SHOCK COMPRESSION OF CONDENSED MATTER 2009

DISLOCATION MECHANICS OF IRON AND COPPER IN HIGH RATE DEFORMATION TESTS

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Grain Size Dependent Slip/Twinning Transition in Iron at the Hugoniot Elastic Limit (HEL)

Hall-Petch Relations:

Slip

$$\sigma = B\exp(-\beta T) + A\varepsilon^{n} + \sigma_G + k_y \ell^{-1/2}$$

$$\beta = \beta_0 - \beta_1 \ln(d\varepsilon/dt)$$

Deformation Twinning

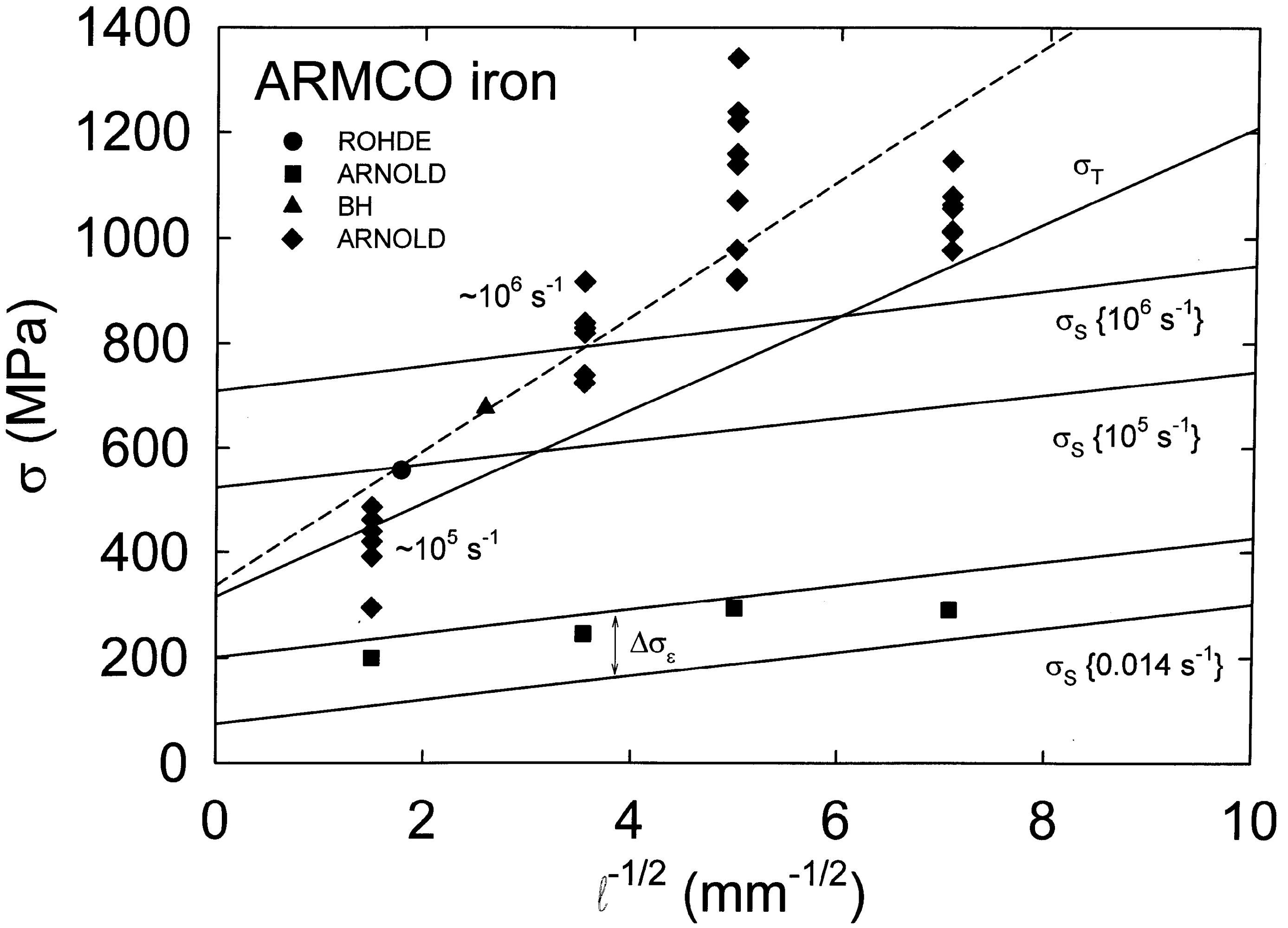
$$\sigma_T = \sigma_{T0} + k_T \ell^{-1/2}$$

References

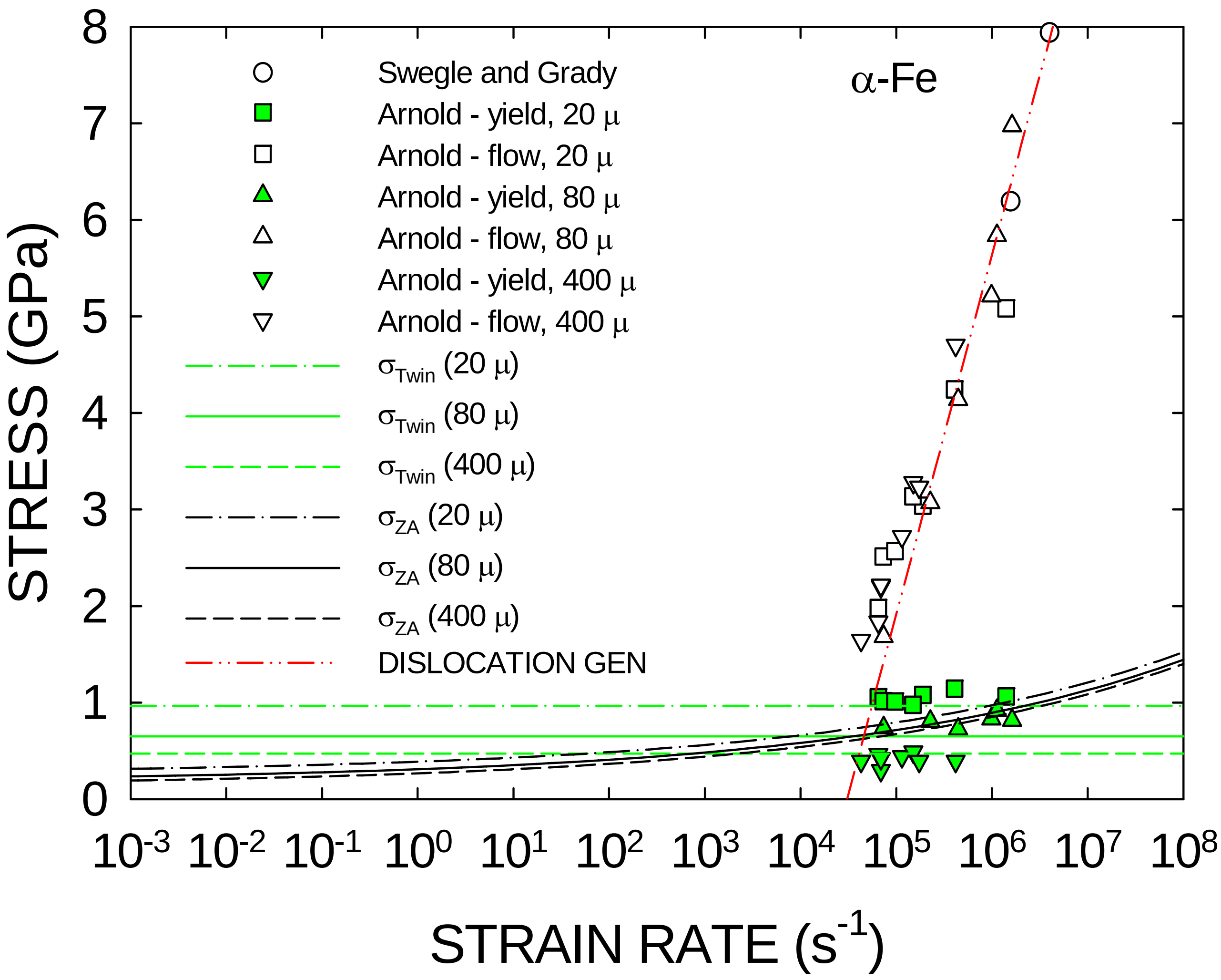
1. F.J. Zerilli, Metall. Mater. Trans. A, 35A, 2547 (2004).

2. R.W. Armstrong and F.J. Zerilli, J. Phys. Coll. 49, (C3), 529 (1988).

Pre-shock Hardness and HEL Measurements as Compared with Model Slip and Twinning Equations



HEL and Shock-induced, Grain Size Independent, Plastic Flow Stresses



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Shock-induced Plasticity Control by <u>Dislocation Generation</u>

Thermal activation at a limiting small *V**

$$\sigma = \frac{2G_{0G}}{V^*} - \frac{2k_BT}{V^*}\ln\left(\frac{\dot{\varepsilon}_0}{\dot{\varepsilon}}\right)$$

Dislocation density characterizations

$$\rho \sim (b_T^2/V^*)^2 \sim (1/b^2) = \sim 1.6 \times 10^{19}\ m^{-2}$$

1. E.M. Bringa, et al., Nature Mater. 5 (2006) 805-809:

$$\rho \sim 10^{18}\ m^{-2}$$

2. M.A. Shehadeh, et al., Appl. Phys. Letts. 89 (2006) 171918:

$$d\rho/dt \sim 10^{28}\ m^{-2}s^{-1}$$

Cu Shockless Isentropic Compression Experiment (ICE)

Instead of dislocation generation control via

$$\frac{d\gamma}{dt} = \frac{d\rho}{dt} b\Delta x_d$$

there is drag control via

$$\frac{d\gamma}{dt} = \rho b v$$

and, in the high velocity limit, with $c = c_0 m^2 \beta_1 / \rho b^2$

$$\sigma^* = \frac{m^2 c_0}{\rho b^2} \dot{\varepsilon}$$

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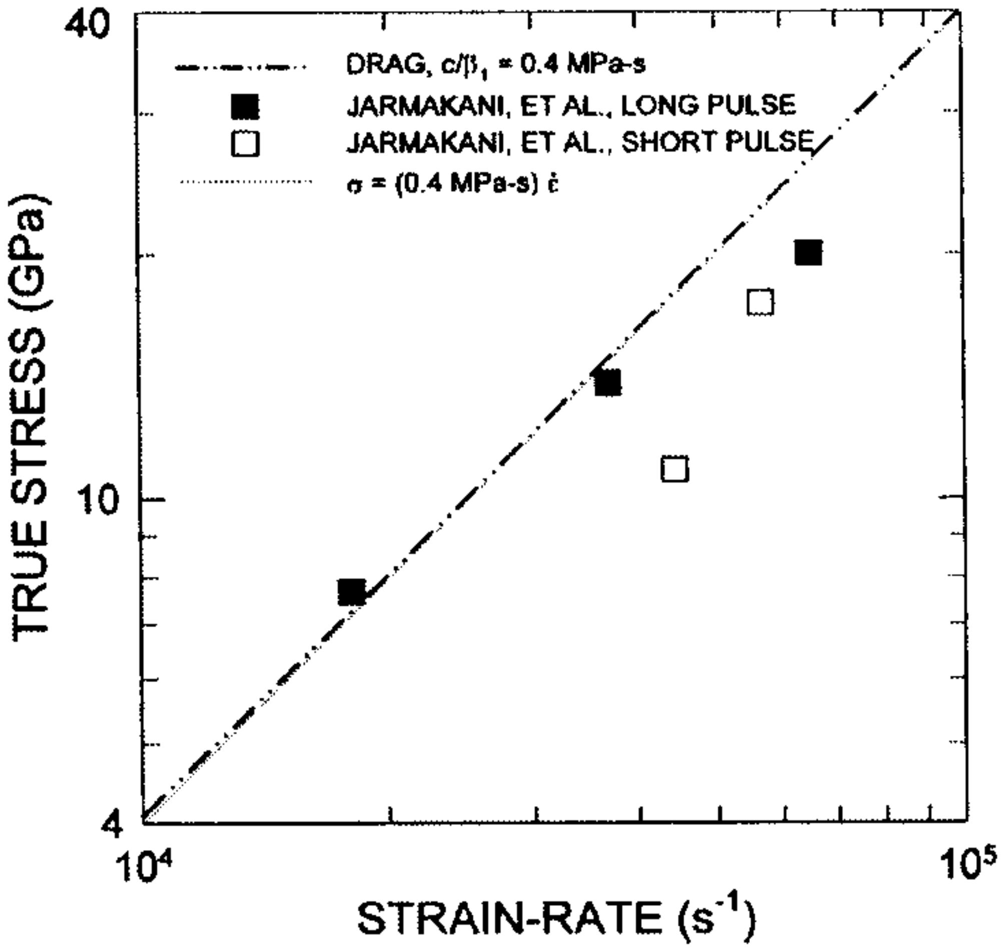
Quasi-ICE Results for Cu Crystals



References

1. H. Jarmakani, J. M. McNaney, B. Kad, et al., Mater. Sci. Eng. A., 463 (2007) 249
2. R.W. Armstrong, W. Arnold and F.J. Zerilli, J. Appl. Phys. 105 (2009) 023511

SUMMARY

1. In shockless-ICE-caused activation of lower, originally resident, dislocation densities, say, of order ~10^{11} m^{-2} in Cu, higher-than-shock, drag-controlled dislocation velocities are achieved at stresses near to the theoretical limit.

2. Shock-front-generated dislocation densities, say, at ~10^{17}-10^{19} m^{-2}, are generated because of the high state of shear stress at all lattice points along the front.

3. Perhaps, at the highest dislocation densities, the shock model consideration is pointing to the possibility of limiting disorder being caused by the creation of clustered interstitial atoms.

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Thank You for

Your Attention !

Any Questions ?

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