MM 60: Mechanical Properties: Plasticity, fracture, fatigue, wear - I

Time: Thursday 15:45–17:15 Location: IFW B

MM 60.1 Thu 15:45 IFW B

Origins of Strength and Plasticity of the precious metal based high entropy alloy AuCuNiPdPt — •Felix Thiel[1,5], Daniel Utt[2], Dirk Seifert[1], David Geissler[1], Alexander Kauffmann[3], Sascha Seils[3], Martin Heilmaier[3], Karsten Albe[2], Mykhaylo Motylenko[4], David Rafaja[4], Jens Freudenberger[1,4], and Kornelius Nielsch[1,5] — [1]Leibniz-IFW Dresden — [2]TU Darmstadt — [3]Karlsruhe Institut für Technologie — [4]TU Bergakademie Freiberg — [5]TU Dresden

The precious metal based High-Entropy Alloy (HEA) AuCuNiPdPt crystallises in a fcc structure and is single phase without chemical ordering. This HEA shows extended malleability during cold work up to a logarithmic deformation degree of $\varphi = 2.42$. The yield strength ranges from 820 MPa in the recrystallised state to 1170 MPa when strain hardened by cold working. The high strength in the recrystallised state is evaluated and found to originate predominantly upon solid solution strengthening. The work hardening behaviour is traced back to a steep increase in dislocation density as well as in deformation twinning. The microstructure and the mechanical properties of AuCuNiPdPt are assessed in detail.

MM 60.2 Thu 16:00 IFW B

Variation of mechanical strength with composition in the Cantor alloy system: Experiments and modeling — •Daniel Utt[1], Tom Keil[2], Alexander Stukowski[1], Enrico Bruder[2], Karsten Albe[1], and Karsten Durst[2] — [1]Fachgebiet Materialmodellierung, Institut für Materialwissenschaft, Technische Universität Darmstadt, Germany — [2]Fachgebiet Physikalische Metallkunde, Institut für Materialwissenschaft, Technische Universität Darmstadt, Germany

We investigate the concentration dependent mechanical properties of the Cantor high-entropy alloy (HEA) system over a wide concentration range and aim to understand the influence of the different chemical elements on the alloy's strength and phase stability. The investigated samples are the different subsystems of the HEA, where one element of the alloy is enriched, while the others are decreased using diffusion couple samples of the HEA and each of its constituents.

The concentration gradient in the interdiffusion zone allows us to determine the concentration dependent phase stability and solid solution strengthening (SSS). Here, the phase stability is measured using electron backscatter diffraction and compared to thermo-calc predictions. The strength of the alloy is determined by nanoindentation hardness measurements. The resulting SSS is described using two models. The Labusch model does not have predictive power but it reveals that Cr is the most potent strengthener. The Varvenne model describes the concentration dependent SSS in the Cantor alloy system well for all investigated diffusion couples.

MM 60.3 Thu 16:15 IFW B

Exploring slip across Laves phase interface in magnesium alloy — •Julien Guénolé[1,2], Muhammad Zubair[1], and Sandra Korte-Kerzel[1] — [1]Institute of Physical Metallurgy and Materials Physics, RWTH Aachen University, Germany — [2]LEM3 - CNRS, Metz, France

The mechanical behaviour of Mg-Al alloys can be largely improved by the formation of an intermetallic Laves phase skeleton, in particular the creep strength. Recent nanomechanical studies revealed plasticity by dislocation glide in the Mg2Ca Laves phase, even at room temperature. As strengthening skeleton, this phase remains however brittle at low temperature. In this work, we present experimental evidences of slip transfer from the Mg matrix to the Mg2Ca skeleton at room temperature. We further explore the associated mechanisms by means of atomistic simulations and identify two type of slip transfer depending on the crystallographic orientation: a direct and an indirect slip transfer.

MM 60.4 Thu 16:30 IFW B

Uncovering Fundamental Subsurface Deformation Mechanisms in High-Purity Copper Induced by Sliding — •C. Haug[1,2], F. Ruebeling[1,2], A. Kashiwar[3,4], P. Gumbsch[1,3,5], C. Kübel[3,4,6], and C. Greiner[1,2] — [1]Karlsruhe Institute of Technology (KIT), IAM, Karlsruhe, Germany — [2]KIT IAM-CMS MicroTribology Center — [3]KIT, INT — [4]Department of Materials and Earth Sciences, Technical University of Darmstadt (TUD), Darmstadt, Germany — [5]Fraunhofer IWM, Freiburg, Germany — [6]KIT, KNMF

Friction and wear in mechanical systems greatly contribute to global energy consumption. Fundamental studies of the mechanisms governing dislocation mediated plastic deformation and friction at metal sliding interfaces may greatly help expedite the development of materials tailored for low friction and little wear. The present work therefore investigates the microstructural changes induced by sliding in the vicinity of a twin boundary in high-purity copper. The formation of two distinct horizontal line features (dislocation trace lines, DTL) parallel to the sliding interface is observed and their interaction with the twin boundary studied by means of automated crystal orientation mapping (ACOM). Utilizing the twin boundary as a marker, three concurrent fundamental deformation mechanisms are discerned: First, a simple shear process affecting the immediate subsurface area. Second, a localized shear process at the lower DTL. Third, a crystal rotation of the areas between the sliding interface and both DTLs. The three processes are found to exhibit a strong compatibility. Their identification is decisive for guiding future experimental and modeling efforts.

MM 60.5 Thu 16:45 IFW B

Size effect in bi-crystalline Cu micropillars with a coherent twin boundary — •Reza Hosseinabadi, Gerhard Dehm, and Christoph Kirchlechner — Max-Planck-Institut für Eisenforschung GmbH

It was recently shown by micropillar compression that the stress for ideal dislocation slip transmission through a Coherent Twin Boundary (CTB) is similar to the stress required for dislocation cross-slip. The difference in shear stress of a single and bi-crystalline micropillar (Δ*2%) can be as low as 7 MPa. A double-hump dislocation shape was proposed to explain the unexpectedly low difference, where an additional curvature of dislocations in bi-crystalline micropillars is necessary to form a perfect screw dislocation required for the cross-slip-like slip transmission.

Aim of this study is to study the size scaling of CTB containing micropillars to validate or revise the double-hump theory. We employ Focused Ion Beam (FIB) machining to mill more than 120 micron-sized single and bi-crystalline pillars with a single vertical Σ3(111) CTB. Subsequently, in situ microcompression experiments inside a scanning electron microscope (SEM) as well as post-mortem imaging using SEM were performed.

Bi-crystalline pillars follow the same size scaling laws as typically observed in micro-pillars, i.e. smaller are substantially stronger. Furthermore, Δ*2% tends to increase with reduced pillar diameters. This effect can be explained by the double-hump theory and will be quantitatively compared to model predictions.

MM 60.6 Thu 17:00 IFW B

How to optimize strength and conductivity in metallization layers by alloying? — •Viswanadh Gowtham Arigela[1], Tobias Oellers[2], Alfred Ludwig[2], Christoph Kirchlechner[1], and Gerhard Dehm[1] — [1]Structure and Nano-/ Micromechanics of Materials, Max-Planck-Institut für Eisenforschung GmbH, Dusseldorf, Germany — [2]Institute of Materials, Ruhr-Universität Bochum, Bochum, Germany

The current trend of ever harsher environments and power densities in microelectronic applications brings the need of enhanced thermo-mechanical and electrical properties in metallization layers. It is of particular interest to develop copper alloys with improved strength at service temperature, which can be up to 400°C. Consequently, mechanical characterization of these systems at their service conditions at the micrometer length scale is required. We have used combinatorial approaches to synthesize binary Cu-Ag and Cu-Zr alloys with the aim of enhancing the mechanical properties. The specimens were fabricated from thin-film material libraries using photolithography. The mechanical properties of the alloys were investigated at temperature of up to 400°C using microtensile specimens. Finally, the deformation mechanisms were investigated by scanning electron and transmission electron microscopy. In the talk we will show a substantial improvement of the thin film performance of the alloys. Furthermore, we discuss the underlying strengthening mechanisms. Based on the results we will discuss how alloys with an optimized combination of strength and conductivity can be realized for microelectronic applications.