

Design Study for An Electro-Thermally Actuator for Micromanipulation

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Abstract. A new design for a polymeric microgripper was developed. Two microgrippers with different dimensions were considered. An evaluation between these models was performed using the simulation results. Finite-element analyses of the microgripper, using COVENTORWARE, are performed in order to evaluate the relation between the displacement, temperatures and the electrical current passing through the metallic layers.

Key words: micromanipulation, microgripper, SU-8 polymer, electro-thermal actuator.

1. Introduction

In last years a variety of microgrippers have been developed for the manipulation of micro-sized objects. Microgrippers are needed for handling and assembly of microparts, for manipulation of biological samples, and for microassembly. In general, microgrippers consists of a pair of tweezers that grab the objects, and an actuator that provides the required force.

Different kinds of materials were chosen to fabricate the microgripper structures, to make the tips compatible with the micro objects gripped.

Polymers as SU-8 are an attractive feature in the MEMS design [1–6]; SU-8 has elastic properties and provides good grasping and safe insulation [2]. Because of its properties, SU-8 polymer can be used in a great variety of bio-MEMS applications [4, 5].

Different kinds of actuations were used: electrostatic, electro-thermal [7, 8], piezoelectric, etc.

This paper presents the development of a new microgripper for micro-assembly and micro-biological applications. An electro-thermally driven microgripper was studied using computer simulations (the Finite Element Method simulations using CoventorWare 2006 software tools). The microgripper consist of some significant parts as named “hot and cold underarms” which have different widths. These arms will have the function to give the deflection in plane of the free microgripper arms.

The temperatures reached in the arms and the deflections of the tips of the microgrippers as function of voltage were investigated.

Two microgripper models having different dimensions were analyzed. Both models were composed by one single metallic layer, with a serpentine shape on the hot arms, between two polymeric layers. This composition design it was chosen in order to have a minimum out of plane deflections.

The new design demonstrates that a low voltage value can be applied on the metallic layer in order to obtain large displacements of the microgripper arms as a result of electro-thermally actuation of the microgrippers and to be able to gripe a micro-object.

2. Design configuration

The microgripper structure consists of some major parts: the fixed part, hot and cold underarms, arms and heaters.

The main dimensions of the first microgripper are $200\ \mu\text{m} \times 200\ \mu\text{m} \times 236\ \mu\text{m} \times 20.6\ \mu\text{m}$. The length of the free arms is $400\ \mu\text{m}$, $2\ \mu\text{m}$ is the thickness of the thermal oxide layer (SiO_2), $20\ \mu\text{m}$ the thickness of the polymer layer (SU-8), $0.3\ \mu\text{m}$ the thickness of the Chromium/Gold layer (which is deposited between two SU-8 layers of 10 micrometers thickness each) (see Fig. 1a).

For the second model the dimensions are two times bigger than first microgripper: $400\ \mu\text{m} \times 400\ \mu\text{m} \times 472\ \mu\text{m} \times 20.6\ \mu\text{m}$. The length of the free arms in this case is $800\ \mu\text{m}$, $2\ \mu\text{m}$ is the thickness of the thermal oxide layer (SiO_2), $20\ \mu\text{m}$ the thickness of the polymer layer (SU-8), $0.3\ \mu\text{m}$ the thickness of the Chromium/Gold layer (which is deposited between two SU-8 layers of 10 micrometers thickness each) (see Fig. 1 b).

In Fig. 2 can be observed the entire microgripper, with one metallic layer between two polymeric layers. This is the 3D model constructed and used in simulations with CoventorWare 2006 tools.

The microgripper structure is initially in the open position with an opening distance of 20 micrometers.

The microgripper is designed to operate through an integrated thermal element which is controlled by applying a voltage. The application of a voltage to the metallic layers of the structure will produce the closing of the microgripper and an object can be gripped.

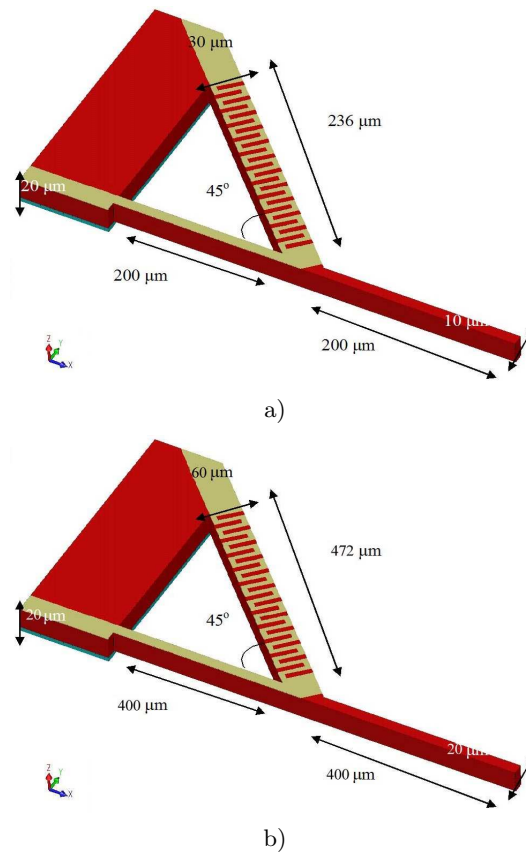


Fig. 1. Design of the half of microgripper model without the SU-8 layer on the top; a) first model; b) second model.

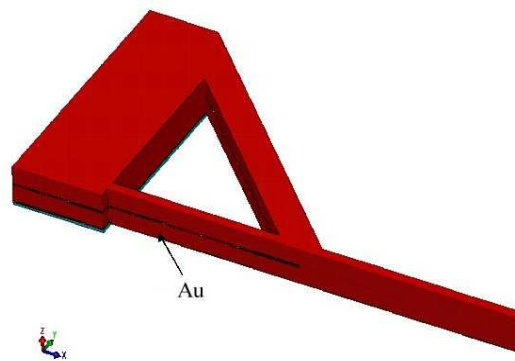


Fig. 2. Design of one arm of the microgripper-3D configuration, modelled with CoventorWare 2006 Tool.

3. FEM simulations

In order to describe the microgrippers behaviours in air as function of the applied voltage, coupled electro-thermo-mechanical simulations (using CoventorWare 2006) have been performed.

As thermal boundary conditions, necessary to be set for simulations, the initial temperature of the whole structure and the temperature of the environment were considered to be 27°C and the air convection coefficient was set to 20 W/m²K.

The model was meshed using hexahedral elements with 27 nodes and the numbers of volume element was optimised choosing the proper size of the mesh element.

In order to study the behaviour of the microgrippers, electro-thermal simulations were performed. The results can be observed in Fig. 3 (an example when 0.2 V is applied on the metallic layer) and Fig. 4. The maximum temperature values obtained were presented and compared for the two designed microgrippers.

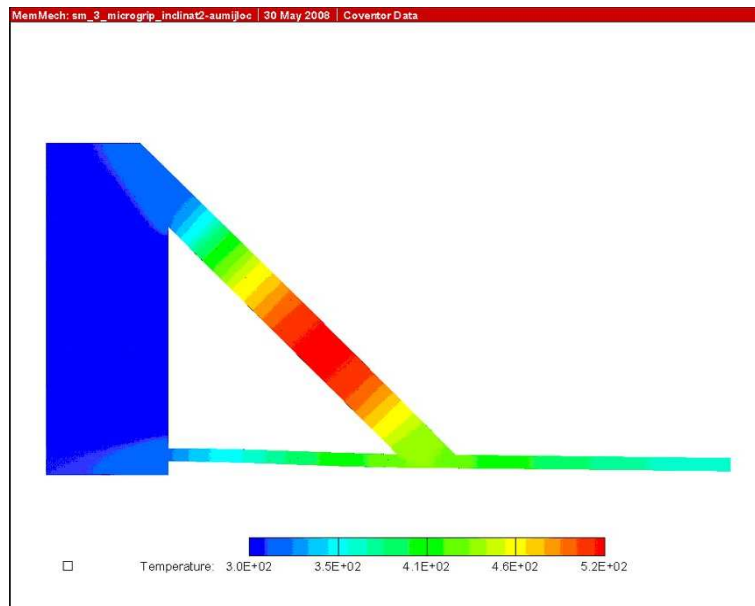


Fig. 3. The temperatures distribution on one arm of the microgripper - FEM Simulation.

For the second microgripper, a low temperature is reached for the same voltage values applied, compared with first model. The maximal values temperatures reached on the hot arms are very high but on the end of the free arms (tips) are below 100°C.

As a consequence of higher temperatures obtained on the hot arms, the polymeric material will expand and the tips will move to close the arms. An example of simulation result for deflection of one microgripper arm is illustrated in Fig. 5. In the next Fig. 6 an evaluation between displacements results of both microgrippers is presented. It can be observed that for the same voltage value the remaining distance between

the arms of the second microgripper is smaller. That means the second model, for which the temperatures obtained are lower, has a bigger deflection of the tips.

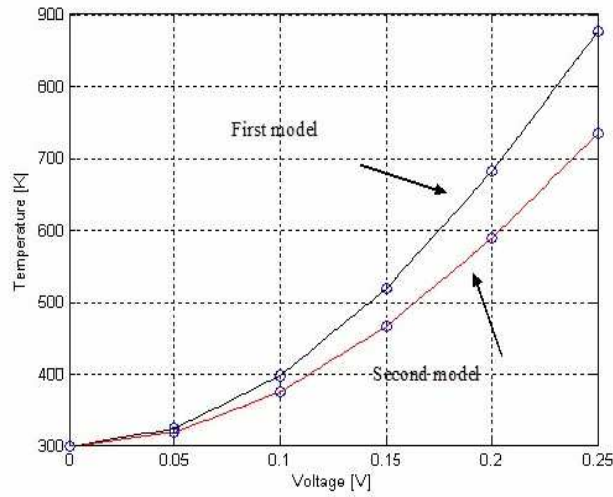


Fig. 4. The maximal values of the temperatures obtained in the microgrippers.

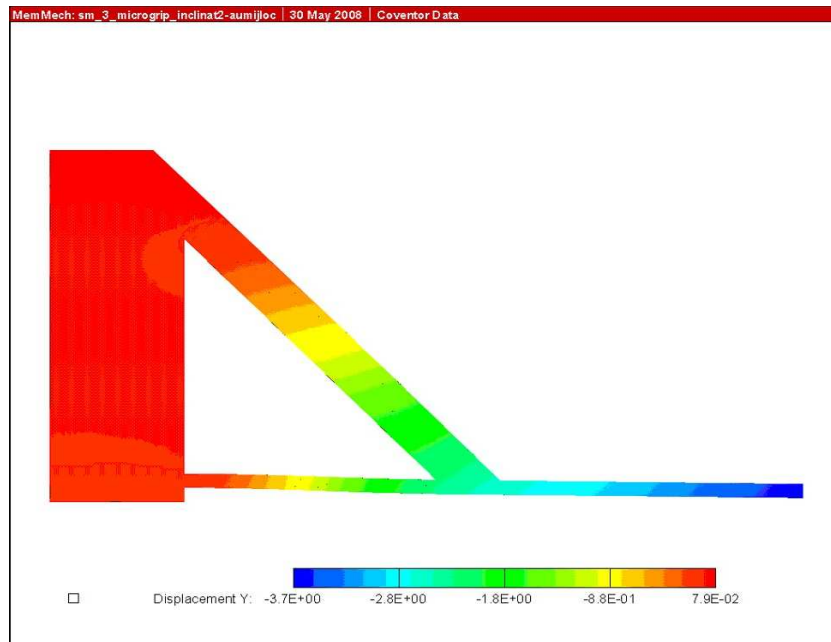


Fig. 5. The deflection of the arm of the microgripper- FEM Simulation.

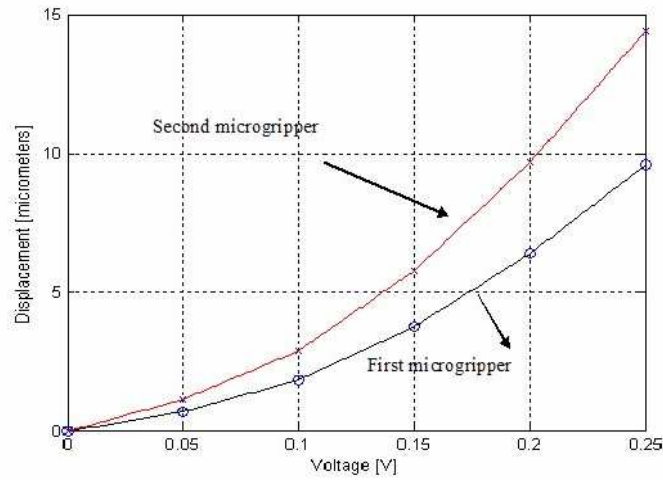


Fig. 6. Comparison of displacements of the tips for both microgrippers with oblique arms.

In [9] we have studied two microgrippers with straight arms and again different dimensions. We have obtained a difference for displacements results. In Fig. 7 we show the design of the microgrippers studied in [9] and in Fig. 8 it can be observed the displacements results.

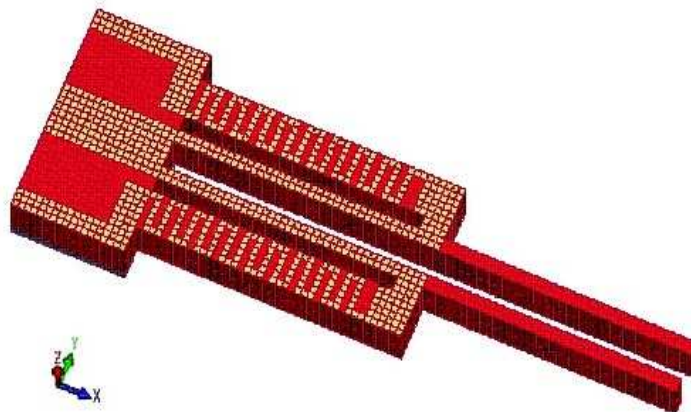


Fig. 7. The design of the microgripper with straight arms-3D model without the SU-8 layer on the top, used in CoventorWare simulations.

From Fig. 6 and Fig. 8 we can conclude that the microgrippers with the oblique arms show a larger displacement as the microgrippers with the straight arms for the same voltage value. These results make the new design suitable for using of the structure for micromanipulation.

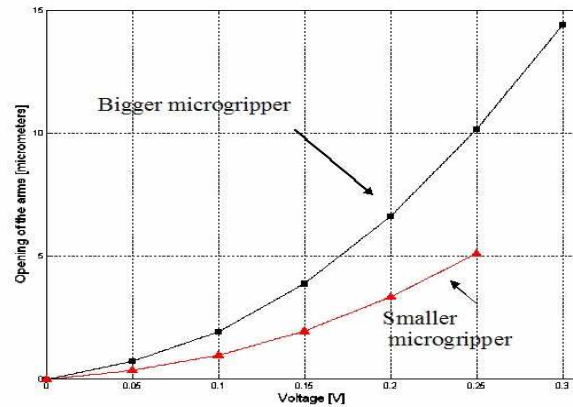


Fig. 8. Comparison of displacements of the tips for both microgrippers with straight arms.

4. Preliminary technological results

The experimental structures of the polymeric microgrippers have been designed for surface micromachining. It was used a 4- masks process. Cr-Au /SU-8 arms were manufactured.

To define the arms we started with the first SU-8 layer deposition and patterning. The polymeric layer was spun coated and hard baked at 150°C on a hot plate, obtaining a thickness of 20 μm (SEM image – Fig. 9). After, we deposited a Cr adhesion layer followed by a gold deposition, using evaporation. Following the configuration of the metallic resistors (SEM image in Fig. 9) we have to deposit and patterned the top SU-8 layer. As can be seen from the above pictures good aspect ratio was obtained, as preliminary result. Further work will be done in order to release the structures using SiO_2 as sacrificial layer.

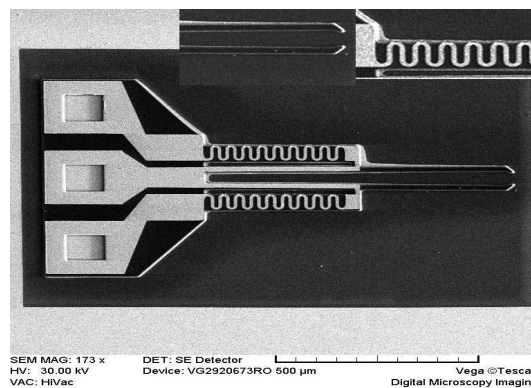


Fig. 9. SEM images of the tips of the structure, the metallic resistors and the structure layers with the straight arms.

5. Conclusions

A microgripper model with a new design was presented and analyzed. The maximum temperature values and the in plane displacements values were analyzed and compared. The behavior of the bigger microgripper seems to be more properly because the temperatures obtained are lower and in plane displacements are bigger.

We observed also that the displacements in the plane direction are higher for the second model and in consequence low voltage values are needed to actuate this structure, since the temperatures are lower.

The new design proposed and analyzed show that low voltage values are possible to be applied on the metallic layers, in order to actuate the microgripper and to obtain a proper opening of the free arms.

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