Multiphysics FEM Simulations Approach for Development of a MEMS Heat Generator

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Abstract

Introduction: Accurate fluid temperature control in microfluidic channels is a requirement for many lab-on-chip and micro-reactors. Frequent applications utilize precise, controlled and localized heating to enable the required process taking place in microchamber closely coupled to the heating source. Before realizing a new microdevice it is important to predict how this system will operates, under given physical or chemical condition, in order to optimize the realization time, the cost of materials and to understand what are the limits of the device. In this work we have designed and developed a microfluidic system based on a single channel integrated with a Ti/Pt micro-heater useful for biosensors applications. The fabrication of this microfluidic device is based on standard photolithography techniques for master realization. Thin films resistive metal heaters have proven to be the best choice for localizing heating applications with integrated microfluidic systems. A thin platinum layer has been chosen as the metal used to realize the meander because of its positive and linear temperature dependence. Other optimal characteristics of platinum, given the application, are an excellent long-term stability, chemical inertness, a well-established manufacturing processe,s and good mechanical properties. The goal of this work is the modeling, design and fabrication of a microfluidic system integrated with a Ti/Pt film microheater to control the temperature ranging between 20-130 °C potentially useful in liquid phase optical sensing application (Figure 1).
Use of COMSOL Multiphysics: A theoretical analysis and computer simulation has been performed in order to understand the effect of heat transfer from the Ti/Pt meander to liquid by Joule heating effect. The theoretical analysis was performed by using two separated models, in the first one the heat transfer inside the Pt/Ti microheater was analyzed and in the second one the effect of the heat transfer in the presence of water liquid flow inside the microchannel was investigated. In the third one a structural mechanics model was integrated to study the mechanical behavior of materials as consequence of thermal stress. The laminar flow model was used to study the fluid dynamics inside the microchannel. In the simulation process the temperature of the inlet fluid was set at room temperature value and the coupling with heat transfer model allowed us to verify the increase of fluid temperature at the outlet.
Results: In Figure 2 are reported a sequence of images showing the variation in temperature of the device as a function of the applied voltage to the electrodes. A comparison with numerical simulations is also reported. The images were acquired applying to the electrodes five different potentials ranging between 5 to 30V and a perfect correlation between the simulated thermal

distribution and the experimental measured values is evidenced in Figure 3. The micro-heater was designed and characterized by using a finite elements method to evaluate and calibrate the suitable temperature values as function of power consumption. Good correlation between simulation and experimental data was obtained. We observed that the total displacement of PDMS cause by thermal stress doesn't affect the device. Applications are expected to be in the optical biosensors field.

Reference

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Figures used in the abstract

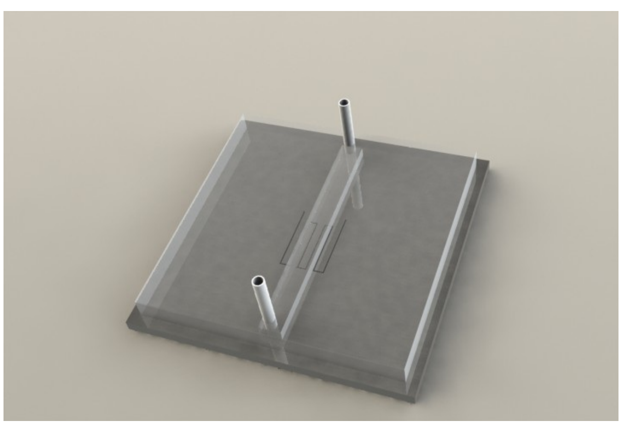

Figure 1: CAD design of device.

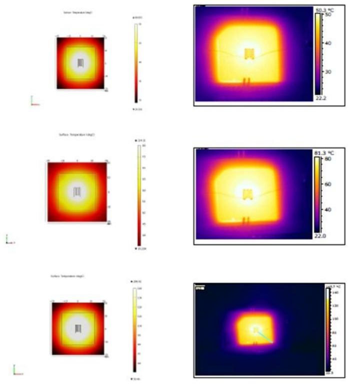

Figure 2: Heat transfer evaluated with simulations and thermalcam.

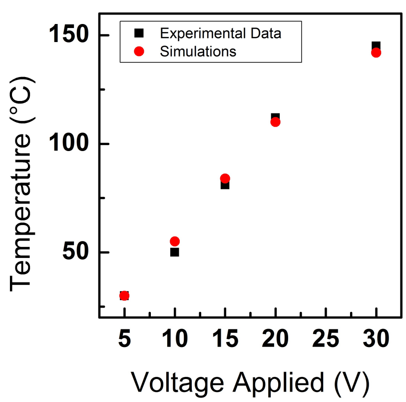

Figure 3: Comparison between simulations and experimental data.