Electrothermal FEM Simulation of Uncooled Titanium-based Microbolometer

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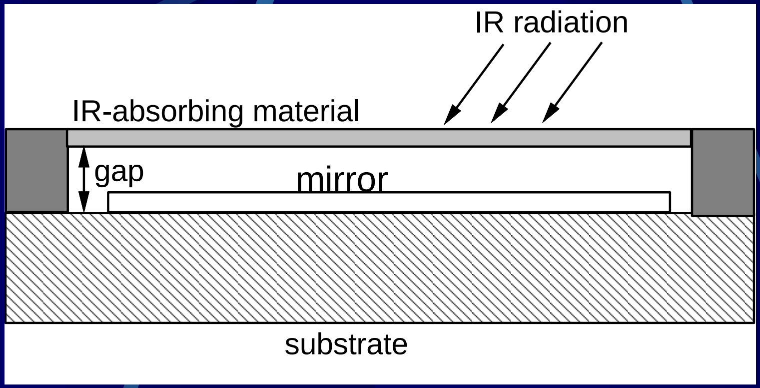
Agenda

- Microbolometer description
- Presentation of simulated structure
- Simulation principle
- Simulation results
- Conclusions

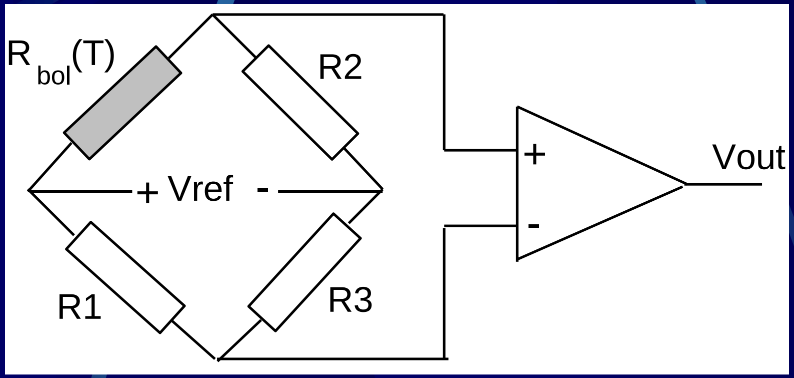
Microbolometer



Simplified microbolometer structure

- Allows measuring electromagnetic radiation
- Normally used in thermal cameras (any body emits IR radiation depending on its temperature)
- Radiation heats up the IR-absorbing material, which changes its resistance
- Mirror reflects back the radiation which passes through the material
- Gap thermally isolates the IR-absorbing material from the rest of the structure

Measuring circuit



- Based on Wheatstone bridge
- Allows measuring even very small changes of resistance
- Measurement is independent of the reference voltage
- Bias current flows through the microbolometer

Microbolometer is not only heated by radiation, but also by Joule heat from bias current

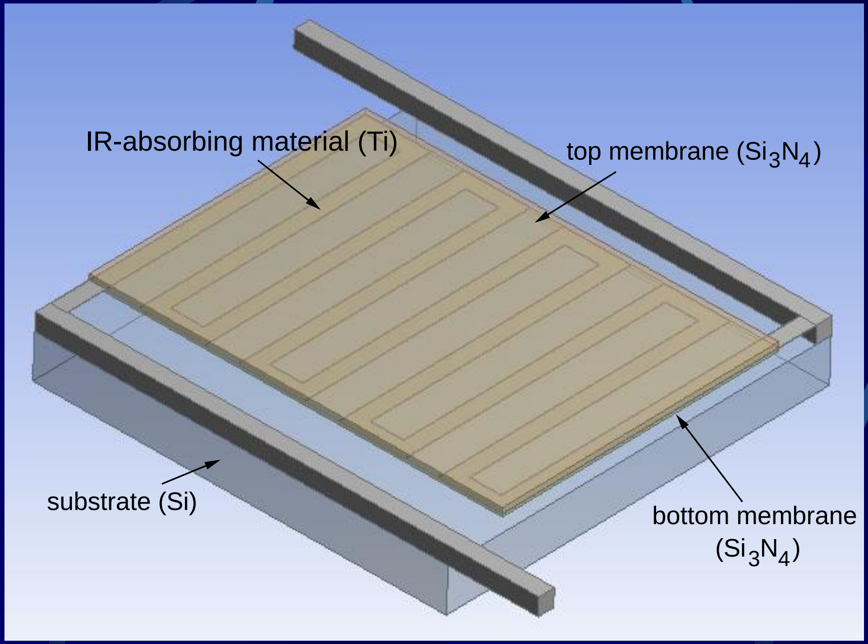
Analyzed problems

- How much the device heats up due to radiation?
- How much the device heats up due to bias current?
- What is the maximal bias current that we can apply to maintain the microbolometer temperature below given T_{max}?

Coupled electro-thermal simulation is needed

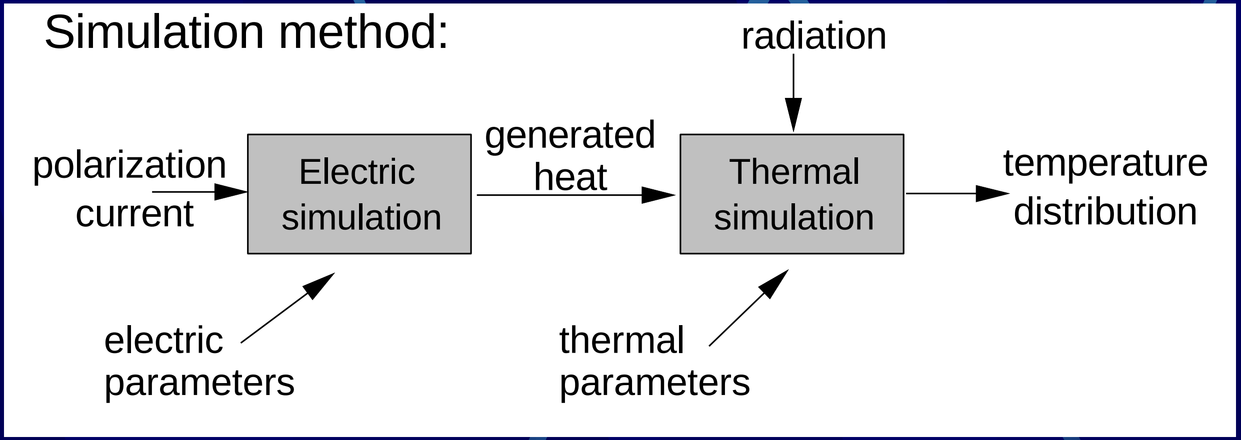
Finite element method (FEM) simulation in Ansys WorkBench environment

Simulated structure



- Structure designed in Ansys Workbench
- 50x50 um^2 total pixel size
- Absorbing material thickness: 0.07 um (titanium)
- Top membrane thickness: 0.6 um (silicon nitride)
- Bottom membrane thickness: 0.35 um (silicon nitride)
- Absorbing material hangs 2 um above Si substrate

Simulation principle



- Electric simulation: constant bias current is applied to microbolometer
- Result of electric simulation is the heat generated in the structure
- Thermal simulation takes into consideration generated heat from electric simulation and radiation, which is modeled as a constant heat flow

Three simulated cases

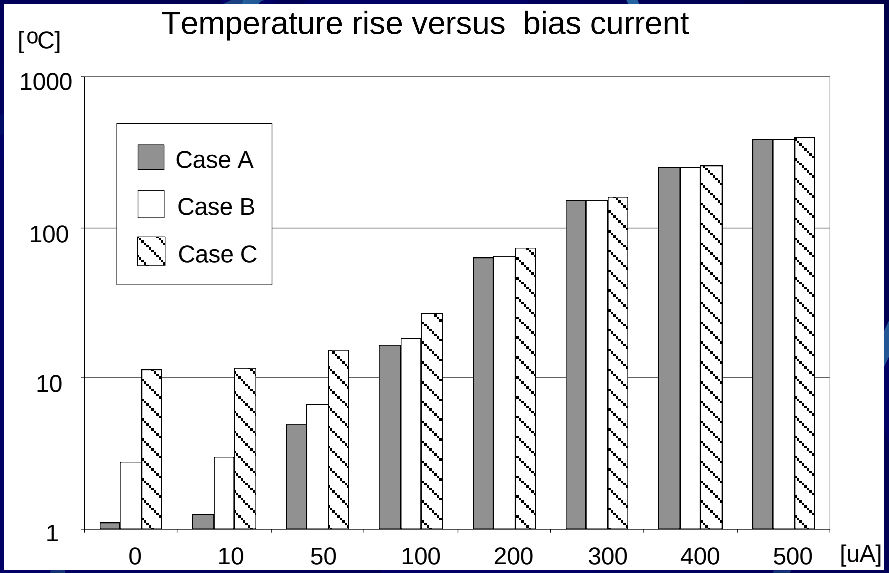
- Case A: the measured temperature is 100ºC
- Case B: the measured temperature is 200ºC
- Case C: the measured temperature is 400ºC

Stefan-Boltzmann Law: $j = \varepsilon \, \sigma \, T^4$

(assumed emissivity=0.6)

- Case A: the radiation power density equals 0.066 W/cm^2
- Case B: the radiation power density equals 0.17 W/cm^2
- Case C: the radiation power density equals 0.7 W/cm^2

Simulation results

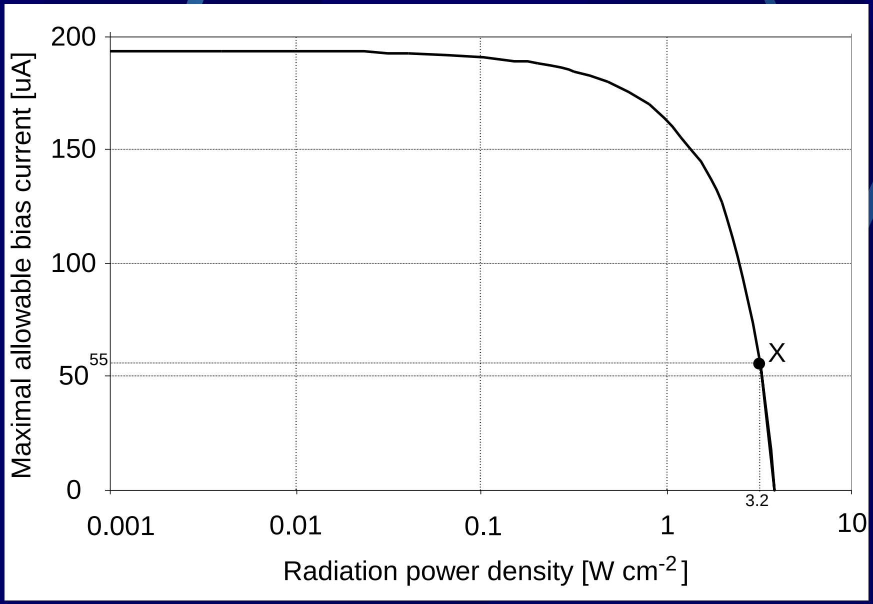


Maximal steady-state temperature rise of the microbolometer as a function of polarization current for various levels of radiation power absorbed by the device.

- Case A: impact of radiation-based heating is insignificant even for low current values
- Case B: impact of radiation-based heating is very small if bias current is above 50uA
- Case C: the impact of radiation-based heating is important and cannot be neglected

Simulation results 2

Question: what is the maximal bias current such that the microbolometer temperature does not exceed 80°C?



- For low radiation power densities the maximal bias current is almost constant
- When radiation power density exceeds 0.2 Wcm^{-2}, the maximal bias current value starts visibly decreasing
- For example point X means that for radiation power density equal to 3.2 Wcm^{-2}, the maximal bias current that we can apply is 55 uA

Conclusions

- New microbolometer model was designed in Ansys Workbench
- Obtained simulation results close to published experimental data
- Thanks to the model it is possible to calculate temperature rise due to bias current and due to radiation
- The model may serve as a useful tool during the process of designing microbolometers and may significantly reduce the time needed for the design
- In the future, authors are planning dynamic thermal simulations of microbolometers