Items of Note from the Field, Profession, and Society

OSU Researchers Examine Aluminum's Ceramic-like Conductivity, Develop New Metal-Forming Process

Researchers at Ohio State University have learned that aluminum may conduct electricity in the same manner as a ceramic or a semiconductor and have developed a new metal-shaping process for manufacturing of aluminum parts.

Ju Li, assistant professor of materials science and engineering at Ohio State, and his associates found that aluminum may endure mechanical stress more than 30 percent better than copper, which is normally considered to be the stiffer metal. The research expands scientists' fundamental understanding of aluminum on the atomic level, said Li. Li and his associates used quantum mechanical equations to model the behavior of thin layers of aluminum and copper atoms under pure shear strain, where one layer of atoms slides over the other. Large shear strain is a common problem in very small electronic devices, where temperature fluctuations cause materials to expand and contract. The materials behavior under strain affects the reliability and durability of the devices.

In their calculations, Li and his colleagues found that one layer of copper slid essentially horizontally over another layer below. Aluminum, however, tended to hop instead of slide. There were also related movements in the bottom layer of atoms, as if they were somehow connected to the atoms on top by an invisible set of hinges.

The aluminum atoms may have exhibited a kind of directional bonding, in which different atoms share sets of electrons Li said. Directional bonding is observed in ceramics and in semiconductors such as silicon, but not in highly malleable metals such as aluminum.

In the shear-strain simulations, aluminum was 32 percent stronger than copper and it endured much larger shear strains before it began to soften.

This research could prove important for nano-indentation experiments, where a diamond shard is pressed into materials to gauge how the material responds to extreme forces. The work also opens the door to a more accurate model of mechanical behavior in structures for nanotechnology. Li, whose research was published in the October 24 issue of *Science*, is continuing his work with a study of nickel. Li has also written *AtomEye,* a software program for visualizing the atomic structure of materials, particularly changes in structure that accompany material strains (Figure 1). *AtomEye* images, including animations, can be seen on the Web at *164.107.79.177/Archive/Graphics/A/.*

In other aluminum research, a team led by Glenn S. Daehn, a professor of materials science and engineering at Ohio State, has developed a new manufacturing process that could be used to manufacture aluminum for use in lightweight, fuel-efficient cars. The process is a modification of the hybrid electromagnetic metal-forming technique developed by Daehn and his colleagues in 1999. In hybrid electromagnetic metal forming, a traditional tool and die stamps the general shape of a part out of sheet metal and then a magnetic field pushes at specific locations of the sheet metal to form fine details or complex shapes.

With the new process, which Daehn calls bump forming, Ohio State engineers use the magnetic field to stretch certain portions of the metal during the stamping operation. The magnetic field bumps against the metal in short pulses—approximately 5–20 times in

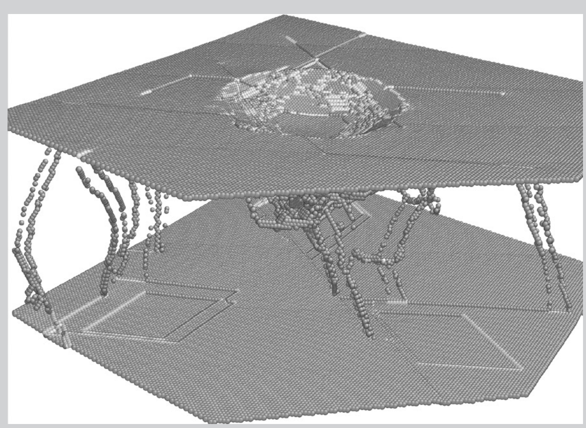

Figure 1. This image, created by *AtomEye* software, simulates a nanoindentation experiment on a thin slice of copper. Here, the crater in the top center portion of the material represents the indentation formed by a diamond. To simplify the view, only the visible atoms of copper that were dislocated during the experiment; atoms largely unaffected by the indentation remain transparent. (Image courtesy of Ju Li, Ohio State University.)

Figure 2. Ohio State University graduate student Jianhui Shang holds two pans stamped from automotive-grade aluminum. The pan on the right was stamped using traditional techniques. The one on the left was stamped using the same equipment, but using Glenn Daehn's electromagnetic bump-forming technique. (Image courtesy of Ohio State University.)