Heat Conduction in Porous Absorption Layers for Thermography Applications

Lars Helmich and Andreas Hütten

Ferroic Cooling
A DFG PRIORITY PROGRAMME

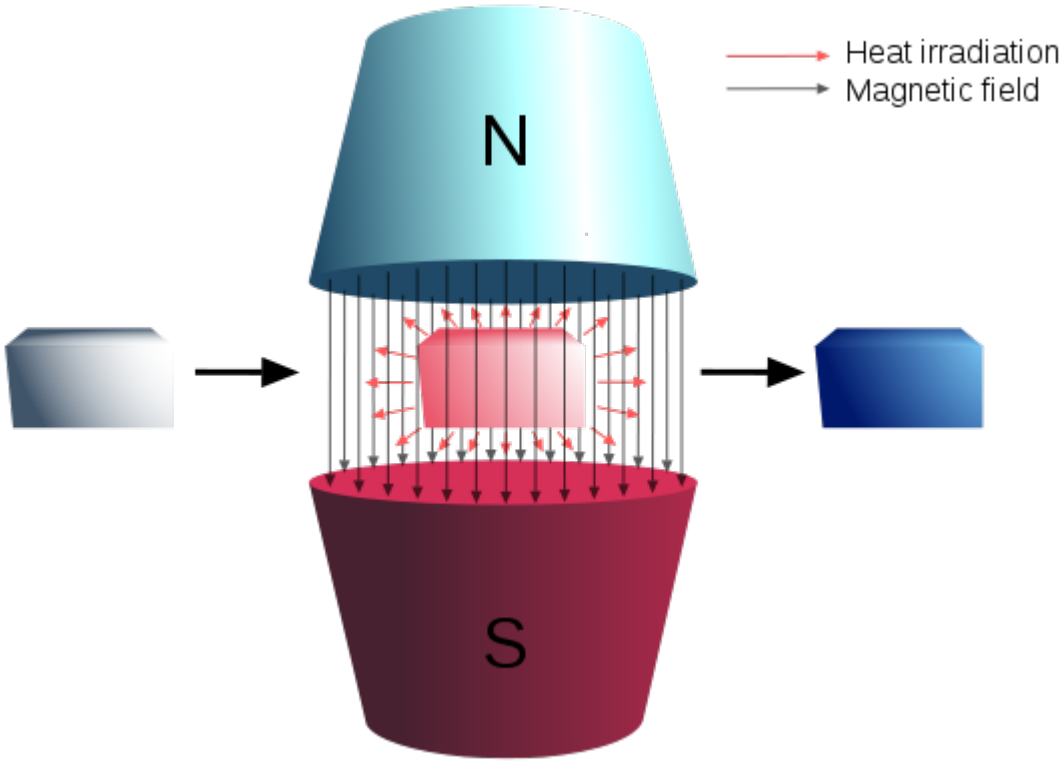
COMSOL CONFERENCE 2014 CAMBRIDGE

Outline

- Magnetocaloric Effect
- Magnetic Shape Memory Alloys
  - ➢Experimental preparation
  - ➢Why do we actually need an absorption layer?
- Simulation
  - ➢Comparison of two different absorption materials

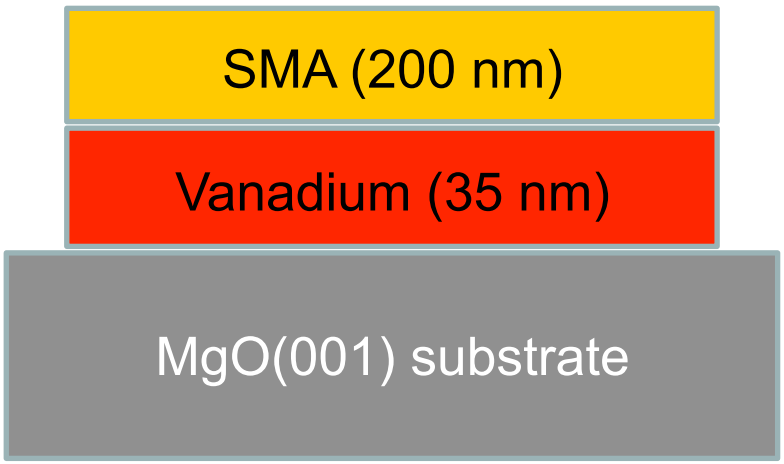
Introduction

- Conventional Magnetocaloric effect



Experimental preparation

1st step

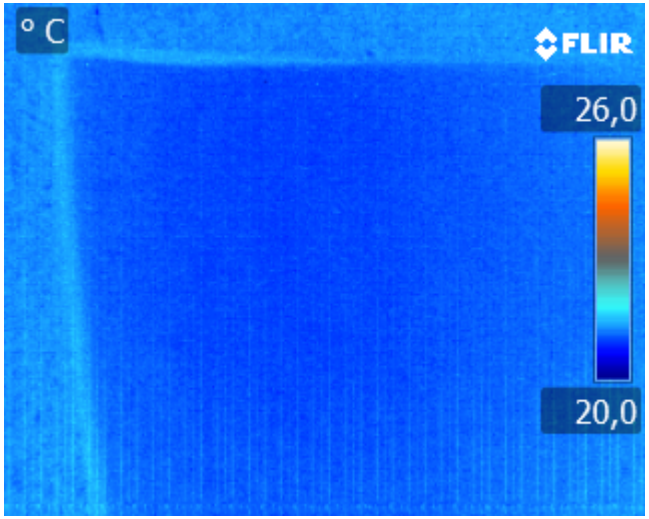


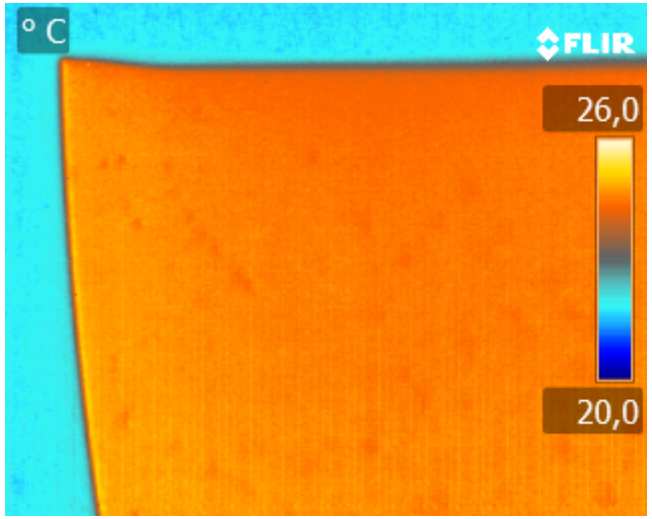
2nd step

Sample holder with a hole

- Sputter deposition
- Selective wet-chemical etching of Vanadium
- Transfer of the sample to a special sample holder

Absorption layer



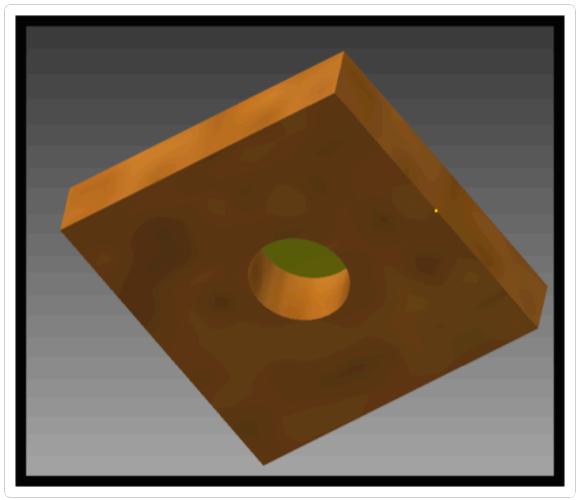


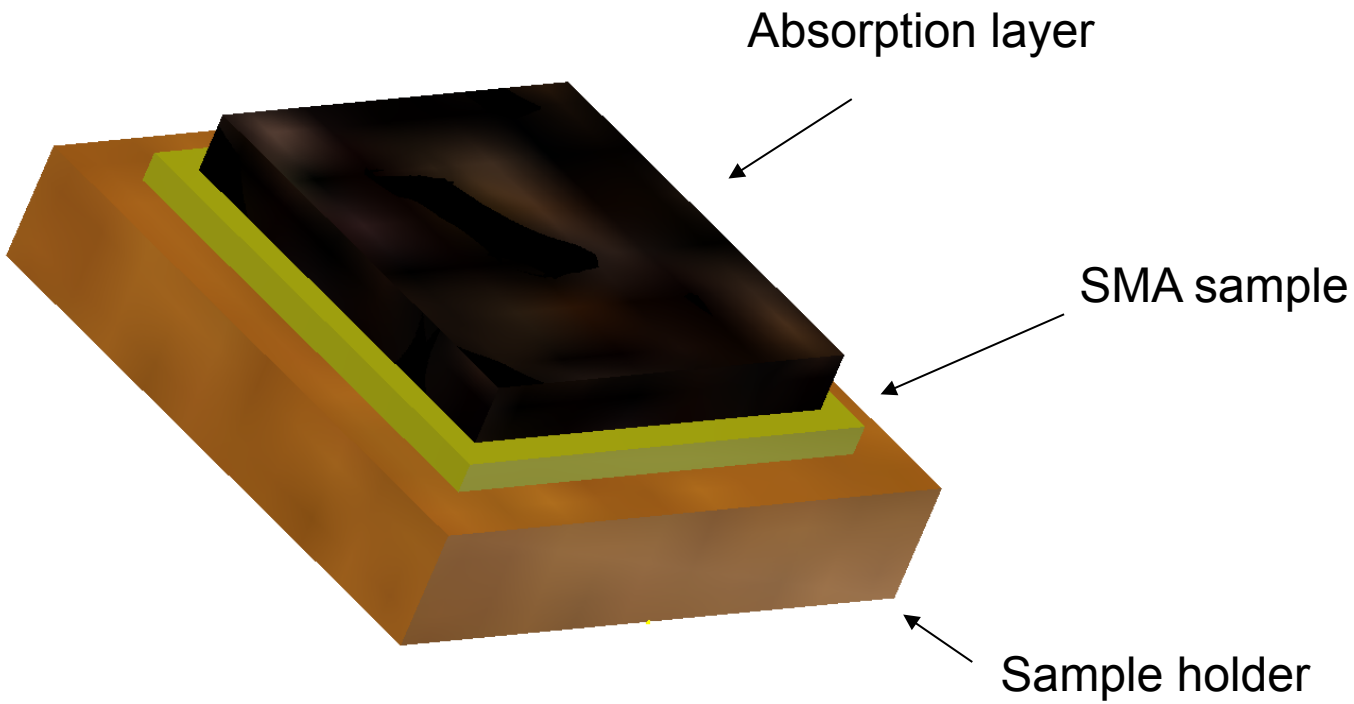
- Two types of absorption layers
  - Commercially available carbon laquer
  - Custom developed „gold black“

➢**Do these absorption layers influence the observed SMA‘s surface temperature?**

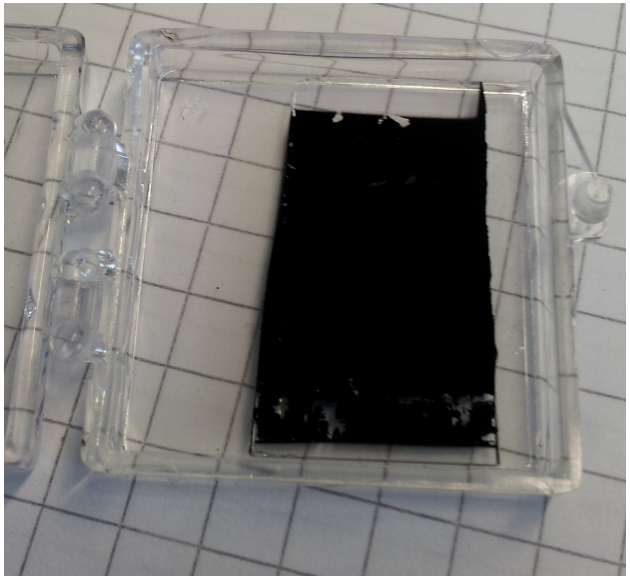
Absorption layer

Backside view

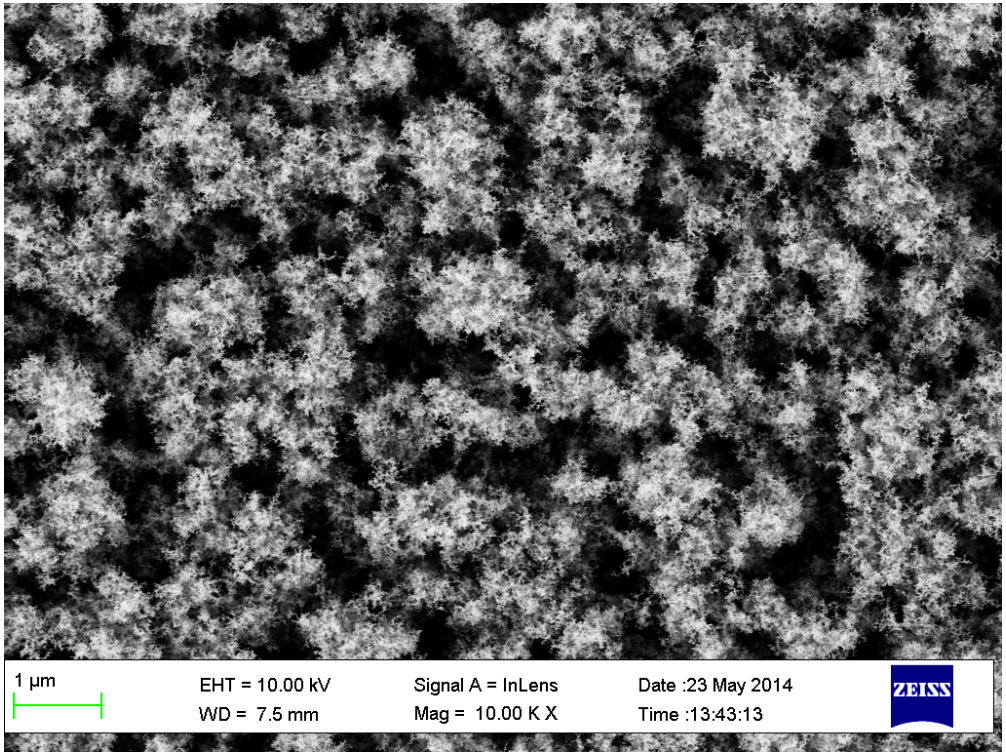




Absorption layer



„Gold black“ on glass



SEM Image of Gold black

Simulation

- Heat transfer in porous media

- Input parameters are determined experimentally
  - Layer thickness: 3µm (AFM)
  - Volume fraction: 0.05 (SEM)
  - Thermal conductivity and heat capacity: bulk values

$$(\rho c_p)_{\mathrm{eq}} \frac{\partial T}{\partial t} + \rho c_{\mathrm{p}} \vec{u} \cdot \vec{\nabla} T = \vec{\nabla} \cdot (k_{\mathrm{eq}} \vec{\nabla} T) + Q$$

$$(\rho c_p)_{\mathrm{eq}} = \theta_{\mathrm{p}} \rho_{\mathrm{p}} c_{p,\mathrm{p}} + (1 - \theta_{\mathrm{p}}) \rho c_{\mathrm{p}}$$

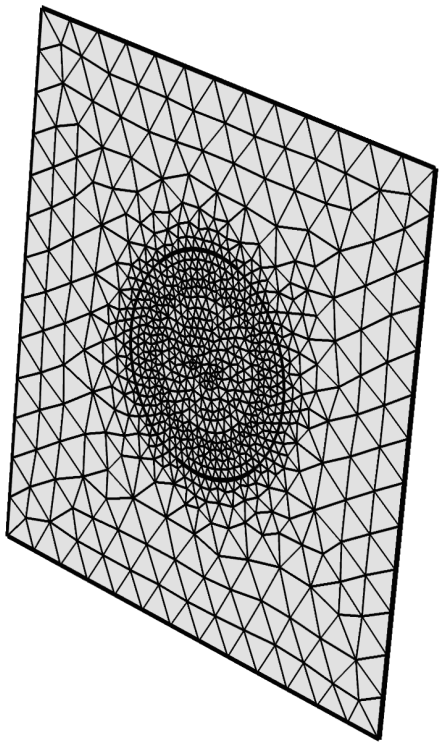
$$k_{\mathrm{eq}} = \theta_{\mathrm{p}} k_{\mathrm{p}} + (1 - \theta_{\mathrm{p}}) k$$

Simulation

- Flat structure (5 mm lateral, 3 µm thickness)
- Automated meshing routines fail
  - ➢Swept mesh

Boundary conditions

- Inward heat flux
- Surface to ambient radiation
- Constant temperature

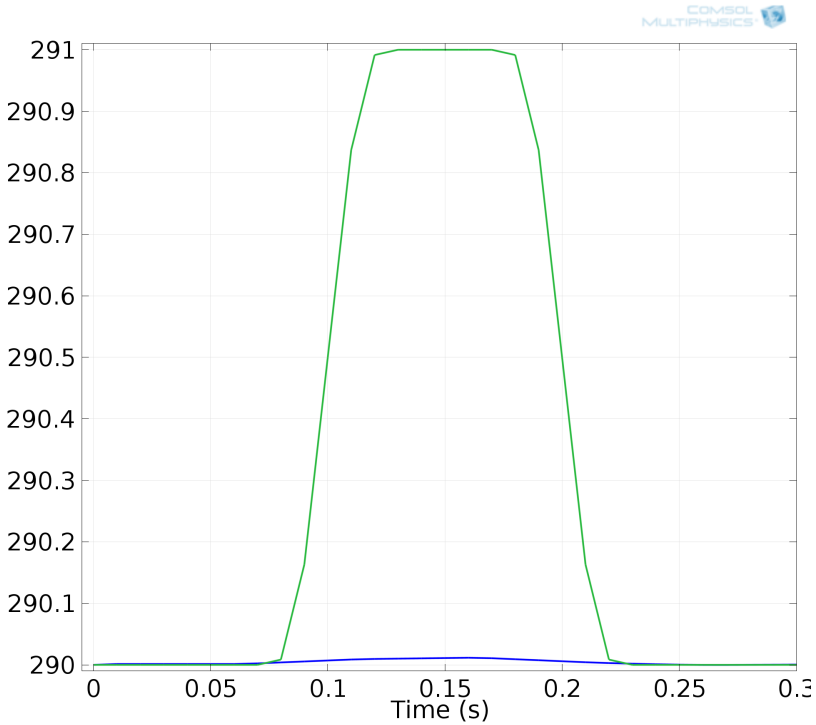


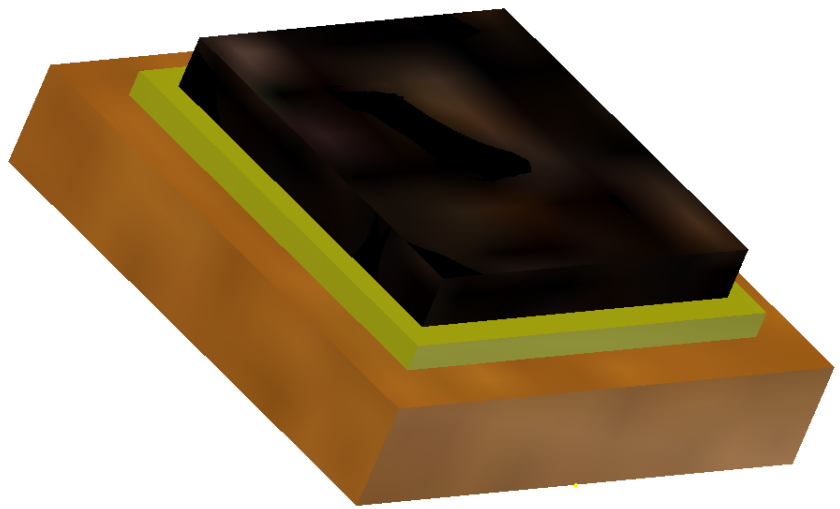
swept mesh

Results

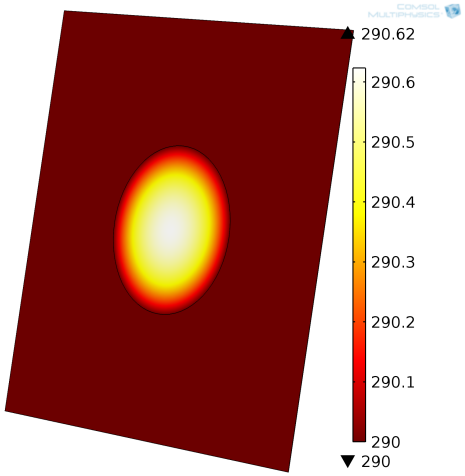
Commercially available carbon black

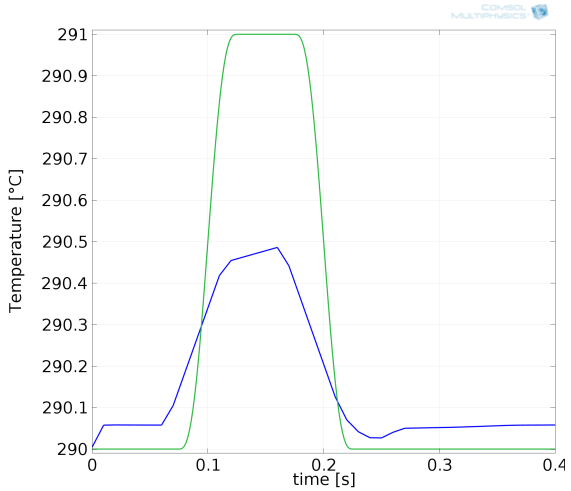
- Heat pulse: 1K
- Surface temperature change: 0.01K
- Cannot be detected

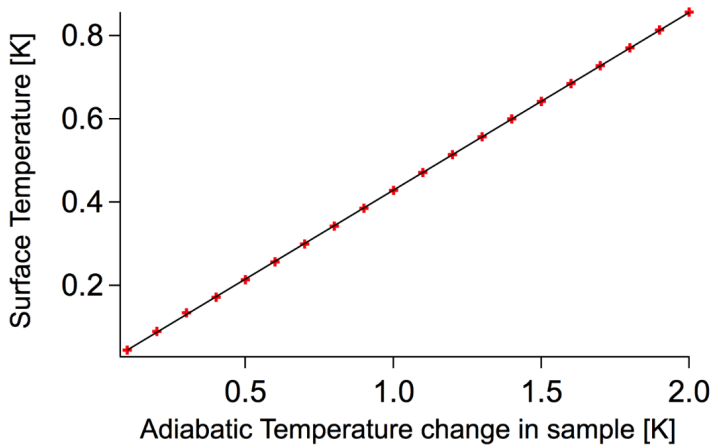




Results: Gold blacks







- Parametric sweep for different heat pulses

➢Linear relation

➢Gold black is an appropriate choice as absorber material

➢Result can be used for calibration of IR sensor

Conclusion

- Gold black absorption layers can be fabricated by thermal evaporation
- Heat transfer in porous media
- Commercially available carbon black is inappropriate for thin films
- Gold blacks are a proper choice for thin SMA samples

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