MM 14: SYM Micro- and Nanomechanics II

Time: Tuesday 10:15–12:15 Location: H16

Invited Talk MM 14.1 Tue 10:15 H16

Micromechanics inside the SEM — •Benedikt Moser — Empa, Materials Science and Technology, 3602 Thun, Switzerland

A large variety of in-situ mechanical experiments have been developed over the last 10 years in a number of research institutes. Many of those experiments can be performed inside the scanning electron microscope, some of them even in the transmission electron microscope (JMR (2005) July issue). These techniques offer a wealth of new information on small scale deformation mechanics to the scientists and may avoid some measurement artefacts in difficult experiments by visual control. In this presentation the author will discuss two examples of in-situ micromechanical experiments based on a custom-built micro-indentation apparatus adapted to a standard scanning electron microscope.

The first part will discuss the in-situ indentation of a metallic glass. Here the formation of shear bands is observed in the SEM during the indentation process and is correlated to the appearance of displacement bursts in the load-displacement curve. The effect of varying deformation rates on the formation of shear bands is also investigated.

The second part will show the potential of the same apparatus to perform micropillar-compression experiments on the example of micromachined Si-pillars. It will be shown that by in-situ SEM-observations distinct deformation mechanisms can be seen: the diameter of the pillars has a clear influence on the failure mode and can be correlated to the Weibull distribution of strength.

MM 14.2 Tue 10:45 H16

Scaling in the mechanical properties of thin metal films: from the micro- to the nanoscale — •Ralph Spolenak — ETH Zurich, Zurich, Switzerland

It is well established that the yield stress of thin metal films inversely scales with film thickness as the micron length scale is approached. For thinner films, however, the scaling law changes and also other mechanical properties such as fracture toughness and modulus become affected by the reduced dimensions. Case studies will be presented for thin Cu, Au and Ta films in the thickness range from 10 to 3000 nm on polyimide substrates. Stress-strain curves are obtained by synchrotron based X-ray techniques. The scaling in fracture toughness and yield stress is critically discussed. In addition the effect of temperature on yield stress will be analyzed. In conclusion, thinner is not always better, but an optimal length scale can be found for nanoscale metals.

MM 14.3 Tue 11:15 H16

Direct-Observation Nanomechanical Testing in a Transmission Electron Microscope — •Oden Warren and Ude Hangen — Hysitron, Inc., 10025 Valley View Road, Minneapolis, MN 55344, USA

The intense research interest in nanostructures and nanomaterials has resulted in a strong demand for direct-observation nanomechanical testing. Over the past two years, pioneering quantitative nanoindentation technology for in-situ experimentation in transmission electron microscopes has been developed. This technology has enabled direct investigation of microstructural changes occurring during nanoindentation, as well as direct investigation of the effects of nanocompression on electron-transparent nanostructures such as nanospheres and nanopillars. This presentation will provide examples of deformation mechanisms revealed by the combination of force-displacement curves and corresponding transmission electron microscopy movies. This synergistic combination of high-resolution techniques has led to a fuller appreciation of the fact that mechanical behavior at the true nanoscale is indeed rich and often counterintuitive.

MM 14.4 Tue 11:30 H16

Bulge Testing of Thin Films in an Atomic Force Microscope — •Elmar W. Schweitzer and Mathias Göken — University Erlangen-Nürnberg, Department of Materials Science and Engineering, Institute of General Material Properties, Martensstraße 5, 91058 Erlangen, Germany

Bulge testing of thin membranes is a method, which allows to record stress-strain-curves of thin films without any substrate influence. Pressure is applied to one side of a free standing sample membrane and the deflection as a function of the applied pressure is recorded. Another advantage compared to nanoindentation is a better definition of the stress state in the sample which can be influenced by choosing an appropriate membrane shape.

As soon as the sample dimension reaches the order of magnitude, where physical phenomena, e.g. dislocation motion, come into play, interesting effects can be observed. For example thin metal films show an increase in strength with decreasing film thickness. Furthermore grain boundaries play a more important role, because their volume fraction increases as well.

A self designed bulge test apparatus, which can be incorporated into a Dimension 3100 AFM will be presented. The device can be operated as a standard bulge tester, i.e. pressure-deflection-data of the membrane in question can be recorded. In addition to that, topography images of the loaded membrane surface can be taken to study plasticity effects on a local scale.

MM 14.5 Tue 11:45 H16

Mechanical properties of micro bending-beams: a comparison between discrete dislocation dynamic simulations and experiments — •Christian Motz, Daniel Weygand, and Peter Gumbsch — IZBS, Universität Karlsruhe, D-76133 Karlsruhe

Due to size-effects the mechanical properties in small dimensions may be different from the macroscopic ones and the knowledge of the related mechanisms is essential for a successful design at these small length scales. In complex systems usually stress and strain gradients arises during mechanical loading, and therefore the influence of these gradients on the mechanical properties is important, too. To investigate this influence 3D discrete dislocation dynamic simulations and experiments were performed on micron-sized bending beams. For the simulations the beam thickness varied between 500 nm and 1500 nm with a thickness to length ratio of 1:3. The deformation behaviour was studied in dependence of beam thickness, initial dislocation density and crystal orientation. All configurations showed a pronounced size dependence, i.e. the resistance to plastic deformation increases with decreasing beam thickness, which seems to be mainly caused by a strong dislocation pile-up in the bending beam that is usually not found in the absence of stress gradients (e.g. in compression tests). A comparison with experimental results shows a good agreement in terms of deformation behaviour and possible dislocation structure. A simple analytical pile-up model is developed, which can reproduce the size effect quite well. Finally, the importance of special dislocation structures on the mechanical properties in small dimensions is discussed.

MM 14.6 Tue 12:00 H16

Stress measurments in small dimensions using Confocal Raman Microscopy: a probe for stress and defect density — •Thomas Wermelinger, Cesare Borgia, Christian Solenthaler, and Ralph Spolenak — Lab. for Nanometallurgy, ETH Zurich, 8093 Zürich, Schweiz

Confocal Raman microscopy is a powerful tool for measuring stresses with a lateral resolution in the submicron range in 3D, which as previously only been possible by synchrotron based X-ray techniques. Moreover, it is possible to observe phase transformations, which appear due to high compressive stresses. Residual 3D stress fields in a sapphire single crystals after indentation are analysed. It can be shown that the symmetry of the residual stress field solely depends on the crystal symmetry and not on the symmetry of deformation. A direct correlation between defect structures observed by TEM and the peak broadening in the Raman spectra was found. Raman spectroscopy offers new potential in micro- and nanomechanics.