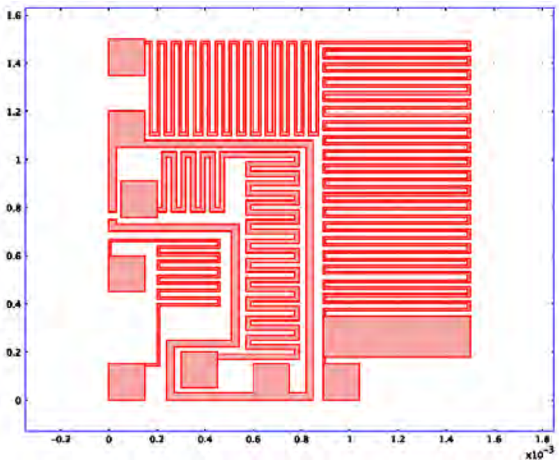


• Heating resistance is located in the center of the Silicon die

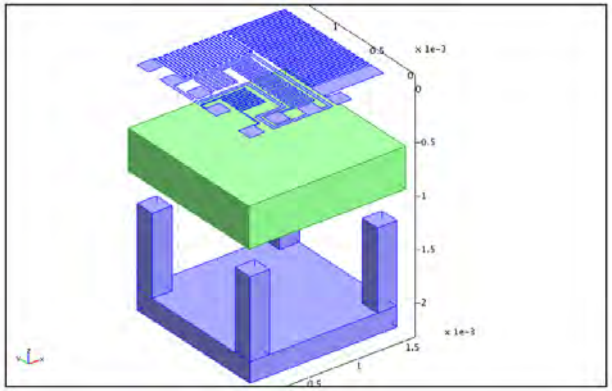
•Sputtering deposition of the thin layers: Titanium (20nm) and Platinum (60nm)

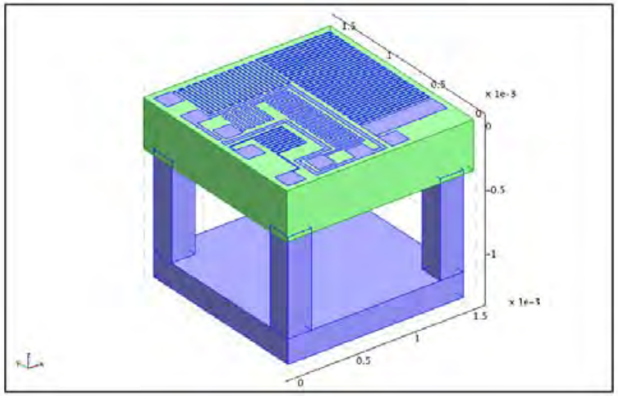


COMSOL model



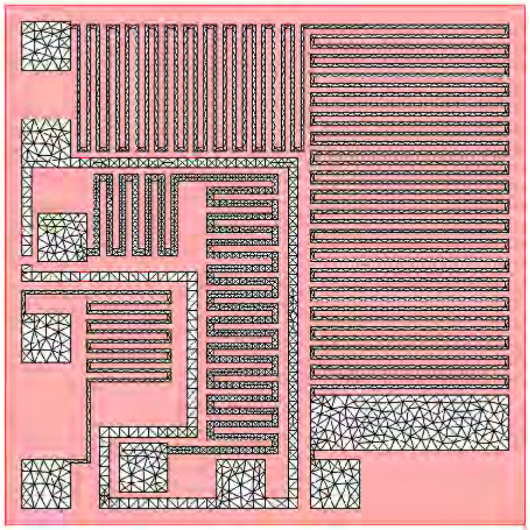
1. Plot 2D shape taken from photolithography mask
2. Extrude 80nm thick Platinum thin film geometry





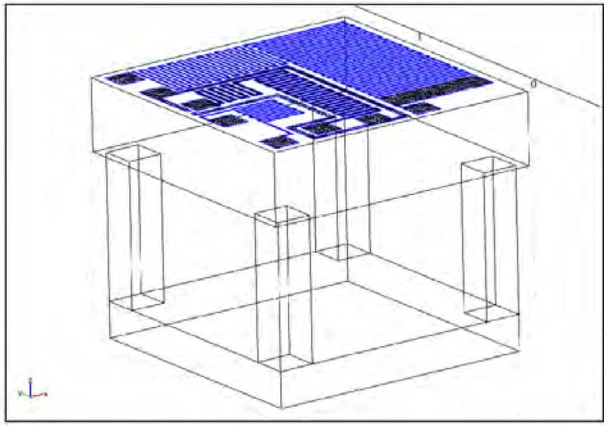
3. Plot Silicon die of size 1,6mm·1,6mm·0,4mm
4. Plot Pyrex support of the inverted table, composed of: four pillars and base

Mesh structure



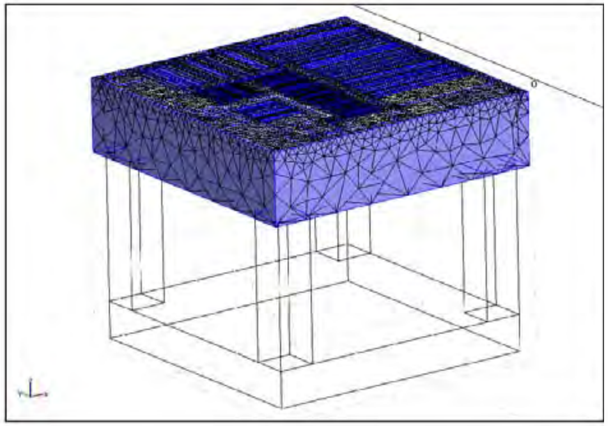
Platinum 2D mesh

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



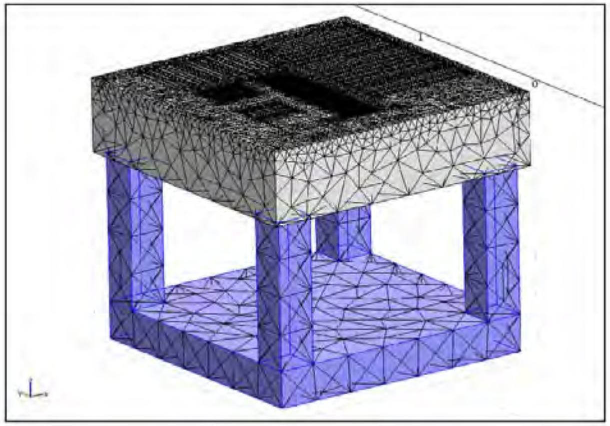
Platinum 3D mesh

+



Silicon 3D mesh

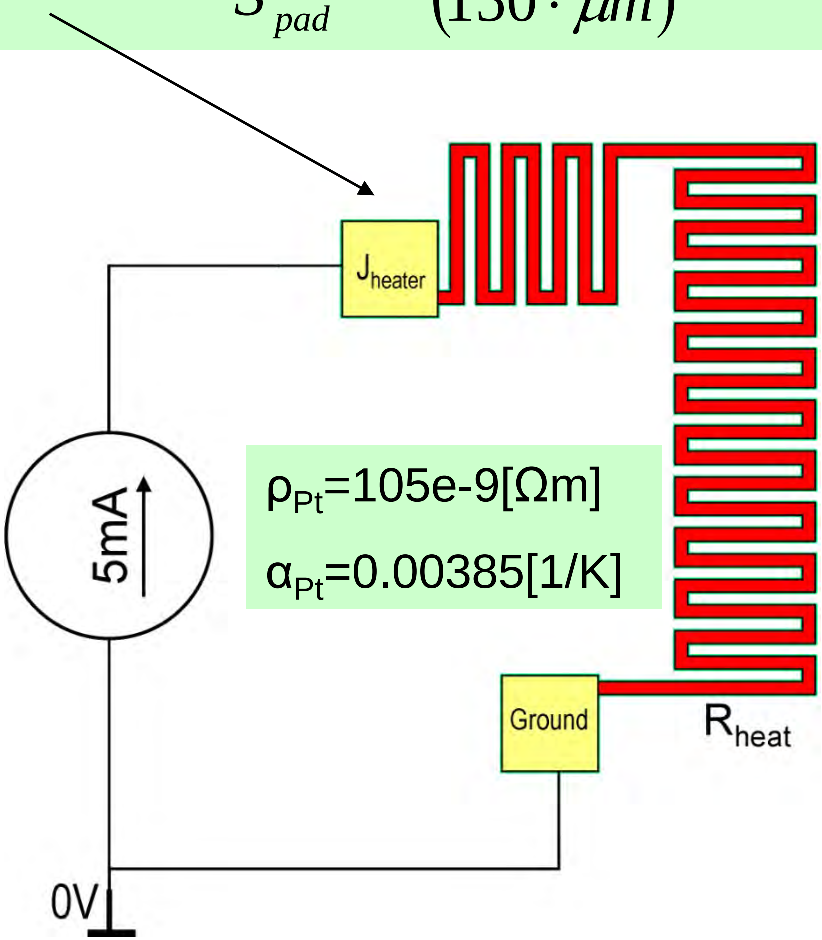
+



Pyrex 3D mesh

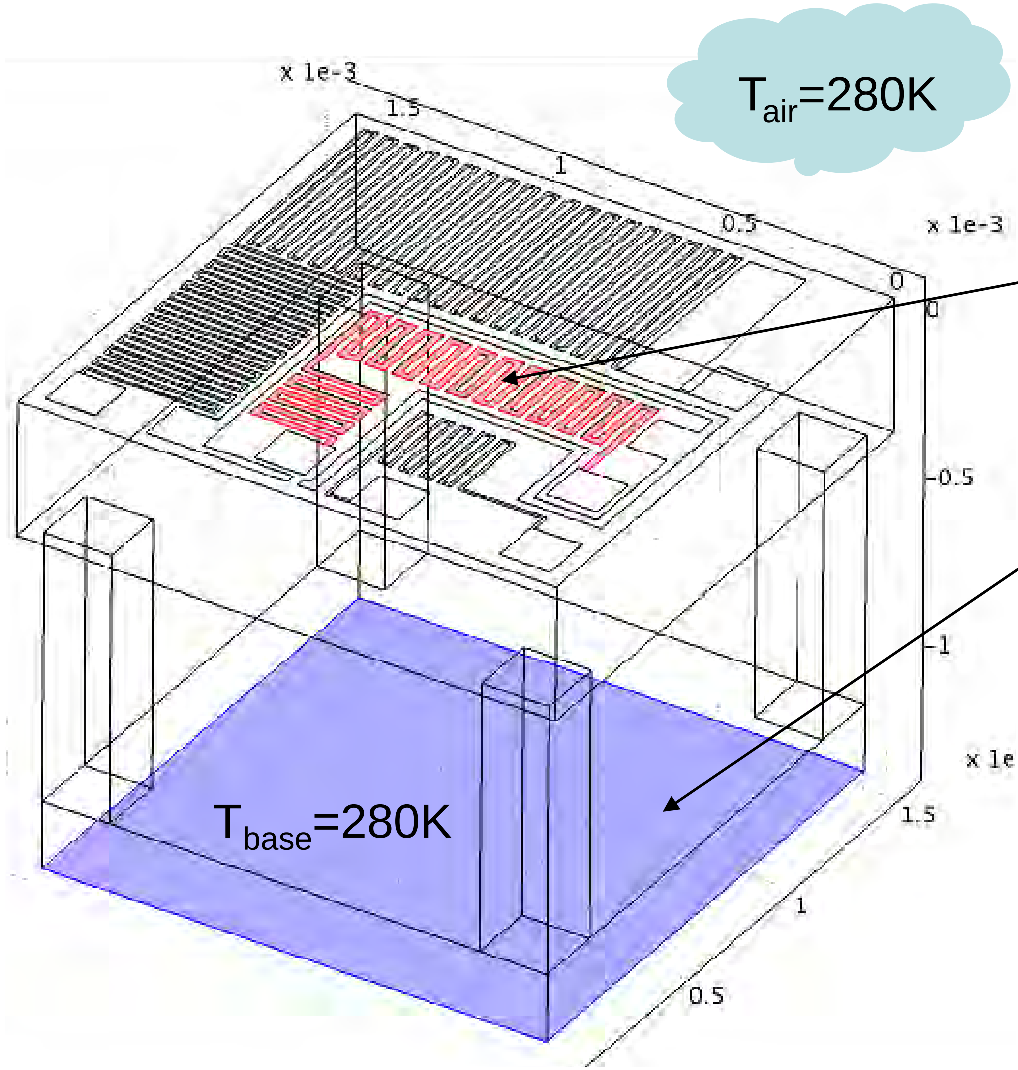
Conductive media DC simulation and boundary condition

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



- 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

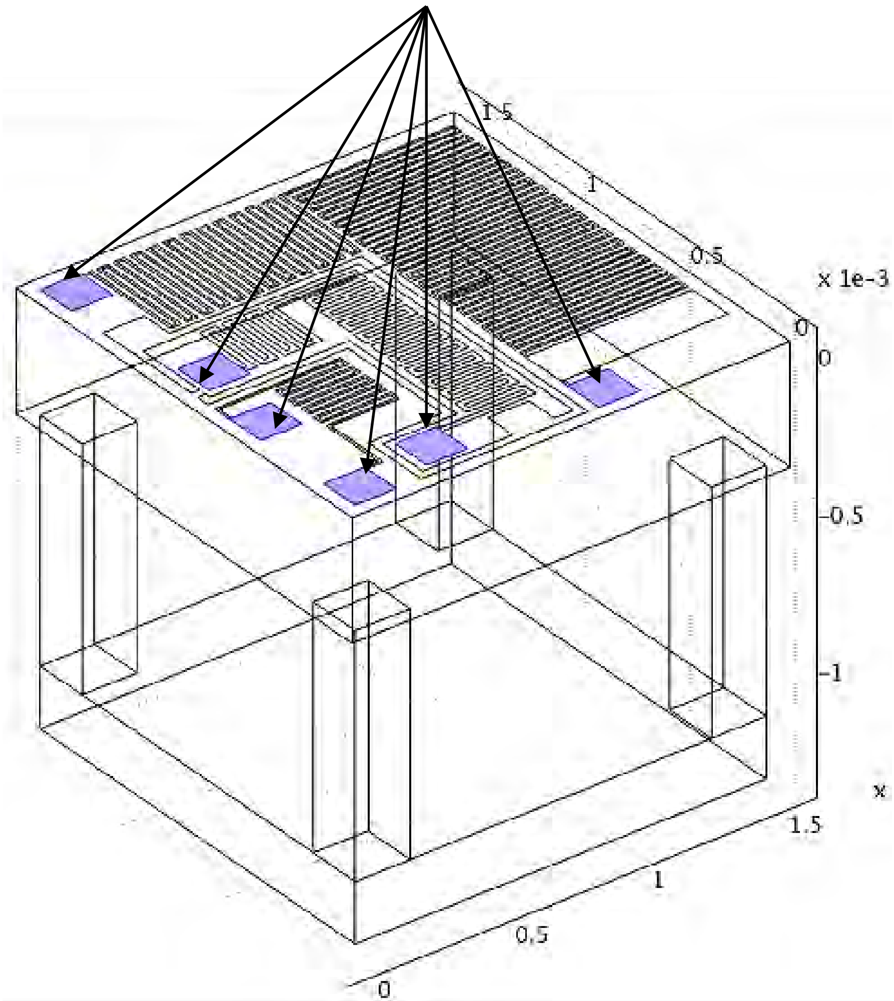
Thermal transfer by conduction simulation and boundary condition, part I



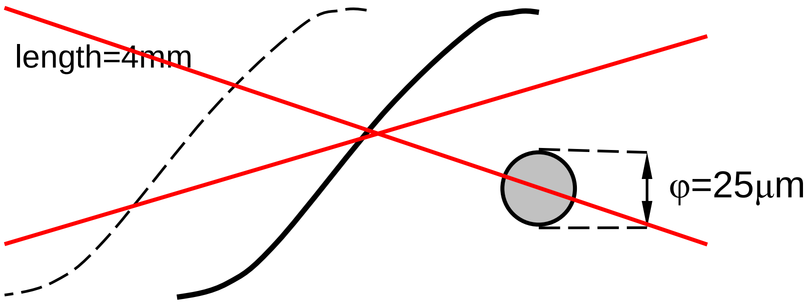
- The whole geometry was included into simulation domain
- The platinum heater resistance was defined as a heat source **Q_d** defined by electrical Joule effect
- The base temperature at the bottom of the Pyrex support structure has been set to 280K
- All external faces have been exposed to the wind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

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

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



• No wire-bonding in the model.

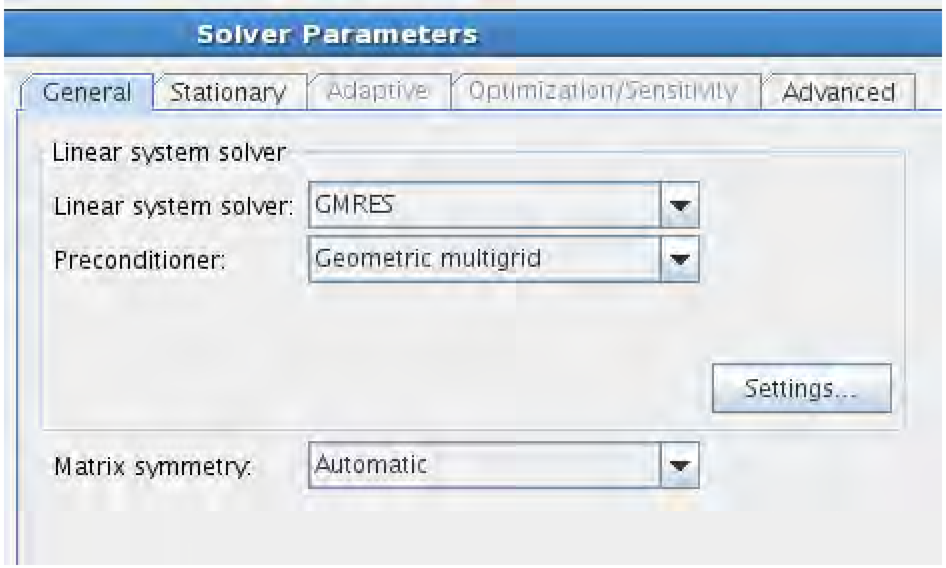


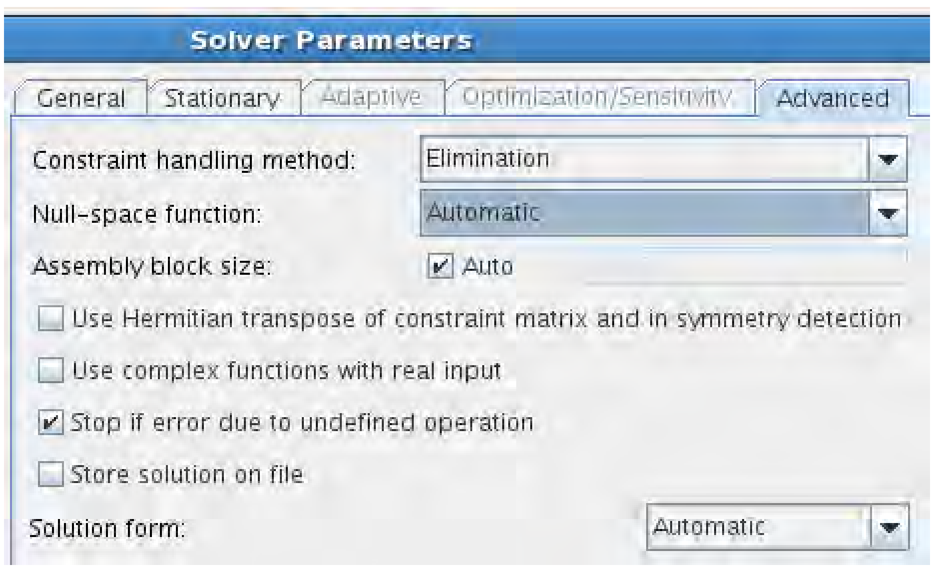
• But thermal conductivity heat looses has been estimated and incorporated into h coefficient!

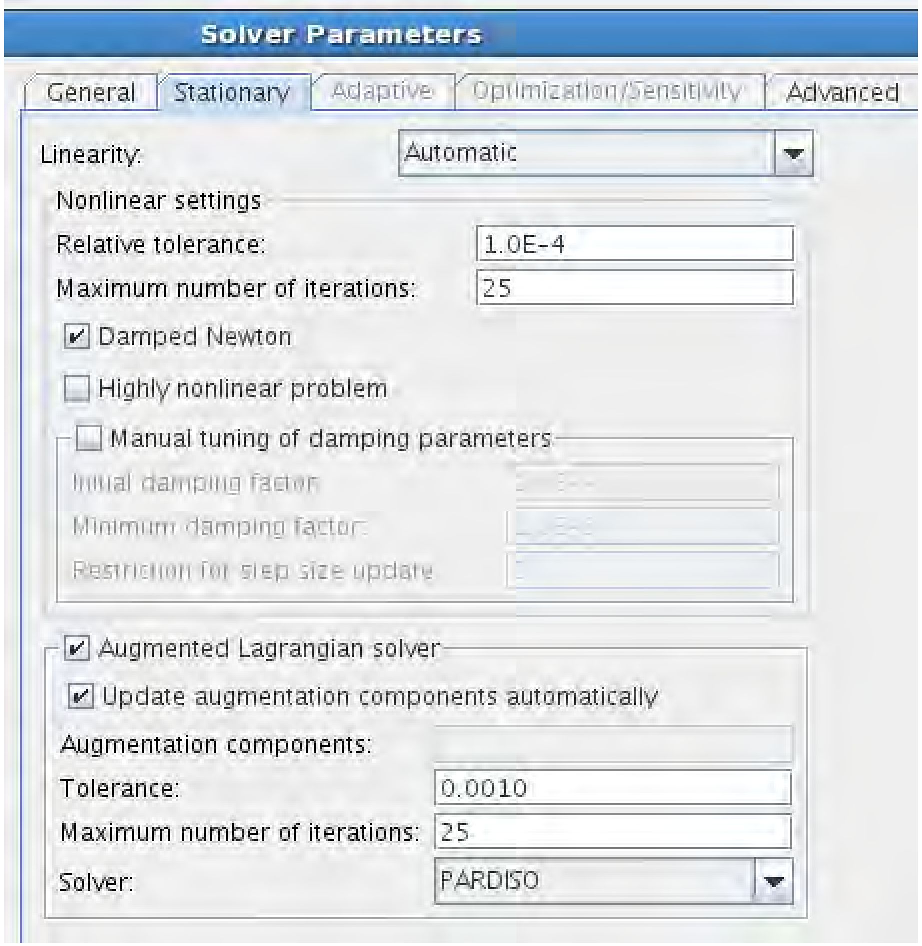
$$-k_{pyrex} \cdot \frac{A_{cross.wire}}{L_{wire}} = -h_{add} \cdot A_{cross.pad}$$

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

Solver parameters screenshots

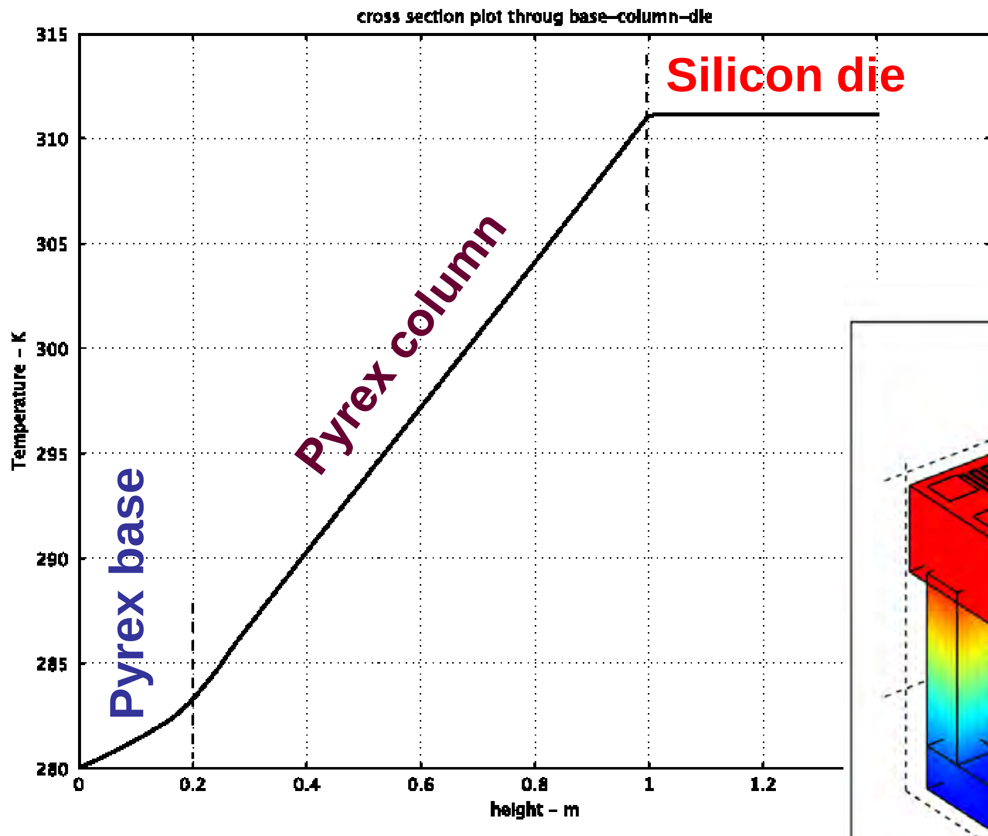




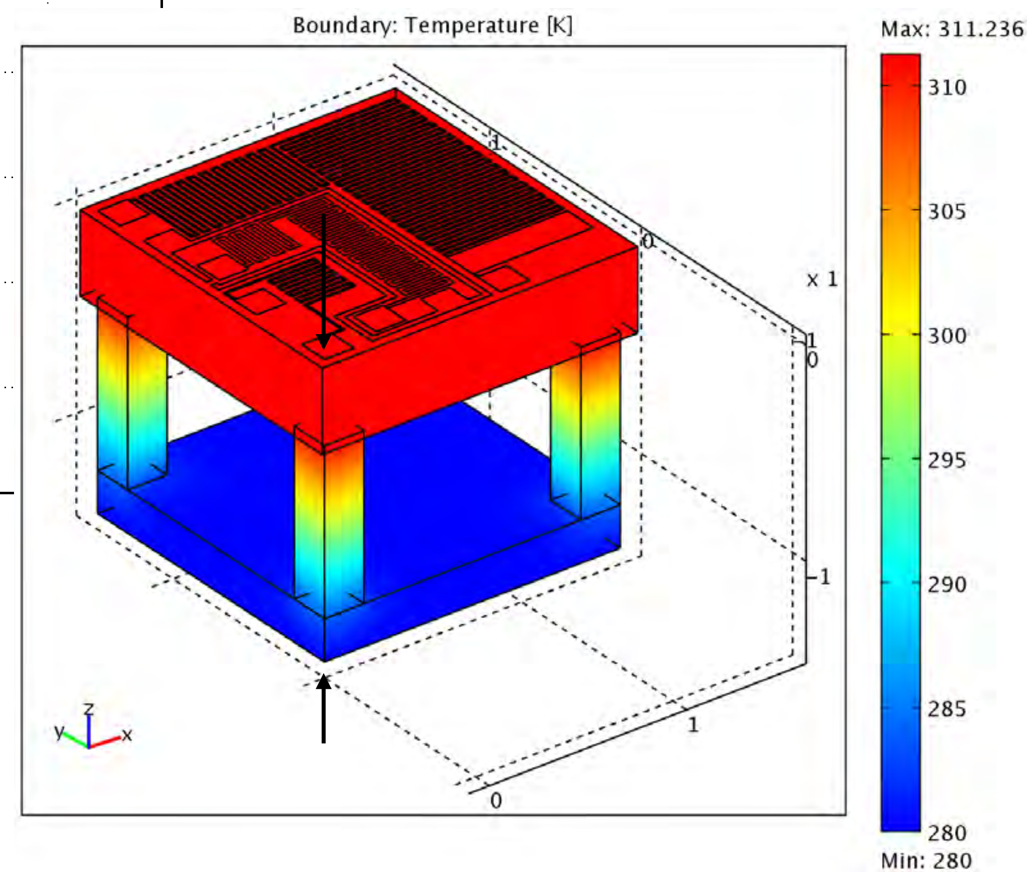


We did not change advanced part of the Solver Parameters

Coarse simulation results

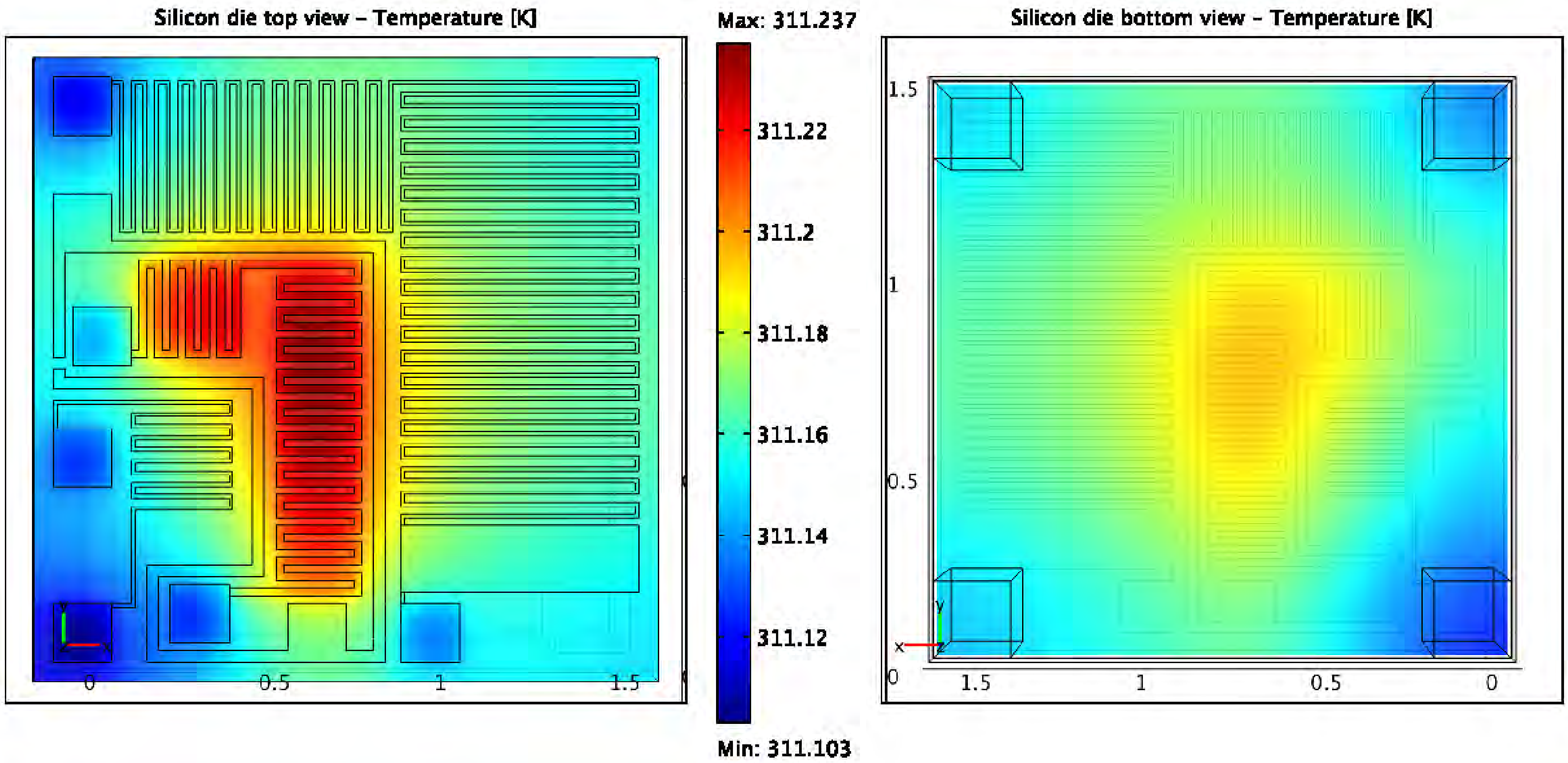


Die average overheat ≥ 30ºC by Joule Heat Power ≈ 17mW



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

Specific simulation results and conclusions



- 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!

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