Metals

Metallurgy: The Science of Metals

Introduction

Metallurgy is the science of making metals and alloys in forms and with properties suitable for practical use. It has played a unique role in human history, having brought us out of the Stone Age into the Bronze Age and then into the Iron Age. The seemingly miraculous conversion of dull earths into shining metals was the very essence of the art and magic of alchemy. No science of metals existed in medieval times to understand and explain the secret methods used to make and form metals and alloys.

Some of the mystery over metallurgy still lingers today. Science fiction novels and moves depict space ships and other objects constructed of “wonder metals” with amazing properties. Such usages are believable because of the remarkable achievements of the modern metallurgist during this century in developing new metals and alloys for jet engines, electronic circuits, and other advanced engineering systems. These successes were not achieved based on the art of the past, but by the application of scientific principles. Metallurgy is now a disciplined applied science focused from a clear understanding of the structures and properties of metals and alloys.

Metallurgy can be separated into three basic components: chemical, mechanical, and physical. Chemical metallurgy deals primarily with the making of metals and alloys from their naturally occurring ores. Most metals are present in the Earth as compounds of some sort, such as oxides or sulphides. Metals must be extracted from these ores for practical use. The first metals were discovered accidentally more than 5,000 years ago. Metals such as copper, lead, and tin melted at low temperatures and were probably formed at camp fires. Great advances came in metal production as furnaces were created to control the ore-melting and metal-forming process.

The importance of metals in history stems primarily from their mechanical behavior and use as construction materials. Metals combine the properties of high strength with the ability to change shape without breaking. This enables them to be shaped into a wide assortment of components, including car bodies, cans, and girders. Mechanical metallurgy deals with testing mechanical properties, the relationships between properties and engineering design, and the performance of metals in service.

The final critical component of the science of metals is physical metallurgy. This aspect deals with the internal world of metals and how internal structure can be designed and produced to give the best

properties. Although metals look like inanimate objects, internally electrons dash about within them, and atoms can move and exchange places while the metal is in solid form. As a result, changes in temperature can cause atoms to rearrange and prompt significant changes in properties. The ability to control these internal changes has led to dramatic improvements in the properties of metals. High-strength steels for building supports, stainless steels for corrosion-resistant applications (water pipes, pans, pots, etc.), and aluminum alloys for high-strength, light-weight airplane skins would not have been created without the ability to control and modify internal structure.

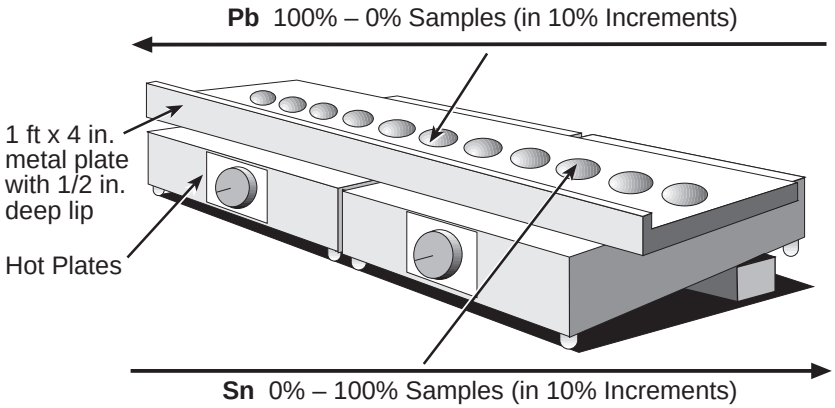

Figure 5.5. Alloying Tin and Lead

5. Compare your results with the phase diagram (Figure 5.4).
6. Return evaporating dishes to original group to continue with Part III.

Part III

1. Add or subtract 6 to your group number and get together with that group. There is no group number higher than 12.
2. Combine the alloy made by each group into one evaporating dish and melt. Allow it to cool. Calculate the lead-tin weight percent of the new alloy.
3. Remelt the alloy. Measure the melt point temperature. What should the melting temperature be? Record in your journal. **Clean the thermometer**.
4. Once your alloy just melts (Do Not Overheat), pour it very carefully and slowly from a height of approximately 2 ft. into a No. 10 can half full of cold water.
5. Retrieve your droplets of lead-tin alloy from the can and dry.
6. Weigh your droplets and record. What should the weight be? Did it weigh what it should have? If not, why not?
7. Turn in your 50/50 alloy to the instructor for use in a future student project.
8. Clean and return equipment to its proper place.

Drawing a Wire
Instructor Notes

Reliability

This lab will work very well. However, as the wire gets smaller some students will experience some difficulty (with breaking, getting started in draw plate, work-hardening, etc.) based on their abilities to work with their hands and with tools.

Estimated Time for Activity

One class period (depending on number of draw plates available).

Teacher Tips

1. The process of drawing a wire (making it smaller in diameter) is a common practice in the manufacture of various types of wire. Whether the purpose of the wire is conducting electricity, bailing hay, or fencing, the process is basically the same. For all of these types of wire, a large diameter (approximately 5/16 in.) metal rod generally in a coil is pulled through a series of continually smaller dies (holes) until the desired diameter is obtained.
2. In the process of going through the dies, certain changes take place in the metal. The crystal structure of the wire changes, and the diameter decreases, but the length increases proportionally, while generating heat because of friction (see your text for in-depth study or Jacobs, pages 158-165).
3. As the wire is formed into a taper by peening, it becomes work-hardened, and therefore, brittle and tends to split or break.
4. Because of friction caused by the wire going through the draw plate and the crystal structure being reshaped, heat is generated.
5. As the wire decreases in diameter, the length of the wire increases inversely proportional to the square of the diameter.
6. The density of the material remains the same.
7. As the wire gets smaller, it gets stiffer, but this is hard to tell because of the smaller diameter.
8. When the wire was annealed it was easier to bend and to form the taper on the end.
9. If you use the lead/tin solder as a drawing activity, be sure you do not transfer materials to other wires drawn with the same plate. This is especially true if you are going to draw silver wire for a later project. Using a suitable lubricant will help prevent problems.

Suggested Questions

10. What happens to the wire as you peen the end?
11. How did the wire feel after immediately pulling it through the die?
12. Explain the changes in the wire's dimensions.
13. What conclusions did you arrive at because of the lab?
14. Did the density change during drawing? Why?
15. Was the wire stiffer after drawing?
16. What changes took place when the drawn wire was annealed?

Safety

1. Be sure no one is standing behind the person pulling the wire. Pliers could slip or the wire could break, and someone could get hit by an elbow.

Activity: Drawing a Wire

Student Learning Objectives

At the end of the activity the student will be able to:

- demonstrate that drawing a wire work-hardens the wire
- describe compression and tangled dislocations and how this work-hardens metals
- demonstrate plastic deformation, causing friction and heat.

Materials

- Copper (Cu) wire 12 ga, 6 in., or solid core tin/lead solder wire or silver wire
- Lubricant (grease)

Equipment

- Safety glasses
- Vise grip pliers/draw pliers
- Bench vise
- Draw plate
- Micrometer
- Ruler
- Tape measure
- Balance
- File

Procedure

1. Measure the length of your wire using a rule, and the thickness using a micrometer. Weigh the wire. Record the data in your journal.
2. Clamp draw plate with its long edge going horizontally in the bench vise. (Be sure the small openings of the draw plate are on the side from which the wire will be pulled, see Figure 5.6.)
3. Taper one end of the wire using either a ball peen hammer or a file (see Figure 5.6).
4. Pass wire through the largest hole in the drawplate that the taper will go through. Apply lubricant to the wire and friction area of the drawplate.