MM 36: Topical Session: Advanced Nanomechanics – Accelerating Materials Physics from the Bottom II

Time: Thursday 15:45–17:15 Location: SCH/A251

Topical Talk MM 36.1 Thu 15:45 SCH/A251

High-temperature micropillar compression for understanding dislocation-precipitates interactions in Ni-Based superalloys — •Subin Lee[1], Sangwon Lee[2], Pyuck-Pa Choi[2], and Christoph Kirchlechner[1] — [1]Institute for Applied Materials, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Department of Materials Science and Engineering, Korea Advanced Institute of Science and Technology (KAIST), Daejeon, South Korea

The mechanical role of plate-like μ phases, topologically close-packed (TCP) precipitates, in Ni-based single-crystal superalloys was investigated using bulk and in situ SEM micropillar compression, supported by electron microscopy and APT. The μ phase showed strong temperature-dependent behavior: it remained rigid at room temperature, enforcing single-slip deformation, but became more compliant at 500 °C through bending and non-basal shearing.

Although acting as local obstacles to slip, μ phases consistently lowered the CRSS of micropillars. This softening resulted from deformation within the μ phase and from microstructural changes in the surrounding γ/γ' matrix. APT revealed Ta enrichment at the μ/γ' interface, enhancing γ' strengthening, while elastic mismatch shifted slip traces away from the interface by tens of nanometers.

Overall, these results highlight the dual role of μ phases. This integrated understanding of μ-phase deformation, interfacial chemistry, and matrix softening provides a fundamental mechanistic understanding for how TCP precipitation shapes the high-temperature mechanical behavior of Ni-based superalloys.

MM 36.2 Thu 16:15 SCH/A251

Nanomechanics of Silicon: Linking Phase Transitions to High-Temperature Plasticity — •Verena Maier-Kiener and Gerald Schaffar — Montanuniversität Leoben, Department materials Science, Leoben, Austria

This presentation focuses on phase transformations in silicon revealed through high-resolution nanoindentation techniques and their interplay with high-temperature deformation behavior. Using a novel unloading contact pressure approach with continuous stiffness measurement (CSM), pressure-induced phase transitions during indentation are investigated with improved precision. The method enables direct calculation of mean contact pressure during unloading and reveals the influence of load-holding segments on transformation onset, aligning well with high-pressure literature data, and was confirmed by Raman spectroscopy. To contextualize these findings, complementary high-temperature nanoindentation studies are discussed. In monocrystalline (100) silicon, a transition from phase transformation to dislocation-controlled plasticity occurs between 300°C and 400°C, with further changes above 800°C. Additionally, spherical nanoindentation on a 1.2μm silicon film at 500°C and 700°C extracts stress-strain behavior, confirming thermally activated dislocation glide. Together, these results provide a comprehensive view of silicon's mechanical response, bridging nanoscale phase transformation analysis with bulk high-temperature deformation mechanisms.

MM 36.3 Thu 16:30 SCH/A251

In situ TEM nanomechanics of neutron-irradiated nanocrystalline carbides and the role of amorphous shells in local mechanical response — •Elchin Huseynov — Institute of Radiation Problems of Ministry of Science and Education, 9 B.Vahabzade, Baku AZ 1143, Azerbaijan

Predicting the mechanical reliability of neutron-exposed ceramics remains challenging because classical micromechanical tests average over complex, irradiation-induced defect structures at the nanoscale. In particular, nanocrystalline carbides develop near-surface amorphous layers and defect-rich shells whose role in governing deformation and failure is still poorly quantified. This work introduces an in situ TEM-based nanomechanical workflow for neutron-irradiated nanocrystalline 3C-SiC. Reactor-irradiated nanoparticles at graded fluences serve as a model for plasma-facing and core structural ceramics. Ex situ HRTEM/SAED reveals pronounced agglomeration and a continuous amorphous shell up to 5 nm thick encasing a crystalline core. Building on this microstructural baseline, in situ TEM traction and gentle indentation experiments on nanoparticle films and micro-sized volumes are used to track shell stability and defect evolution under load via ring broadening, lattice-fringe de-coherence and defect coalescence at the shell/core interface. The results reveal a critical amorphous-shell thickness above which deformation concentrates in the disordered layer and promotes early crack initiation, whereas thinner or discontinuous shells favour more homogeneous load transfer across the crystalline core.

MM 36.4 Thu 16:45 SCH/A251

Mechanical Properties of Irradiated Zircaloy Cladding and Their Impact on Structural Integrity During Dry Interim Storage — •Tzu Yen Lin[1], Michel Herm[1], Volker Metz[1], Maria Vrellou[2], and Christoph Kirchlechner[2] — [1]Karlsruhe Institute of Technology, Institute for Nuclear Waste Disposal, P. O. Box 3640, 76021 Karlsruhe, Germany — [2]Karlsruhe Institute of Technology, Institute for Applied Materials, P. O. Box 3640, 76021 Karlsruhe, Germany

In Germany, spent nuclear fuel is planned for disposal in a deep geological repository after 2050. The SNF assemblies are stored in dual-purpose casks, while delays in repository commissioning may extend storage beyond licensed periods. Evaluating the safety of Zircaloy-4 cladding during extended dry storage requires assessing the effects of irradiation damage, hydride formation, and microstructural evolution. This work aims to establish a reliable micromechanical testing methodology for irradiated Zircaloy-4. As a precursor to irradiated samples, Electron Backscatter Diffraction (EBSD) and nanoindentation were performed on non-irradiated cladding in hydrogenated and non-hydrogenated states. EBSD revealed variations in grain size, texture, anisotropy, and dislocation density from manufacturing processes, with further increases from hydrides. Nanoindentation showed higher hardness and reduced modulus in hydride regions compared with the α-Zr matrix. Occasional pop-ins in load-displacement curves indicate dislocations or microstructural discontinuities, consistent with misorientation patterns observed in EBSD.

MM 36.5 Thu 17:00 SCH/A251

Experimental evidence and first-principles verification of deformation of basal twist grain boundaries in Ti — •Biaobiao Yang[1,2], Samuel Hémery[3], Wei Shao[1,2], Victoria Tucker[1,4], Michael S. Titus[1,4], Miguel A. Monclús[1], and Javier LLorca[1,2] — [1]IMDEA Materials Institute, C/Eric Kandel 2, Getafe, 28906 - Madrid, Spain — [2]Department of Materials Science, Polytechnic University of Madrid / Universidad Politécnica de Madrid, E.T.S. de Ingenieros de Caminos, 28040 - Madrid, Spain — [3]Institut Pprime, ISAE-ENSMA, Université de Poitiers, CNRS UPR 3346, Téléport 2, 1 avenue Clément Ader, BP 40109, Futuroscope-Chasseneuil Cedex, 86961, France — [4]School of Materials Engineering, Purdue University, 701 West Stadium Ave., West Lafayette, IN 47907, USA

Recent studies show that Basal Twist Grain Boundaries (BTGBs) are important fatigue-crack nucleation sites in Ti alloys. Micropillar compression combined with high-resolution microscopy revealed extremely easy interfacial shear: one basal grain slides over the other at very low critical resolved shear stresses (45-205 MPa), far below those required for common <a> basal slip. To explain this behavior, first-principles calculations were used to determine the grain boundary energies of BTGBs with different twist angles. The results show that variations in twist angle or in-plane translation produce only negligible changes in grain boundary energy, indicating intrinsically low shear resistance. Together, these experimental and computational findings clarify why BTGBs serve as potent crack-nucleation sites in Ti alloys.