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Abstract Details

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Abstract

TITLE: Micromechanical Testing Lab-on-chip for Nano-sized Materials.

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ABSTRACT BODY: Robust design of micro- and nano-systems requires proper knowledge of the mechanical properties of the system components. As size effects play a prominent role at the submicron scale, materials must be tested at the relevant structural scale. Measurements of mechanical properties on submicron sized specimens are extremely challenging due to difficulties for manipulating samples, for applying small load and for extracting accurate stresses and strains. We present a novel, versatile concept of micro and nano-machines to measure the mechanical response, up to large strains and fracture, of metal, polymer or ceramic films or beams with dimensions ranging between 10 to 1000nm, allowing multiple loading configurations and geometries.

This new concept constitutes a change of perspective in the mechanical testing of submicron scale materials. The first idea is to rely on mature microfabrication techniques destinated to the production of microelectronic devices. The second idea is to take benefit of one of the greatest advantages of microfabrication technology, i.e. the ease for reproducing extremely large numbers of elementary patterns. Hence, the idea is to multiply elementary machines rather than to build one complex multi-purpose micromachine. The third idea is to use internal stresses to actuate and impose the load to the tested sample. The actuator is a beam of material chosen for its capacity to generate, after deposition and cooling down, large internal stresses. The actuator beam is deposited on a sacrificial layer. The tested film is deposited on the same sacrificial layer and covers partly the actuator beam and partly the substrate. By releasing the actuator beam and the test sample through chemical etching, the actuator beam contracts and imposes a displacement to the film. The measurement of the displacement of the actuator beam provides the value of the mechanical strain applied to the film. Subtracting the displacement from the displacement of a free actuator beam leads directly to the value of the stress by assuming that the actuator remains elastic. One machine corresponds to one specific stress/strain couple. Different strains are imposed to the film by using various combinations of film and beam lengths.

For the sake of illustration, uniaxial stress strain curves of Al films with thicknesses between 100 and 1000 nm have been obtained, showing the expected linear evolution of the strength as a function of 1/thickness. Similar samples with notches exhibit a ductile fracture process involving very large strains and a void growth process similar to the process observed at the macroscopic scale.

The versatility of the concept allows other loading configuration than simple tension: machines for conducting shear, biaxial, compression, three-point bending and double cantilever opening tests have already been processed. About 5000 micromachines have been built on a single silicon wafer leading to a true on-chip mechanical laboratory.