"liquid" metals

GOAL:

Visitors will understand that the nano-scale structure of amorphous metals determines their elasticity.

MATERIALS:

Real Product

- Cylindrical base of aluminum
- Cylindrical base of aluminum with amorphous metal disk
- 2 plastic tubes
- 2 small metal balls
- Graphic of regular metal atomic structure

Macro-scale

- Cylindrical base of fragmented glass
- Cylindrical base of fragmented glass with solid glass disk
- 2 plastic tubes (same as for Real Product)
- 2 glass marbles
- "Regular metal" frame
- "Amorphous metal" frame

- Graphic of amorphous metal products

PROCEDURE:

Set-up:

1. Keep tubes, balls, and marbles in the storage container to prevent them from rolling away (a paper cup can be handy for the balls). You may want to store the frames out of sight for optional use with older visitors.

Doing the demonstration:

1. Show visitors the two metal bases and ask what differences they observe between the surfaces. Place a plastic tube over each metal base. Give the 2 small metal balls to a visitor and have them drop one ball into each tube at the same time. The ball on the amorphous metal surface will bounce longer. (Optional: Switch the balls around and repeat to show that the effect is not to due to a difference in the balls.)

2. Use the graphic to explain that the difference in bouncing is due to the nano-scale structure of the metals. The graphic is a scanning electron micrograph showing how a regular metal is composed of tiny chunks with edges in between where the ball loses energy. In contrast, an amorphous metal ("amorphous" = having no shape) is one blob of metal, with very few cracks to dissipate energy. Bounce the ball in the respective tubes as you talk to emphasize the phenomenon.

3. The macro-scale model made from glass demonstrates the same idea. Explain that the glass bases are made of chunks of glass stuck together, while one base has a solid glass disk on the surface. Ask visitors to identify which surface represents the amorphous metal. Place a plastic tube over each glass base. Give the 2 marbles to a visitor and have them drop one marble into each tube at the same time. The marble will bounce longer on the solid glass disk.

4. Allow younger visitors to explore the "trampoline" phenomenon further with different combinations of balls and bases, or proceed to step 7. For older visitors familiar with the concept of atoms, bring out the two frames to explain the difference in atomic structure. The balls represent individual atoms that make up the metal.

5. Show visitors the "regular metal" frame first. Ask visitors how many sizes of balls they see. Shake the frame and hold it at a gentle angle to allow the balls to settle. Since the atoms are all the same size they try to line up, but there are edges in the structure where different parts of the metal do not come together properly – this is how the chunks and cracks form. (By orienting the frame diagonally, you can collect the balls in a corner to induce more irregularities in the pattern.)

6. Next show visitors the "amorphous metal" frame. Ask visitors how many sizes of balls they see. Again, shake up the frame and then allow the balls to settle. This time, since atoms of different sizes are mixed together, they do not fit together in an organized pattern and there are very few edges.

7. Use the product graphic to show how amorphous metals are used in everyday products because they are more elastic and durable. They are being used in the hinges of cell phones, in sports equipment (where amorphous metal can help drive a ball further given the extra bounce of the ball), and in casings for small electronics.

Clean-up:

1. Gather all materials and return to storage.

EXPLANATION:

The atomic structure of a solid material is extremely important in determining its physical and chemical properties. A typical metal is *polycrystalline*, meaning that it is made up of many small crystalline grains (i.e. chunks) that are stuck together. Each grain consists of a single ordered crystalline arrangement of atoms. The cracks between grains are called "grain boundaries." The crystals often contain missing atoms, impurities of other materials, or misaligned planes of atoms. Upon an impact with a crystalline metal, these weak points will deform and dissipate kinetic energy. (In particular, energy is lost when planes of atoms slip past each other at a weak point called a dislocation). However, these defects can also be functionally important. For example, copper wire is flexible because the misaligned planes slip easily along one another.

Unlike crystalline metals, *amorphous* metals contain few of these types of defects. Amorphous metals are alloys containing atoms of multiple sizes that do not fit into an organized arrangement. When heated to a molten state, there is little free space between the atoms. If atoms of enough different sizes are present, crystals do not form during solidification even when cooled at a slow rate. One company that has pioneered the commercial application of amorphous metals is Liquidmetal® Technologies (named for the preservation of the molten state atomic arrangement in the solid form). Liquidmetal®, from which the amorphous metal disk in this demonstration is made, is composed of five different elements: zirconium, beryllium, titanium, copper, and nickel. Not all alloys are amorphous – stainless steel is a crystalline alloy in which the repeating structural unit consists of more than one atom.

Liquidmetal® products extend beyond everyday applications; industrial coatings, armor-piercing ammunition for the military, and surgical blades are all being developed with amorphous metals. Advantages include not only resilience and strength but also the ability to be molded into near-final shape. However, when an amorphous metal does break, it tends to crack and fall apart rather than just bend and deform. Scientists are trying to mix different types of metals together to create alloys that have both amorphous regions and nanometer-sized crystalline regions. This mixture of two different kinds of structures strengthens the alloy by making it easier to bend but harder to crack. Amorphous metals can also cost more than regular metals. One high-end cell phone with a leather casing inlaid with Liquidmetal® costs thousands of dollars – but it can survive being run over with a car!

Amorphous materials exist in nature as well, such as obsidian, a type of volcanic rock formed from lava. Here, the lack of organized structure is not due to differently sized atoms; instead, the material cools so quickly that even though the atoms are the same size, they have no time to form an ordered arrangement.

WHAT COULD GO WRONG?

Keep balls and marbles in the storage container when not in use to prevent loss or swallowing by small children. If lost, any small ball with some mass should work. A plastic ball is too light – most of the deformation upon impact is in the plastic, not in the metal surface, so both metals can bounce back almost equally well.

Over time, the aluminum base will acquire dents where the ball has bounced on it. This is a normal result of many impacts causing permanent deformation. Explain this to interested visitors as a visible accumulation of repeated nano-scale atomic movement.

If any golf enthusiasts want to try bouncing golf balls off the faces of a regular club vs. a Liquidmetal® club, note that the balls must be dropped from a much greater height (at least a few feet) or a much larger, more massive metal ball must be used in order to observe an effect.