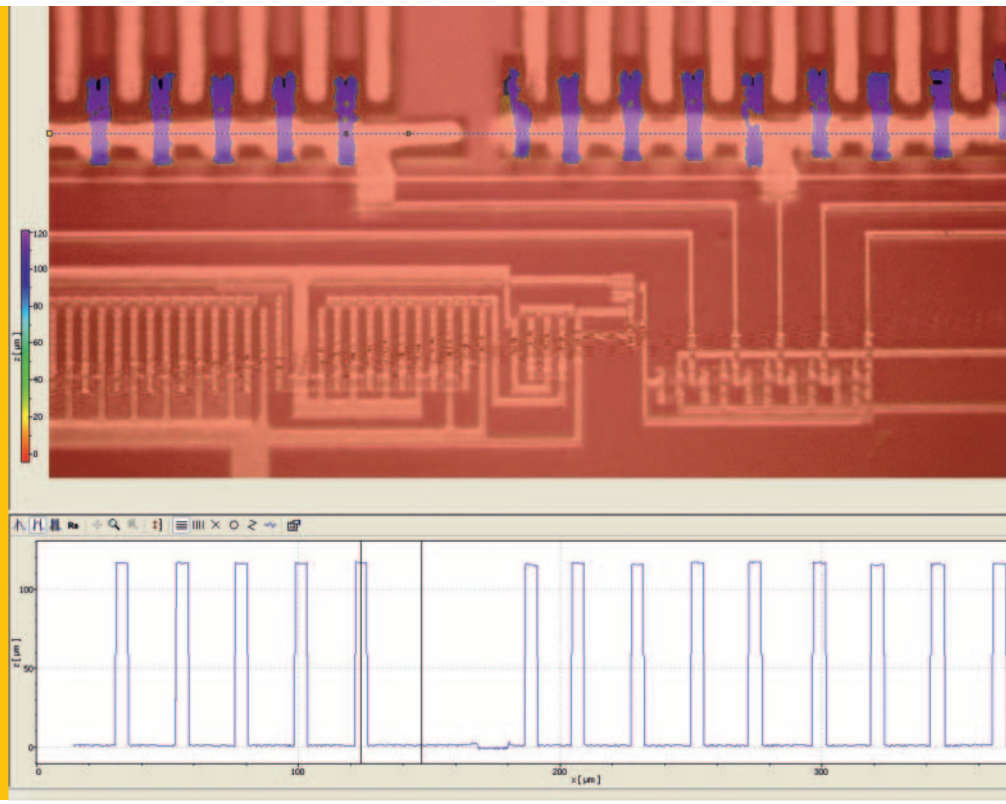
The Ups and Downs of Microsensors

Out-of-plane Topography of 3-D Surface Micromachined Microsensors

In this article, Polytec's MSA-500 Micro System Analyzer enables characterization of the topography of two microsystems that use large out-of-plane deflections as sensor elements. The scanning white light interferometer incorporated in the MSA-500 was first used to measure an integrated magnetometer (magMEMS) whose detection principle is based on deflecting a current half-loop with a magnetic field (Lorentz force) and then to measure a flow micro-sensor that uses cantilever deflection induced by incident air flows.



Introduction

Starting with a Silicon-on-Insulator (SOI) wafer and standard CMOS technologies, an out-of-plane (3-D) movable part was created through surface micromachining by adding several CMOS-compatible steps such as a chemical release and a low temperature annealing to achieve structures that are sensitive to air flow or magnetic field. Such mechanical structures are interfaced with electronics on the same chip and target applications where requirements include a low power consumption, a high and tunable sensitivity, and a small footprint.

Successful assembly of 3-D CMOS-compatible MEMS sensors relies on the chemical release of the microstructures and on the control of the residual stresses built up in multilayered structures undergoing a complete thermal process. The deflection of multilayered structures made of both elastic and plastic thin films results from the thermal expansion coefficient mismatches between the layers and from the plastic flow of a metallic layer. Meeting the deflection specification for multilayered micro-cantilevers is attained a posteriori by monitoring the process thermal budget and the stack thickness.

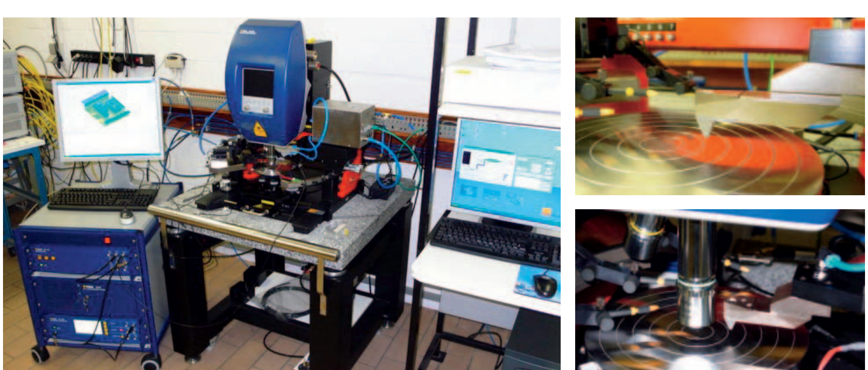


Fig. 1: Measurement and test system including the Micro System Analyzer and pressure unit (to the right, close views of the pressure nozzle).

Experimental Setup

To test these MEMS sensors, Polytec's Micro System Analyzer was mounted to a probe station sitting on a vibration isolation table (Fig. 1). Two additional items are part of the system – a pressure unit with nozzle and a goniometer.

Results: 3-D half-loop magMEMS (Integrated Magnetometer)

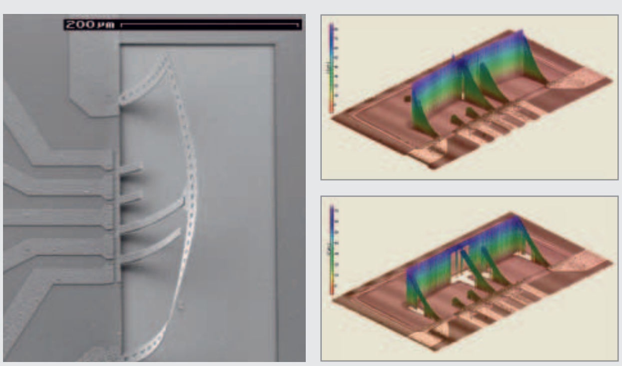
An SEM image of this CMOS-compatible magnetic field sensor is shown in Fig. 2. Within the device, an out-of-plane magnetic flux is converted into a mechanical force on the M-shaped cantilever via the Lorentz force. A Wheatstone bridge composed of four piezoresistors is integrated at the anchors of the magMEMS. The colored visualizations show the resulting deflection for the off and the on state of the device.

Results: CMOS/MEMS Co-integrated Flow Microsensor

A magnified SEM view of the flow microsensor is shown in Fig. 3. Under air flow the cantilevers bend downwards which leads to an increase of their capacitance and a lowering of the oscillating frequency of the integrated ring oscillator. Such electrical measurements, combined with real-time monitoring of the cantilever topography enabled by the pressure module, are under investigation. A topographic scan at rest position is shown in Fig. 3.

Conclusion/Outlook

New CMOS-compatible microsystems are taking advantage of Silicon-on-Insulator (SOI) technology for building three-dimensional surface micromachined sensors and actuators. Topographic analysis using Polytec's MSA-500 Micro System Analyzer is critical to their development. By using accessories that inject static pressure or constant air flow in association with a compensated objective lens, flow sensors can be topographically scanned and measured. The MSA-500 also features dynamic out-of-plane and in-plane vibration measurements that could be applied in future studies.



off-state deflection = 78 µm

on-state deflection = 67 µm

Fig. 2: SEM view of a magMEMS (on the left); resulting deflections for off and on states (on the right).

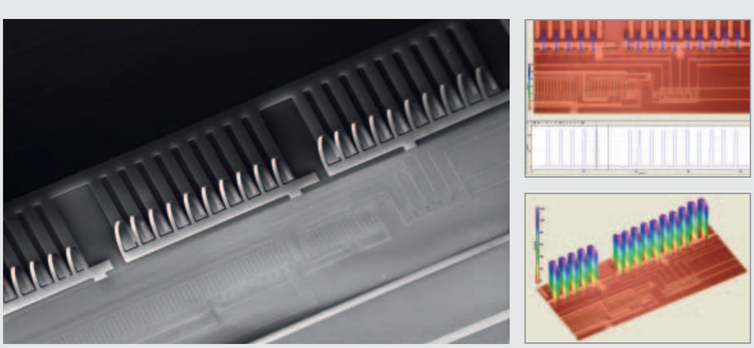
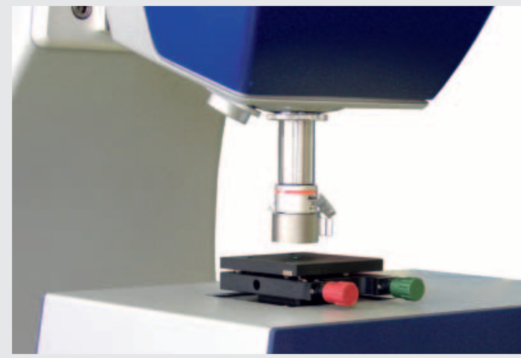


Fig. 3: MEMS flow microsensors co-integrated with SOI CMOS circuits: SEM view (on the left), 2-D and 3-D topography profiles (on the right).

MSA-500

Micro System Analyzer



The MSA-500 is the premier measurement technology for the analysis and visualization of structural vibrations and surface topography in micro structures such as MEMS (Micro-Electro-Mechanical Systems) devices. By fully integrating a microscope with Scanning Laser-Doppler Vibrometry, Stroboscopic Video Microscopy and White Light Interferometry, the MSA-500 is designed with an all-in-one combination of technologies that clarifies real microstructural response and topography.

Incorporated in the MEMS design and test cycle, the MSA-500 provides precise 3-D dynamic and static response data that simplifies troubleshooting, enhances and shortens design cycles, improves yield and performance, and reduces product cost. For the vibration measurement, the MSA-500 features also direct geometry scan data acquisition.

More Info:
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