UNIVERSITY OF CAMBRIDGE

CAPE Centre for Advanced Photonics and Electronics "Technology from Science"

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3D Multiphysics Model of Thermal Flow Sensors

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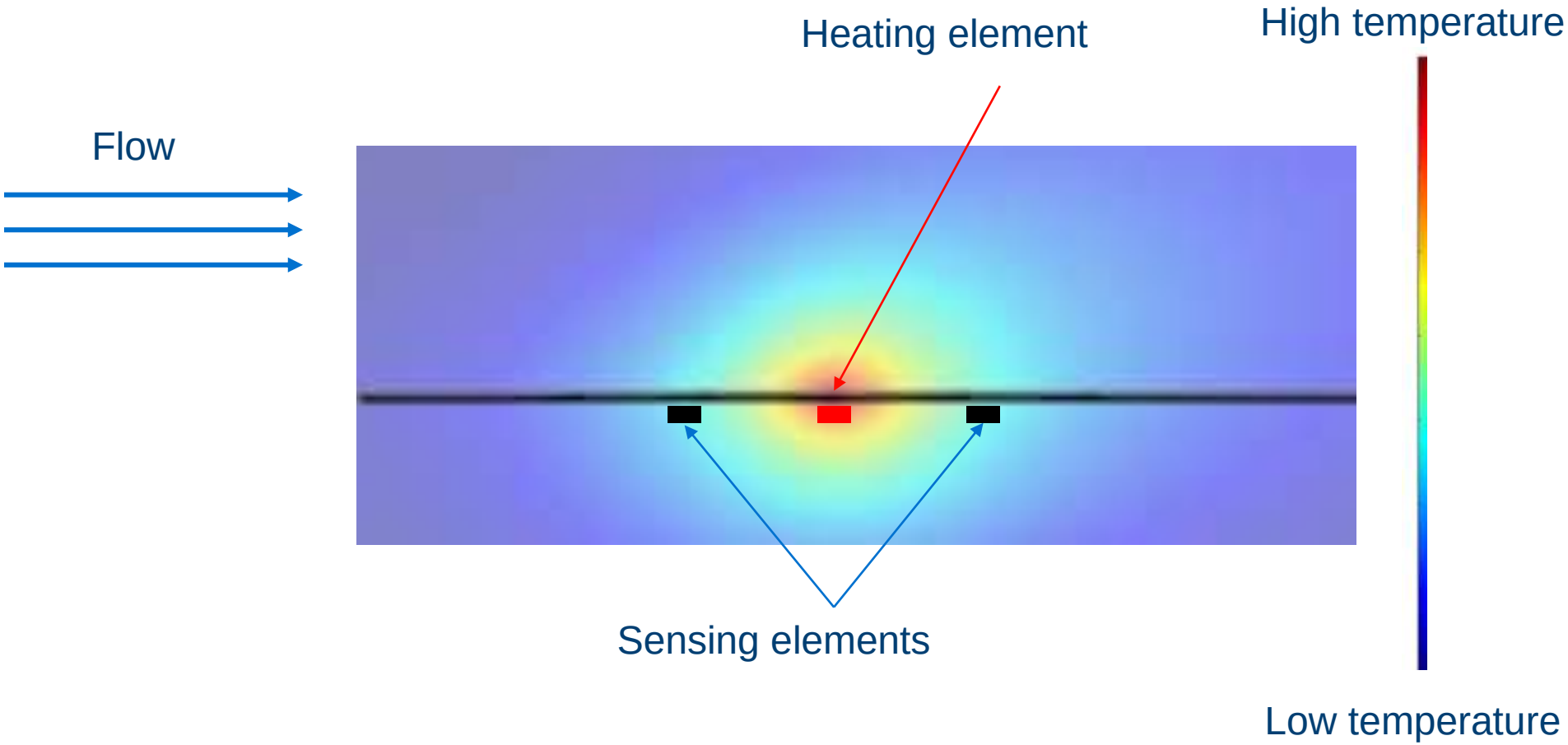
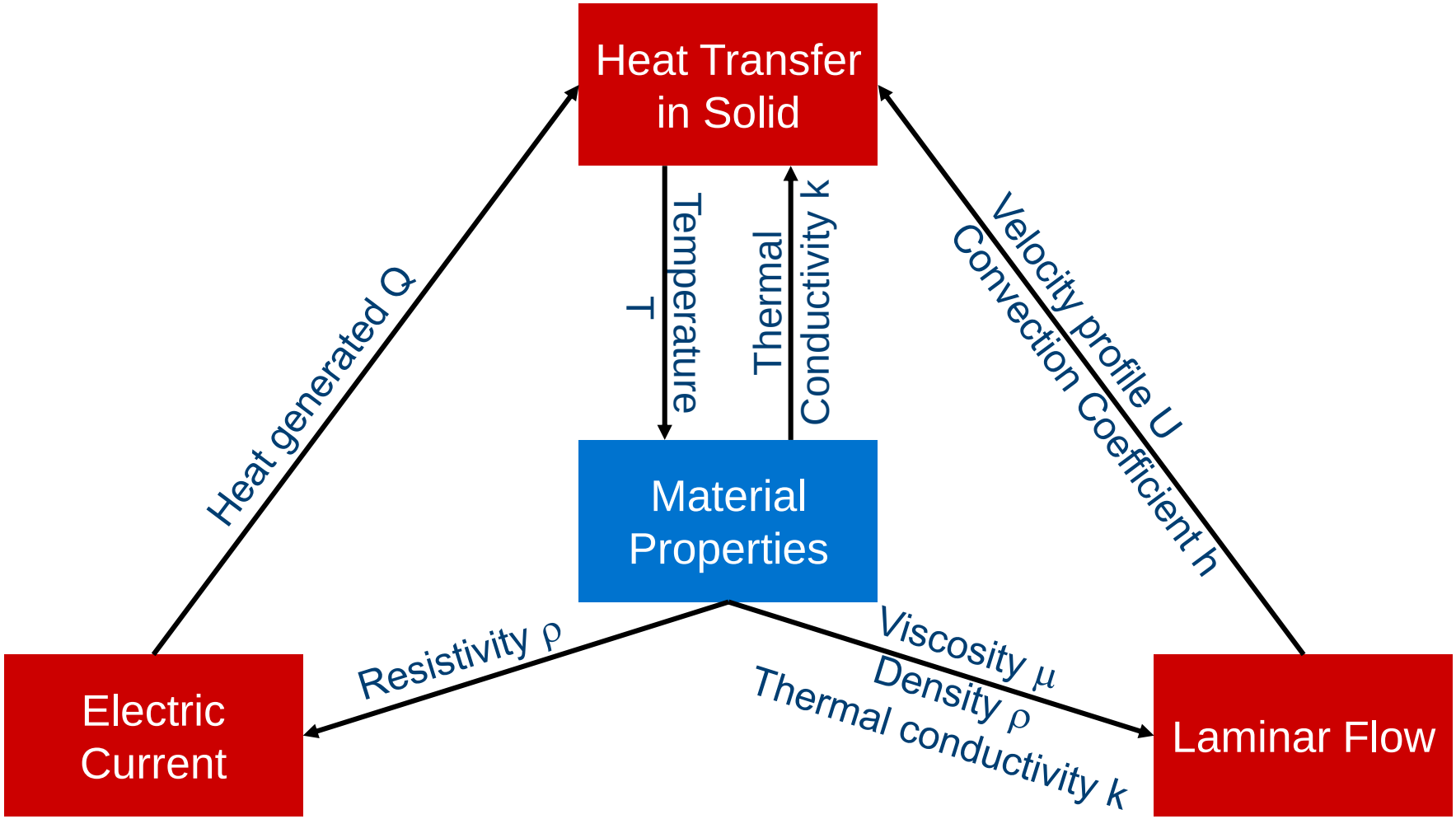
Outline

- Thermal Flow Sensors Working Principle
- Modules interaction in a Multiphyisical model
- Validation Device Structure
- Application: Wall Shear Stress Sensing
- Model Validation
- Conclusions and Future Work

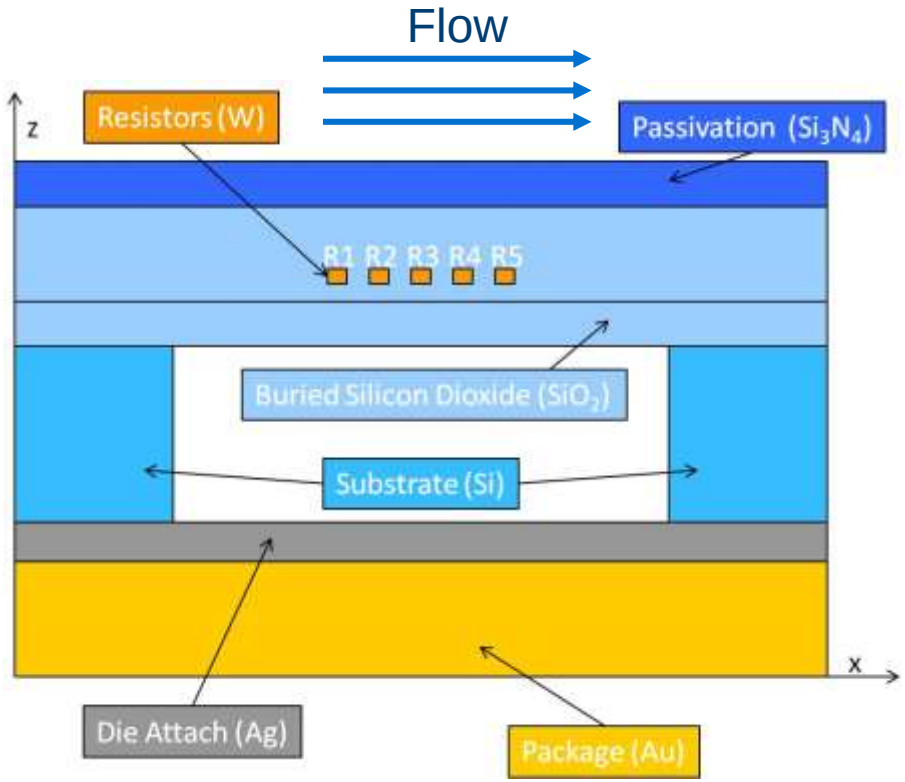
Thermal Flow Sensors Working Principle

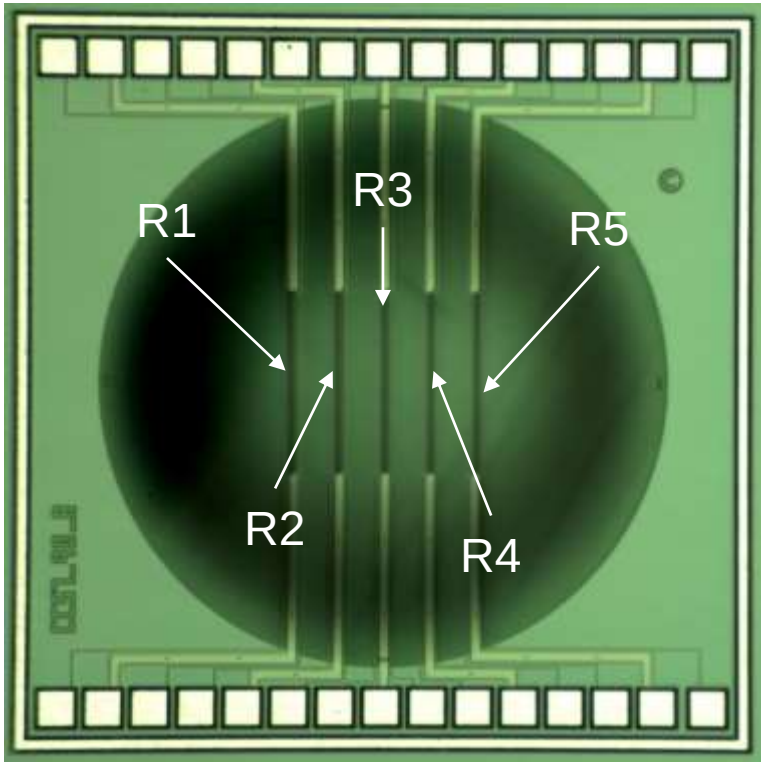


Modules Interaction in the Multiphysics Model

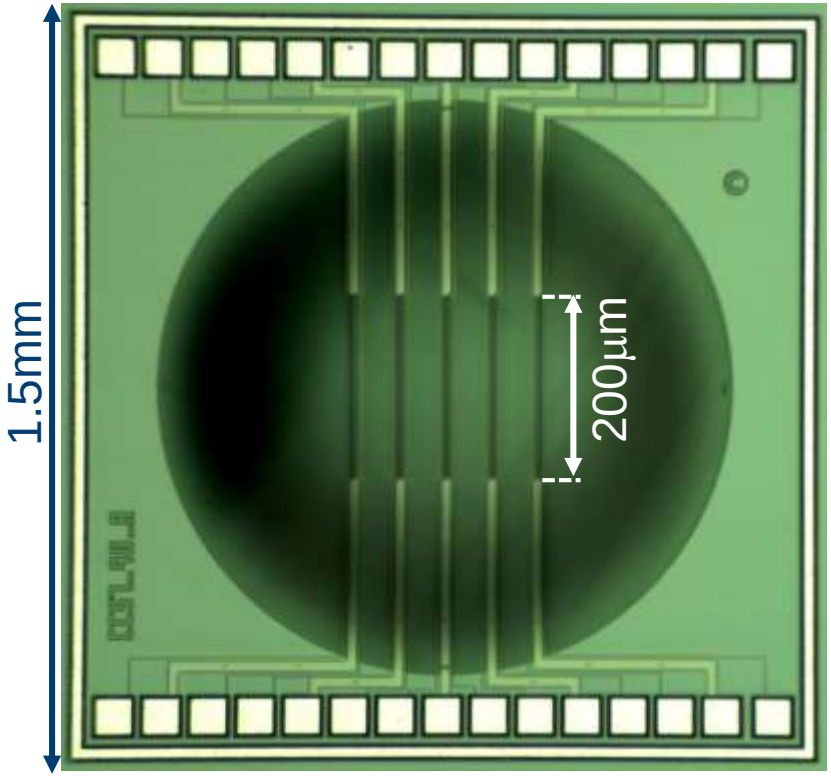


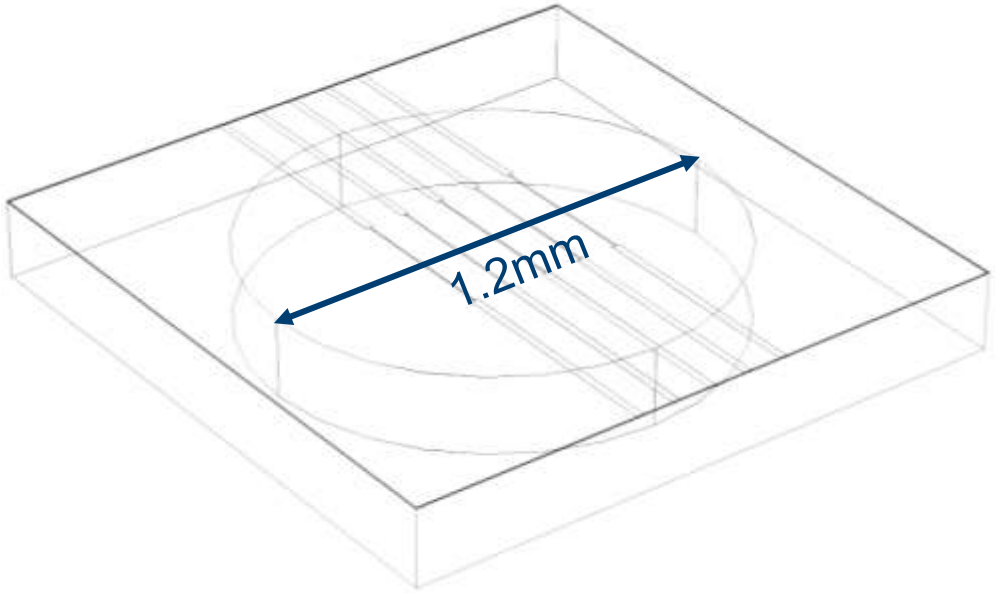
Validation Device Structure



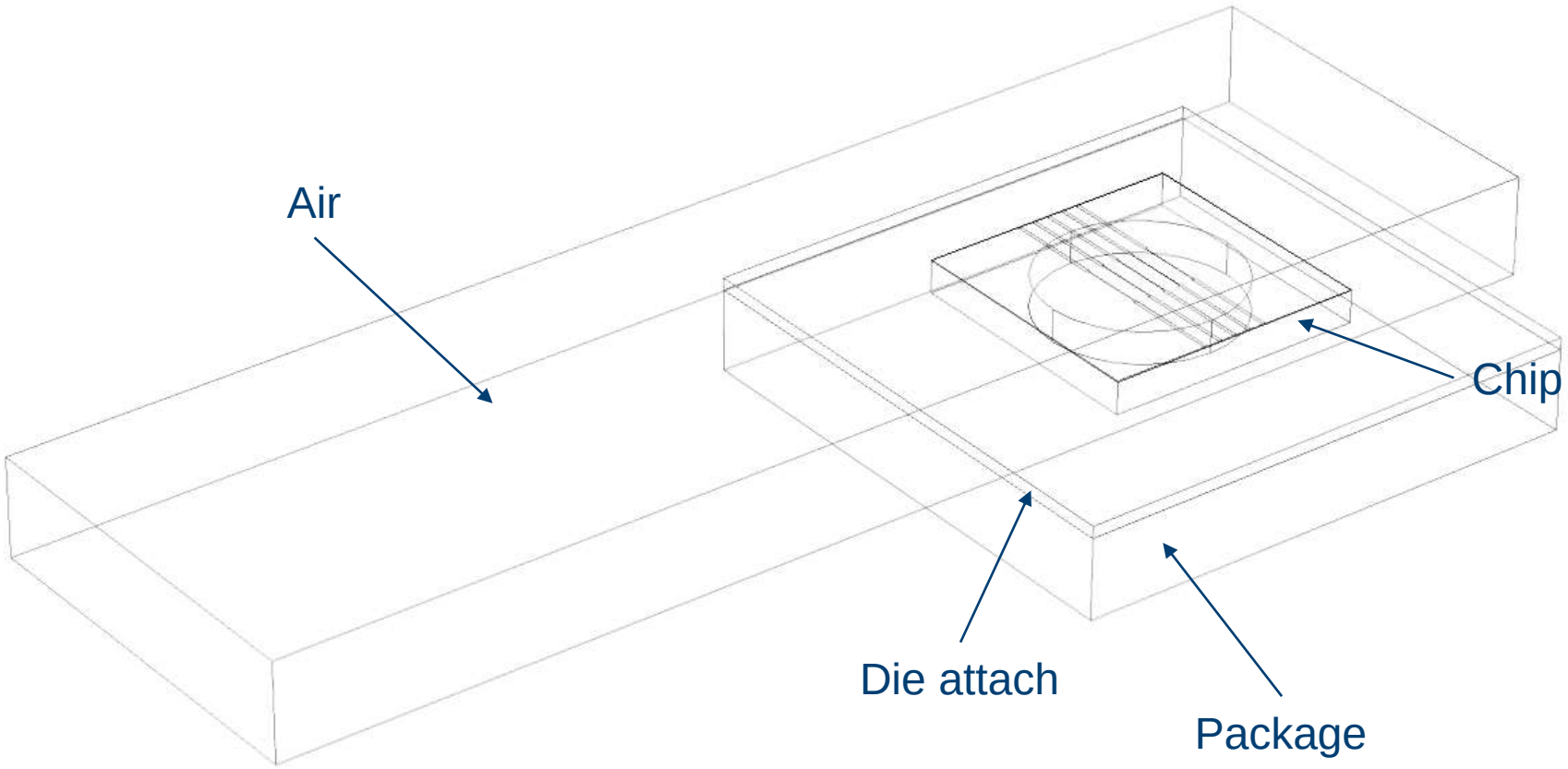


Validation Device Simplified Geometry

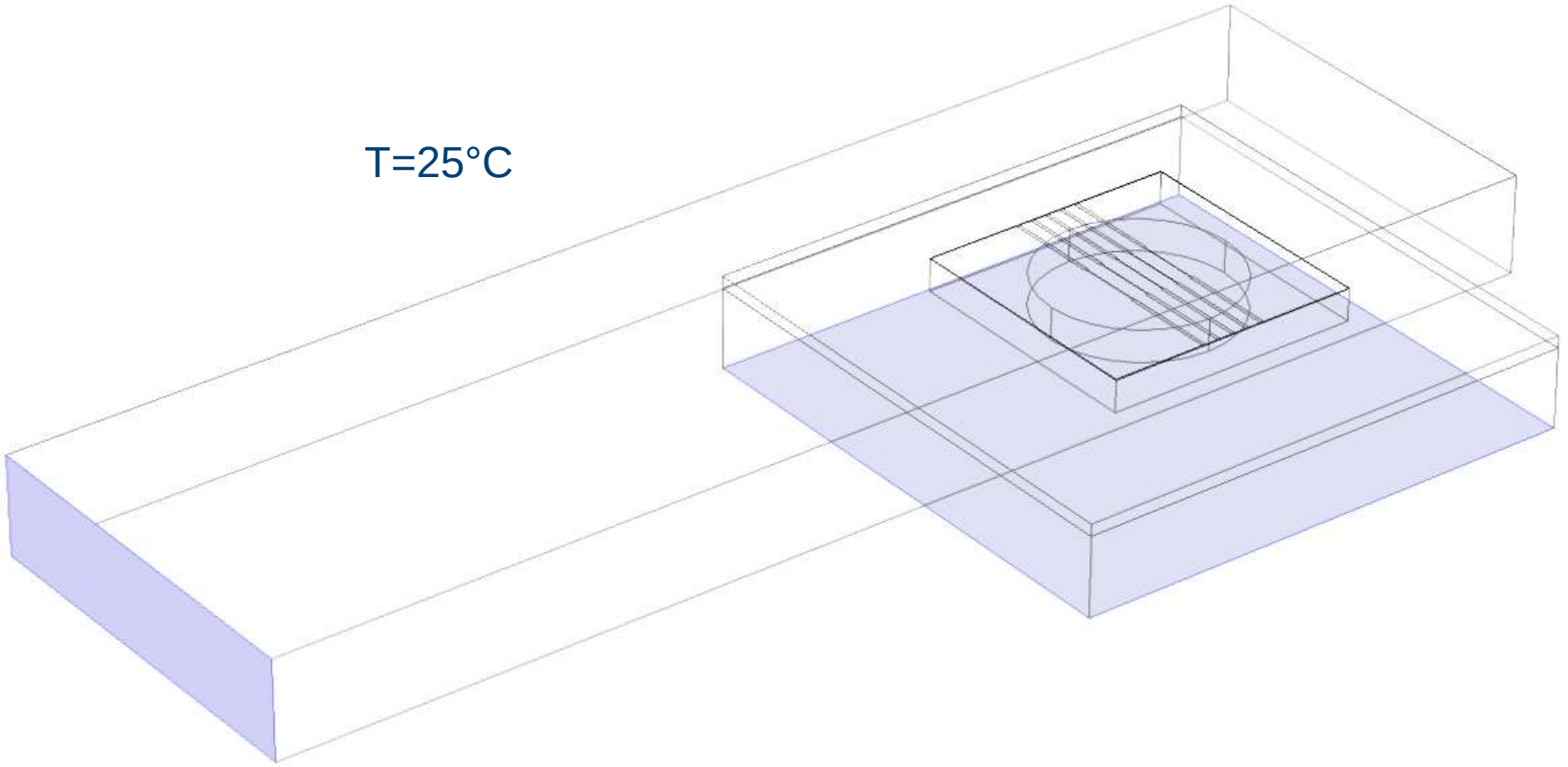




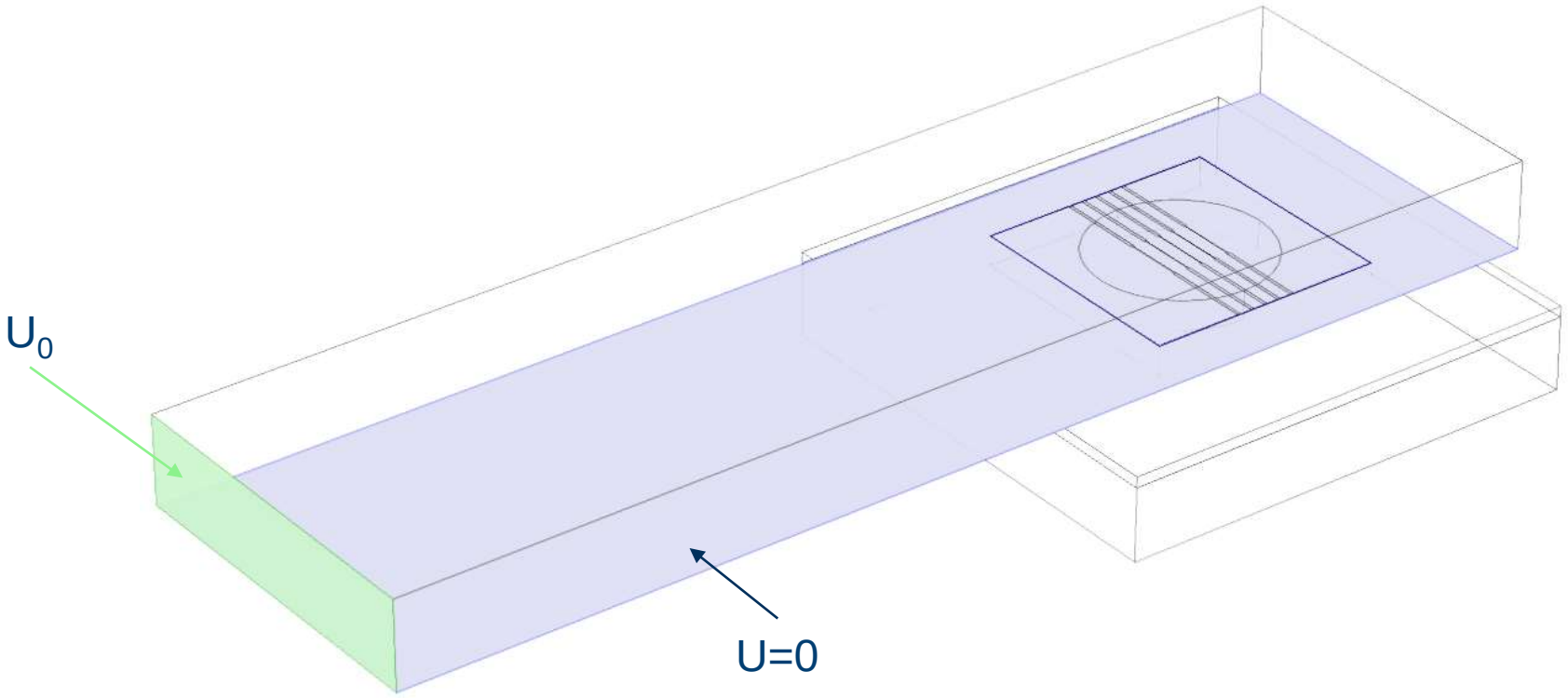
Validation Device Full Structure



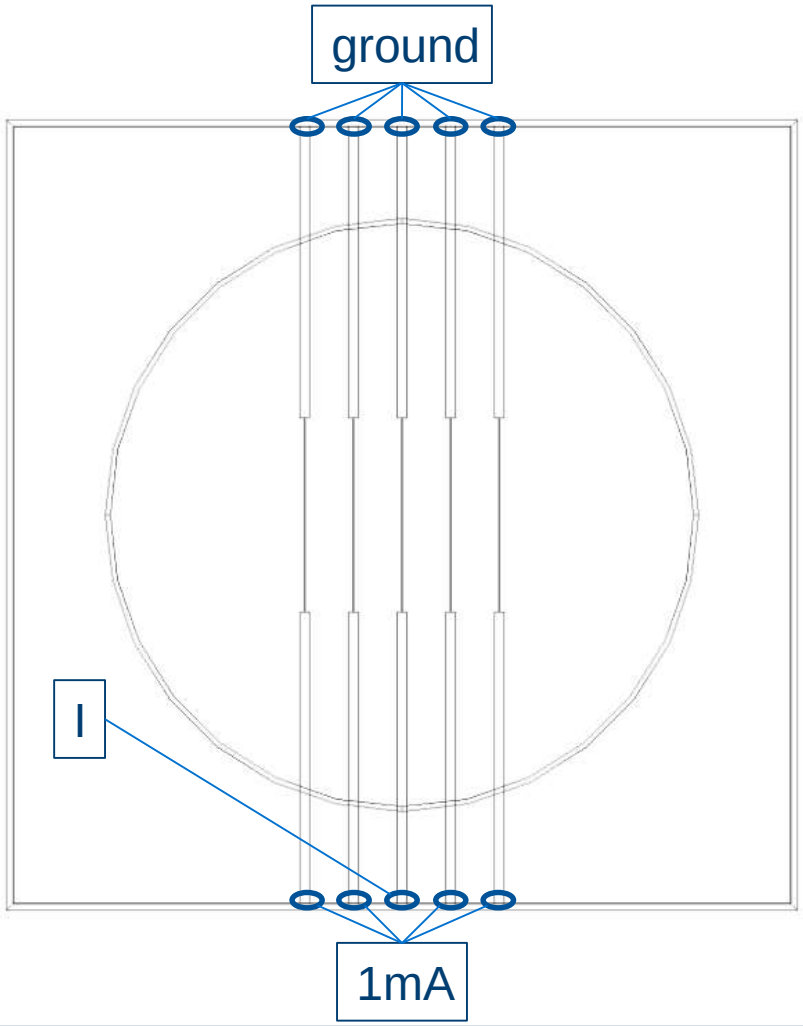
Validation Device Thermal Boundary Conditions



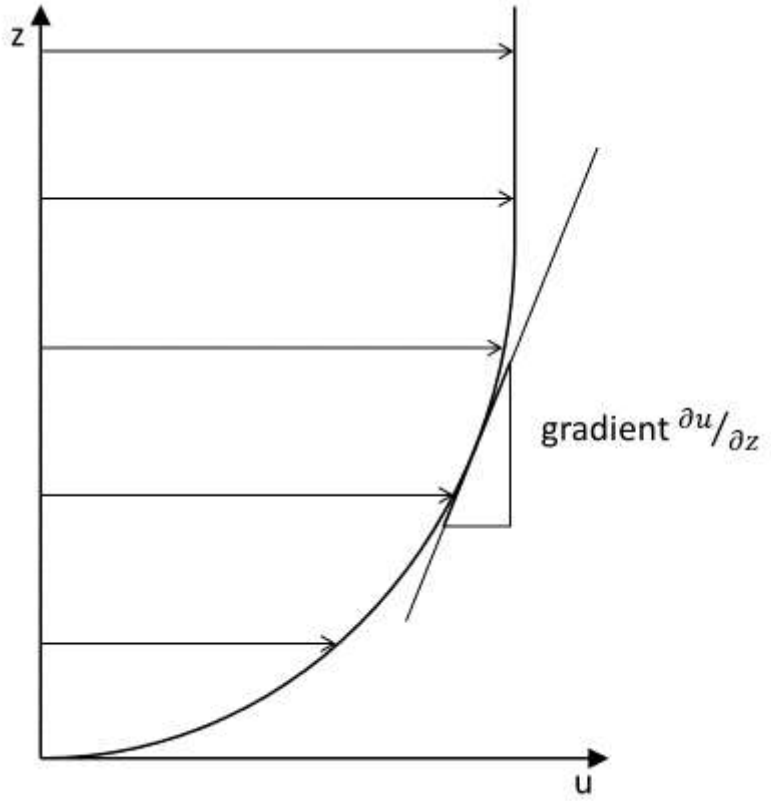
Validation Device Flow Boundary Conditions



Validation Device Electric Boundary Conditions



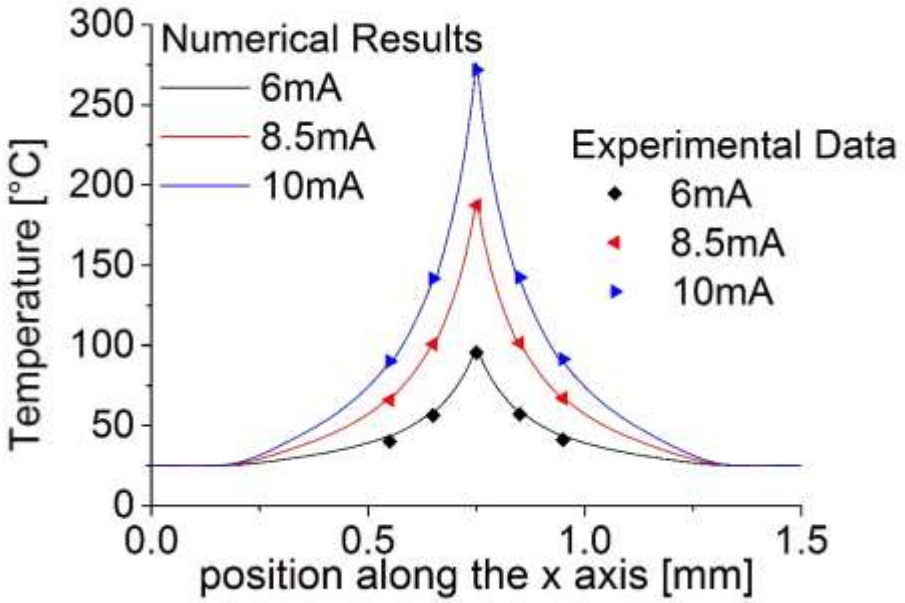
Wall shear stress

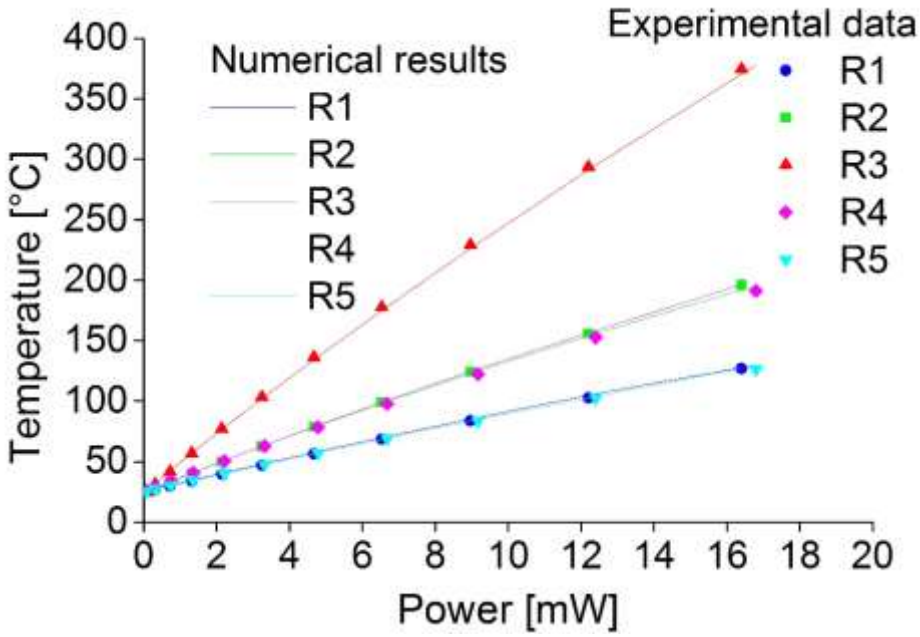


$$\tau \overset{\text{def}}{=} \mu \left. \frac{\partial u}{\partial z} \right|_{z=0}$$

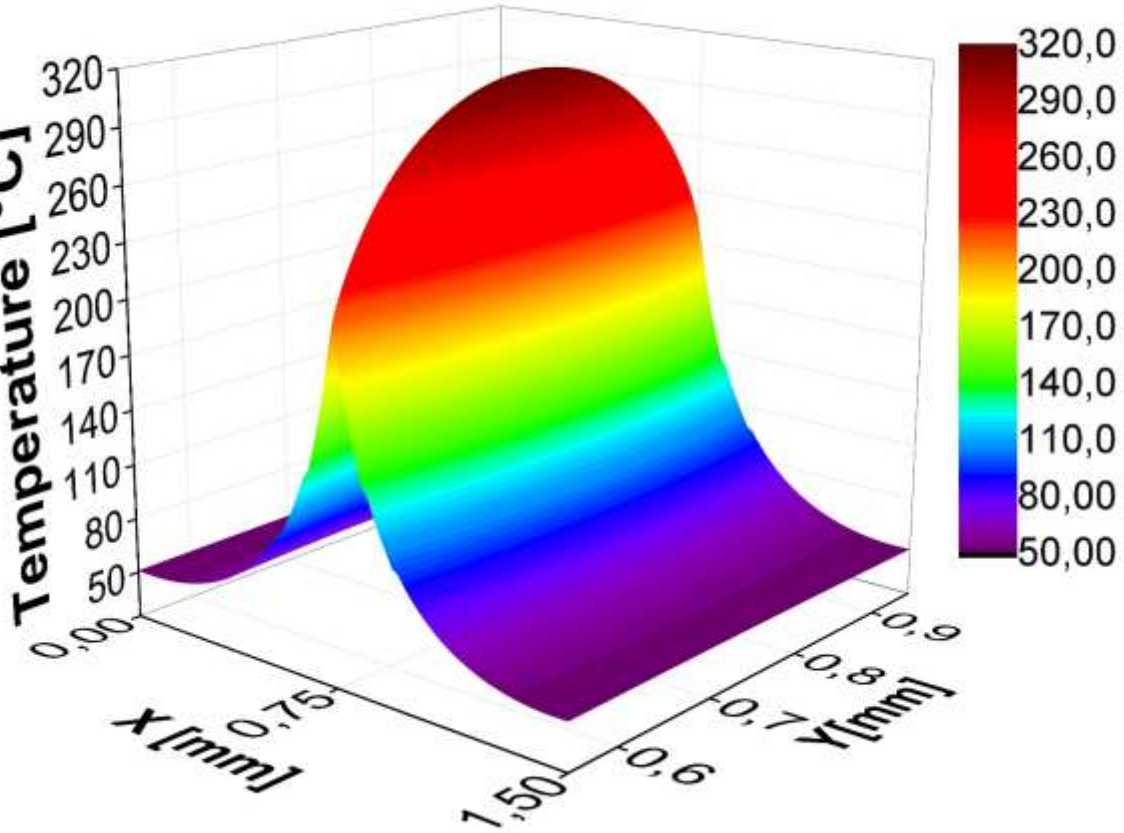
Application in: automotive, oil and gas transoceanic pipes, health, etc…

Model Validation: Still Air

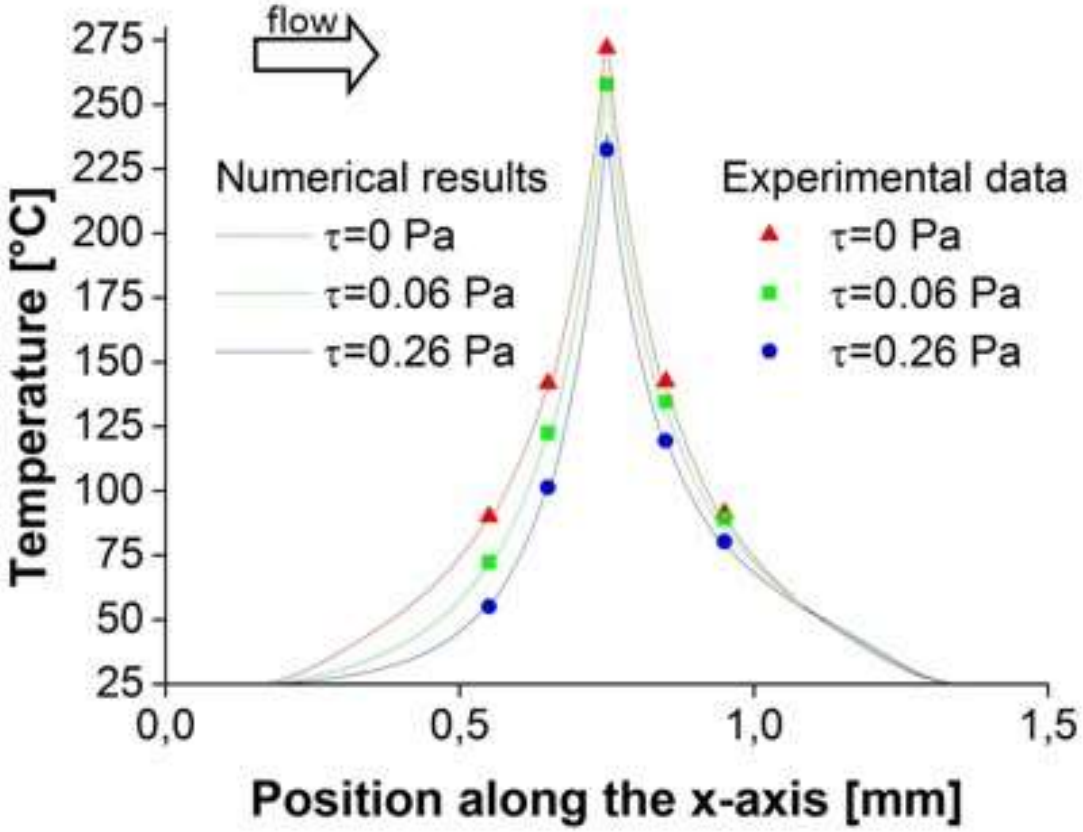


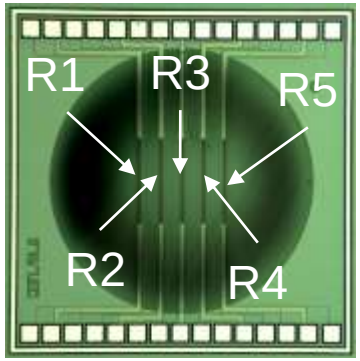


Model Validation: Temperature Profile



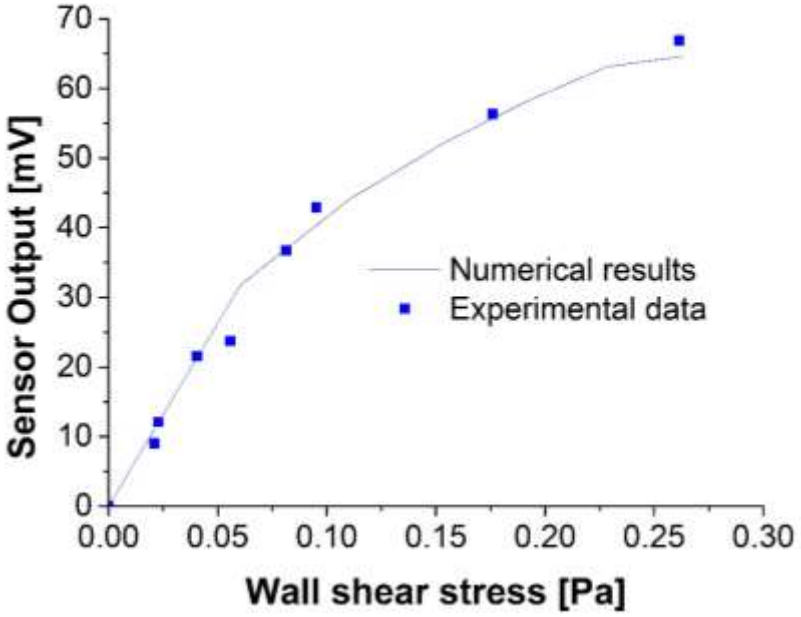
Model Validation: Moving Flow



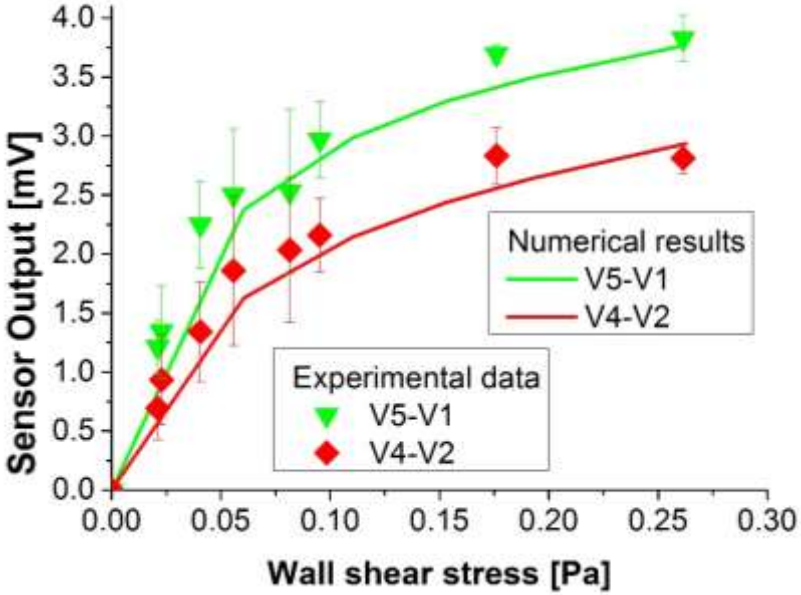


Model Validation : Output Voltage

Anemometric configuration



Calorimetric configuration



Conclusions and Future Works

- A 3-D multiphysics model has been developed for the analysis of thermal flow sensors.
- The model has been applied to a specific SOI CMOS wall shear stress sensor.
- The numerical results show excellent matching with experimental data in both stagnant air and moving flow.
- This model will allow an optimization of the device geometry in order to meet specific application requirements.

Acknowledgements

This work was partly supported through the EU FP7 project SOI-HITS (Smart Silicon-on-Insulator Sensing System Operating at High Temperature)

Thank you for the attention!

Model Equations

- Heat Transfer in Solid

$$\rho C_p \hat{u} \cdot \nabla T = \nabla (k \nabla T) + Q$$

- Electric Current

$$Q = \rho \cdot \boldsymbol{J}^2$$

- Laminar Flow

$$\nabla \cdot (\rho \boldsymbol{u}) = 0$$
$$\rho (\boldsymbol{u} \cdot \nabla) \boldsymbol{u} = \nabla \cdot [-p\boldsymbol{I} + \mu (\nabla \boldsymbol{u} + (\nabla \boldsymbol{u})^T)]$$