Memorandum

Purpose

The microstructure lab explored the crystal structures of copper, cast iron, and two allotropes of steel. The lab intended to demonstrate the procedure used to experimentally determine crystal structure and evaluate the effect heat treatment has upon crystal structure, including the size, shape and uniformity of crystals.

The microstructure lab required several pieces of equipment. It required several sanding/polishing tools used to polish the metal sample to a mirror finish, a etching solution used to etch the sample to make the grains visible, and a camera equipped microscope used to take photographs of the crystals.

Procedure

Several steps were taken to prepare the material samples for the lab. Before the material came to the laboratory for experimentation, it was prepared in a machine shop. Preparation of the sample included cutting the material to specified dimensions and mounting the sample to be testing in a potting compound.

The actual experiment consisted of three major steps. First, the sample was polished to a mirror finish. Second, nitric acid was used to etch the sample. Third, the sample was photographed using a camera-equipped microscope. Each of the steps will be covered in more detail below.

Polishing the sample took the majority of the time needed to complete the experiment. Six machines were used for material removal. The metal first was ground using the coarsest wet sandpaper machine, moved to the next coarsest station, and moved to the finest wet sandpaper station. Keeping distilled water on the sandpaper helped prevent scratches caused by the sandpaper. Between each station, the sample was examined to ensure all previously induced scratches are removed. The fourth station was a polish station, where the polish medium was dissolved in solution. Again, the sample was polished as much as possible at the station, then washed off to prevent mixing of the solutions, and taken to the next station. At the end of the third polish station, the metal had a mirror surface.

After the material was polished to a mirror surface, the metal was placed in a Nitral acid-etching bath. The acid etched the metal for about 20 to 30 seconds, and then the acid was washed off. The sample was air dried and examined with a microscope.

Before taking the photograph of the metal sample, several possible sites were looked at to insure an accurate grain count. After the best site was selected, a photograph was taken and developed.

The final part of the lab involved selecting a portion of the photograph and counting the number of grains. A circle was drawn on the photographs, and all of the grains within the circle were counted. The results of the count were used to calculate the ASTM size of the grains.

Results

Obtaining the results of the lab was not a complicated procedure. A circle was marked on the photograph and the individual grains were counted within the circle drawn. Using the diameter of the circle, the area of the circle was calculated and used in the equation.

Three equations made up the mathematics of calculating ASTM grain size.

$N_m = \frac{Number of grains}{Designated area}$ Equation 1

$N_{400} = N_m \bullet \left[\frac{M}{100}\right]^2$ Equation 2

Where M is the amount of magnification.

$N = \frac{\ln(N_{400})}{\ln(2)} + 1$ Equation 3

Using the number of grains and the area of the circle drawn on the photograph for equation 1 and solving the equations, the ASTM grain size was calculated.

The final results obtained from this lab are in the following table:

Material	Number of Grains	ASTM Grain Size	Comments on Microcrystal Structure
Copper	11	8.37	Large and semi- uniform crystals
1080 Steel	23	9.44	Non-uniform crystals
Heat-Treated Steel	32	9.92	Very small and uniform
Cast Iron	4.75	7.16	Very large and uniform

Interpretation of Results

Accuracy of Results

The results of the microstructure lab should be quite accurate. It is difficult to alter the crystal structure significantly after the samples have already been potted. While the friction caused by grinding and polishing can raise the temperature of the metals, the amount of liquid used while grinding should have kept the material cool. Mechanical issues, such as severe scratching or sawing, should not have occurred after the material had been polished.

The greatest source of errors is the counting the crystals. While etching the metals make the grain boundaries more visible, it can still be difficult counting every crystal. Some crystals are very large and others are very small. Not all crystals have distinct grain boundaries; as a result, a single crystal may be counted not at all or as two crystals. Despite the possibility of error, the grain boundaries were distinct and should be accurate.

Comparison of the samples

The four samples had very different microstructures. The grain sizes of copper and cast iron were very large and the grain sizes of the two steels were very small. In the cast iron sample, the grain boundaries were distinct and precise, while in the copper the grain boundaries were wide and not as distinct. The boundaries in heat treated steel were the least distinct of the four materials and had a wide variety of grain sizes. Plain 1080 steel had very uniform grain sizes and shapes.

Heat-treating the sample caused some of the grains to merge and form larger grains, but all of the grains did not merge. Some of the grains remained very small. The regularity of the grain boundaries was much lower in the heat treated steel than it was in the plain 1080 steel.

Please see the figures in the appendices for photographs of the materials.

Conclusion

Application of Results

Understanding how the microstructure of metal effects material properties pertains to several applications, including welding and casting. In welding, due to the rapid temperature changes, a very brittle allotrope of the material being welded can easily form, rendering the project nearly useless. Understanding microstructure and being able to examine the microstructure of a metal before and after welding can help alleviate this issue. In casting, understanding microstructure allows the cast to analyzed to determine the effectiveness and the material properties of the final cast.

Recommendations for improvement

The lab worked well as it was setup, however, one or two changes may improve the experimental accuracy. A continuous stream of water on the grinding pads worked the best to ensure all the scratches were removed before moving to the next station. The use of water was encouraged, however, suggesting using a continuous stream of water would improve accuracy. In addition, using a digital camera would make the photography part of the lab much easier. A digital camera eliminates the need for scanning the photographs. In addition, having the photographs digitally stored on a computer allows for manipulation of the photograph, including sharpening, lightening, and artificially coloring the picture. This would make it easier to obtain an accurate crystal count.

Bibliography

Schaffer, et. al, The Science and Design of Engineering Materials. 2nd ed. McGraw-Hill: New York, 1999.

Appendicies

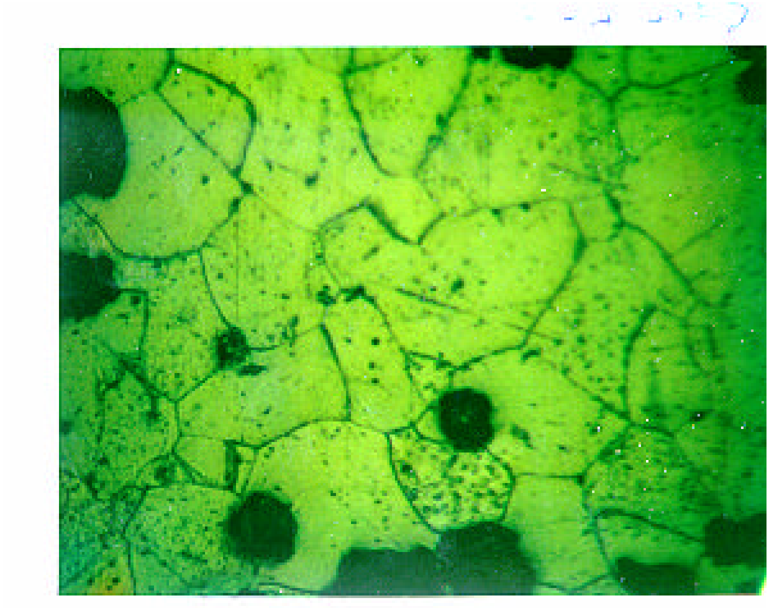

Figure 1: Cast Iron

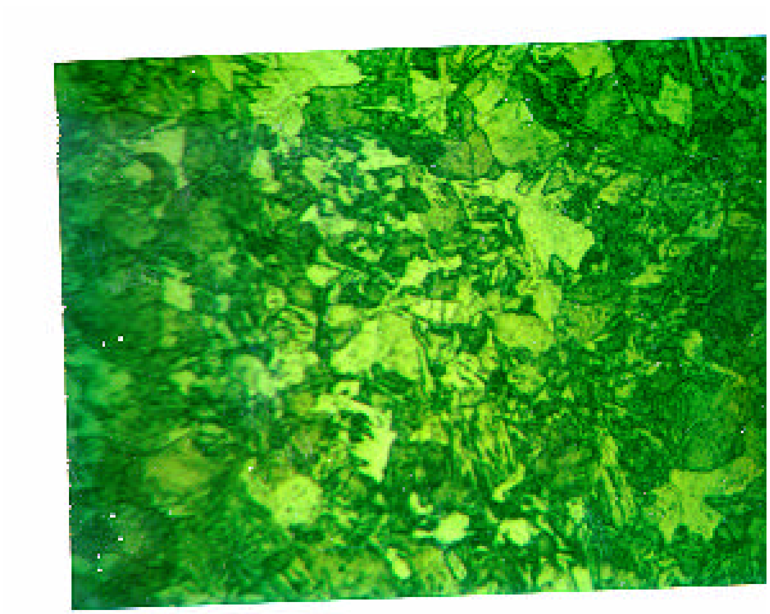

Figure 2: Heat Treated Steel

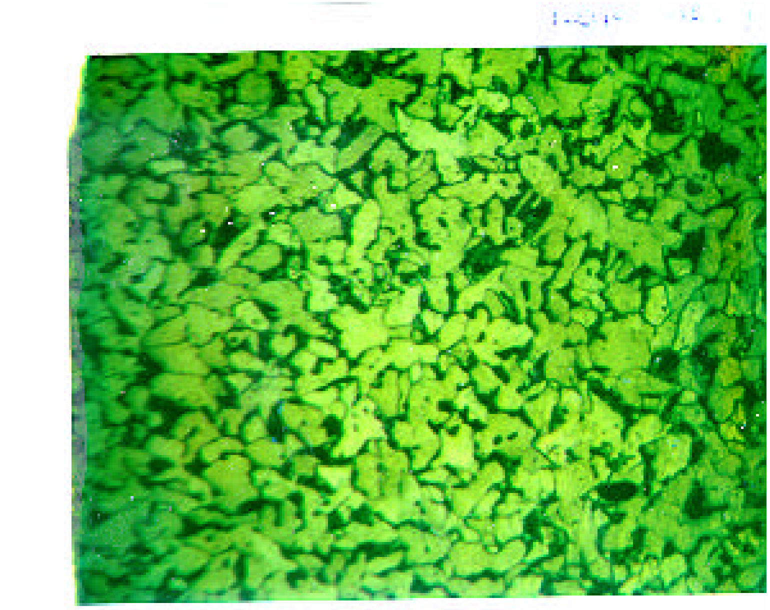

Figure 3: 1080 Steel

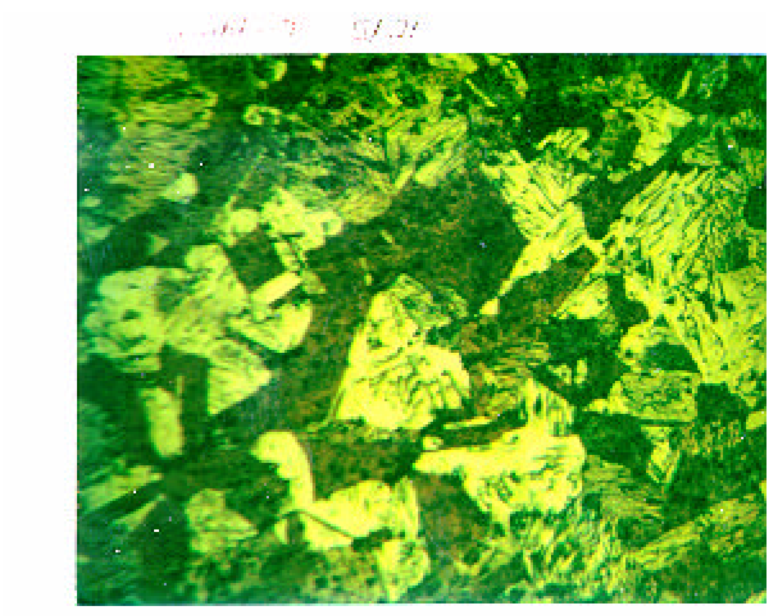

Figure 4: Copper