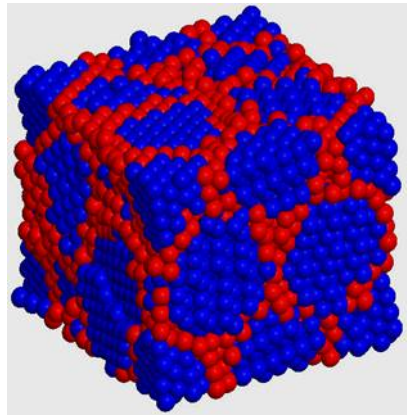
Physical Metallurgy

12/09 Lecture Review

Nanocrystalline Metals

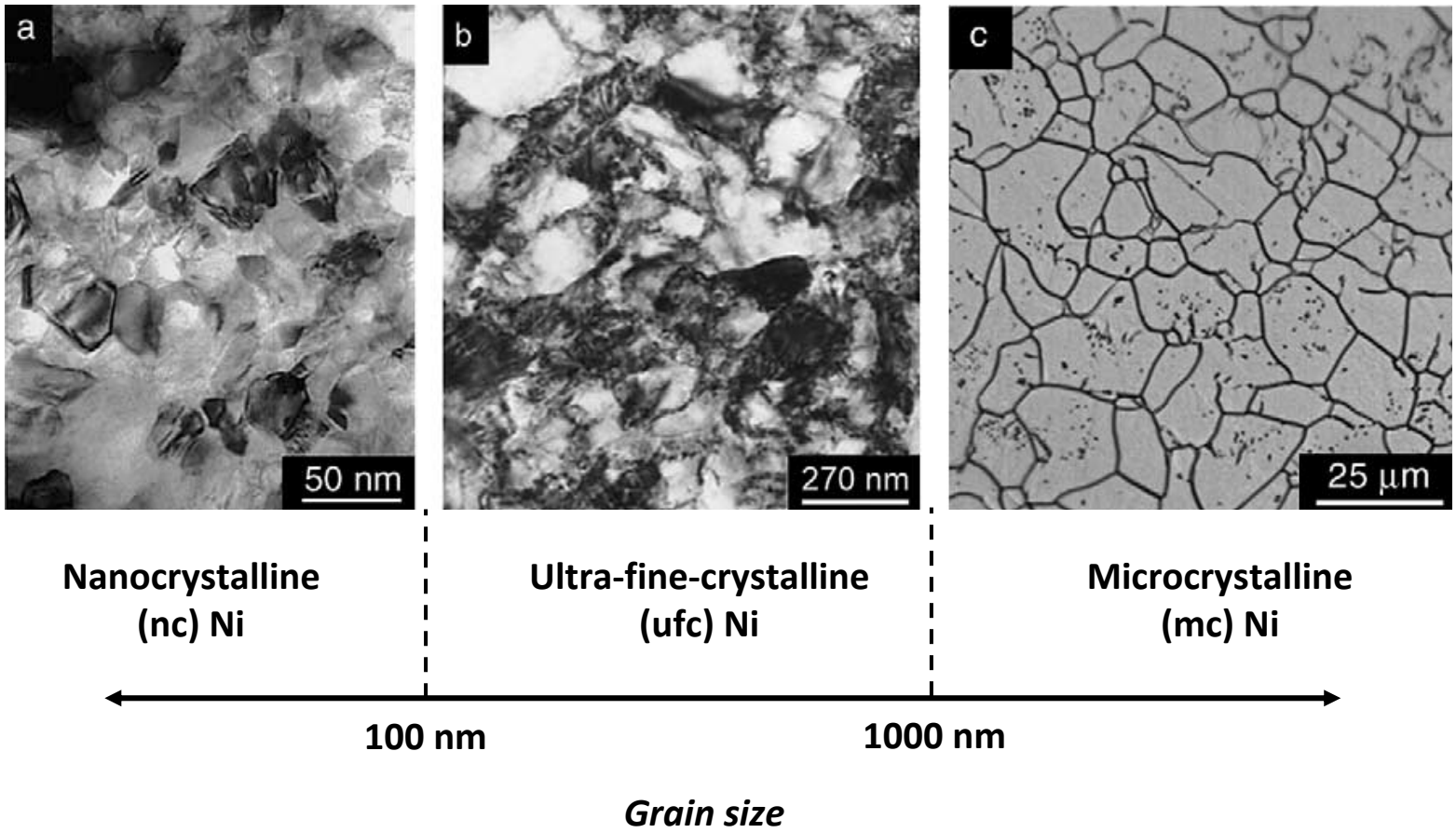


Courtesy of Chris Schuh.
Used with permission.

Dept. of Mechanical Engineering, MIT

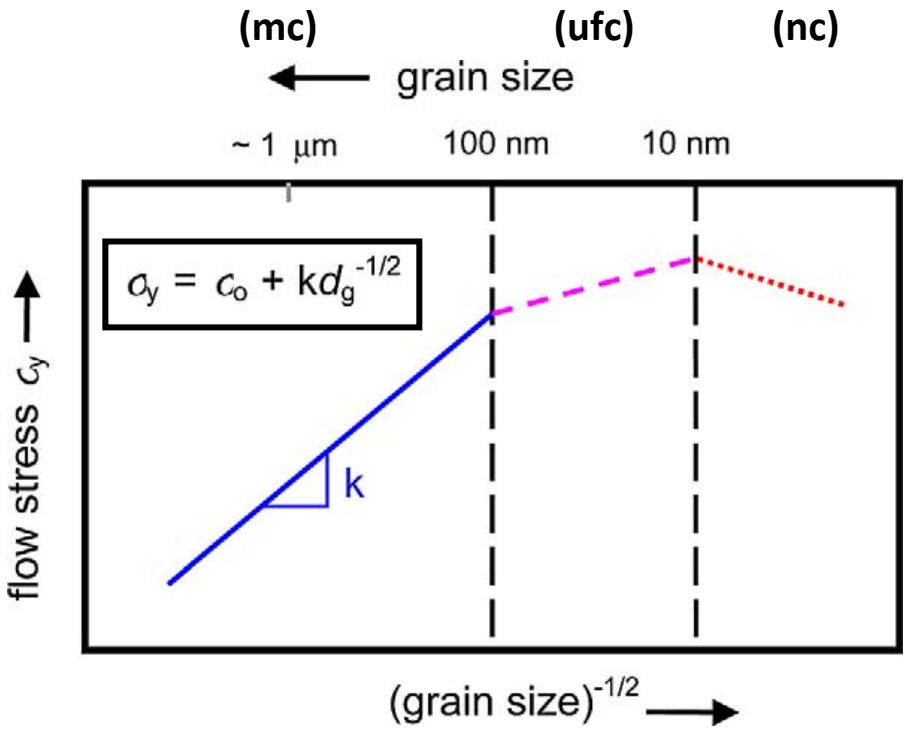
http://schuh.mit.edu/research/images/nanox_3Datomicstruct.jpg

nanocrystalline metals



T. Hanlon, Y.-N. Kwon, S. Suresh (2003) Scripta Materialia

strengthening effects of grain size



- mc

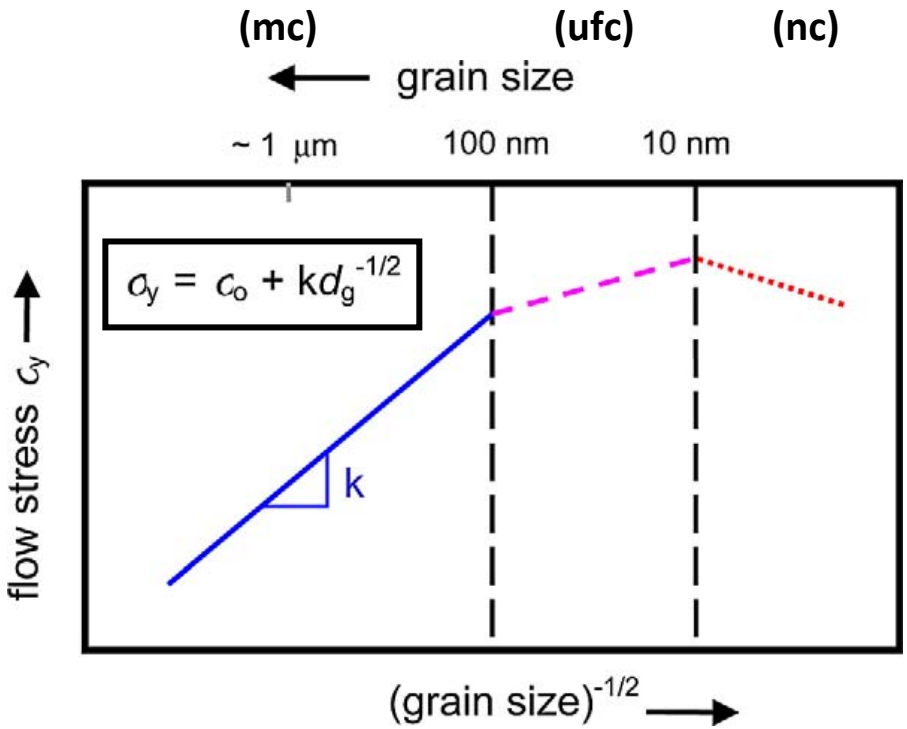
  Hall-Petch relationship ($\sigma \sim d^{-½}$)
- ufc

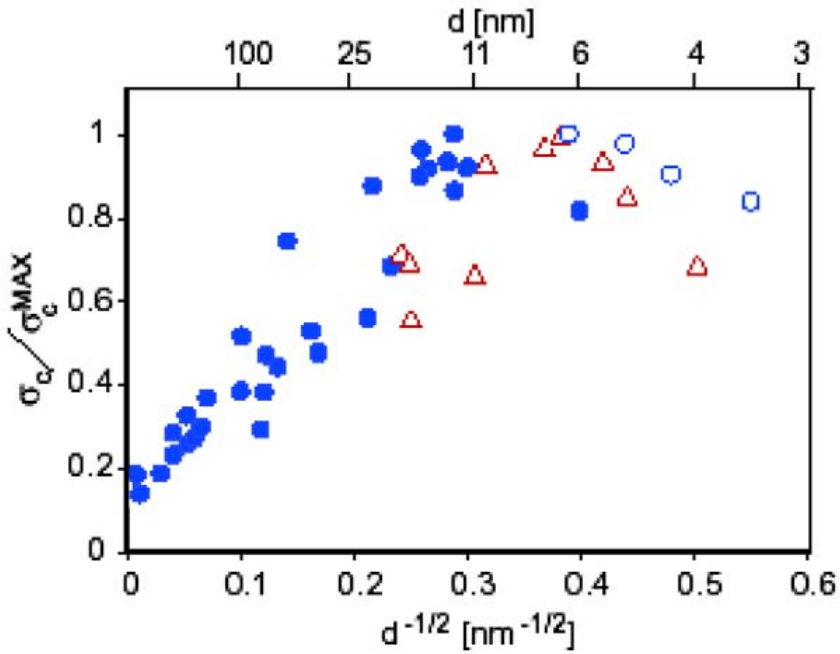
  $\sigma \uparrow$ as d $\downarrow$, but not like H-P
- nc

  σ plateau or <u>decreasing</u>!

K. S. Kumar, H. Van Swygenhoven and S. Suresh (2003) Acta Materialia

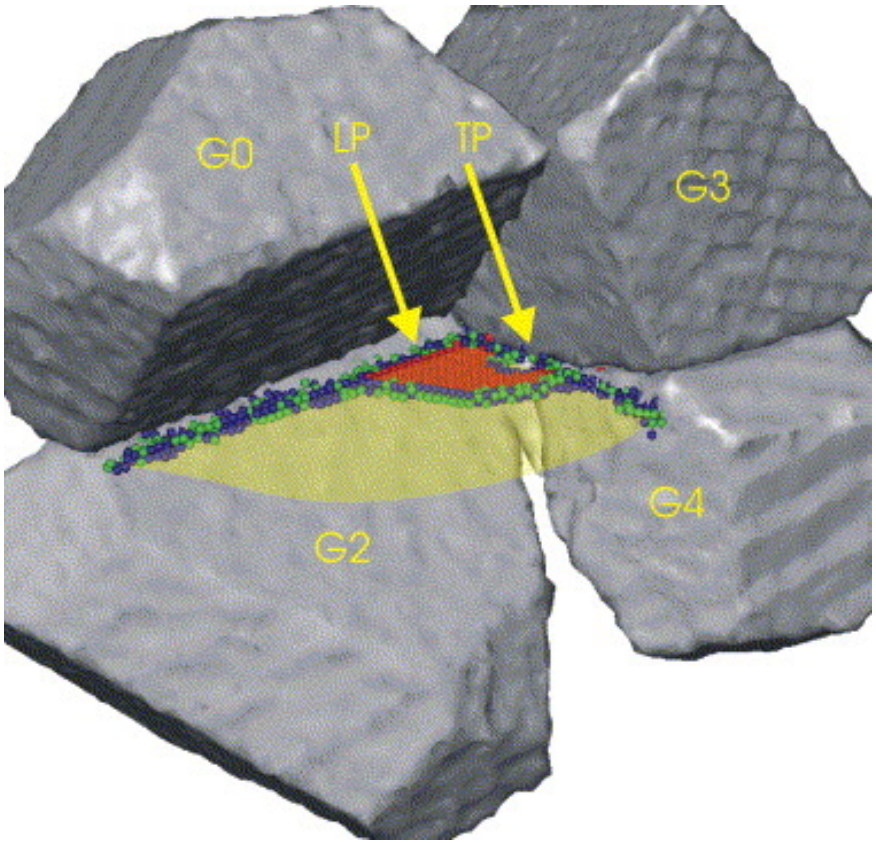
strengthening effects of grain size





K. S. Kumar, H. Van Swygenhoven and S. Suresh (2003) Acta Materialia

dislocation motion in nc materials



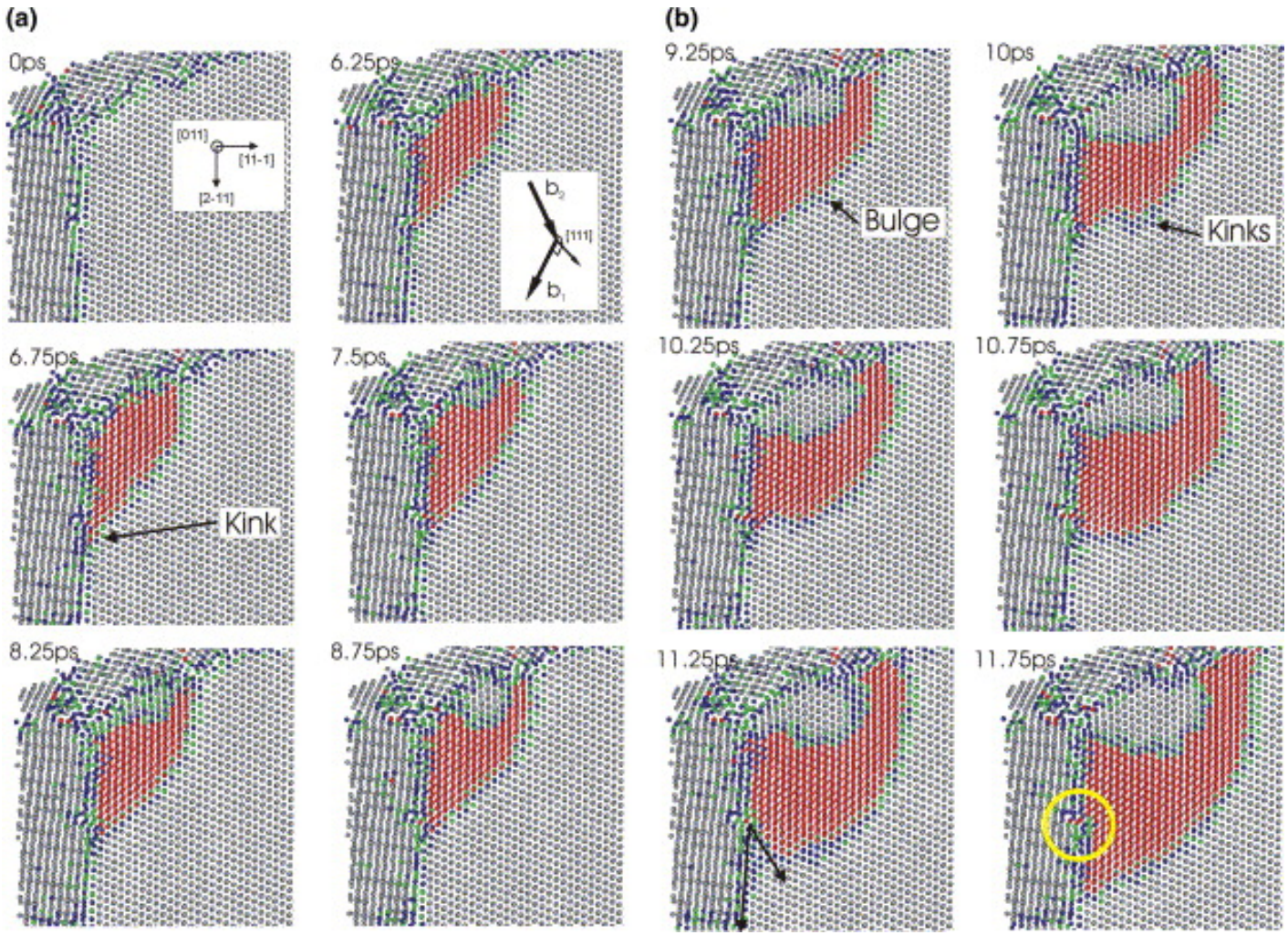
Grain Boundaries (GB) can act as dislocation sources

3 step process:

- Nucleation
- Propagation
- Reabsorbed at GB

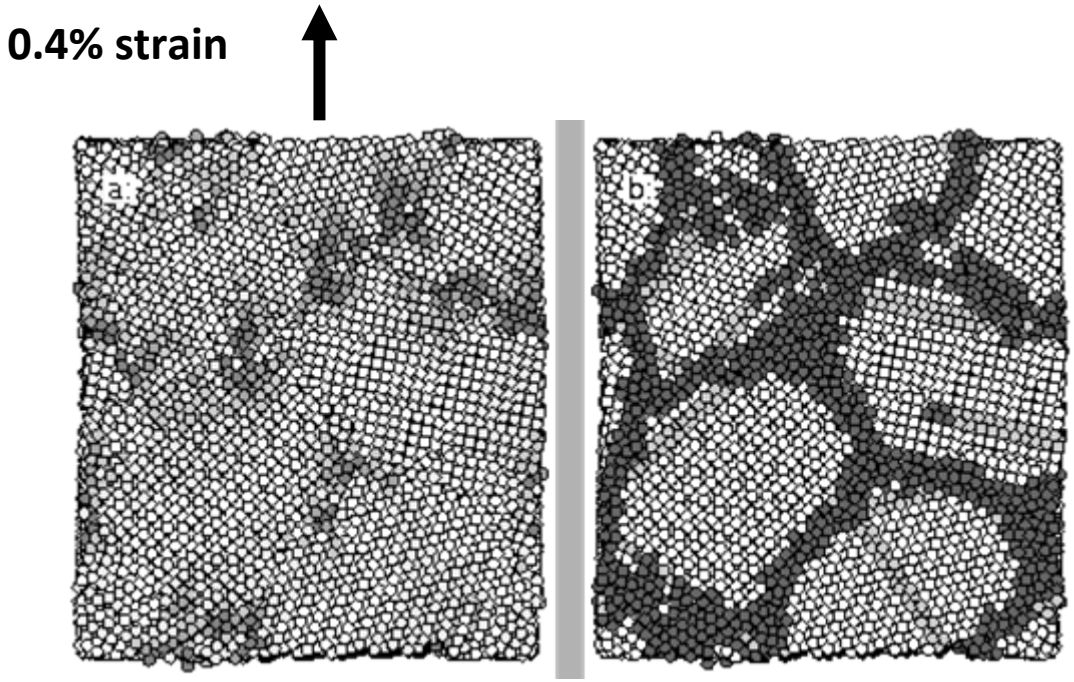
H. Van Swygenhoven, P.M. Derlet and A.G. Frøseth (2006) Acta Materialia

nc (partial) dislocation emission



H. Van Swygenhoven, P.M. Derlet and A.G. Frøseth (2006) Acta Materialia

with very fine nc grains (d < 10 nm)



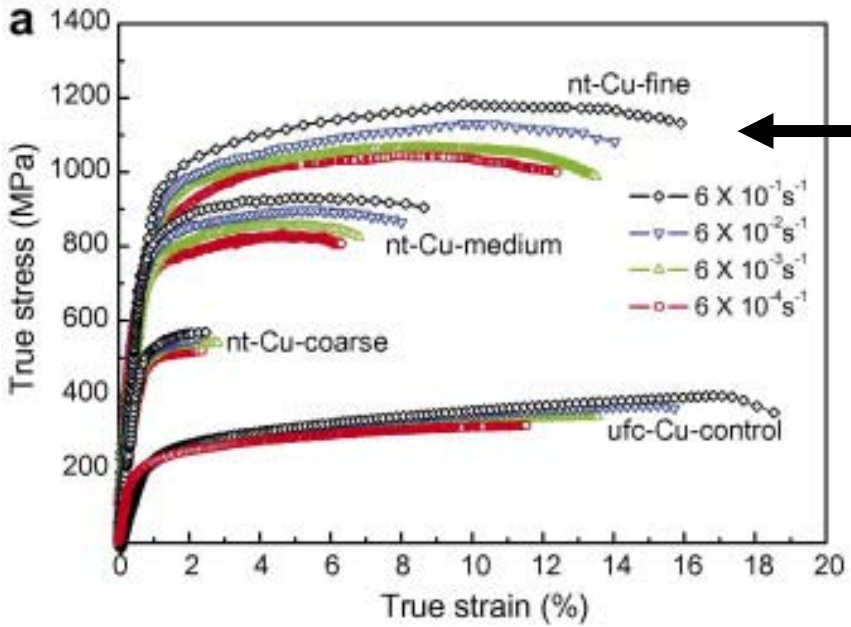
Courtesy of Jakob Schiøtz. Used with permission.

plasticity mainly occuring @ GB's (dark atoms indicate movement)

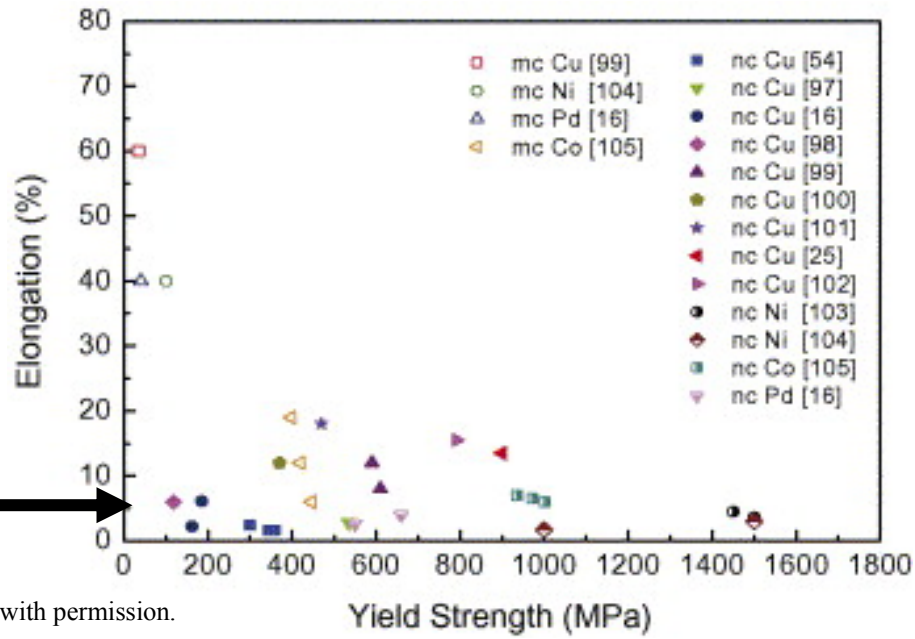
before ***after***

H. Van Swygenhoven, P.M. Derlet and A.G. Frøseth (2006) Acta Materialia

nc tensile testing data



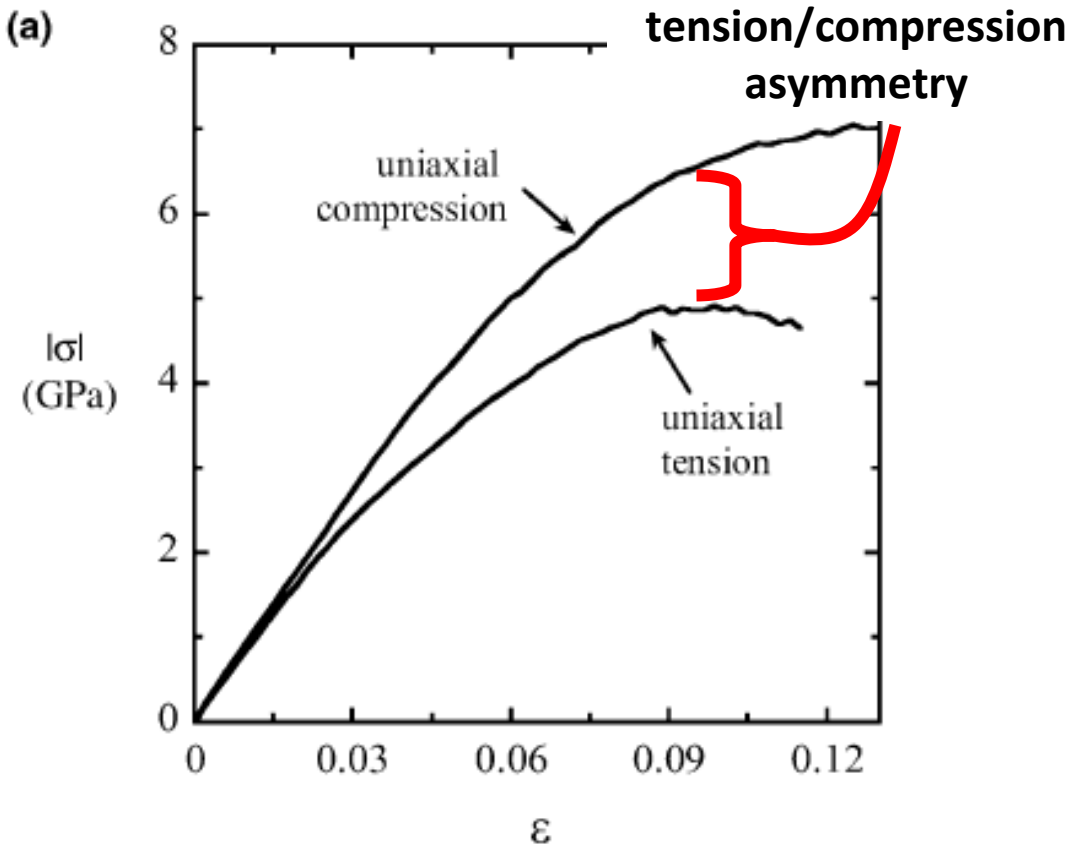
increased strain rate sensitivity



very low ductility (<10%)

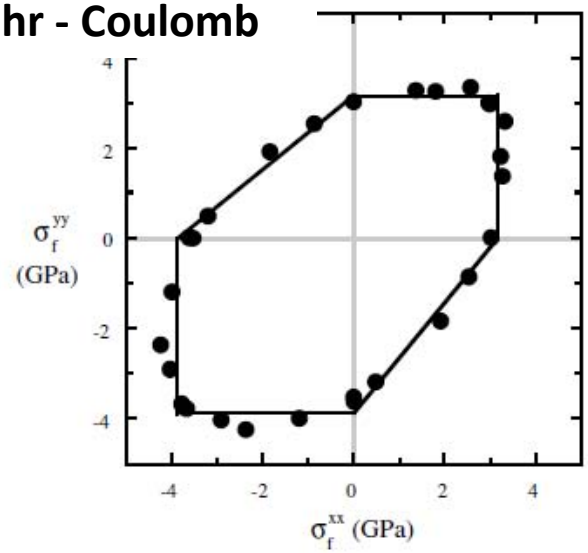
M. Dao, L. Lu, R.J. Asaro, J.T.M. De Hosson, E. Ma, Toward (2007) Acta Materialia

nc yield criteria

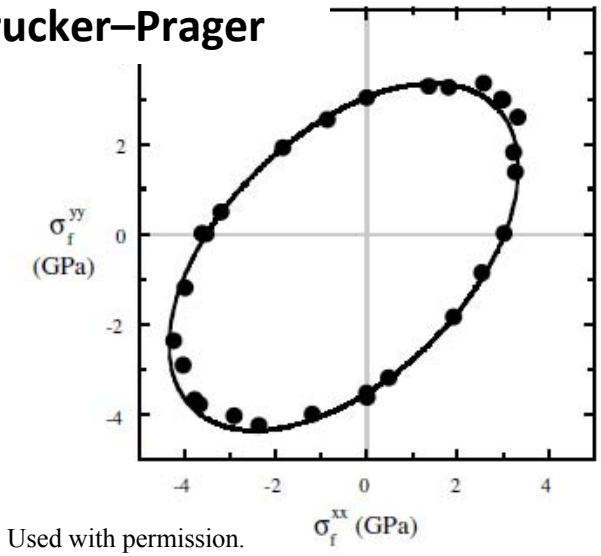


atomistic simulations for d = 4 nm

Mohr - Coulomb

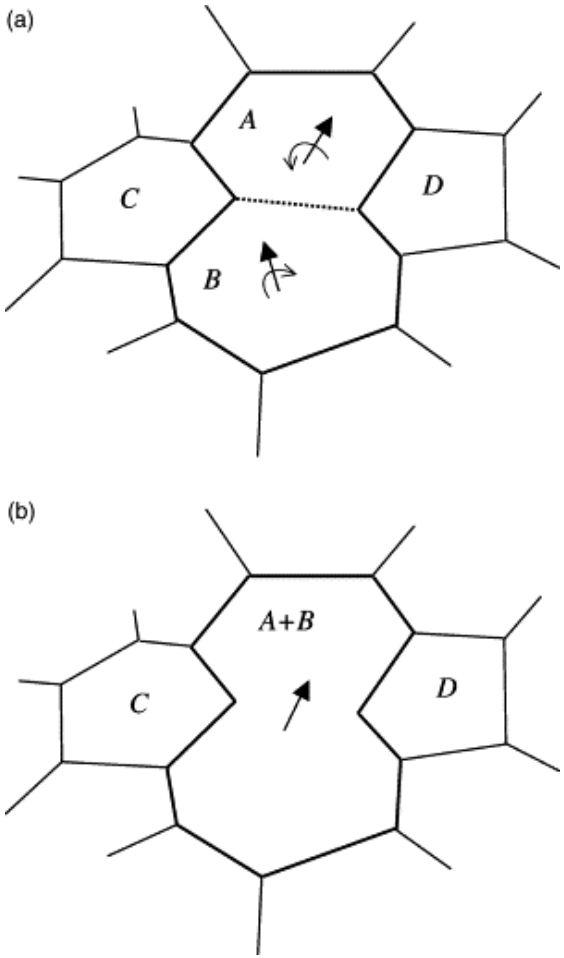


Drucker–Prager



A.C. Lund, C.A. Schuh (2005) Acta Materialia

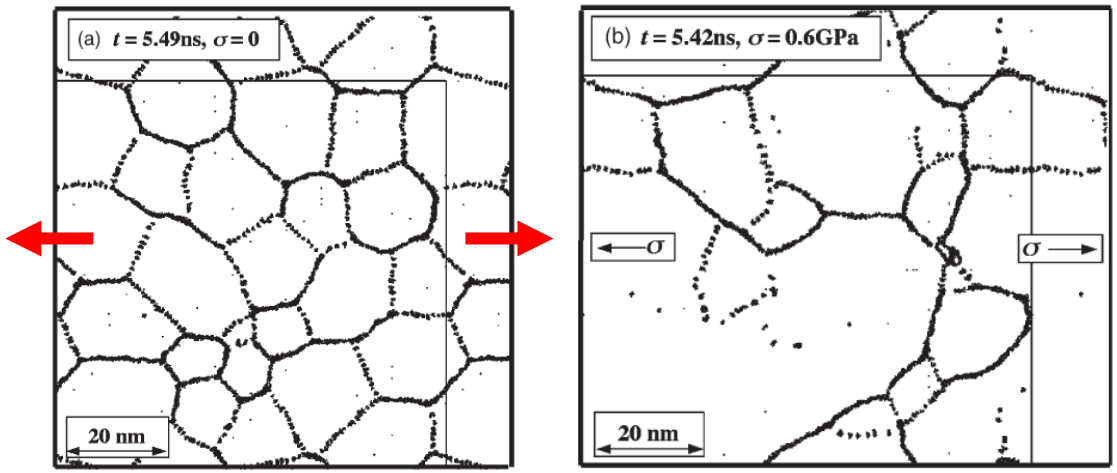
mechanically-induced grain growth



GB rotation

Driven by mechanical force

- GB migration
- GB rotation



before ***after***

D. Moldovan, D. Wolf, S. R. Phillpot, A. J. Haslam (2002) Acta Materialia
A.J. Haslam, D. Moldovan, V. Yamakov, D. Wolf, S.R. Phillpot, H. Gleiter (2003) Acta Materialia

“Nanovated” material

“Integran’s patented Nanovating process, creates materials with 1000 times smaller grain sizes.”

“Integran’s Grain Boundary Engineering (GBE®) process enhances reliability and durability by altering the internal structure of materials on the nanometre-scale.”

Images removed due to copyright restrictions. Please see “Nanovate Technology.” Integran, 2008.

conventional grains **average “nanovated” grain size ~ 20 nm**

http://www.integran.com/tech/nanovate.htm

video – nc testing

- Atomistic simulation of nc Al:

  Psuedo1ntellectual. “Mechanical Properties of Nano-phase Metals (Tensile test).” August 7, 2007. YouTube. Accessed May 14, 2010. http://www.youtube.com/watch?v=QVJ1DOIDl2A

- Bending test of nc Ni-W coating on steel:

  TJRupert. “Bending test – 25 nm grain size – Nanocrystalline nickel-tungsten.” October 6, 2009. YouTube. Accessed May 14, 2010. http://www.youtube.com/watch?v=xl8Ziy3H8CI

Have a good day!

3.40J / 22.71J / 3.14 Physical Metallurgy

Spring 2009