High-Rate, in situ DTEM Mechanical Testing

How We Fit

Development of a new sample preparation technique
- Samples have to be small enough to reach high strain rates but big enough to avoid damage during handling
- Femtosecond laser machining -> Samples 10μm thick, 400μm wide and 2mm long with a central gauge region
- Ion milling -> Electron transparent area in the gauge region

Dynamic TEM at LLNL
- Generation of ultrashort and intense electron pulses by photo-emission
- Time resolution < 30 ns
- Space resolution = 20 nm

Key Goals

- Visualize in-situ when metals deform at high strain rates inside a TEM
- In-situ TEM studies provide information on defect (dislocations and twins) mobility, nucleation mechanisms, and interactions.

Technical Approach

New generation of high strain rate TEM holder
- Strain gauges record displacement and force
- Two pieces working in bending load the sample
- Limited force: 200mN
- Max block speed: 200 mm.s⁻¹

Major Results

High strain rate Dynamic TEM tensile tests: Pure Copper
- Strain rate 4x10⁶ s⁻¹
- Formation of slip bands or twins
- Deformation transmitted b/w grains by dislocation pre-ups
- Stress concentration -> initiation site for cracks
- Propagation of the crack through the grains mainly along (111) planes at 0.6m/s

Key Accomplishments

- Developed:
  - Unique straining holder using piezo actuators to produce high strain rates inside DTEM
  - New sample preparation technique to produce electron transparent sample using Femtosecond laser machining and ion milling
- Testing of pure Copper at 4x10⁶ s⁻¹:
  - Twins narrower and more numerous than quasistatic tests
  - Triple junctions act as twin and crack nucleation sites
  - Cracks propagate through grains along (111) planes at 0.6 m/s
- Testing of pure Magnesium at 4x10⁶ s⁻¹:
  - Trans-granular cracking instead of at grain boundaries
  - Crack speed affected by grain boundaries

Future Directions in 2017

- Shorter time delay between pictures (50ns)
- Improvement of the spatial resolution
- Testing AZ31B and Mg binary alloys (Mg-9%Al, Mg-6%Al, Mg-6%Y, Mg-8%Y)