Be-Cu PRECIPITATION HARDENING EXPERIMENT

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PREREQUISITE KNOWLEDGE: The student performing this experiment should have a knowledge of binary phase diagrams.

OBJECTIVES: The objectives of this experiment are: to give the student a hands-on approach to changing materials properties through heat treatment of a specimen; to quantify the amount of strengthening obtained in the specimen; to encourage the student to speculate about the structural changes that have occurred in the material to cause the changes in strength.

EQUIPMENT AND SUPPLIES: 1) small furnace with capability of maintaining a temperature of 500 C +/- 5 C. (If solution anneal is to be done in the same furnace, temperature capability should be 800 C); 2) hardness tester with a range of 60 - 350 Brinell hardness; 3) small (1 gallon) water quench tank; 4) tongs to handle hot specimens; 5) insulated glove; 6) conversion chart for R_B and R_C to Brinell hardness (not needed if you have Brinell tester) 7) a Cu-Be phase diagram for the 0 - 10% Be region (see Fig. 1) 8) several (9) 2.5 cm diameter x 1 cm thick specimens of Cu - 1.8 Be or Cu - 2.0 Be.

PROCEDURE: Precipitation hardening depends upon the controlled precipitation of a constituent from a supersaturated solid solution. The precipitation rate depends upon the treatment temperature. As the temperature approaches the solvus line for the alloy of interest the faster the reaction will be.[1]

The students are provided with approximately ten solution-annealed disks of Cu - 1.8 Be and they develop a hardness vs. aging time graph at a specific temperature (i.e., 400 C).

Instructions to the students are as follows:

1. Equip the hardness tester to take readings on the Rockwell B scale (100 kg load - 1/16" ball penetrator). Check the reading of the tester with the standard block.

2. Take three hardness readings on each disk. Average the readings on each disk and record them.

3. Check the furnace temperature. It should be at the temperature specified for your group.

4. Place the disks in the furnace near the center. Orient them so there will be easy access to remove them individually.

5. At the following times specified, remove the disks and quench them immediately: 2, 4, 6, 8, 10, 20, 30, 45, 1 hr., overnight.

6. Measure the hardness of the aged specimens and record the values.

7. Plot the Brinell hardness vs. log of time in seconds for the specimens. (If the hardness readings for the solutionized disks vary more than ± 3 points Rockwell B, plot hardness increase vs. aging time.)

The students follow the above procedure to obtain their data. They are then required to do the following in the discussion of the experimental results.

1. Relate the micro-structural changes that are occurring in the specimen as it is solution annealed and quenched, reheated and quenched repeatedly to the Be-Cu phase diagram.

2. Explain why the hardness of the specimen is increasing. Relate this change in hardness to the micro-structure.

3. What would you expect the aging curve to look like if the aging temperature was 50° lower?

4. 50° higher?

5. Explain answers to 3. and 4. based upon the phase diagram.

6. Did overaging occur for any of the specimens? If it did, explain what happened.

7. Sketch how you would expect the micro-structure to appear for a hardened material prior to over-aging.

8. Same as 7 except after over-aging.

9. Sketch the micro-structure if the material had cooled under equilibrium conditions from the solutionizing temperature.

10. For 9, would the material be harder or softer than if it was quenched?

11. Comment on 7, 8, 9, and 10.

12. At what temperature do you think the material was solutionized?

SAMPLE DATE SHEETS: Self-Evident

INSTRUCTOR NOTES: Specimens can be cut from round, square, or other available bar stock. They should be solution annealed at approximately 750 C. They may begin to melt if you heat them to 850 C. At 700 C the disks will not solutionize in a reasonable amount of time.

Samples that have been cut approximately one centimeter thick will solutionize in 20-30 minutes at 750 C. They should be removed from the furnace and immediately quenched and agitated in water. Specimens solutionized in this manner will have an approximate hardness of 40 Rockwell B.

Take hardness readings after solutionizing, and then group disks by hardness range so that you minimize initial hardness spread for the students. One group of 6 or 7 samples may be in the range of Rockwell B 40-45; another group in the range of Rockwell B 35-40.

Aging times are cumulative so that the students do not need a separate disk for each aging time. Students should be told to take hardness readings on one side only. After a few cycles through solution annealing and aging, the disks can be faced in a lathe and the sequence can start again. This can be continued until there is no longer enough material to grasp in the lathe collets or chuck.

> Whenever the material is machined the machine operator must take precautions to avoid breathing any dust generated. The material should be machined wet, or in a hood, or the operator should wear a mask.
>
> No harmful oxides are generated at the aging temperatures. The oxides that form on the surface are copper oxides.

Different groups of students can age their specimens at different temperatures. Then when they compare results they can see the shift in the aging curve.

Best control of properties is obtained when the specimens are aged at 350 C. But, it takes over two hours to obtain maximum strength and most lab schedules are not long enough to permit using this temperature. Temperatures used to aging are 400 C, 450 C, 500 C, and 550 C.

Metallography is not an appropriate addition to this experiment because the precipitates that increase the hardness cannot be seen in an optical microscope.

REFERENCES: Askeland, D. R. The Science and Engineering of Materials, Alternate Edition, PWS Engineering, 1985, pp 215; pp 251.

Metals Handbook, Volume 8, American Society for Metals, 8th Edition, Sept. 1973.

SOURCES OF SUPPLIES: Cu-1.8 Be bar stock from Brush-Wellman, Inc., 17876 St. Clair Ave., Cleveland, OH 44110. The material, solution annealed or as drawn, costs $10.50 to $15.00 per pound.

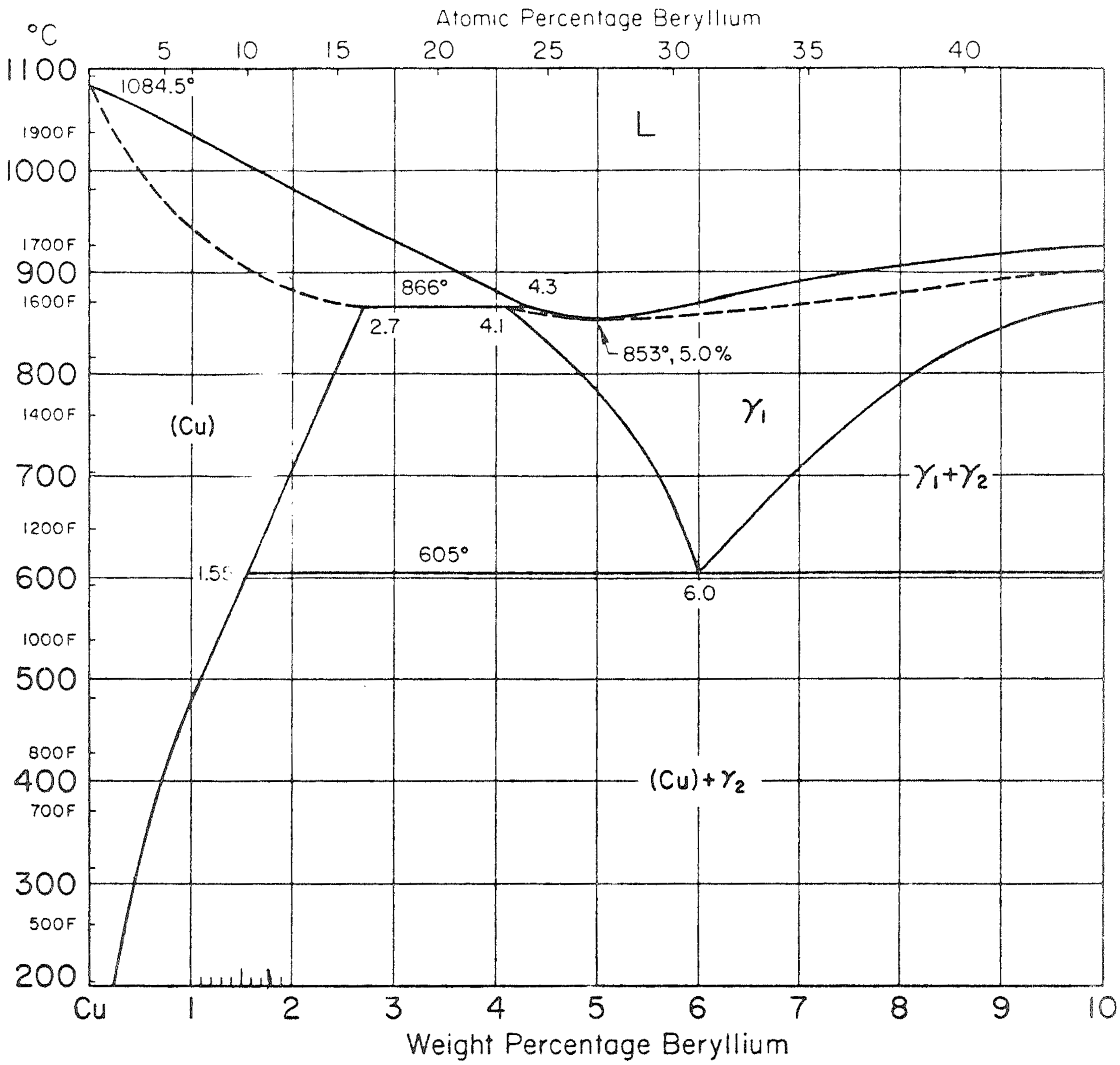

Figure 1. Cu-Be Phase Diagram [2].