In-situ SEM nanomechanical testing

J. Michler, Empa Thun

Mechanical engineering of materials at micro- and nanoscales requires a fundamental understanding of effects of microstructure and of sample size on mechanical properties. Research at EMPA focuses on in-situ nanobending, nanotensile, nano-/microcompression, nanotensile, nanoresonance and nanoindentation experiments in scanning electron microscopes and in a dual beam FIB. This allows to manipulate small samples like nanowires or nanotubes, to fix them on a test bench, to control visually the experiment, to observe deformation mechanisms on the sample surface and to use the analytical power of SEM-based microanalysis techniques to gain information on composition (EDX), crystallography (EBSD) and dislocation movement (STEM). Information on electronic and optical properties can be obtained at the same time for instance via four point probes or electron beam induced current (EBIC) measurements, respectively.

Silicon micropillars loaded in uniaxial compression show brittle behaviour with increasing strength the smaller the pillar diameter. GaAs micropillars exhibit a similar behaviour, but if the pillar diameter is in the submicron regime or smaller then the material behaves plastic, which is attributed to movement of partial dislocations enabled because the extension of stacking faults becomes comparable to the pillar diameter. Silicon nanowires were subjected to bending tests and ZnO nanowires to both bending and tensile tests using an atomic force microscopy setup inside a scanning electron microscope. The average strength calculated from the maximum nanowire deflection or elongation before fracture in both cases approaches the theoretical limit of 10% of the Youngs Modulus. Monocrystalline Rhenium nanowires fail by plastic yield associated with a strain localisation. The yield stress represents again roughly 10% of the Young modulus. Finite element simulations show that the elastic anisotropy has to be taken into account to assess accurately the yield strength in the bending experiment. Inverse finite element simulations of the nanobending experiment allow to extract values of the strain hardening coefficient.