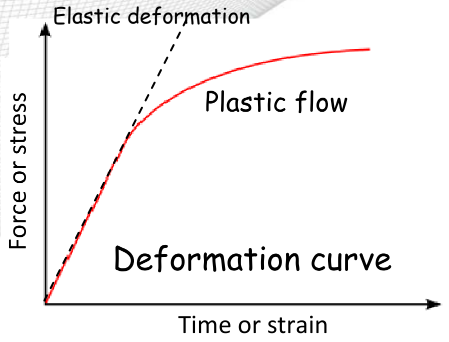
Multiscale correlations in unstable plastic flow

M.A. Lebyodkin[1], T.A. Lebedkina[1,2]

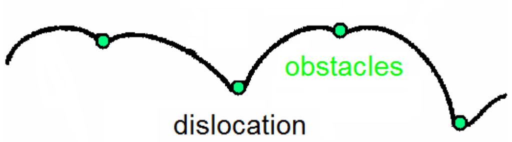
[1] *LEM3 UMR 7239, CNRS / Université de Lorraine, Ile du Saulcy, 57045 Metz, France*
[2] *Laboratoire d'Excellence 'LabEx DAMAS', Université de Lorraine, Ile du Saulcy, 57045 Metz, France*



Plasticity of crystals

Plastic (irreversible) deformation is possible due to the motion of defects of the periodic crystal lattice, mainly dislocations – linear defects

Classical view



Microscopic scale: thermally activated motion of dislocations through obstacles ⟹
Averaging over a statistically large number of non-correlated movements of dislocations (10^{10}-10^{12} cm-2) ⟹
Macroscopic scale: homogeneous plastic flow and smooth deformation curves

Complexity in plasticity

Plastic flow – *nonlinear, irreversible, dissipative*

Dynamics of the dislocation system

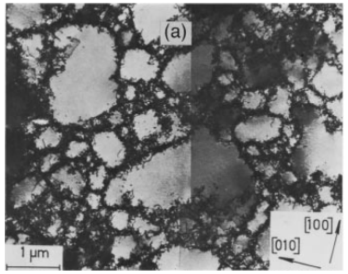
- ✓Lattice friction
- ✓Interactions with other defects (pinning/depinning)
- ✓Long range interactions with each other ("jamming")
- ✓Multiplication, annihilation, reactions

Complexity of the dislocation itself

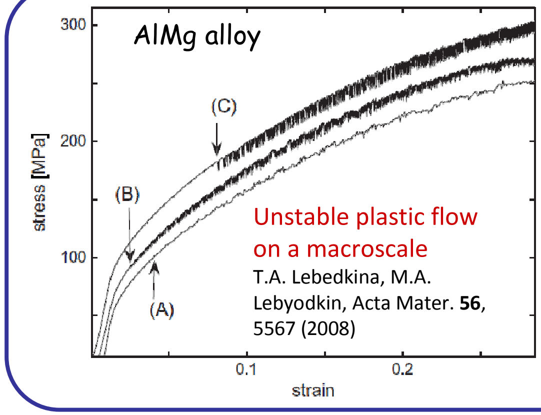
- ✓Out of equilibrium
- ✓Many degrees of freedom
- ✓Glide is bound to crystallographic planes
- ✓Non conservative motion (climb to another plane)

Mesoscopic scale: various collective phenomena, including avalanches

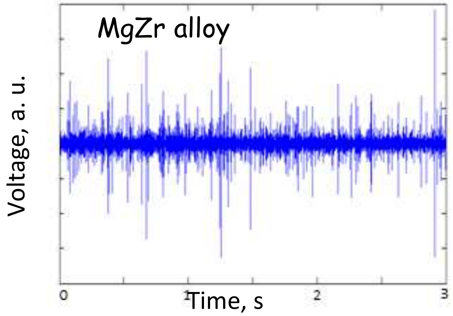
Examples of complexity



Dislocation patterning
H. Mughrabi, et al. Phil. Mag. A, 1986



T.A. Lebedkina, M.A. Lebyodkin, Acta Mater. **56**, 5567 (2008)



Acoustic emission during smooth plastic flow, unpublished

Objects of the investigation

Some results

Macroscopic plastic instability: Portevin-Le Chatelier effect in alloys

Statistical analysis of stress serrations (macro) and acoustic emission (meso):

- Transition from Self-Organized Criticality (high strain rate) to the phenomenon of Synchronization (low strain rate) in the dislocation dynamics
- Deterministic chaos at intermediate strain rates

Mesoscopic scale

Local extensometry:

- Competition between wave-like and burst-like behavior
- Similar patterns in AlMg, Cu, TWIP steel, Ti,…: general dynamical mechanisms