

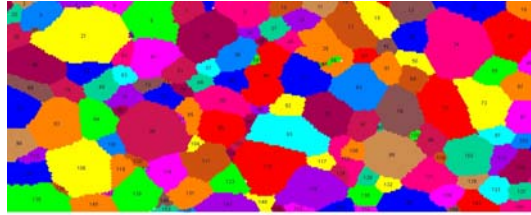


Multiscale Experiments and Modeling of Polycrystalline Plastic Flows

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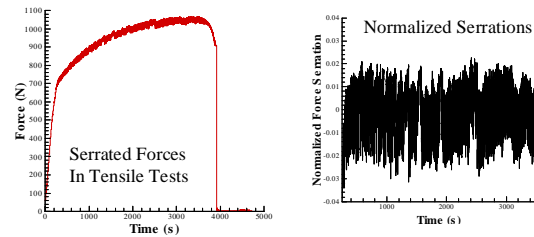
Microtexture of a Polycrystal



120.0 μm = 60 steps Unique Grain Color

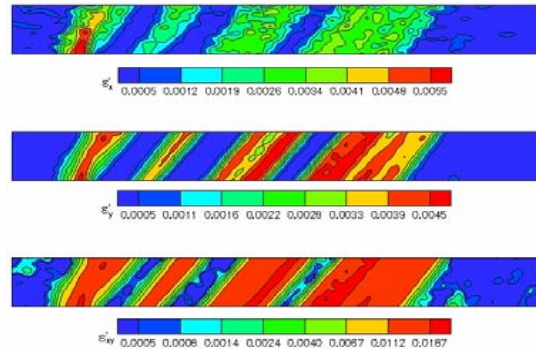
Based on the automated analysis of electron backscatter diffraction patterns (EBSD) inside SEM, a polycrystal solid can nowadays be characterized in greater details in terms of grain size, shape, and orientation. The challenge is how to develop models to predict the mechanical behavior (strength, flow, fracture and fatigue) of a material from its microstructure.

Unstable Plastic Flows in Al Alloys



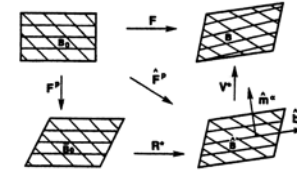
Aluminum alloys are increasingly used in aerospace, automotive, and other industrial applications but some of them exhibit anomalous unstable plastic flow behaviors that have detrimental effects on their mechanical properties.

We have developed a technique that allows detailed temporal (above) and spatial (below) characterization of unstable plastic flows in metals at mesoscopic and macroscopic scales.



Propagative shear deformation bands observed in an aluminum tensile coupon.

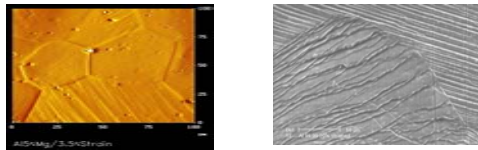
Crystal Plasticity Models of Grains



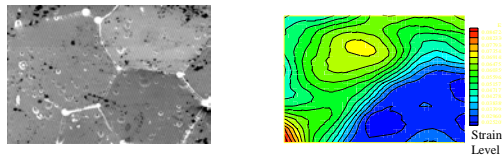
$$\mathbf{F} = \mathbf{V}^* \mathbf{R}^* \mathbf{F}^p, \quad \mathbf{F}^p = \mathbf{I} + \sum_{i=1, \dots, n} \gamma^{(i)} \mathbf{s}^{(i)} \otimes \mathbf{m}^{(i)}$$

Constitutive models of grains and grain boundaries are being developed based on our microscale experiments. Each crystal is modeled to undergo plastic deformation by crystallographic slip \mathbf{F}^p , a lattice rotation \mathbf{R}^* , and elastic stretching \mathbf{V}^* . Particular emphases are on alloying effects on the slip activation and transmission in a polycrystalline solid.

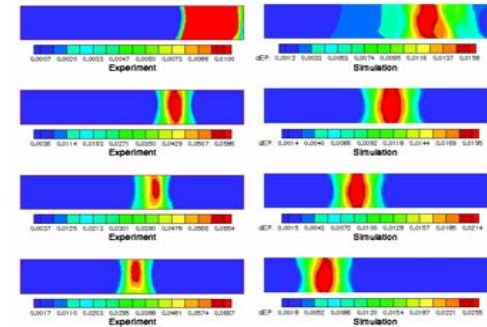
Microscale Experiments on Grain Deformation and Grain Interactions



We carry out micromechanical experiments to investigate the grain deformation and grain interactions. AFM and SEM are used to detect active slip systems via slip-plane traces on crystal surfaces (above). Correlation of digital microimages of grains is used to measure plastic strain fields at grain interiors and near grain boundaries (below).



Nonlinear Finite Element Simulation



A polycrystal sample is modeled grain-by-grain using finite elements and the deformation and interaction of grains are described by the crystal plasticity constitutive equations. The collective behavior of grain aggregates is simulated and compared with experimental observations.

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