On chip testing of thin films

T. Pardoen[1], M. Coulombier[1], M.-S. Colla[1], U. K. Bhaskar[2], V. Passi[2], S. Houri[2], J.P. Raskin[2]

1. Institute of Mechanics, Materials and Civil Engineering (iMMC), Université catholique de Louvain, B-1348 Louvain-la-Neuve, Belgium
2. Information and Communication Technologies, Electronics and Applied Mathematics (ICTEAM), Université catholique de Louvain, B-1348 Louvain-la-Neuve, Belgium

Mots Clés

Thin films, strength, ductility

INTRODUCTION

The characterization of the mechanical response of thin films, nanowires or nanobeams by indentation methods involves a series of complications related to the confinement effect of the substrate on which the nanostructures are lying. In order to overcome some of these limitations, a new lab-on chip suite of freestanding test structures has been developed in order to allow the measurement of the mechanical properties of films with thicknesses below typically 200nm, see Figure 1 and references [1-5].

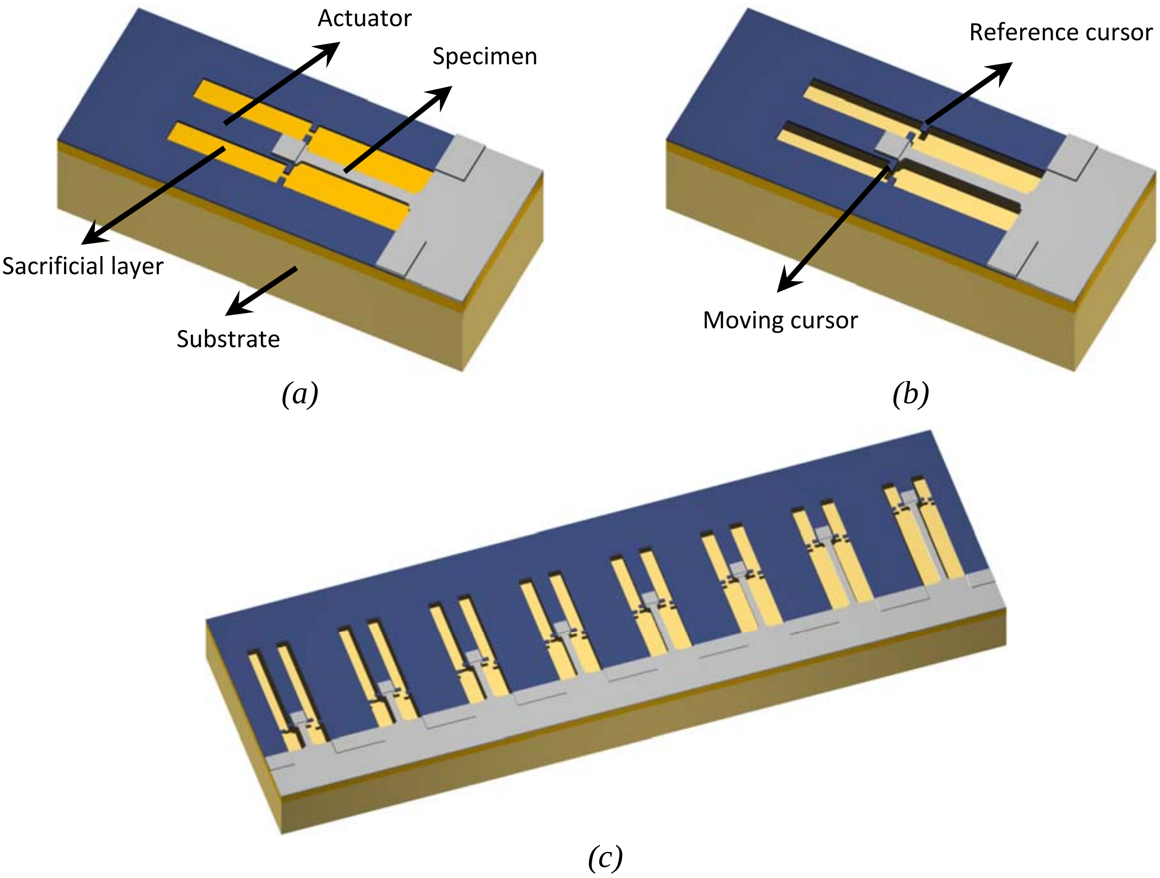

Figure 1: Concept of self-actuated tensile stage (a) before and (b) after etching of the sacrificial layer; (c) suite of elementary tests structures with different lengths and leading to different imposed deformation to the test specimen.

This new method relies on an actuation concept based on one long beam involving high internal stress, which, after release from the substrate, pulls on a specimen attached to it through adhesion in the overlap region. The measurement of the displacement of embedded cursors allows extracting the stress and strain applied to the specimen, if the Young's modulus and mismatch strain of the actuator beam are known. Several additional structures are devoted to the measurement of these two quantities. The stress in the specimen can alternatively be evaluated using resonance frequency measurements. Series of these tensile test structures with varying dimensions of both the actuator and specimen are fabricated in order to characterize the mechanical response of various types of materials involving the strength, ductility, strain hardening, fracture stress and creep/relaxation. Mechanical tests can also be performed in the presence of an electrical current as well as under other loading conditions such as shear, biaxial loadings or tension on cracked specimens. The implementation of this new concept is based on traditional MEMS fabrication techniques and will be described through examples on Al, Pd and Si films and nanowires.

This lab on chip technique, which does not make use of any external equipment for actuation, is both competing and co-operating with nanoindentation. Nanoindentation is an essential tool to complement the analysis made with the on chip freestanding test structures to provide for instance compression data on pillars, to independently measure the Young's modulus or strain rate sensitivity indicator, to introduce precracks in brittle films, and/or to bend freestanding structures. These tests structures can be included on the same lab on chip giving rise to a fully versatile and combinatorial testing kit for thin films.

References

[1] S. Gravier, M. Coulombier, A. Safi, N. André, A. Boé, J.-P. Raskin, T. Pardoen (2009) «*New on-chip nanomechanical testing laboratory - applications to aluminum and polysilicon thin films*», Journal of MicroElectroMechanical Systems, **18** (3), pp. 555-569.

[2] A. Boé, A Safi, M Coulombier, D Fabrègue, T Pardoen and J-P Raskin (2009) «*MEMS microstructures for nanomechanical characterization of thin films*», Smart Material and Structures **18**, pp. 115018 (8 pages)

[3] H. Idrissi, B. Wang, M.S. Colla, J.-P. Raskin, D. Schryvers, T. Pardoen (2012) «*Ultrahigh strain hardening in thin palladium films with nanoscale twins*», Advanced Materials, **23**, pp. 2119–2122.

[4] M.-S. Colla, B. Wang, H. Idrissi, N. Schryvers, J.-P. Raskin, T. Pardoen (2012) «*Large strain hardening in palladium thin films: experimental study and modelling*», Acta Materialia **60** (4), pp. 1795-1806

[5] V. Passi, U. Bhaskar, T. Pardoen, U. Södervall, B. Nilsson, G. Petersson, M. Hagberg, J.-P. Raskin (2012) «*High throughput on-chip large deformation of silicon nanowires*», Journal of Microelectromechanical Systems, in press