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Some Recent Advances in Nanomechanical Testing: High Strain Rates, Variable Temperatures, Fatigue and Stress Relaxation, Combinatorial Experimentation

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In the first part of the talk, I will present two recently developed platforms for high temperature nanomechanical testing. The first platform allows for variable temperature and variable strain rate testing of micropillars in situ in the scanning electron microscope. By utilizing an intrinsically displacement-controlled micro-compression setup, which applies displacement using a miniaturized piezo-actuator, we've recently extended the attainable range of strain rates to up to~ 10^3 s^{-1}, and enabled cyclic loading up to 10^7 cycles and load relaxation tests. Stable, variable temperature indentation/micro-compression in the range of -45°C to 600°C is achieved through independent heating and temperature monitoring of both the indenter tip and sample and by cooling the instrument frame. A second system allows for measurements at lower loads ex-situ in a dedicated vacuum chamber in the range of -150 °C to 700 °C. The cryo temperature is achieved by means of a liquid nitrogen line, while the high temperature is generated by three independent heat sources for the sample and the two tips of the differential displacement measurement system, establishing an infrared bath in the measurement area.

In the second part several case studies will be presented. Using these new capabilities, we examine the plasticity of electrodeposited nanocrystalline Nickel, of combinatorial thin film libraries, of hard nanocrystalline ceramic thin films. Activation parameters such as activation volume and activation energy were determined and discussed in view of the most probable deformation mechanism. High strain rates and cyclic fatigue tests were performed on nanocrystalline Ni. The strain rate sensitivity seems to increase for strain rates higher than 10 s-1 suggesting a change in deformation mechanism with increasing strain rate. Cyclic fatigue tests up to 1 million cycles were performed on nanocrystalline Ni microbeams and compared with existing data from literature. Combinatorial libraries of bulk metallic glasses were synthesized by a combination of gradient sputtering and evaporation. Hardness and Young's modulus was mapped as a function of temperate, strain rate and composition. The results are discussed in the light of shear band kinetics.
Finally, a wide range of chromium nitride-based hard coatings was investigated using in situ micro-cantilever bending and compression testing. This allowed the first direct measurement of the high temperature compressive strength and fracture toughness.