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Raffaele Capuano
Ph.D. Candidate
Delft University of Technology
Process & Energy Laboratory
Delft
The Netherlands
R.capuano@tudelft.nl

Excerpt from the Proceedings of the 2012 COMSOL Conference in Milan

Numerical Analysis of Conjugate Heat Transfer in Foams

Authors:

N. Bianco[1], R. Capuano[2], W. K. S. Chiu[3], S. Cunsolo[1], V. Naso[1] and M. Oliviero[1].

[1] DETEC, Università degli studi Federico II, Napoli, Italy

[2] Delft University of Technology, Process & Energy Laboratory, Delft, The Netherlands

[3] Department of Mechanical Engineering, University of Connecticut, Storrs, CT, USA

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Framework agreement

Università di Napoli Federico II

University of Connecticut

December 2010

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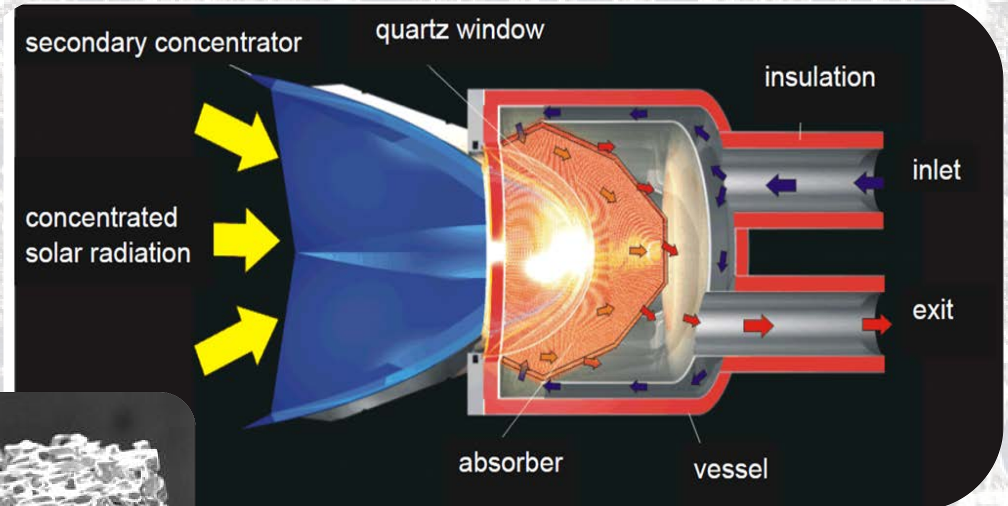
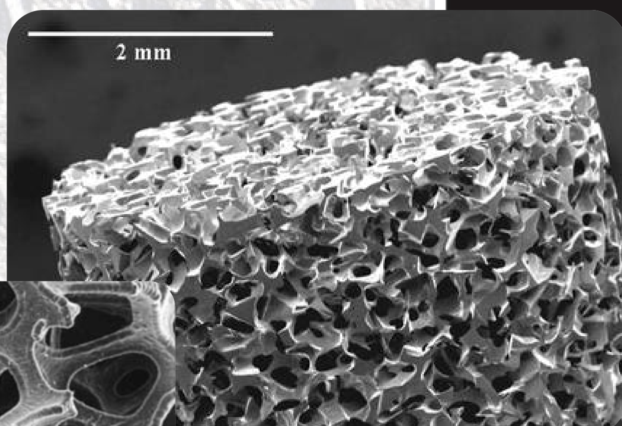
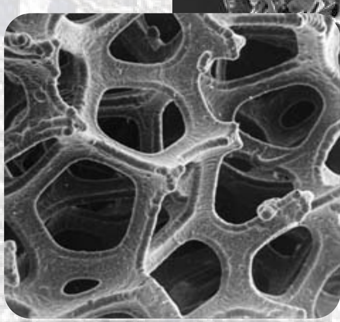
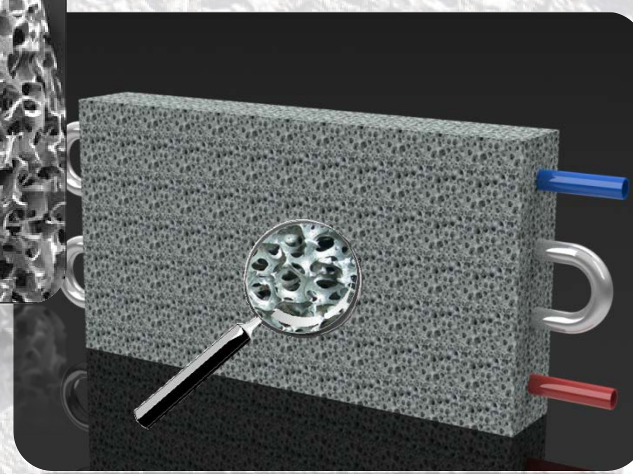
Some applications of open cell metallic foams

An accurate knowledge of the thermal behaviour of the foams is required









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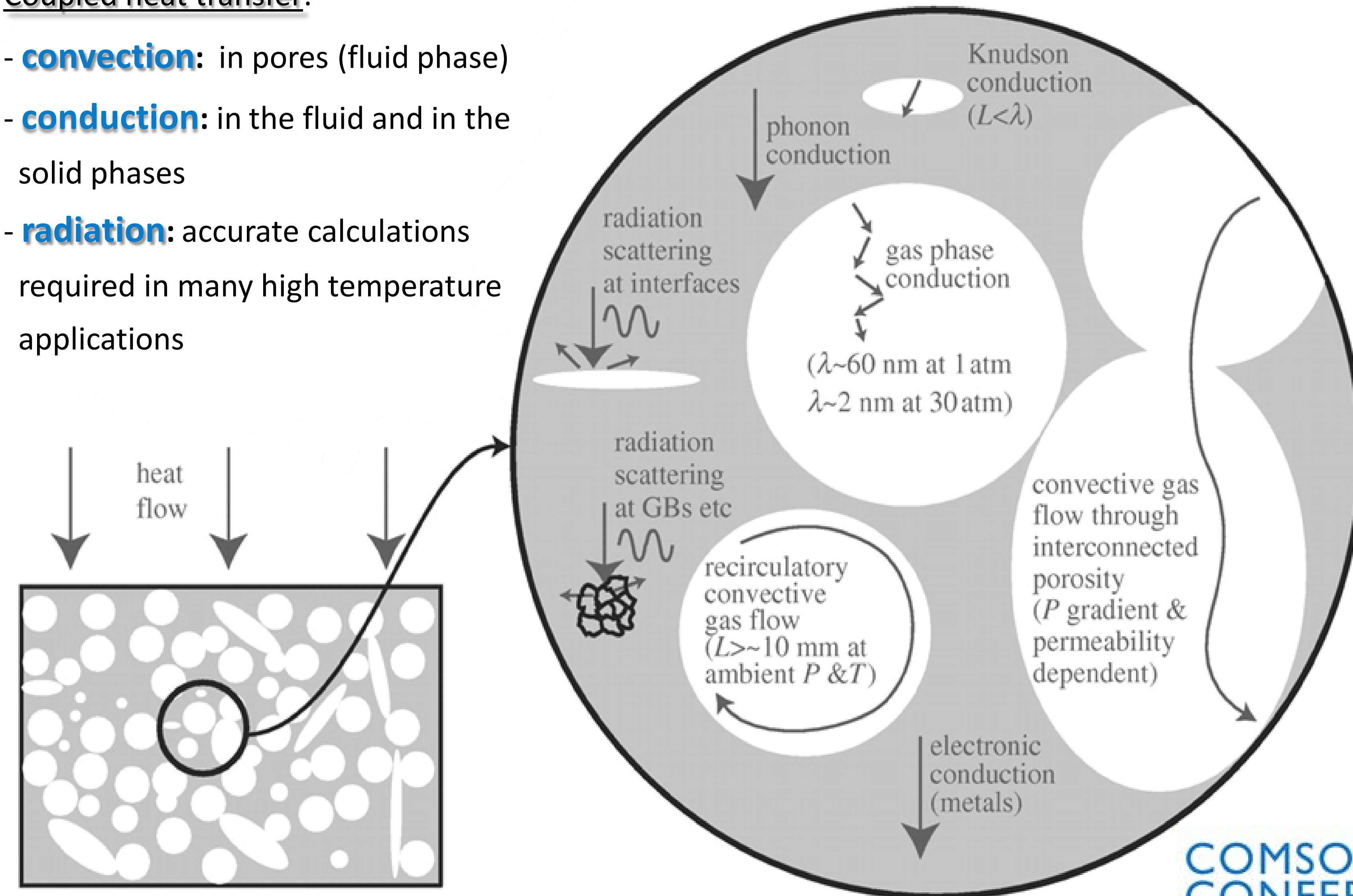
Mechanisms of heat transfer in foams

Coupled heat transfer:

- **convection**: in pores (fluid phase)
- **conduction**: in the fluid and in the solid phases
- **radiation**: accurate calculations required in many high temperature applications



Clyne T et al. Phil. Trans. R. Soc. A 2006;364:125-146

AIM

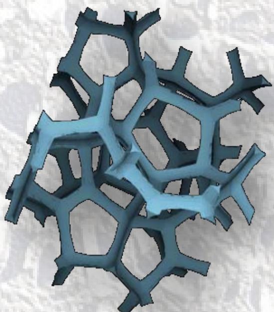
CONJUGATE HEAT TRANSFER SIMULATION IN A FOAM USING THE BUILT-IN COMSOL® MULTIPHYSICS

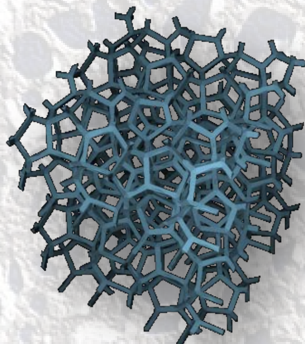
- *Distribution of the cell surface temperature, velocity and pressure.*
- *Temperature, pressure and velocity fields in the mid-sections of the cell.*

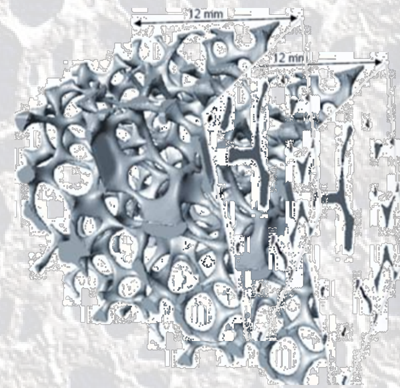
3D DISCRETE REPRESENTATION OF THE FOAM

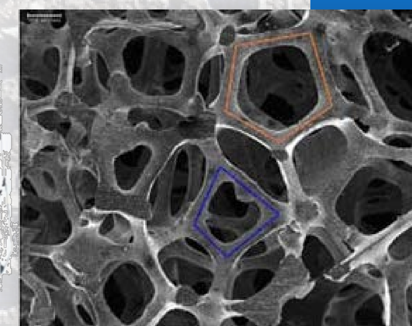
Full-numerical approach
Digital reconstruction

Tomography-based tecnique

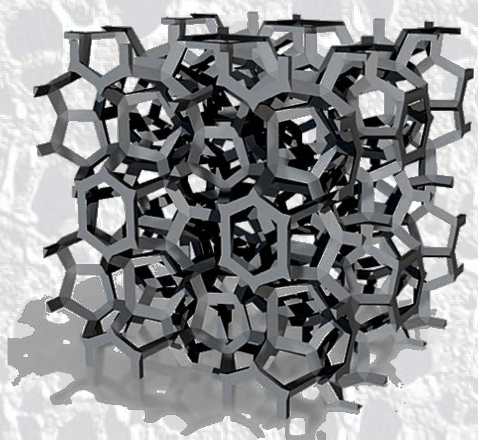








Our choice → *Weaire – Phelan* Cell Structure



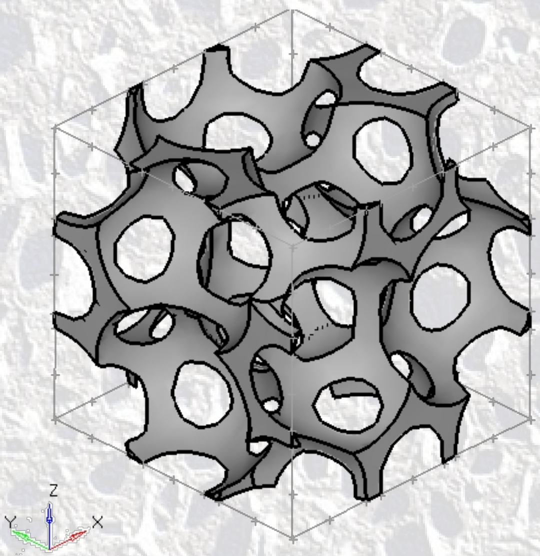
PROCEDURE LINEUP

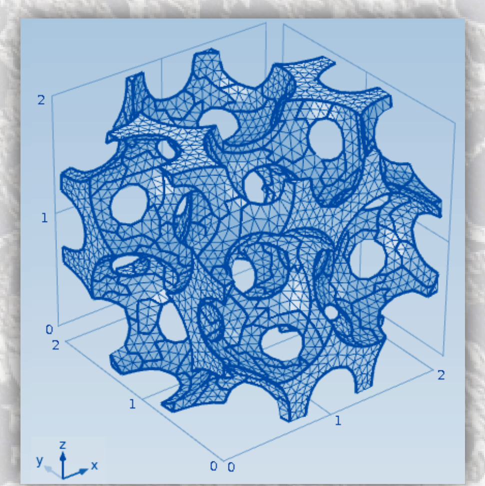
3D STRUCTURE REPRESENTATION

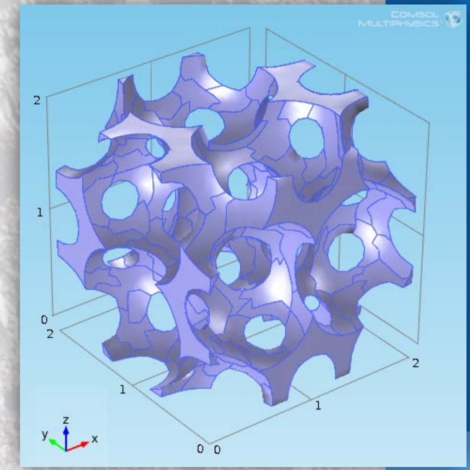
SURFACE EVOLVER

MESHING AND CFD ANALYSIS

COMSOL MULTIPHYSICS ®

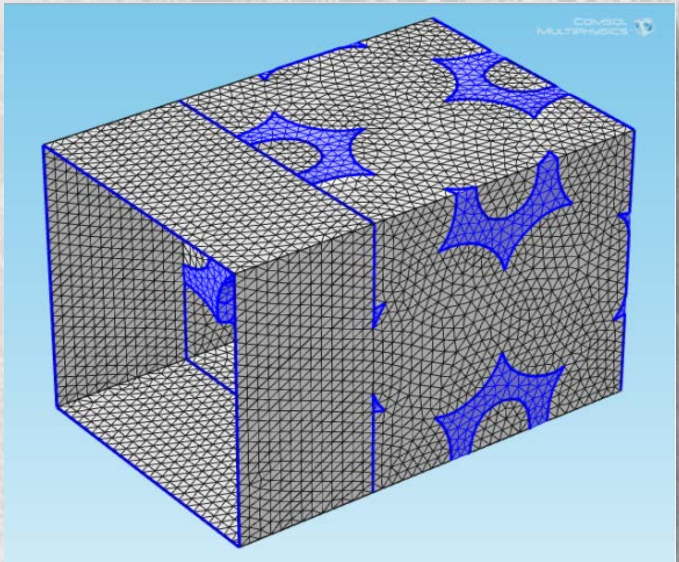






Setup

- Weaire-Phelan cell structure inscribed in 2 mm·2·mm·2 mm cubic volume
- Fictitious inlet section
- SiC (silicon carbide ceramic foam)
- 92.5% cell porosity
- Steady-state
- Incompressible flow
- Homogeneous and constant properties of gaseous and solid phases
- Grey body solid surfaces



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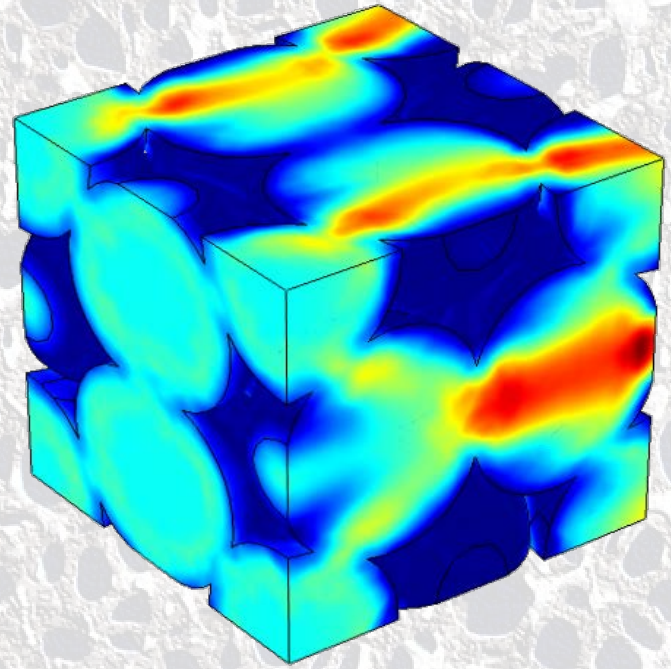
Conjugate heat transfer

Conjugate heat transfer

Convection

Flow modulus
within the structure



Laminar flow: COMSOL® Inlet and
Outlet built-in
conditions

Inlet velocity: 1.0 $^{m}/_{s}$
Outlet pressure: 0 Pa

Heat transfer: COMSOL® built-in
Outflow condition

Physic Domain

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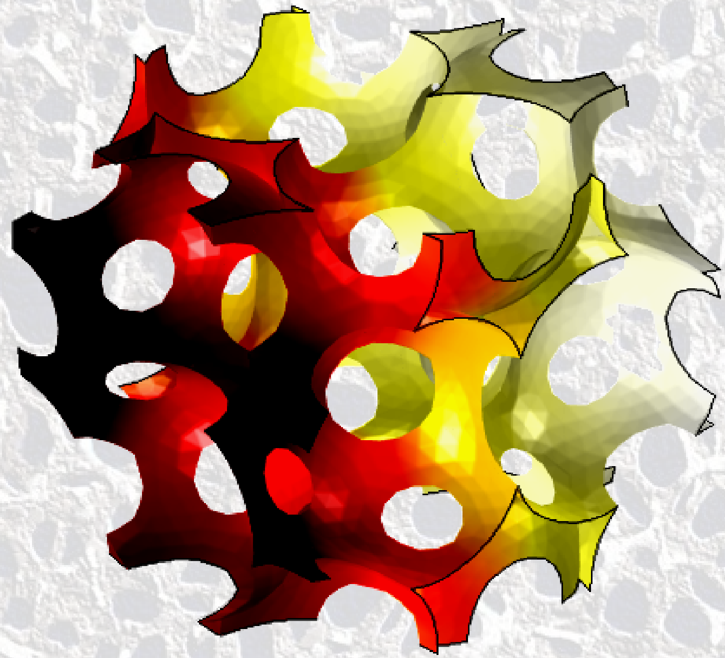
Conjugate heat transfer

Radiation and Conduction

COMSOL® built-in Surface-to-surface radiation model



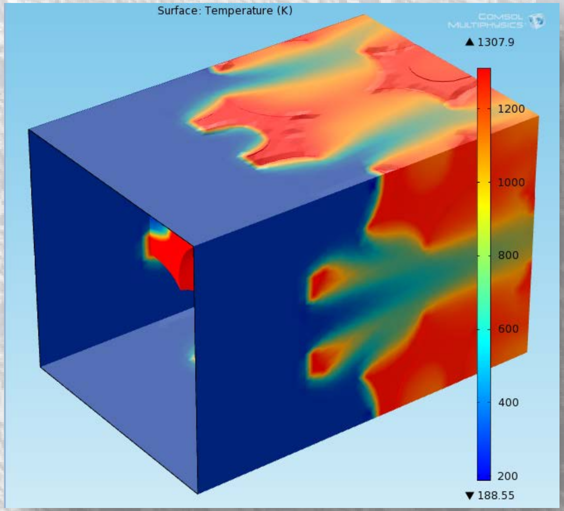
Prescribed radiosity

Incident radiation = $7.5 \cdot 10^5\ {}^{W}/_{m^2}$

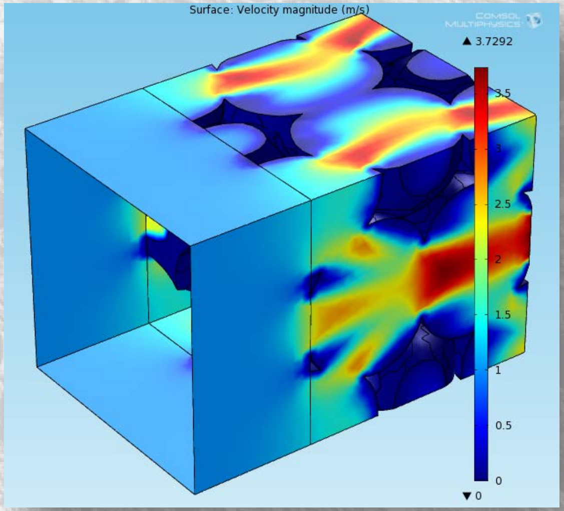
Reradiating surfaces

Incident radiation = Hemispherical emissive Power

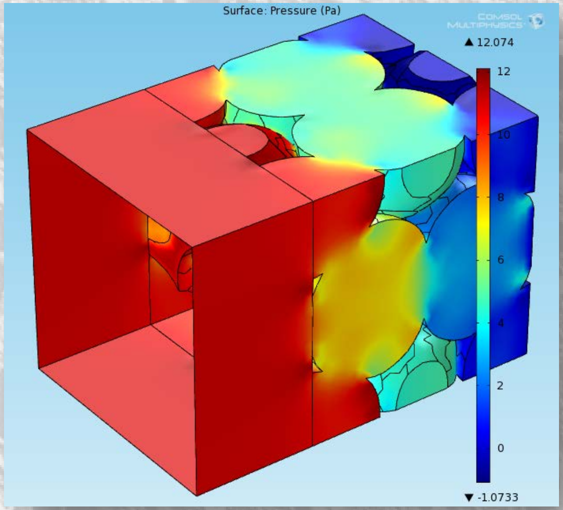
Results



Distribution of cell surface temperature (K)



Distribution of cell surface velocity (m/s)



Distribution of cell surface pressure (Pa)

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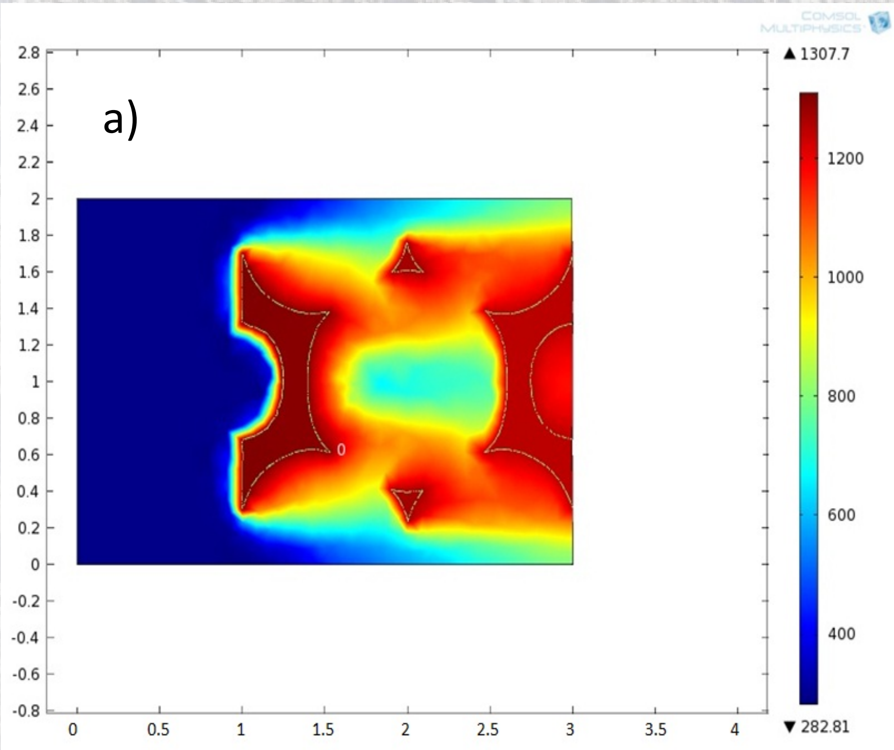
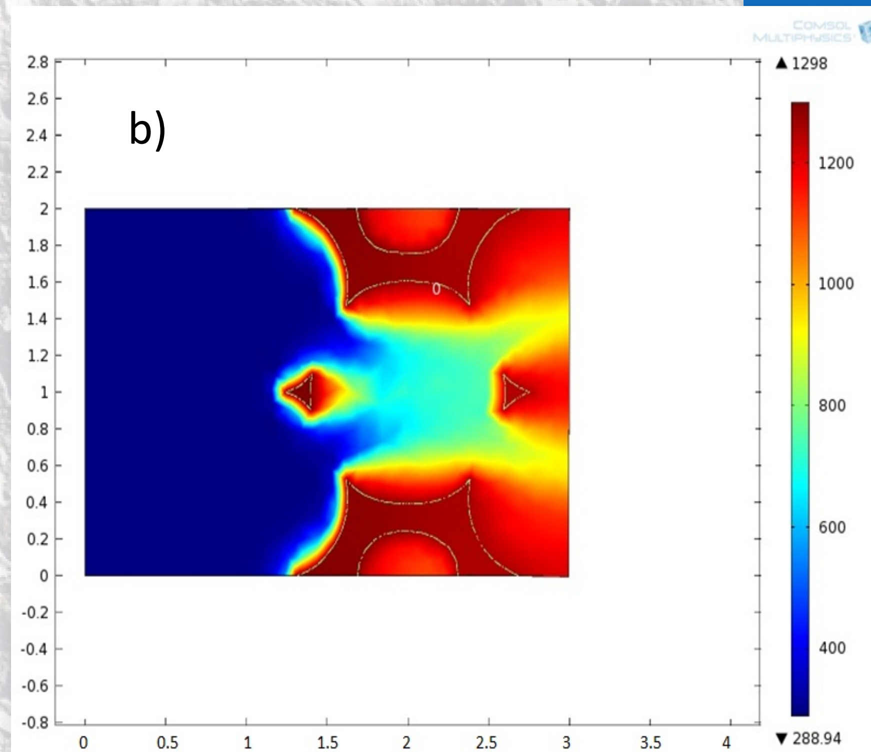
RESULTS



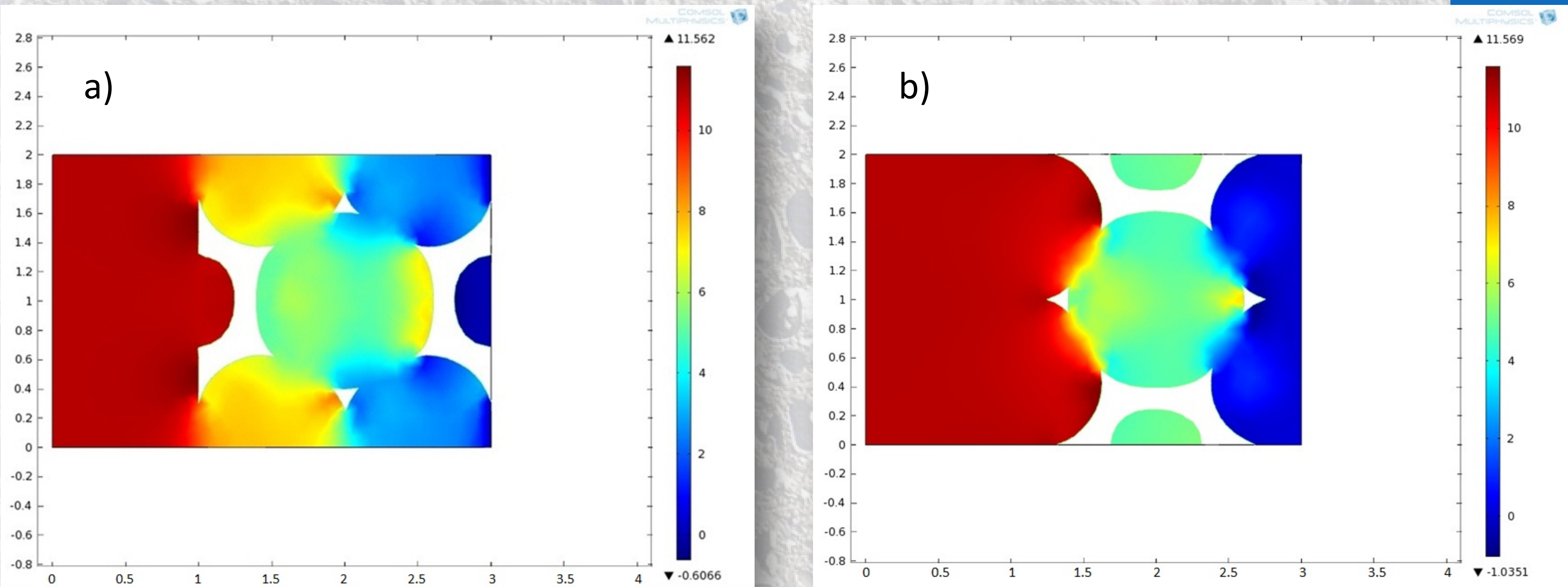


TEMPERATURE (K) FIELDS:

a) Y = 1 mm

b) Z = 1 mm

RESULTS

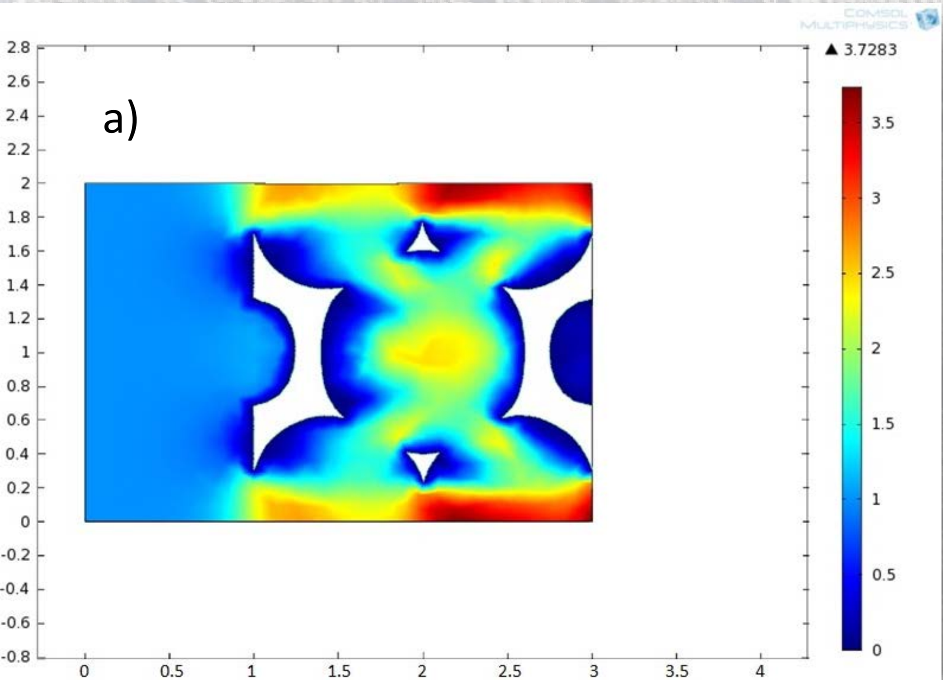


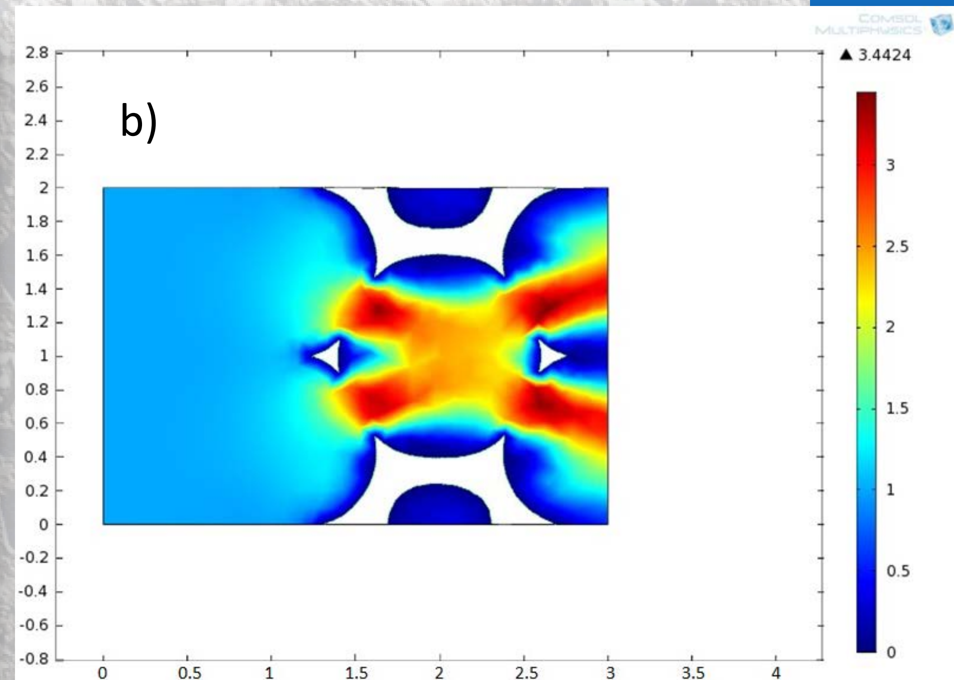
PRESSURE (Pa) FIELDS:

a) Y = 1 mm

b) Z = 1 mm

Results





Velocity (m/s) fields:

a) Y = 1 mm

b) Z = 1 mm

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CONCLUSIONS

- A 3D reconstruction based on *W&P* model has been imported into COMSOL® Multiphysics
- Conjugate conductive – convective - radiative heat transfer in air saturated SiC ceramic foams has been evaluated
- Results obtained by these simulations are useful to evaluate coefficients and parameters to be used in continuous models of the foam.

FURTHER DEVELOPMENTS

The continuous approach could be applied to the study of different applications where a discrete representation of the foam required unsustainable computational costs.

- high-temperature solar power plants
- electric or thermal insulation

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