Multiphysics Simulation of Micro-Thermoelectric Generators Based on Power Factor Optimized Materials

V. Barati, H. Reith, D. A. Lara, G. Li, G. Schierning, K. Nielsch
Leibniz Institute for Solid State and Material Research, Dresden, Germany
Contact: v.Barati@ifw-Dresden.de

Motivation:

- Micro thermoelectric generators (µTEG) convert heat direct into electrical energy [1]
- Promising candidates for autonomous sensors (IoT)
- Design optimization for max. Power output by COMSOL Multiphysics®

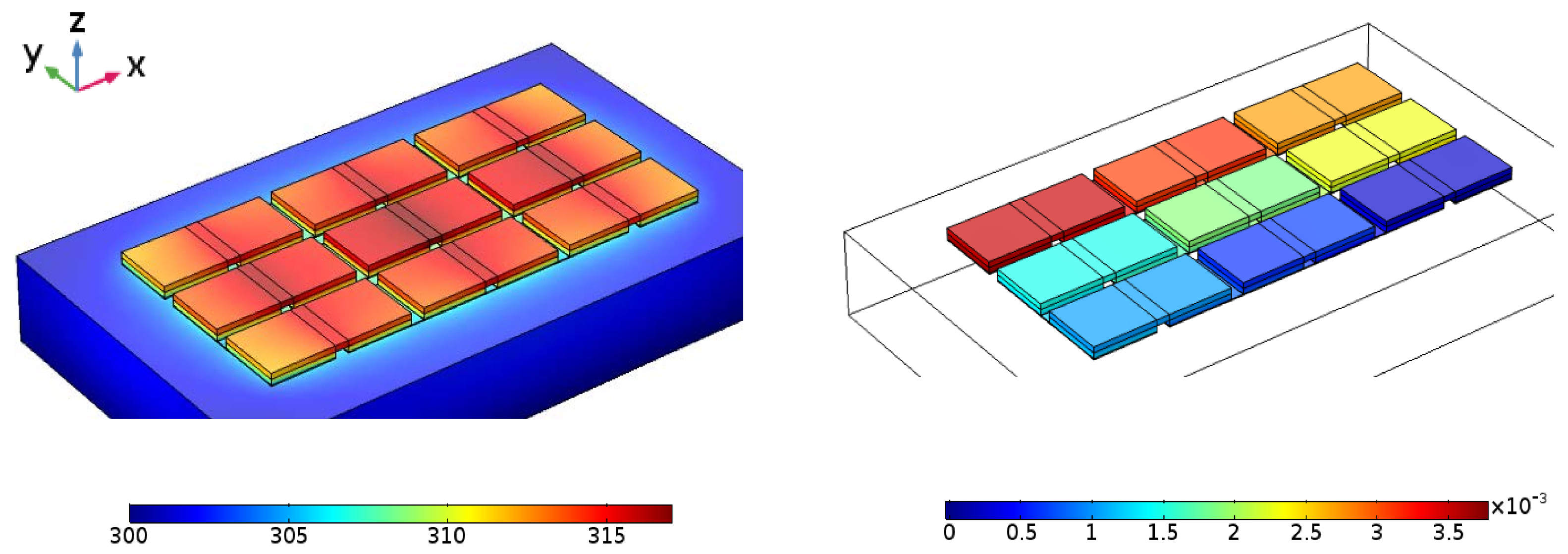


Figure 1. Temperature and voltage distribution of µTEG

Computational Methods [2]:

Heat transfer: $\rho C_P \frac{\partial T}{\partial t} + \nabla . q = Q$, $q = -k\nabla T$

Electronic Currents (ec): $\nabla . J = 0$, $J = \sigma E + J_e$, $E = -\nabla V$

Thermoelectric effect: $q = PJ$, $P = \alpha T$, $J_e = -\sigma \alpha T$

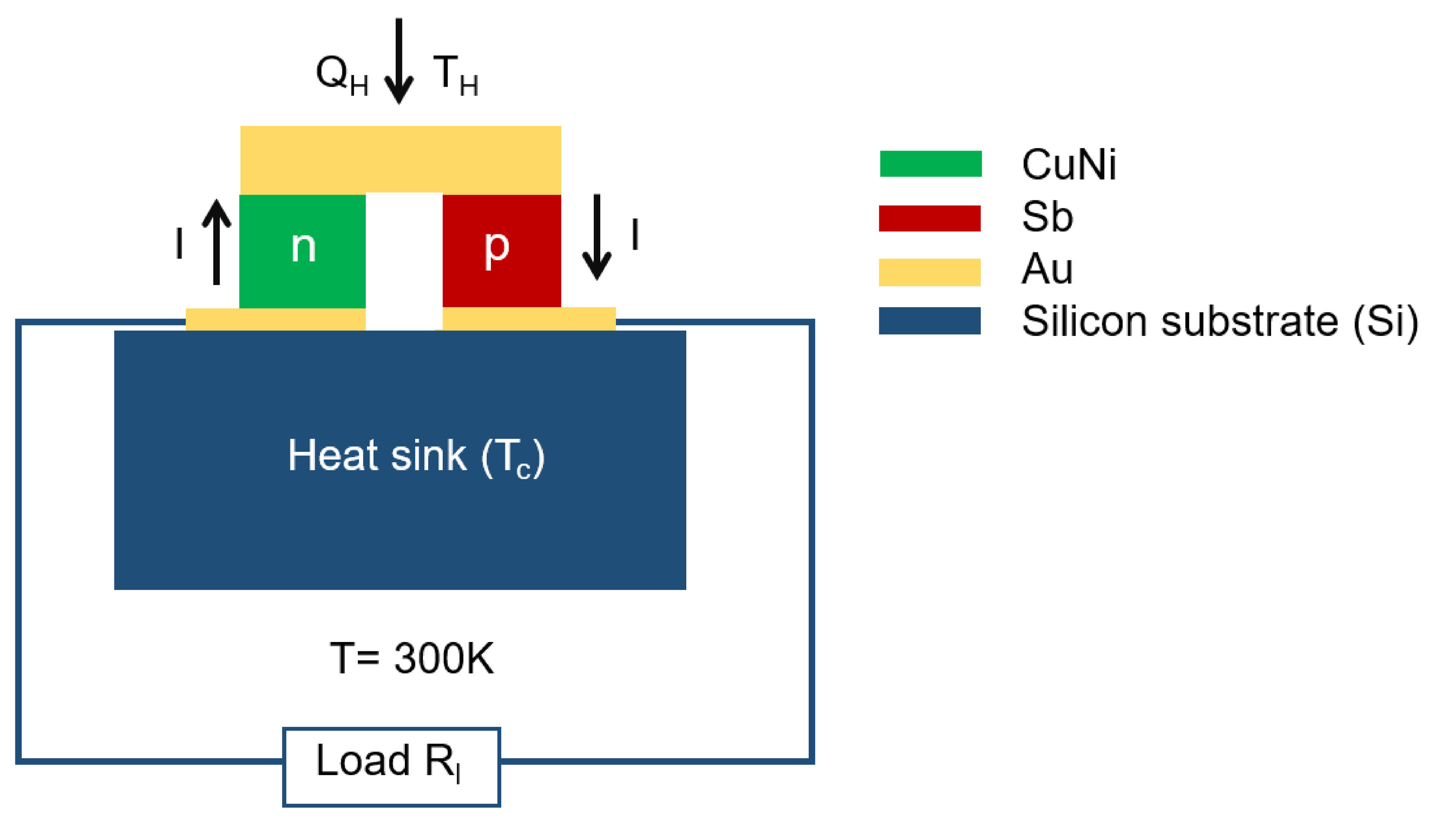
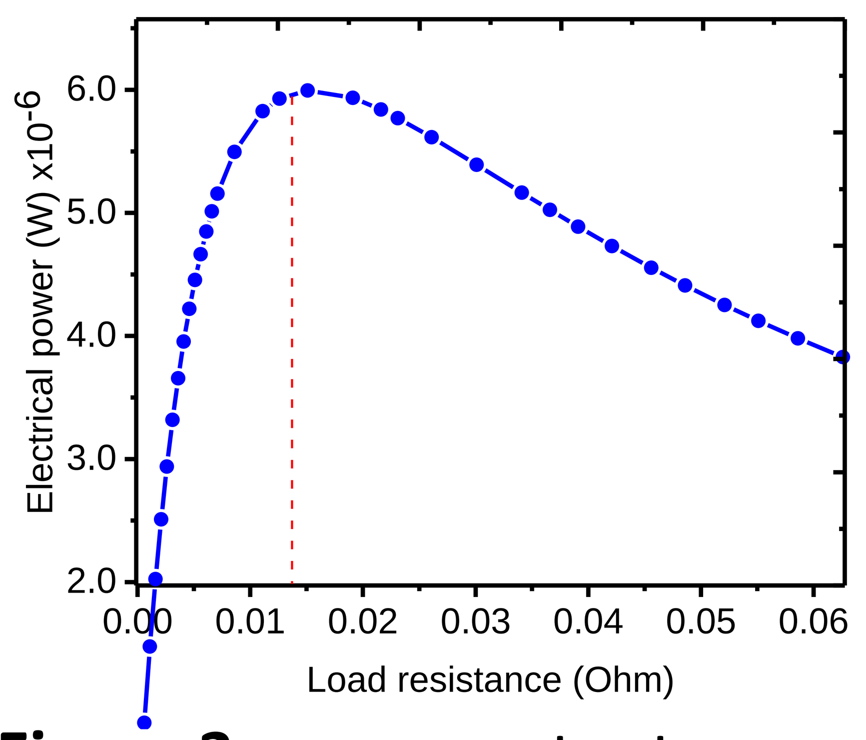


Figure 2. Schematic setup of a µTEG with boundary conditions



Parametric sweep of the load resistor (R_{load}) to determine the optimal power output.

$$R_{load} = R_{internal}$$

Figure 3. power output across load resistance

Material	Dimensions [µm]	Electrical conductivity	Thermal conductivity	Seebeck coeff.
CuNi	50x50x20	2.0E6 S/m	22 W/mK	-41 µV/K
Sb	40x50x20	2.6E6 S/m	25.5 W/mK	32 µV/K
Au	40x50x3 40x50x10	4.88E7 S/m	319 W/mK	6.5 µV/K
Si	300x210x150	-	130 W/mK	-

Table 1. material properties used in simulation

Results:

- Design study with varied heating power was performed at a single leg pair
- Study of the parasitic heat in the substrate (heat sink condition)
- Influence of the contact film can be neglected
- Min. Voltage for DC/DC converter~10mV can be achived with 25 leg pairs (Demonstrated case)

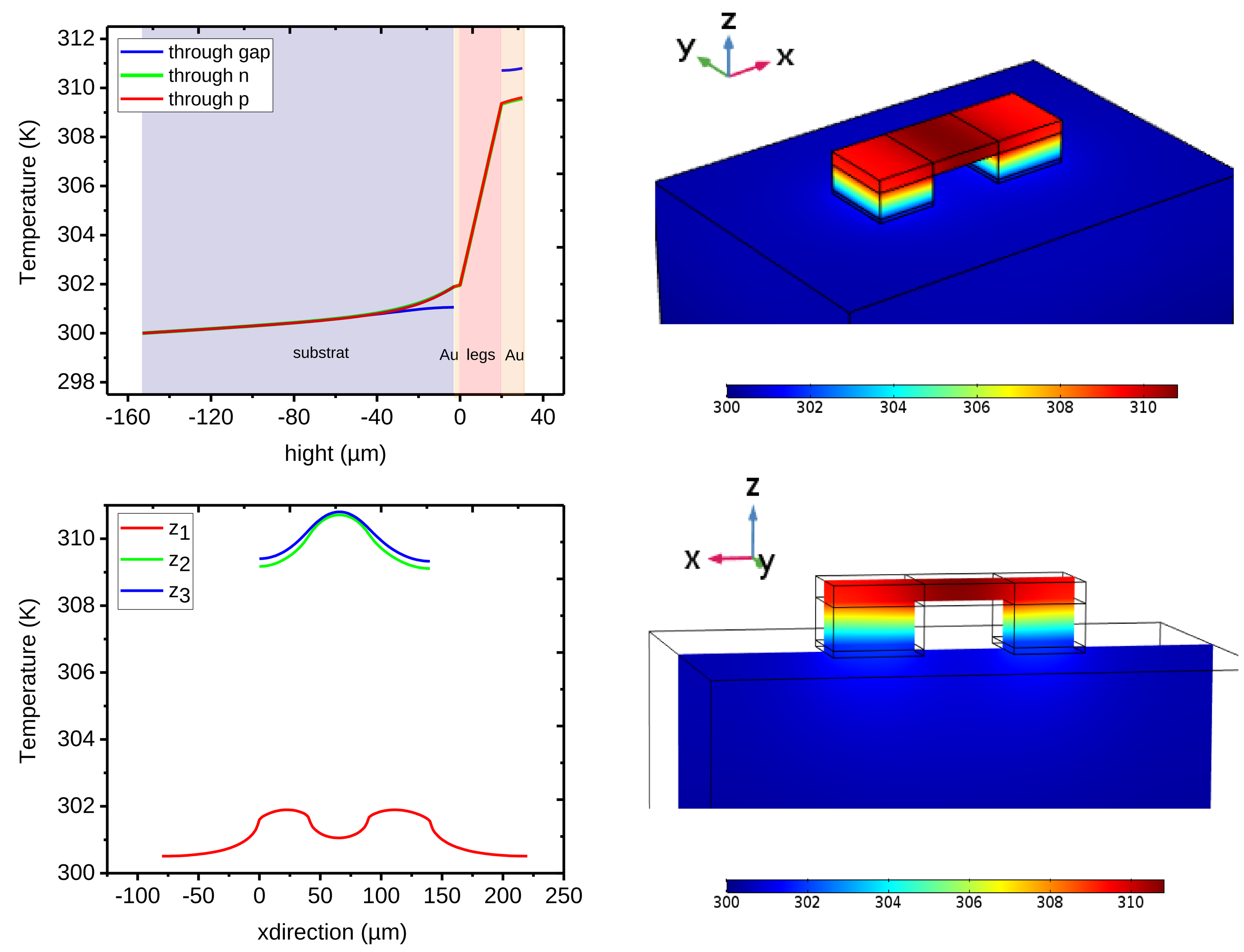


Figure 4. temperature distribution of µTEG with a heating power of 0.04 W

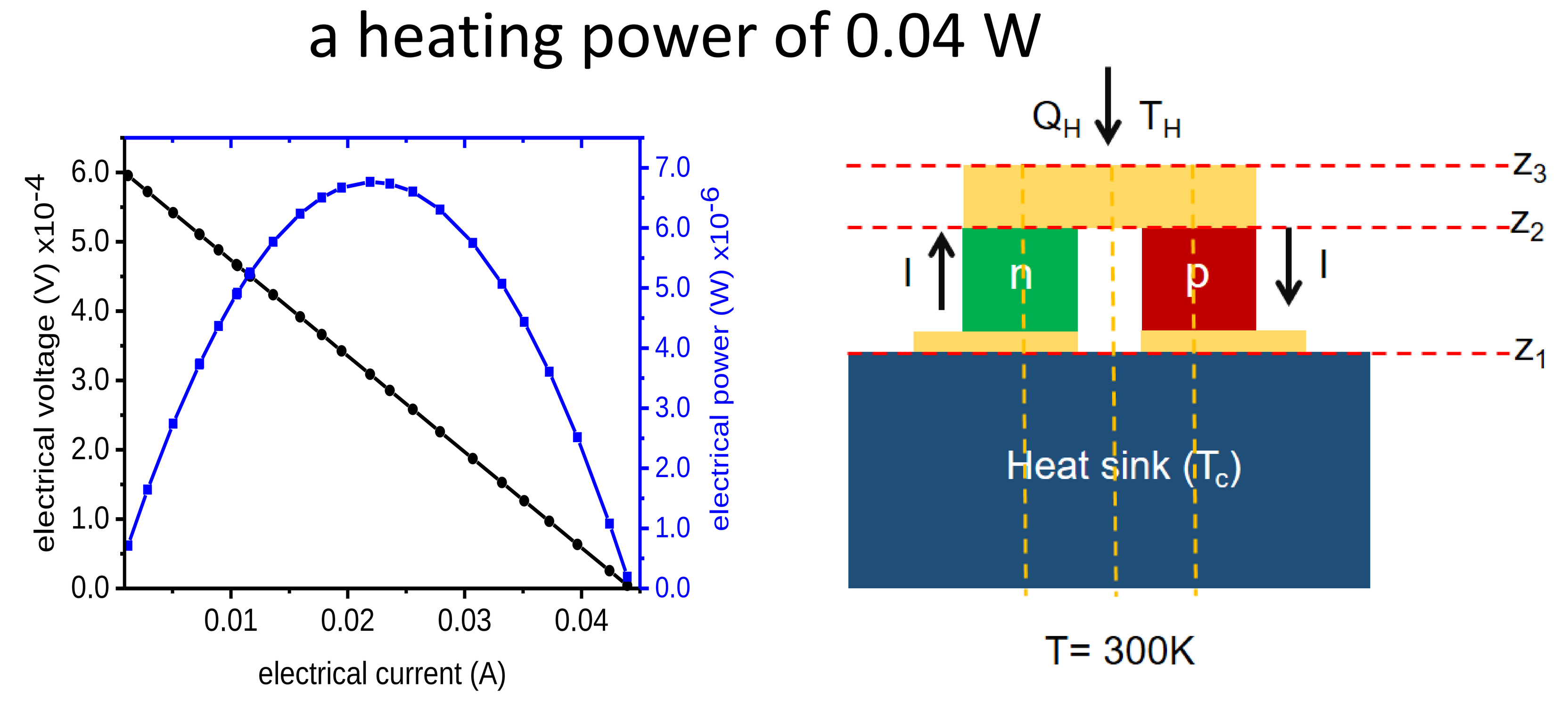


Figure 5. power and voltage- Current of µTEG

Conclusions:

- Utilizing of COMSOL® to analyze temperature and electrical characteristic of µTEG
- A finite element model allows a design optimization as well as a development of best practices for the manufacture of the µTEG.

References:

1. Goldsmid, H. J., Introduction to Thermoelectricity, Springer (2010)
2. COMSOL Multiphysics 5.3 Documentation, www.comsol.com