Investigation 5: Changing the Shape of a Memory Metal Rod

Supplies

NiTi wire (######)
Bunsen burners
Hot water
Gloves
Access to an art kiln (optional)
BB boards (optional)
Cobs of corn (optional)

Teacher Notes

Questions may arise as to how the memory was imparted to the metal in the first place or whether or not the memory may be altered. It should first be noted that if the transition between phases were represented by the thermochemical equation below:

Martensite + energy _ Austenite

the energy required would be in the neighborhood of only a few kJ/mol. The Ni and Ti atoms within one of the many crystalline regions (called grains) within a sample of memory metal in the austenite phase are almost perfectly arranged with a few imperfections here and there. (A piece of galvanized metal clearly shows such crystals, and the BB board discussed earlier in the Background Information section shows defects within the crystal) These defects in the austenite phase along with the grain boundaries, another kind of defect, are responsible for giving the austenite its "remembered" shape. To give the metal a new shape it is necessary to create a new set of defects that will in turn force the metal to return to this new shape upon mild heating through the martensite-to-austenite phase change. This new set of defects can only be obtained by heating the metal sample to approximately 500^{o}C while it is secured in the new shape. This large amount of thermal energy excites the atoms. As the metal cools, atoms settle into lower energy positions specific to the new shape, thus creating a new set of defects.

It is highly recommended that these phenomena be fully explained before proceeding with the investigation. The generally straight rows of corn on a corn cob can be used to demonstrate how some grains of corn that do not fit into these neat rows form a **defect** in the pattern. These unique defects in the corn are like the defects in the NiTi. These defects give the NiTi its "remembered" shape. BB boards are also very useful tools for helping students understand what is happening in this investigation.

The activity simply involves having the students bend the wire into a new shape. They hold it at its ends (using gloves) and heat the center in the flame of a candle. The wire resists bending until it reaches the temperature of the flame at which point it yields and can be bent into a V-shape. When it is cooled, it can be straighten, heated with hot water and returned to the V-shape. Note that memory metal samples may become brittle and break after repeated heating and cooling.

Extension

If a metal frame of some type is available, it is possible to produce more complicated shapes (even your name) with the memory metal. This would require that you have access to some sort of metal rack or basket capable of withstanding the annealing temperatures and a heat source capable of providing those temperatures. The kiln in the art department would certainly be adequate; or perhaps the physics department has a muffle furnace that would work as well. The wire would have to be secured to the template and the entire assembly placed in the heat source for a period of about 15 minutes, removed, and allowed to cool. Longer heating may destroy the memory feature of the wire. Annealing produces the "remembered" shape by creating a new set of defects. Prolonged heating, however, will destroy the shape memory feature that relies on these defects. See http://mrsec.wisc.edu/EDETC/memmetal/index.html to find out more about obtaining a memory metal kit that contains a piece of memory metal that has been "trained" to spell out a word.