Robots for Microscopes. imina technologies

APPLICATION NOTE

Piezoresistive response analysis of CNT/SU-8 nanocomposites integrated into organic MEMS cantilevers

In collaboration with:

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Imina Technologies products in use:

- miBot™ BT-11 Micromanipulators
- miBase BS-42 stage
- syDrive SD-10 piezoelectric controller

Since a few years, actuated microcantilevers have become a growing field of research and development in the MEMS community. Their use as sensors have found multiple applications in various domains. For instance in Biology and Chemistry, a large panel of compact and portable substances detectors (e.g. explosives, gazes) are based on a micro- or nanocantilever technology.

This application note reports about the electromechanical characterization of the enhanced sensitivity of organic piezoresistive microcantilevers developed at the IMS Laboratory of the Université de Bordeaux, France [1]. Together with their electrical probing capabilities, the sub-micron positioning resolution and the high mechanical stability of the miBot™ micromanipulators were exploited to carry out the characterization procedure of these systems.

IMS microcantilevers

Two types of U-shaped microcantilevers have been designed and manufactured at IMS. Both the geometry and the material design played a key role in the development process. The resulting MEMS consists of a thin piezoresistive film of carbon nanotubes and epoxy-based photoresist (2wt% CNT/SU-8 composite) deposited at the anchor section of a SU-8 arm with gold coated electrical pads (Figure 1).

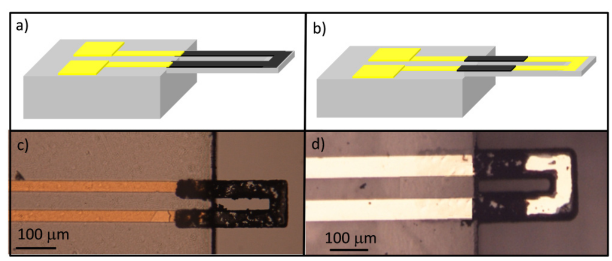

Figure 1. Schema of both designs: a) fully coated cantilever, b) coated on the clamped parts connected with a gold coating, and their respective imaging under an optical microscope (c & d). (Source: [1]).

The deflection of the beam induces a measurable change on the thin film resistance ruled by its gauge factor:

$$GF = \frac{\Delta R / R}{\Delta \varepsilon}$$

where R and ΔR are the resistance and its variation. ε corresponds to the strain which can be described as:

$$\varepsilon = \frac{3h\delta}{2L^2}$$

with h and L respectively the thickness and the length of the cantilever, and δ the tip deflection

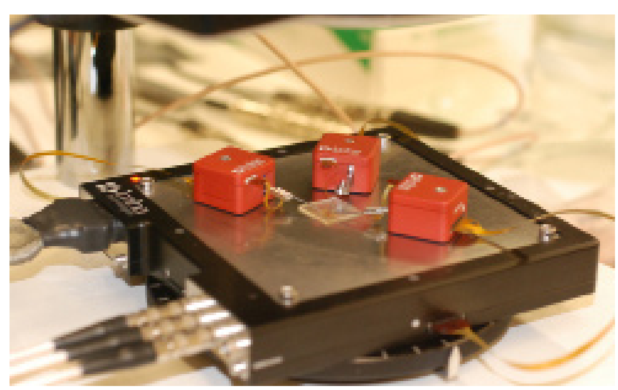

Figure 2. The sample under test is centered on the miBase BS-42, with three miBot BT-11 used to interact with it. This platform is placed under an optical profilometer. (Source: [1])

Method

The sensitivity of the microcantilevers is characterized by measuring the change of resistance ΔR induced by a known deflection δ. For this, a first miBot is applying gradual normal strains precisely at the tip of the beam to deform it from a few hundred nanometers up to 55 µm. The profiles of induced deflections is monitored by an optical profilometer (Veeco NT 9080), giving access to the corresponding strains (Figure 3).

Simultaneously, two other miBots are used to bring electrical probes in contact with the pads of the cantilever and measure the impedance of the piezoresistor. That measurement is made with a Network Analyzer Agilent E5061B connected to the coaxial I/O channels of the miBase.

Results

Figure 4 shows side-by-side the experimental results for both cantilevers designs. At low strains, their GF is similar. However, for ε>1.5%, the second design drastically overpasses the first one and even reaches a GF up to 200 at ε=4% which makes this configuration a perfect candidate for a highly sensitive stress sensor.

Conclusions

The characterization results assess the combination of CNT based nanocomposites integrated into organic microcantilevers to design highly sensitive, compact and low-cost strain MEMS sensors.

The ease-of-use of Imina Technologies micro-robots made it possible to quickly carry out several experimental runs in order to evaluate different mass-fraction of CNT/SU-8 nanocomposite and select the optimal design (2wt%).

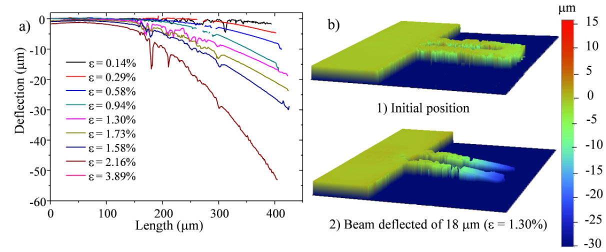

Figure 3. Deflection profile along the cantilever axis for different strains ε. b) MEMS profile subject to mechanical strength collected by an optical profilometer. (Source: [1])

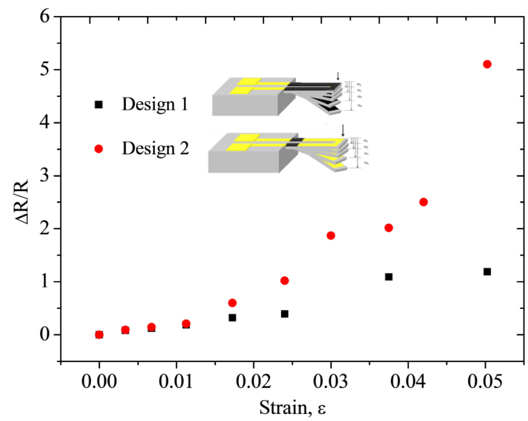

Figure 4. Experimental results of the resistance change as a function of the applied strain. (Source: [1])

[1] D. Thuau C. Ayela, P. Poulin, I. Dufour, Highly piezoresistive hybrid MEMS sensors, Sensors and Actuators A 209 (2014) 161–168 http://dx.doi.org/10.1016/j.sna.2014.01.037

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