Multiphysics FEM Simulations Approach for Development of MEMS Heat Generator

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Introduction: Accurate fluid temperature control in microfluidic channels is a requirement for many lab-on-chip and micro-reactors, especially in biotechnology and in chemistry where most process are highly temperature sensitive. Frequent applications utilize precise, controlled and localized heating to enable the required process taking place in microchamber closely coupled to the heating source.

Computational Methods: Theoretical analysis was performed by using three different models, in the first one the heat transfer inside materials of Pt/Ti microheater was analysed;

$$\rho C_p \frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left(k \frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(k \frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(k \frac{\partial T}{\partial z}\right) + Q$$

$$Q = I^2 R = \frac{V^2}{R}$$

the laminar flow model was used to study the fluid dynamics inside the micro-channel.

$$\rho \frac{\partial \mathbf{u}}{\partial t} - \nabla \cdot \eta\left(\nabla \mathbf{u} + (\nabla \mathbf{u})^T\right) + \rho(\mathbf{u} \cdot \nabla)\mathbf{u} + \nabla p = 0$$

$$\nabla \cdot \mathbf{u} = 0$$

With third model we studied mechanical deformation of materials caused by thermal stress.

$$-\nabla \bullet \sigma = \vec{F}$$

$$\sigma = \vec{D}\varepsilon$$

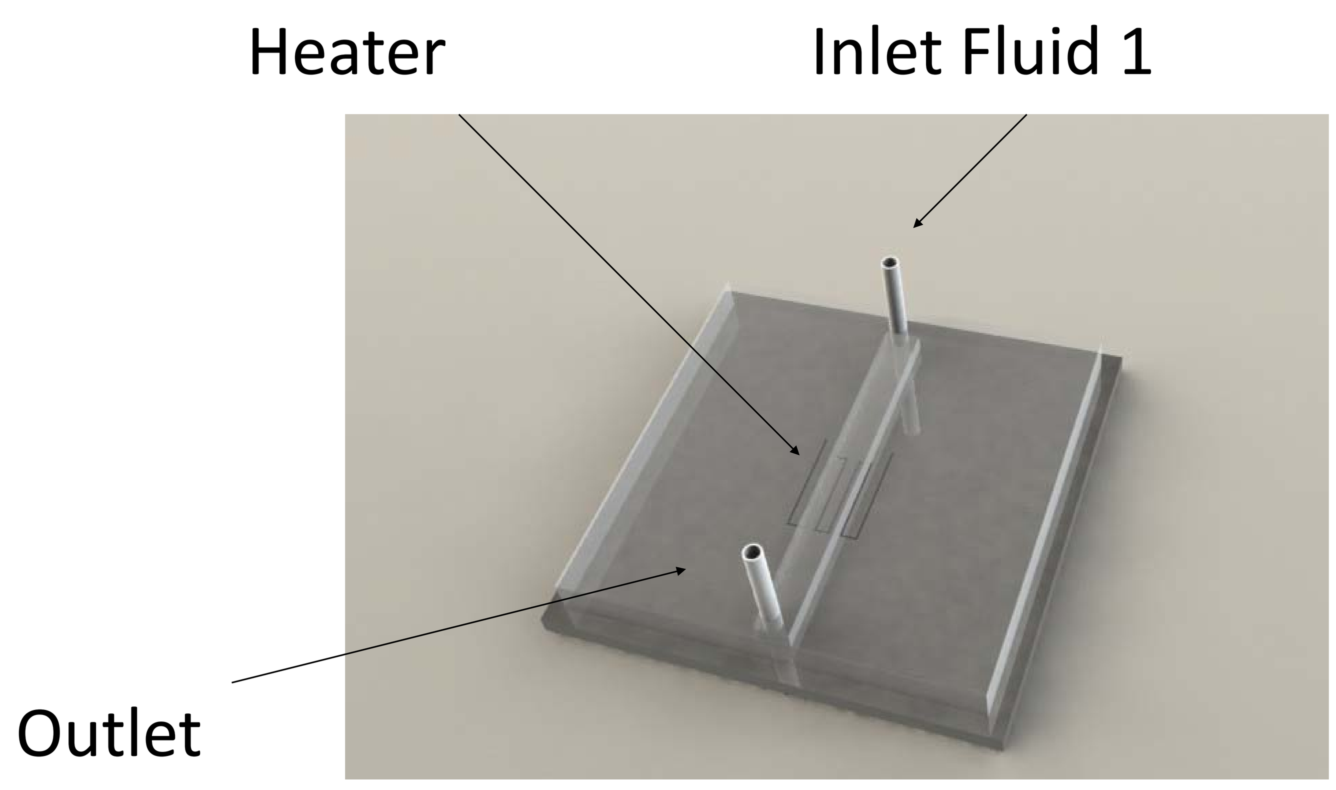

Figure 1. CAD rendering of device

Results: Numerical simulations and experimental data are compared. The values were acquired applying to the electrodes five different potentials starting with 5V to 30V. A perfect correlation was found

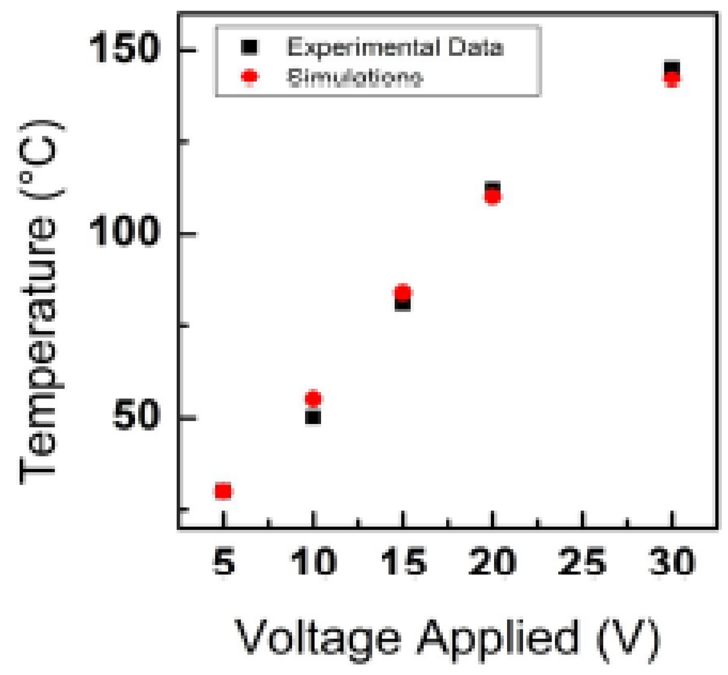

Figure 2. Theoretical and experimental data comparison of the temperature of the microdevice as a function of the voltage applied to the electrodes of the resistance.

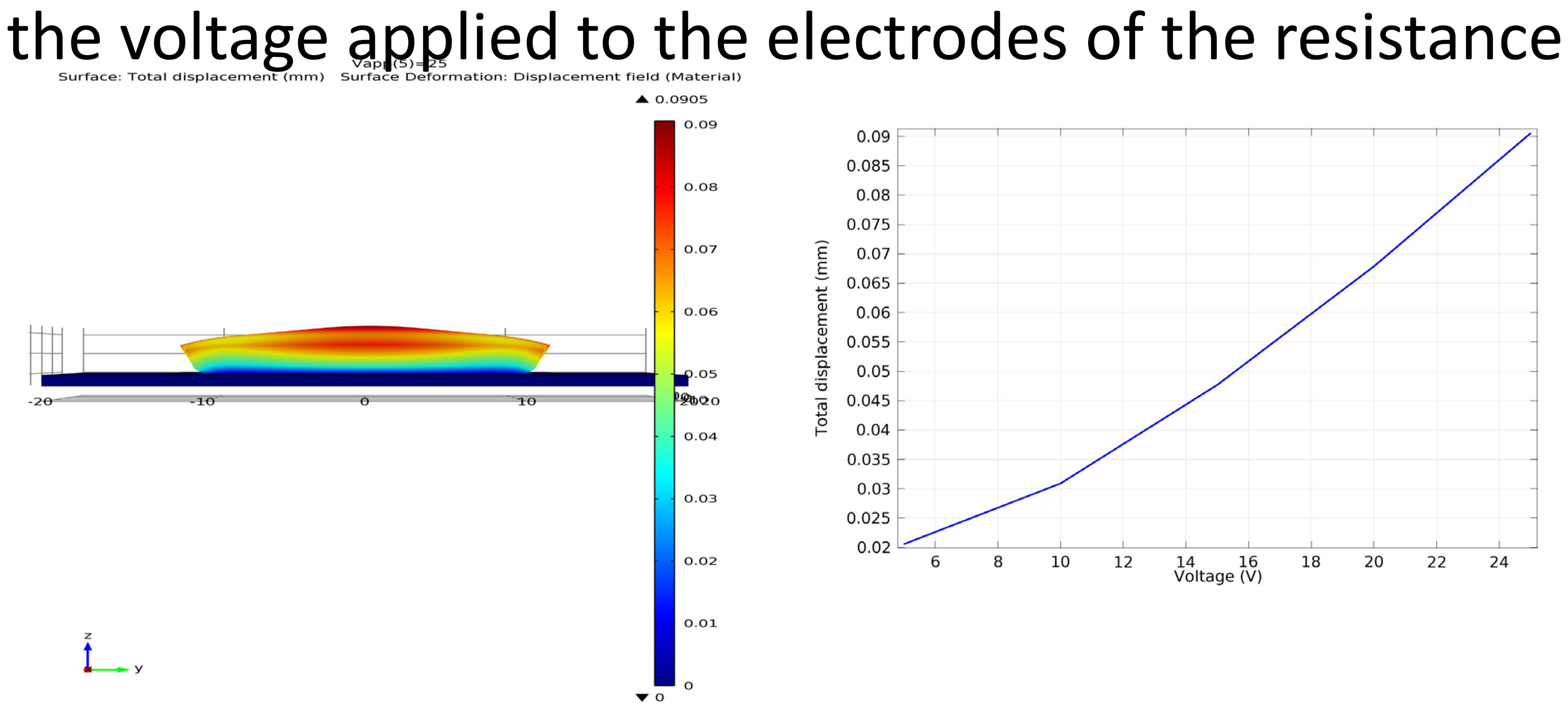

Figure 3. Total displacement as function of voltage applied to resistance

Conclusions: Good correlation between simulation and experimental data was obtained in the temperature range between 25 130 C. The good match between theoretical model and experimental data confirms the applicability of the model to study microheaters behaviour. Modifications of materials and geometries can be made using the explained model which can be used also to optimize the design of heater to reduce energy required for actuation even further.

References:
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