Solid mechanics on a chip

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The top down approach to testing small scale material objects, as exemplified by nanoindentation, involves a series of challenges such as the integration of tiny probes into a macroscopic equipment, the accurate positioning of the probe with respect to the specimen, and the sensing of extremely small loads and displacements. Alternatively, the bottom up approach consists in building up the test device at the scale of the object. This is the approach we have followed over the last ten years to build a versatile nanomechanical test platform able to perform a wide variety of mechanical tests on freestanding specimens and to address issues related to solid mechanics at small scale [1,2]. The processing of the test device relies on microfabrication methods typically used to build MEMS. The core element of the technique is to use internal stress as a way to provide the actuation means directly on chip. This avoids the connection to macroscopic equipment or the integration of a sophisticated actuator design. More precisely, beams with large internal stress are deposited and patterned in order to deform other specimen beams made of the material of interest. Different types of loading configurations have been implemented from pure uniaxial tension to fracture mechanics geometries in order to perform both static or creep type tests. Obviously, this approach also involves many challenges related to the processing of the test platform, without damaging the objects, and to the extraction of the relevant mechanical quantities.

After reviewing the current state of the technology and of the associated data reduction schemes, we will present several examples of representative results obtained on thin film materials. The focus will be on the mechanisms controlling the ductility of metallic films, crystalline and amorphous, taking into account rate sensitivity, hardening and imperfection effects. Data obtained on ZrNi metallic glass films [3], irradiated and non-irradiated Cu films [4], and Pd films [5] will demonstrate the importance of the rate sensitivity as a way to ductilize thin films. In HRTEM situ observations will be combined to classical solid mechanics plastic localization and cracking analysis to rationalize the results.

References

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