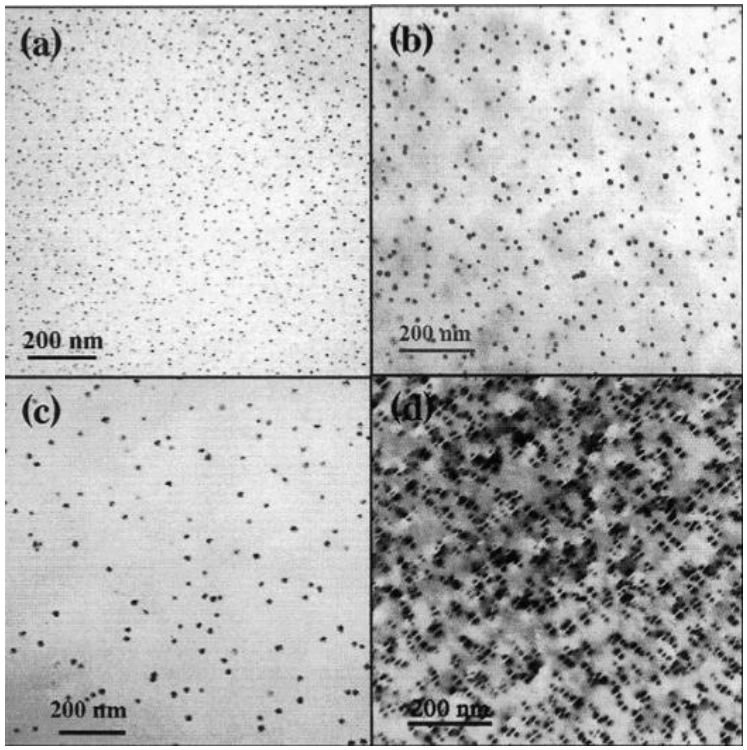
RECAP OF LECTURE 11-4-2009

Precipitation Hardening

Precipitation hardening refers to the increased strength resulting from the presence of small finely dispersed second phase particles, commonly called precipitates within the original phase matrix

How can we design a heat treatment to achieve these microstructures in a binary alloy?



Heat-treatable Al(Sc) transmission electron micrographs from D.N. Seidman et al. Acta Materialia 50 (2002) 4021-4035.

Heat Treatments

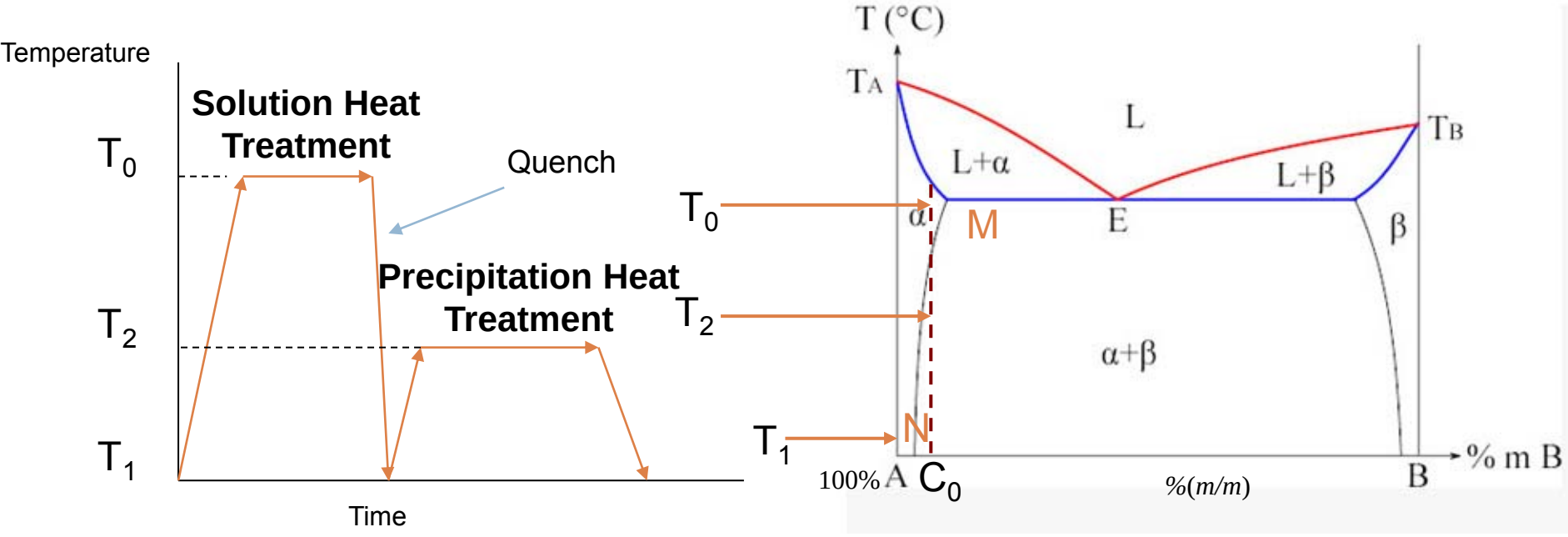
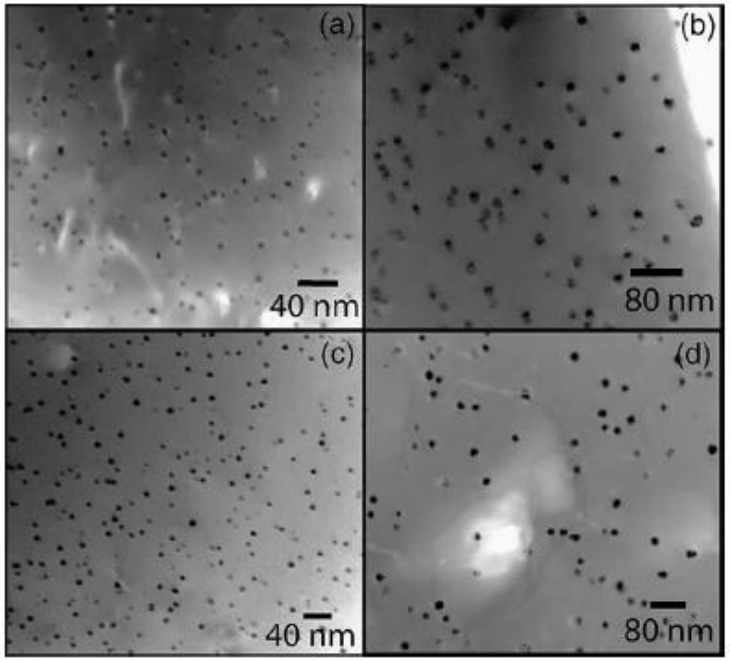


Image from Wikimedia Commons, http://commons.wikimedia.org

Time and Temperature Dependence of the Final Microstructure

Lower Precipitation Temperature Longer Ageing Time

Higher Precipitation Temperature Shorter Ageing Time



Lower Precipitation Temperature Longer Ageing Time

Higher Precipitation Temperature Shorter Ageing Time

Al(Sc,Zr) transmission electron micrographs C.B. Fuller et al. / Acta Materialia 51 (2003) 4803–4814

Lower Volume Fraction of Precipitate Al-0.07 Sc-0.011 Zr

Microstructure a was aged at 300° C for 72 hours

Microstructure b was aged at 320° C for 24 hours

Higher Volume Fraction of Precipitate Al-0.09 Sc-0.047 Zr

Microstructure c was aged at 350° C for 17 hours

Microstructure d was aged at 375° C for 3 hours

Interactions Between Dislocations and Precipitates

A dislocation may cut through a precipitate

A dislocation may bow around a particle and leave behind a dislocation loop

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Please see http://en.wikipedia.org/wiki/File:Particle_strengthening.png
Fig. 7.1 in Shewmon, Paul G. *Transformations in Metals*
New York, NY: McGraw-Hill, 1969.

Hardening Mechanisms

Coherency Hardening

An energy barrier to dislocation motion results from the strain field produced by the mismatch between a particle and the surrounding matrix

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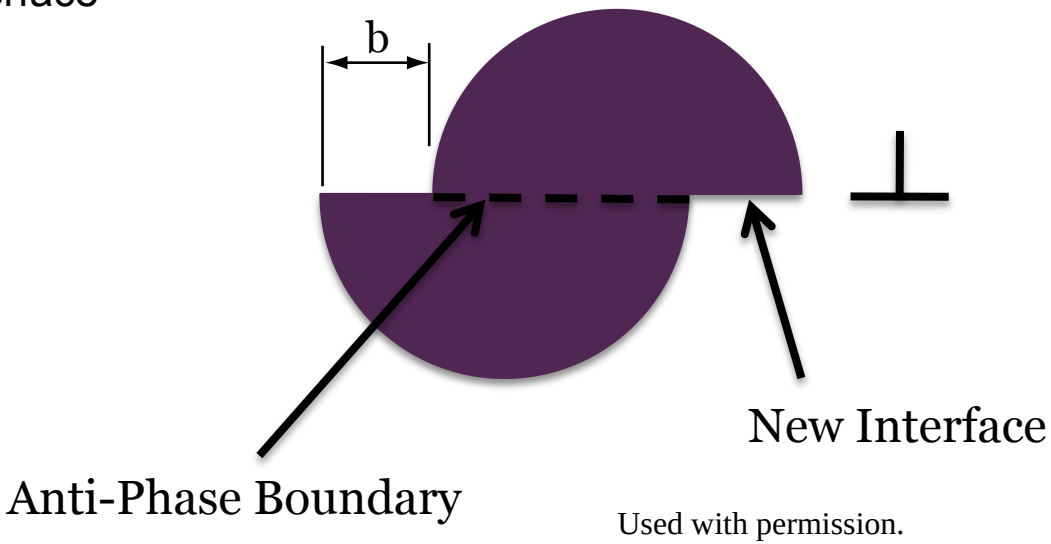
Please see:
http://en.wikipedia.org/wiki/File:Substitutional_interstitial_solute.png
Fig. 7.20 in Shewmon, Paul G.
Transformations in Metals. New York, NY: McGraw-Hill, 1969.

Modulus Hardening

The energy of a moving dislocation is altered when it enters a precipitate with a different modulus than the matrix

Chemical Strengthening

Extra energy is required for a dislocation to pass through a particle due to the formation of a new interface



$$\Delta\tau \cong \frac{\pi\gamma}{b}\nu_f$$

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3.40J / 22.71J / 3.14 Physical Metallurgy

Fall 2009