match to the NTSC-recommended blue. In the mean time, the researchers believe that they have found a material with a blue emission already suited for many other video display applications.

PAMELA JOHNSON

Dislocations in Copper Observed to Form Preferentially at Twin Grain Boundaries

A team of scientists from the University of Idaho, Washington State University, and the Idaho National Engineering and Environmental Laboratory (INEEL) has discovered that dislocations in metals tend to form at twin grain boundaries. The research team further reported that while grain size determines at what stress level a material begins to deform, it has little effect on the ultimate strength a material can attain through deformation processing.

As published in the June issue of *Acta Materialia*, the researchers created copper samples with a range of crystal sizes by first straining the samples to create a high density of imperfections, and then heat-treating the metal at different furnace temperatures. Different grain sizes developed during recrystallization, depending on both the temperature and the number of imperfections in the original material. The team then tensile tested the material—stretching it at room temperature and monitoring the load generated by the applied strain. Using high-magnification microscopy, they periodically analyzed the deformed microstructure of each sample for clues to the formation of dislocations, dislocation density, and dislocation behavior.

"This is a basic mechanism of dislocation behavior not previously reported," said John Flinn, adjunct professor with the University of Idaho and retired INEEL researcher.

This observation is a departure from conventionally accepted materials-science theory stating that dislocations can form within the crystal grain itself or at any grain boundary—not just primarily at twin grain boundaries. This is the crux of understanding the role grain size plays in material strength, the researchers said.

By observing when and where dislocations develop, the research team documented that grain size plays a role only when plastic deformation begins. Materials with very small grain size can remain elastic longer than materials with larger grain size, and it takes more strain and higher stress to cause dislocations to develop. However, after dislocations have developed, grain size makes little difference. The increasing resistance to further deformation (strengthening) as a function of strain once plastic deformation was initiated was the same for materials of all grain sizes. The team analyzed samples with grain sizes ranging from 3 μm to 60 μm and found that strain-hardening from plastic deformation was completely independent of grain size.

"Once you exceed the elastic limit of a material, the deformation behavior of the metal and improvements in mechanical strength from hardening is controlled by the interaction of one dislocation with another and not through interactions with grain boundaries," said INEEL scientist Tom Lillo.

For this research, the team initially strained the copper samples to induce a very high density and uniform distribution of imperfections before heat treatment. The combination of a high number of imperfections and low heat treatment temperatures enabled the researchers to create a range of grain sizes for experimentation. Using the technique called equal channel angular extrusion (ECAE), metal was extruded through a die with an internal 90° corner, rotated, and re-extruded. ECAE was much more effective in creating a high density of twin grain boundaries during heat treatment and subsequent recrystallization than the traditional cold-rolling. With ECAE, the research team achieved a density of almost 50% twin grain boundaries.

Flinn said, "The challenge now will be learning how to use this knowledge to design new high-strength, light-weight alloys." Such knowledge, Flinn said, will also help researchers to develop techniques for fabricating metals into various geometric forms for industrial utilization.

Silicone Polymer Scaffolds Facilitate the Growth of Lifelike Cardiac Tissue

Researchers at the University of Illinois at Chicago (UIC) and Loyola University Medical Center have grown lifelike cardiac tissue for possible use in the scaffolding and repair of damaged heart cells. The researchers first built scaffolds made from silicone polymers, which enabled them to study the grooves, pegs, and bumps of heart tissue. They were also able to mechanically manipulate the surface of the scaffolds to mimic the pumping of heart cells.

In the final phase of the project, the researchers attached heart cells firmly to the silicone surfaces of the scaffolds so that the mechanical activity could be mimicked in the laboratory. Luke Hanley, associate professor of chemistry and bioengineering at UIC, applied a rf discharge plasma to form hydroxy groups on the surface, followed by wet chemical reactions with amine-terminated silanes and maleimide cross-linkers to link polypeptides to the silicone surfaces, fusing the cells to facilitate growth into healthy tissue.

Brenda Russell, professor of physiology and biophysics at the UIC College of Medicine, said, "The cells... migrated, found a micro projection, or a peg, and attached to it. More than 90% of the cells attached to a peg and stayed attached when mechanically pulsed." She explained that this is mainly due to the vertical topography, not the material itself. However, Russell said that the polypeptides are also enhancing the cell binding to the surface, presumably by activation of integrin-based cell adhesion mechanisms.

Silane Shown to Adhere to Phosphate Glass Surface

Sodium aluminophosphate glasses, doped with rare-earth elements such as erbium and ytterbium, are used in optical and photonic systems as laser sources and as waveguide amplifiers. In order to combine glass with another material to create a composite, an intermediary polymer coupling agent can be used, typically the silane aminopropyltrethoxysilane (APS). At the 19th International Congress on Glass, Amy Barnes, a graduate student at The Pennsylvania State University, reported, "We have shown that we can get silane to adhere to phosphate glass surfaces. The coating can protect the surface, minimizing corrosion, or can be a mediator between the glass and a polymer." The conference was sponsored by the Society for Glass Technology in Edinburgh, Scotland, in the beginning of July.

The researchers at Penn State studied the phosphate glass without the rare-earth elements to see how the silane adhered to the surface of the phosphate glass. The glass was dipped in APS and rinsed to remove loosely bound molecules. The researchers found that the silane forms a single or multiple molecular layers on the glass surface. The acidity of the silane solution affects the coverage of the surface differently than on traditional silicate glasses. The researchers said that the stability of the bond that forms may be different if the surface corrodes during coating.

For silicates, the maximum amount of adsorbed silane is reported to occur when the solution pH is near the natural pH of the molecule (pH of 10.5). In contrast, the maximum amount of adsorbed silane on the multicomponent phosphate glass occurred at a solution pH ~7 and decreased with both increasing and decreasing pH. At very high pH values (pH = 13), the corrosion rate of the phosphate glass surface was so rapid that the silane could not form a stable bond with the surface and no APS could be detected by x-ray photoelectron spectroscopy (XPS).

The researchers also determined that the concentration of silane on the surface of silicate glasses increases with increasing solution concentration until a critical value is reached where the surface concentration then becomes constant, independent of solution concentration. The adsorbed concentration of silane on the surface of the phosphate glass also increased with increasing solution concentration.

In contrast though, after forming a monolayer, the concentration of silane on the surface then begins to rise rapidly with increasing solution concentration, due to the formation of multilayers. Additionally, said Barnes, the shape of the high-resolution spectra peak by XPS changes with solution concentration. This peak can provide information concerning the state of the nitrogen in the adsorbed silane layer, showing both a free amine ($-NH_2$) and a protonated amine ($-NH_3^+$) at different binding energies. At low concentrations, the nitrogen is almost entirely in the free state, Barnes said, suggesting that APS is adsorbing to the surface through the hydrolyzed alkoxy group (the silane end). As multilayers begin to form, the protonated amine concentration begins to increase.

Barnes said that very little literature is available on the surface of phosphate glasses and even less on the factors effecting silane adsorption to phosphate glasses. She said that phosphate glasses are finding ever-increasing uses in both photonics and optics applications and the ability to couple the glass with other materials to form composite or hybrid structures is important in both present and future applications. Understanding how to effectively adsorb a coupling agent to the surface is the first step to expanding the potential applications of multicomponent phosphate glasses, she said.

"Applications to join two phosphate glasses, phosphate glass and polymers, or phosphate glass and other organic chemicals are just beginning," said Barnes. "With a silane coating, these glasses can be used as hybrids rather than stand-alone materials. We can connect and combine them with dissimilar materials."

Various Avenues Taken in Search for Diamonds

Geological studies are exploring evidence from Venus to several hundred kilometers under the Earth's surface to determine ways to locate diamonds.

Some of southern Africa's most profitable diamond mines are located near areas where the earth is exceptionally stable and cool up to 250 km below the surface, according to Matt Fouch, assistant professor of geological sciences at Arizona State University; David James and John VanDecar of the Department of Terrestrial Magnetism, Carnegie Institution of Washington; and Suzan van der Lee of the Institute of Geophysics, Zürich, Switzerland. Geologists think diamonds develop up to several hundred kilometers deep within ancient cratons—such as over 3 billion years old—and are then driven straight up to the surface.

Fouch said, "Nearly all diamonds come from cratons, but not all cratons contain diamonds. So the question is, why do some cratons produce diamonds and others don't?"

By imaging the earth at depths of several hundred kilometers beneath the crust, Fouch and his colleagues looked at the source of diamonds. The seismic team created three-dimensional images of deep layers of the earth by using an array of 82 seismometers. As reported by David James and co-workers in the July 1 issue of *Geophysical Research Letters*, the seismometers, placed at roughly 100-km intervals across South Africa, Zimbabwe, and Botswana, recorded data from more than 200 earthquakes occurring over a two-year period, mainly from the Himalayan and Andean mountain ranges. The team used seismic tomography to produce the images.

Fouch said, "The seismic waves from each earthquake bounce off of different layers of the earth and illuminate different internal features."

The researchers found that in diamond-producing areas, the mantle is "seismically fast," meaning that it propagates earthquake vibrations quickly because the mantle rock may be cooler or chemically different from the surrounding areas.

Fouch said that nearly all diamond sources are found in regions of cratons with thick underlying lithosphere—the tectonic plate. Seismological techniques are some of the highest-resolution methods used to determine the thickness of the plate, as well as the strength of the variations in elastic properties. Therefore, he said, making precise measurements of relative seismic velocities of the lithospheric plate provides important constraints on the relationship between the lithosphere and diamondiferous regions. One of these regions, the research team reported, is beneath the Kaapvaal craton in South Africa and one is beneath the Zimbabwe craton.

Fouch said, "Most of the gem-quality diamond mines in southern Africa lie very close to these regions."

Looking to Venus for clues, Richard Ghail, a research associate at the Imperial College in London, believes the sister planet is key to understanding what early Earth was like during the Archaean and early Proterozoic time periods when precious resources were formed.

While modern Venus is in a quiet state most of the time, it enters into short periods of intense volcanic activity where the old surface of Venus is destroyed and a new one is created. In its early history, Earth worked in a similar way to modern Venus.

"By understanding the 'early Earth,' we can predict where to find precious resources—such as platinum and diamonds," said Ghail.

In preparation for his presentation at the Earth Systems Processes Conference on June 27, in Edinburgh, Scotland, Ghail said that "from the evidence from Venus, the early Earth did not have modern plate tectonics, but did have something that looked similar to it."

The evidence for this derives from the evidence of higher mantle temperatures (200°C or higher) and higher heat flow in the Archaean Earth, which prevented subduction, and hence modern-style plate tectonics, from taking place, by causing the lithosphere (the cool, rigid outermost layer of the Earth) to be thin and buoyant. Venus is in a similar state today because it has a high surface temperature (450°C) that also results in a thin buoyant lithosphere. Research over the last 10 years has shown that Venus operates in two modes, Ghail said. For the most part, Venus exists in a state of relative quiet in which platelike movements occur (creating rifts, mountain belts, and strike-slip faults, all with associated volcanism) but then, every 500–1000 million years, there is a short period (100 million years or less) of intense volcanism that resurfaces most of the planet. The reason for this strange behavior, Ghail said, is that without subduction, neither modern Venus nor the early Earth could cool efficiently enough to prevent their upper mantle from heating up and eventually melting.

The release of all the melt to the surface in a short time cools the mantle down and resets the clock. Eventually, Earth was sufficiently cooled by one of these episodes that plate tectonics could start. So, according to the research, Venus provides an analogue of the types of tectonic settings that existed on the Archaean Earth, in which many precious resources were formed.

The conference was sponsored by the Geological Society of America and the Geological Society of London. □