Quantitative infrared on screen-printed metallic electrothermal microactuators, comparison with a model

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Abstract

Microelectromechanical systems (MEMS) are of great interest in many applications fields including telecommunications, medical instrumentation, etc. At present, several physical principles have been used to conceive microactuators which are the best examples of MEMS. Among the different principles, it is well known that actuators based on the thermal expansion effect provide large planar displacements and output forces compared to those using the electrostatic actuation mode [1]. As polysilicon [2-4], metals [5] have been investigated as potential materials for electrothermal actuators. In comparison to silicon microactuators, the larger thermal expansion coefficient of metallic devices gives rise to greater deformations for a same temperature difference. Therefore, a metal actuator can operate at lower temperature with lower power consumption.

An alternative hybrid process based on a screen-printed sacrificial layer [6] has been here used for the fabrication of U-shaped [7] lateral electrothermal microactuators. Such actuators with larger active film thickness are likely to deliver strong output forces and energy.

Deflection measurements have been done on copper actuators and compared with finite element simulation results. To completely validate the working principle of the actuators, infrared measurements have been achieved to obtain the temperature profile along the actuator and the results are also compared with finite element simulations.

The asymmetric thermal actuator consists of two linked beams of different widths, partially suspended above the substrate to which they are bounded (Fig.1, left). When current passes through the actuator from one anchor (4) to the other (5), the higher electrical resistance of the thin beam (1) causes it to heat and expand more than the wide one (2), made with the same material. The actuator is constrained to deflect laterally in an arcing motion towards the cold arm.

The moving part of the actuator was fabricated using a new thick-film sacrificial layer process developed in the laboratory [6, 8]. The sacrificial layer acts as a stable mechanical support during the firing of the structural layer and is totally removed after the final thermal treatment of the sample in a weak acidic solution.

Copper actuators have been fabricated using the basic dimensions (170 µm width for the hot arm, 610 µm width for the cold arm, 3 mm length, thickness 60 µm). Whilst increasing dc voltage between both anchors of the electrothermal microactuator, the tip deflection d was optically measured using a calibrated CCD camera (Fig.1, right).

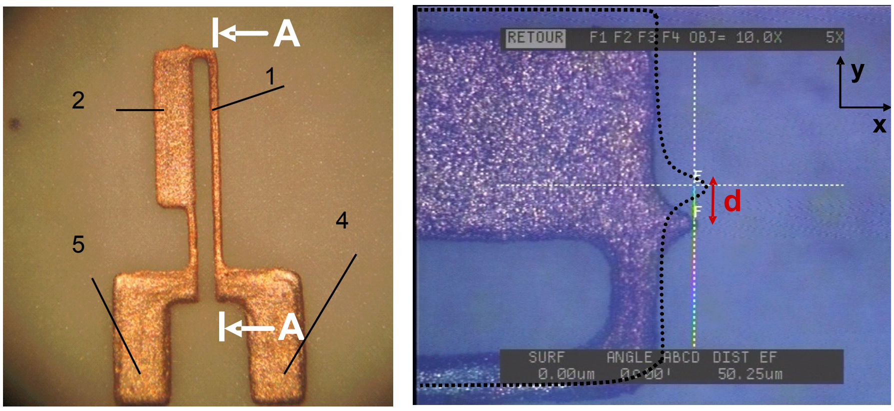
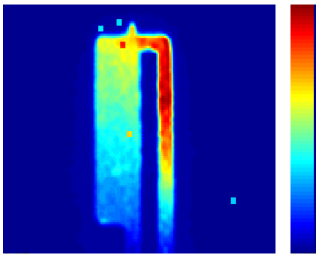


***Fig 1** Measurement of actuator tip deflection d.*

In order to simulate the behaviour of our actuators, we used a Multiphysics simulator based on the finite element method.

The MEMS is considered as a film, which means that the temperature is uniform across the section of the copper layer. It is thus considered as a lumped system along the thickness *d*. Temperature is a parameter difficult to measure accurately, especially for micron size microsystems. Actually, in a thermal microactuator high temperature gradients are distributed on a small thermal mass and temperature measurement must not interact with this temperature distribution. Thus, as a non-contacting measurement, infrared thermography has been used for about ten years as a thermal characterization technique of MEMS.

In our study, the thermography has been achieved with a Cedip J550M infrared camera. In order to make the emissivity of copper surface more uniform, a thin carbon layer (150nm) was deposited on the actuator by thermal evaporation. Infrared measurements were carried out for input power between 190 and 425mW. The results are compared with FEM simulation results in Fig.5 where we can notice that the location of the hottest part of the actuator is well calculated by the finite element analysis. For input powers between 190 and 425mW, maximum hot arm's temperatures between 345 and 434K are expected from FEM simulations. For the same input powers, infrared measurements revealed maximum hot arm's temperatures between 338 and 472K that are very close to the simulated temperatures. However, the average temperature difference between the hot arm and the cold arm seems to be higher in infrared measurements than in finite element simulation results (see Fig. 2).



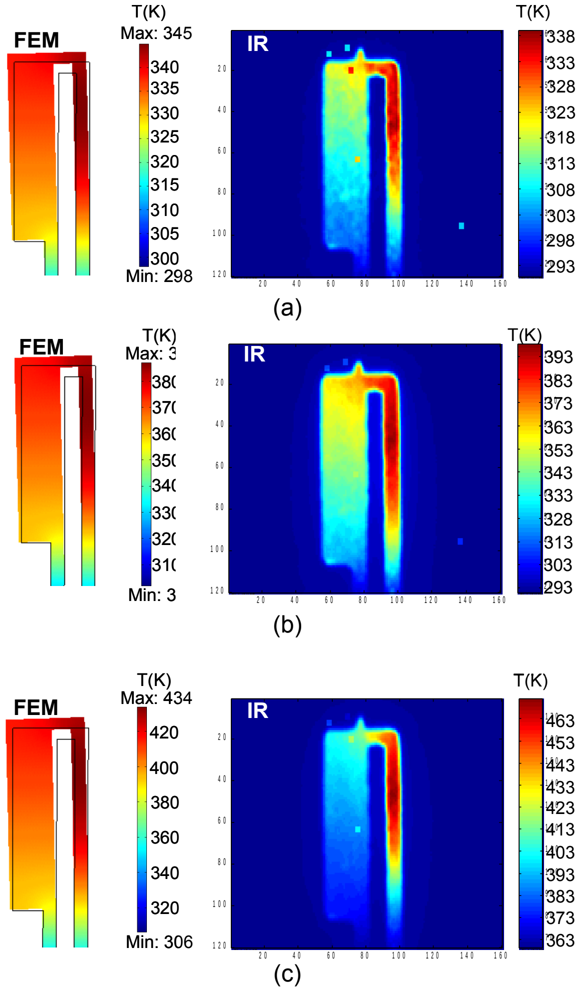


***Fig.2**. Comparison between IR measurements and FEM simulation results (a) 190mW input power, (b) 305mW input power, (c) 425mW input power*

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