Hardness of Brass:

Effects of Rolling and Annealing

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What is Hardness?

- Hardness measures the ability of a material to resist plastic deformation:
  - Rebound hardness (previous lesson) is more a measure of elastic properties
  - Direct hardness measurements use an indenter
  - Measurement depends on depth of the indentation and its geometry
- Direct measurement related indirectly to strength.

Hardness Test Methods

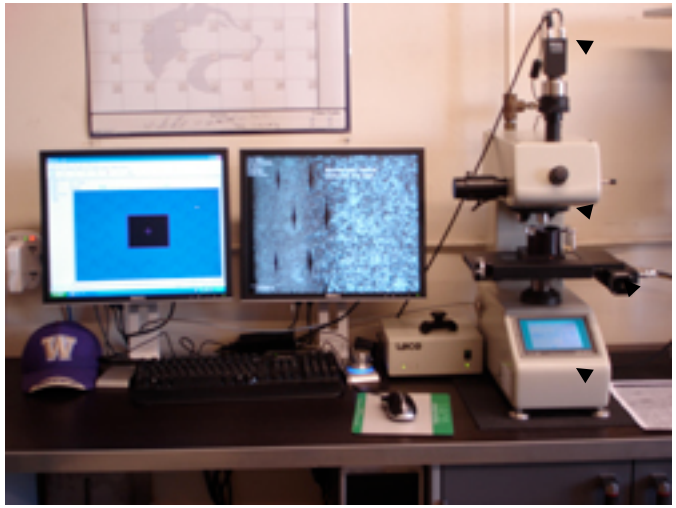
- Rockwell hardness tests use a pyramid-shaped indenter
  - Measurement related to depth of penetration
- Brinell hardness uses a spherical ball
  - Damage to the test specimen often limits is use
- Vickers hardness uses a pyramid-shaped diamond indenter
  - Highly adaptable to all kinds of materials

Vickers Hardness Test

- Hardness value independent of size of indenter
- Indenter can be used for all classes of materials
- Yield strength of material is approximated by $H_v / 3$ where the emperical constant 3 may vary slightly depending on geometrical factors.

Hardness Testing System

In general, a fully automatic microhardness testing system consists of:



- Computer/software with image analysis algorithms
- Video camera and control box
- Certified and calibrated Vickers hardness indenter
- Calibrated optical objectives and carriage
- Automated stage and mounting system
- Certified hardness tester

The Vickers hardness testing system used in the conducted hardness tests is a LECO AMH-43 Automatic Microhardness Testing System (as shown).

Vickers Hardness Number HV

- Diamond indenter with square base
  - 22 degree incline
  - HV determined by ratio of applied force F to surface area A of resulting indentation:

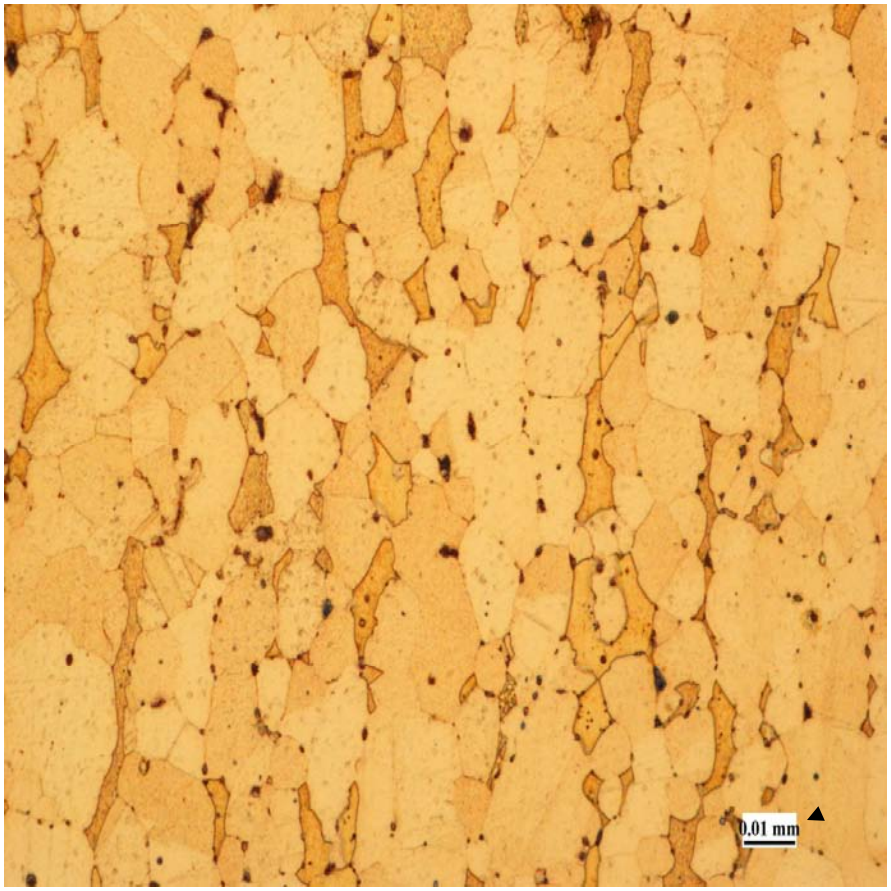
$$HV = F/A = 1.854F/d^2$$

    - d^2 is the square of the average length of the diagonal left by the indenter, and
    - 1.854 is derived from the geometry of the indenter

Property Examination

- Hardness of Brass will vary depending on preparation and treatment:
  - Hardness will increase with cold work such as rolling, swaging or bending
  - Hardness of cold worked brass will decrease with annealing at elevated temperatures
  - Fully annealed brass has a HV of about 91
- Typical microstructure shown on following slide:

As received microstructure
HV = 91



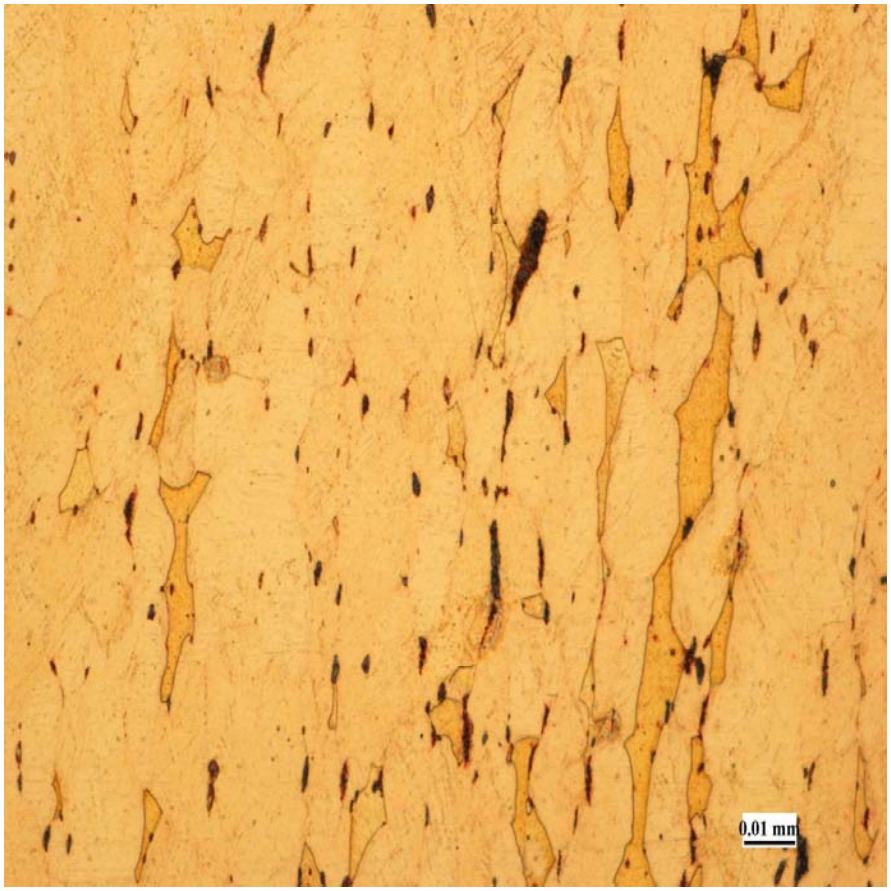
Scale Bar

Please note that all micrographs were taken for comparison using same optical objective (i.e. Magnification).

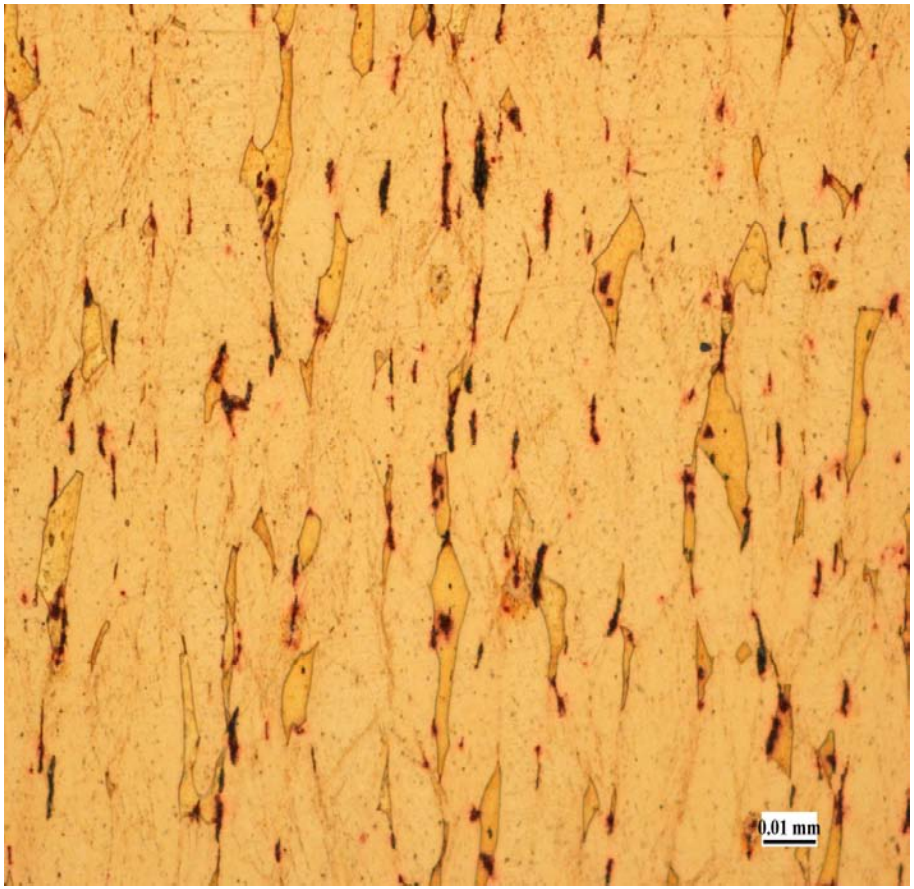
Property Changes upon Rolling

- Cold rolling of sheet brass
  - Causes elongation of the specimen
  - Causes elongation of the grains
  - Introduces defects into the material
  - Increases strength and hardness
- Example microstructures are shown on the following slides as a function of cold rolling:

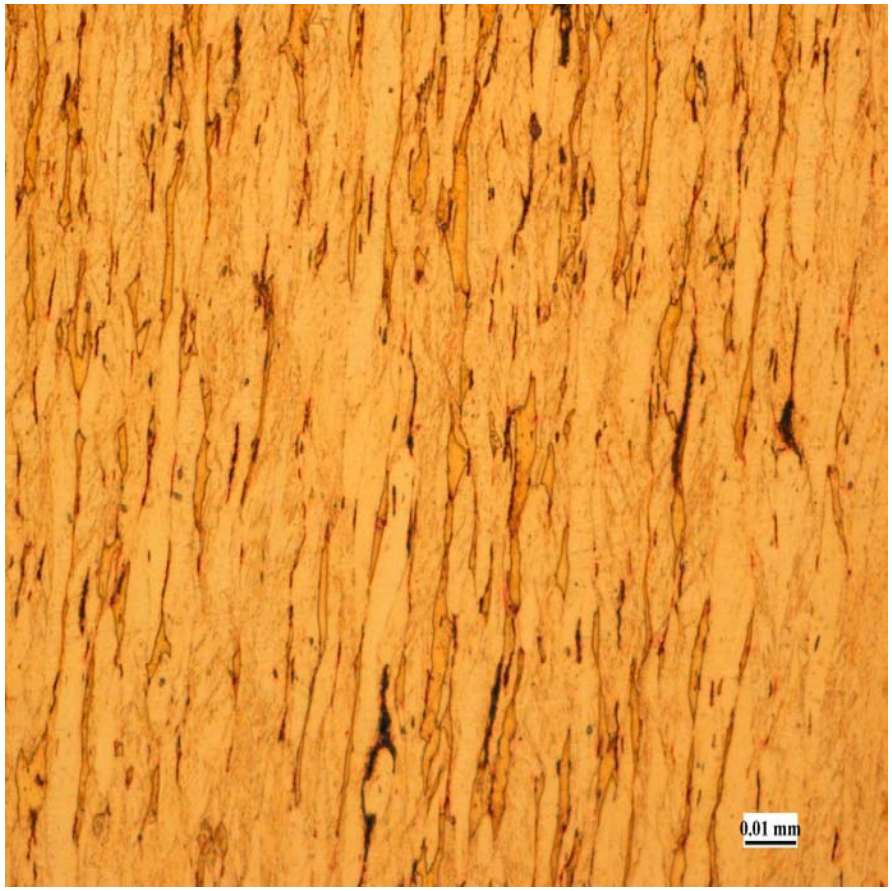
20% cold rolled—note slightly elongated grains
VH = 167



40% cold rolled with more elongated grains
VH = 183



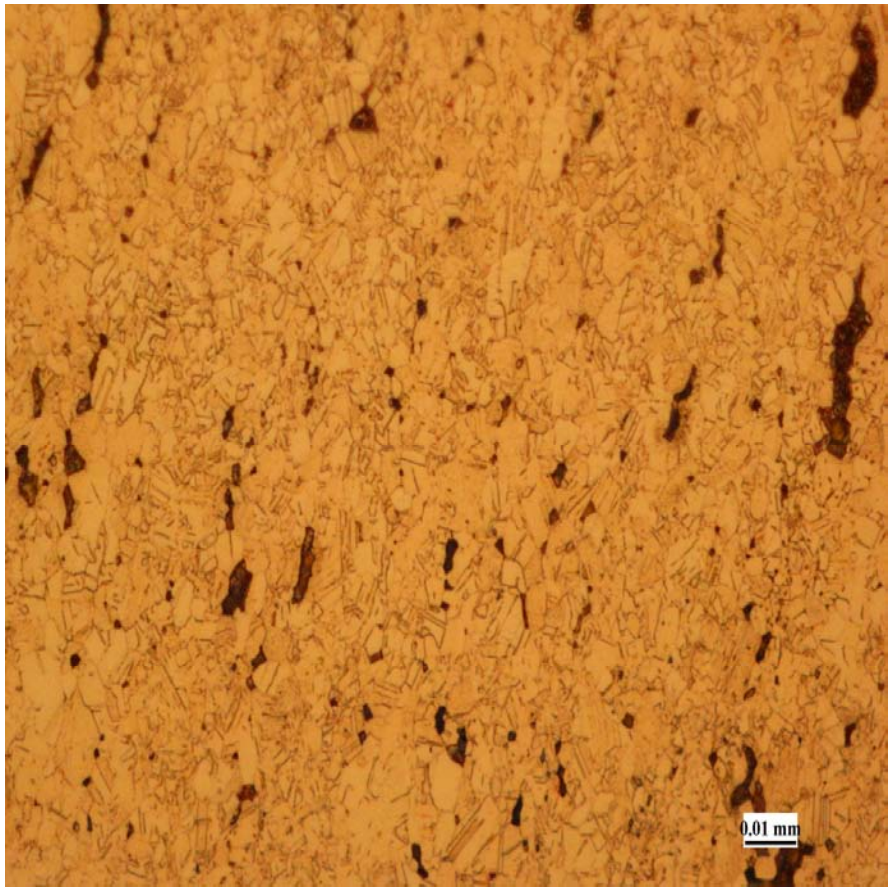
60% cold rolled with greatly elongated grains
HV = 183 (no hardness increase)



Effects of Annealing

- Annealing typically done at over half the melting temperature (measured in degrees absolute)
  - Removes damaged grains
  - New virgin grains grow in their place
  - Hardness decreased to original value
- The following samples show the effects of annealing on microstructure

Microstructure after 500C anneal, 15 minutes
VH = 111



Effects of Annealing

- In slide 14, the hardness has not decreased to the original.
  - Some original (strained) grains remain
  - Smaller grain size typically has higher hardness
  - Both effects result in higher hardness

- Further annealing will cause grain growth and reduced hardness, as shown on the following slide:

Fully annealed sample
HV = 91