

MEMS-based platforms for characterization of advanced functional materials

Liviu Nicu¹, Susan Trolier-McKinstry², Gabor Molnar³, Azzedine Bousseksou³, Maria Dolores Manrique Juarez¹, Fabrice Mathieu¹, Daisuke Saya¹, Karsten Haupt⁴, Denis Dezest⁵, Thierry Leichlé^{1,6}

¹LAAS-CNRS, Université de Toulouse, France

²Department of Materials Science and Engineering and Materials Research Institute, The Pennsylvania State University, PA, USA

³LCC-CNRS, Université de Toulouse, France

⁴Université de Technologie de Compiègne, CNRS Laboratory of Enzyme and Cell Engineering, Compiègne, France

⁵CEA-Leti, Grenoble, France

⁶Georgia Tech-CNRS Joint International Laboratory, GA, USA

E-mail: nicu@laas.fr

Website: www.laas.fr

Abstract

The integration of new advanced functional materials in the production chain of microelectromechanical systems (MEMS) requires a fundamental in-depth knowledge of their physical and chemical properties. In recent years, there has been a significant increase in publications reporting on performant transduction properties of classes of materials partially or completely unknown by the production chain mentioned above [1], [2]. These materials are generally synthesized and characterized in a form (powders, single crystals, etc.) that is not suitable for MEMS manufacturing processes, rather requiring homogeneous thin films. Thus, despite the announced performances, which are very convincing and promising, there is no guarantee that they can be easily integrated into MEMS devices, nor can there be any guarantee that their performances will be preserved once the integration phase is successful.

Our work over the past few years was to assess the performance of materials, which either by their nature or by the way they are structured, still remain exotic for conventional micro / nanofabrication pathways. This assessment goes through the same stages, which are: the deposition and patterning of these materials at the micro-scale (by conventional or alternative techniques), their integration into basic micrometric structures (passive or active levers) and their characterization.

In this talk we will present our contribution to the characterization of three classes of materials: molecularly imprinted polymers (MIP), spin crossover materials (SCO) and piezoelectric materials (sol-gel lead zirconate titanate or PZT). In each of the cases presented, the same process flow and characterization methodology are followed, namely:

- in case of SCO materials (Figure 1.a): evaporation onto microfabricated cantilevers with actuation and sensing capabilities, assessment of the post-process spin cross-over capabilities;
- in case of MIPs (Figure 1.b): deposition and patterning of the MIP (by spin-coating and photolithography) fully integrated within the process flow of the microcantilevers' fabrication, assessment of the post-process mechanical integrity of the MEMS and chemical functionality preservation;

- in case of sol-gel PZT (Figure 1.c): integration of the active material into the process flow of microcantilevers' fabrication by means of micro-contact printing in order to assess the actuation and sensing capabilities.

As a general conclusion, we will demonstrate that by appropriately integrating thin films of these advanced materials and using the MEMS transduction capability, MEMS platforms are powerful tools for the physical and chemical characterization of these materials. As exemplified by the works presented here, these materials can be organic or inorganic, deposited by evaporation, micro-contact printing, spray coating or other types of techniques adaptable to MEMS manufacturing chain. The anticipation of the compatibility with MEMS process flow should allow, when a new material with high transduction potential is identified, its integration into the whole device architecture starting with the design phase.

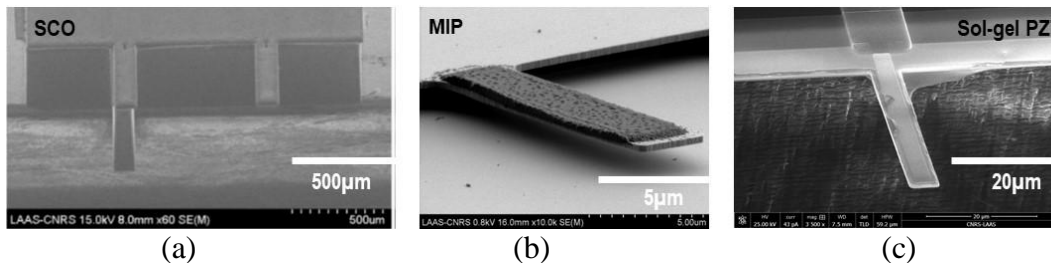


Figure 1. (a) Silicon microcantilevers bearing spin crossover material deposited by thermal evaporation; (b) silicon microcantilever bearing a photosensitive micro-imprinted polymer patterned by photolithography; (c) silicon microcantilever bearing PZT layer patterned by micro-contact printing

References

- [1] M. D. Manrique-Juárez *et al.*, « Switchable molecule-based materials for micro- and nanoscale actuating applications: Achievements and prospects », *Coord. Chem. Rev.*, vol. 308, p. 395- 408, févr. 2016, doi: 10.1016/j.ccr.2015.04.005.
- [2] E. Ahmed, D. P. Karothu, et P. Naumov, « Crystal Adaptronics: Mechanically Reconfigurable Elastic and Superelastic Molecular Crystals », *Angew. Chem. Int. Ed.*, vol. 57, n° 29, p. 8837- 8846, juill. 2018, doi: 10.1002/anie.201800137.

Biography



Liviu NICU is currently senior scientist at the French National Scientific Research Center and is General Director of the CNRS Systems Analysis and Architecture Laboratory in Toulouse, France. After obtaining his PhD degree in Electrical Engineering from Paul Sabatier University in Toulouse, he joined Thales Avionics Valence (France) where he took charge of the company's inertial silicon microsensor projects from 2001 to 2003. He joined the Systems Analysis and Architecture Laboratory since 2003 where he conducted research in the fields of bioMEMS and MEMS for the physical and chemical characterization of advanced functional materials. Liviu NICU is co-author of over 100 peer-reviewed articles, 2 books / book chapters and has co-invented 3 patents. The laboratory he is heading since January 2016 brings together more than 700 people working in the fields of automation, robotics, computing and micro-nanotechnologies.