Copper Grain Growth
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Theory

- Grain growth occurs through the migration of grain boundaries by the process of short range diffusion.
- Atomic motion of boundary motion are inversely related. As the atoms migrate across the boundaries toward the interior of the grain, the grain boundary moves outward.
- Grain growth occurs more rapidly at elevated temperature. Because grain growth is driven by diffusion as the temperature increases the rate of growth increases.
- The restoration of mechanical properties to a strain hardened or cold worked material involves recovery, recrystalization, and grain growth.
- Grain growth does not need to be proceeded by recovery and recrystalization, it may occur independently in a polycrystalline material.
- In recrystalization the grains grow but the driving process is different. Short range diffusion is still present but it is driven by the difference in energy between the strained and unstrained material. The small nuclei grow and consume the parent material.
- Strain free grains will continue to grow by the previously discussed process if left at elevated temperatures.
Procedure

- We cut five samples from a pure copper rod.
- The samples were placed in an oven preheated to 1700 F.
- Each sample was pulled from the oven after a specified amount.
  - Sample 0 – 0 minutes
  - Sample 1 – 2 minutes
  - Sample 2 – 10 minutes
  - Sample 3 – 60 minutes
  - Sample 4 – 120 minutes
- The samples were all mounted, sanded, polished and etched.
- Etching was done with a $\frac{1}{3}$ ammonia, $\frac{1}{3}$ peroxide, and $\frac{1}{3}$ deionized water solution.
- The samples were all polished using the finest polish available, 0.3 micron.
- The etching was as follows
  - Place surface of the sample in a small bath of solution
  - Remove and use cotton swab to clean, making sure to only rub surface gently.
  - Repeat two or three times depending on desired depth of etch.
  - Rinse the sample of excess solution under running water.
  - Dry using heat gun.
Results

100x magnification

Sample 0 – 0 min.

Sample 1 – 2 min.

Sample 2 – 10 min.
Sample 3 – 60 min.

Sample 4 – 120 min.
200x magnification

Sample 0 – 0 min.

Sample 1 – 2 min.

Sample 2 – 10 min.
Sample 3 – 60 min.

Sample 4 – 120 min.
Discussion

Due to time constraints we were unable to accomplish our initial goal of growing grains to the size where they would be visible to the naked eye. However, we were able to see a large difference in grain size from the original sample starting as early as ten minutes. Even though we did not accomplish our original goal, this experiment was great practice for preparing samples for inspection due to the ease at which it was to both etch and polish. That being said, it was also easy to not get a good polish or etch because copper is so easily scratched during sanding.

What follows is the results of an alternative etching solution, Ferric Chloride, on Sample 2. We opted not to continue to etch with this solution due to color change and multiple poor etches as the solution is much stronger than the ammonia-peroxide solution.

Sample 2 – 10 min. 1700 F
Etched with Ferric Chloride
200x magnification
Sample 2 – 10 min. 1700 F
Etched with Ferric Chloride
200x magnification
Bibliography

• Materials Science and Engineering: An Introduction, Callister-Rethwisch, 7th edition, 2006