Magnesium Deformation Lab

Purpose

Two basic deformation modes have been identified during the plastic deformation of crystalline solids: **slip** and **twinning**. Whether slip or twinning will be the predominant mechanism depends on which mechanism requires the lowest stress. This stress is not constant for a given material, but varies with test temperature, strain rate, alloy content and other extrinsic and intrinsic variables. In this experiment, only the effect of test temperature will be investigated (while other factors are kept constant) on the deformation modes of magnesium as an exemplary close-packed hexagonal (HCP) material.

It has been observed that magnesium slips on the **basal plane** at **ambient temperatures** and on the **basal** and **prismatic planes** at **higher temperatures** (**Figure 1**). It also deforms by twinning on **pyramidal planes** at **ambient and lower temperatures**. Therefore, the object of this experiment is to examine these two deformation modes (slip and twinning) metallographically at three different temperatures.

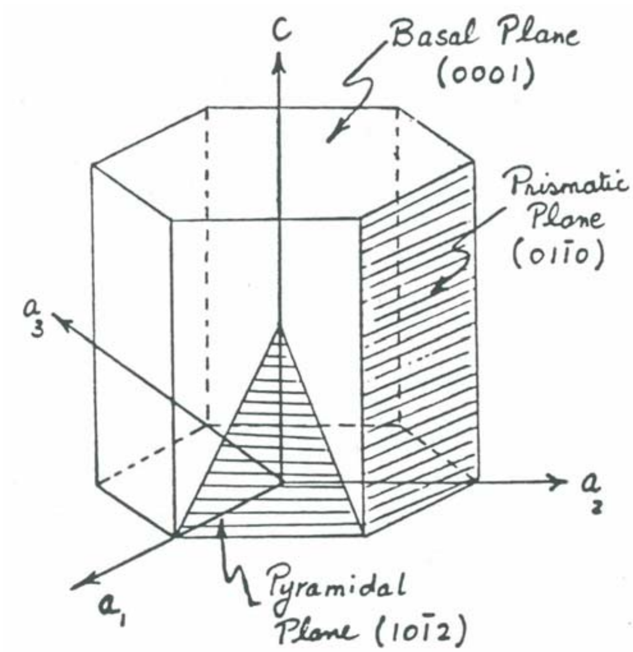

Figure 1: Slip and Twin Planes in HCP system.

Background

The usual method of plastic deformation in metals is slip, which can be visualized as sliding of blocks of crystal over one another along definite crystallographic planes, called slip planes. Under shear stress, dislocations move on these planes in specific crystallographic directions, called slip directions. Generally, the slip plane is the plane of greatest atomic density and the slip direction is always the closest-packed direction within the slip plane. The slip plane together with the slip direction establishes a slip system.

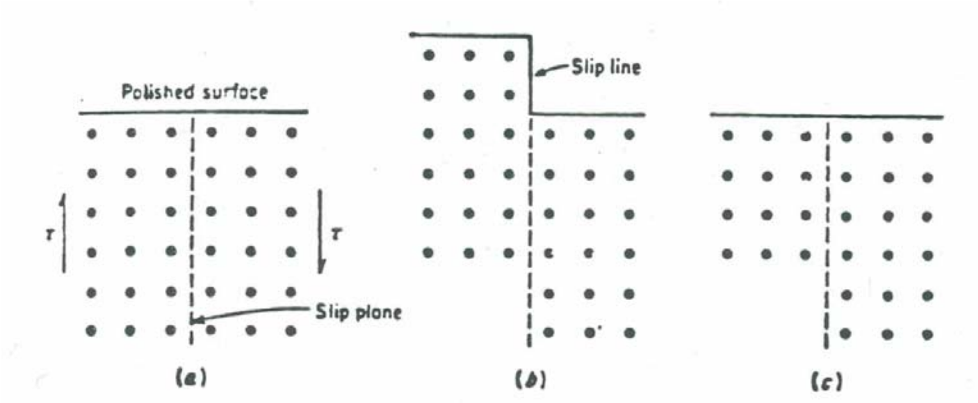

Figure 2: Atom Movement During Slip

Figure 2 illustrates schematically the classical idea of slip. The atoms move an integral number of atomic distances along the slip plane and a step is produced in the polished surface (**Figure 2b**). When the polished surface is viewed from above with a microscope, the step shows up as a line, which is called a slip line. If the surface is then repolished after slip has occurred, so that the step is removed, the slip line will disappear (**Fig. 2c**).

A second important mechanism by which metals deform is a process known as twinning. Twinning is a process in which layers of atoms move in such a manner as to bring the deformed part of the crystal into a mirror image orientation relative to the undeformed portion. The plane of symmetry between the two portions is called the twin plane, as shown in **Figure 3**.

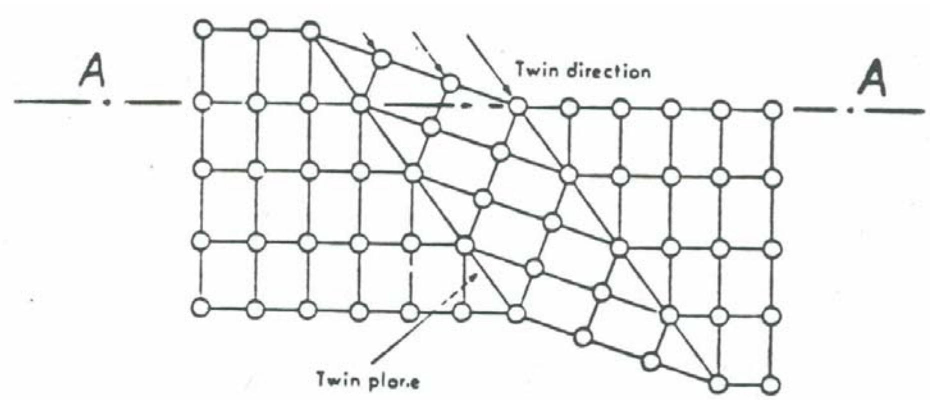

Figure 3: Atom Movement During Twinning

In the twinned region, each atom moves by homogeneous shear, a distance proportional to its distance from the twin plane. Such motion is parallel to a certain direction called the twin direction. The twin is visible on the polished surface because of the difference in crystallographic orientation between the deformed and undeformed regions. However, unlike slip lines, if the surface were polished down to section AA, the difference in elevation would be eliminated, but the twin would still be visible because it possesses a different orientation from the parent crystal.

Procedures

You are provided with three polycrystalline magnesium specimens in the annealled condition. Grind off the edges of (only) one side of each specimen. Prepare this side for metallographic examination by first grinding it on the successive set of sand papers (**240 grit through 600 grit**), and then by polishing on the two polishing wheels (**1 micron and 0.05 micron powders**). The specimens are ready for chemical polishing (**etching**); immerse them in the solution labeled Magnesium (~15% nitric acid) for about 5 to 10 seconds. The specimens should come out of the polishing solution with a brilliant surface rather than a grey one. Examine the three specimens afterwards under the microscope and observe the grain structure.

1. Heavily deform the first specimen at room temperature using a vise to squeeze two edges; examine it again under the microscope. What deformation markings do you observe on the surface of the specimen in the above region of interest? Can they be divided into two types:
(a) thin straight lines (usually observed at lower magnification) and
(b) lenticular (form of a double-convex lens) bands of appreciable width? What can you deduce about the modes of deformation that took place in magnesium at ambient temperature? Give your specimen a further etch in the Magnesium solution for about 10 seconds and reexamine. Are both types of markings still observable? If not, which one has disappeared? Can you correlate this result with your understanding of the nature of each type of marking?

2. Immerse the second specimen in the dry ice - acetone bath and then immediately deform it in the vise. CAUTION: DO NOT TOUCH THE COLD SPECIMEN WITH YOUR HANDS, USE TONGS. When the specimen has warmed up, examine it under a microscope. Make sure that you are looking at the same area that you identified before. Are both deformation markings in evidence? Take photographs with the microscope software and explain your results.

3. Immerse the third specimen in boiling water, and then immediately deform it in the vise. CAUTION: USE TONGS TO HANDLE THE SPECIMEN. When the specimen has cooled, examine it under a microscope. Are both deformation markings in evidence? Take photos and explain your results.

Write up

NO report is required. However, the photos of your visual examinations corresponding to the three previous experimental steps should be included in your laboratory notebook. Also, answer the following questions in your lab book.
1. In close-packed hexagonal crystal (e.g. Mg) what is the common slip plane, slip direction, twin plane, and twin direction?
2. Why is twinning a very common deformation mechanism in low symmetry crystals (as Mg) while it is not for FCC metals for instance?
3. Describe briefly the main differences between slip and twinning.

References

1. D. G. Rethwisch and W. D. Callister Jr, Fundamentals of Materials Science and Engineering: An Integrated Approach, John Wiley & Sons, NY, 3rd Edition, 2008.
2. R. W. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, 4th Ed., J. Wiley & Sons, 1996.