JULY ISSUE 1998

WHERE SCIENCE MAKES A DIFFERENCE

DATELINE LOS ALAMOS

U.S. DEPARTMENT OF ENERGY
UNIVERSITY OF CALIFORNIA

LOS ALAMOS GOES NEW AGE

SCIENCE TURNS TO CRYSTALS FOR SOLVING NUCLEAR QUESTIONS

New-age therapists would be proud: A nuclear weapons laboratory has turned to crystals.

➔ Researcher Ken McClellan opens the halves of the chamber to show the photographer what the apparatus looks like with low-level lighting. Normally, the chamber is closed while growing crystals.

Los Alamos has recently developed a facility using four different techniques for growing pure crystals that are flawless down to the atomic level. Researchers are studying the material properties of unusual crystals made from ceramics, intermetallics and metals.

Laboratory scientists grow crystals that are a few inches long and subject them to a variety of durability tests. Particularly of interest to researchers are crystals made from certain oxides that exhibit resistance to radiation.

Some of these crystals can also be used to bind plutonium and other actinides within their lattices. Such compounds may prove useful for nuclear fuel rods in reactors or may solve some handling problems associated with nuclear waste.

"This technology is helping to build the science underpinnings for both waste and energy," according to researcher Ken McClellan.

One of the crystal growing processes involves two chambers with opposite gold-coated ellipsoidal mirrors that resemble a large egg shell. One end of each mirror houses a light bulb, and the mirrors focus the light to a small point in the center of the chamber. Researchers bring a rod from the top and one from the bottom very close together to begin the process of crystal growing.

When the rods enter the hot zone where the mirrors are focused, the top rod containing a low-grade version of the material begins to melt onto the bottom rod.

The rods spin in opposite directions suspending the melted material in space between the two rods, creating a spinning vortex that defies gravity. Surface tension holds the suspension together and slowly the high-grade crystal cools and grows.

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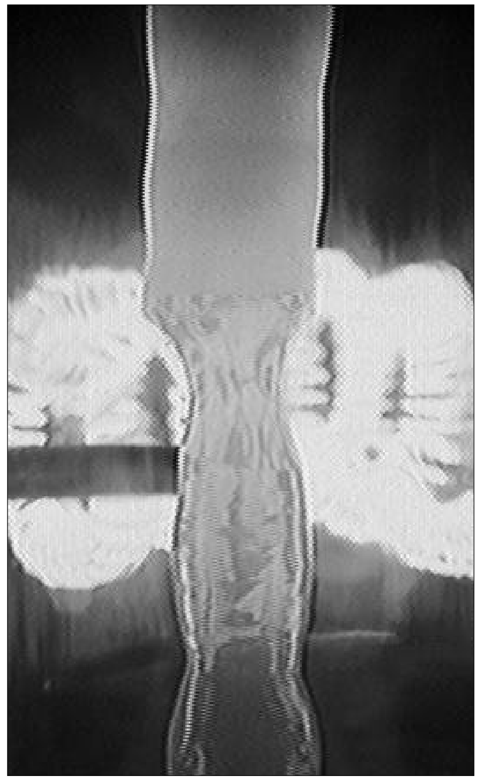
Depending on the material, the crystal grows at rates ranging from 15 millimeters per hour, which is a fast growth rate, or as slowly as 1 millimeter per hour. Metals grow faster than ceramics.



← Inside the chamber, the crystal grows from the top rod to the bottom rod. The glowing coils are from the light bulb and are focused in the middle of the growing crystal, forming the hot zone.

The facility has two versions of this furnace that can melt metals, intermetallics and ceramics over a broad range of temperatures under carefully controlled atmospheres or pressures.

Another system, called the tri-arc, uses an arc welder with three stingers focused on a heat-resistant hearth. This type of unit can melt materials up to around 5,500 degrees Fahrenheit.

The starting amount of material is placed in the bottom of the hearth. After the material melts, the crystal is pulled upward by a rod so that it grows with a constant diameter. The platform and the seed-rod counter rotate, while the rod pulls a crystal out of the molten charge. This method is best for producing single crystals of conductive materials.

The facility will also house a fourth crystal-growing technique similar to the tri-arc method, but it will use radio frequencies to melt the material. This method will be used for growing larger-diameter crystals, about 2 inches in diameter.

Single crystal studies are important because they allow researchers to understand the properties of the crystals in a more pure form. In lower-grade crystals, the atomic structure is jumbled and the material behaves differently.

McClellan and fellow researchers are studying crystal technology for use in the stockpile stewardship program. McClellan is growing an unusual crystal for use in an advanced imaging system for an X-ray facility being built at Los Alamos.

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The new facility will send rapid pulses of X-rays to image a high-explosive detonation to study the effects of aging on nuclear weapons components.

But current technology cannot provide a fast enough imaging system for such high-energy X-rays. Technicians cannot change X-ray films in microseconds so a solid-state detector will be employed.

Instead of imaging film, Los Alamos scientists are relying on a high-tech video system that will turn the X-rays into visible light to be displayed on a screen. Called a digital scintillator, the device must be dense, fast and bright. It must resist the blast of X-rays, display the X-rays and fade rapidly to receive the next dose, and it must do this all within a certain visible wavelength to be seen by digital cameras.

Television screens use phosphorescent screens to display an image. The digital scintillator will have similar technology but instead of phosphorescent screens, the screen will consist of a unique crystal that the Laboratory will grow in bulk.

The lutetium oxide crystal is made from one of the rarest of rare-earth oxides. No company in the United States can meet the Laboratory's demand for this material. So the Laboratory will grow the crystal in the soon-to-be assembled, radio frequency crystal growing chamber.

Crystal technology has many other applications, including creating superalloys for materials that can withstand extreme environments, such as inside an aircraft engine. Crystals may play an important role in creating photovoltaic materials that convert a certain wavelength of electromagnetic energy into electrical current similar to the way solar energy cells work. Colossal magnetoresistors could be created by the technology, in which the current flow is almost completely shut off by the presence of a magnetic field.

Crystals may create a new class of magnetoresistors that could play an important role in magnetic storage technologies such as computer hard drives.

While these applications may be years away, McClellan believes private industry will benefit from the Laboratory's crystal research. The payoffs may apply to any industry that demands unique material science or advanced materials.

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A BETTER SOLAR COLLECTOR

SCIENTISTS HOPE TO HARVEST THE SUN'S ENERGY THE WAY PLANTS DO

Los Alamos researchers are developing methods to use thin films of dyes to capture the sun's light and convert it into energy, the way plants do.

"We're studying energy transfer processes that are analogous to photosynthesis," said researcher Greg Van Patten. "We ultimately hope to develop a more efficient means of grabbing solar energy and converting it into electrical power."

Van Patten and his Los Alamos colleagues are developing a simple, environmentally friendly method of depositing thin layers of dyes on a

Researcher Greg Van Patten dips a glass plate into a beaker of dye to create one layer of a coating that may be able to capture light and convert it into energy. Van Patten and his colleagues are working to make light-harvesting films that turn light into energy in the much the same way as plants harness energy through photosynthesis.

glass substrate to create a better solar collector. Each dye, able to absorb a certain wavelength of light, would be deposited on the substrate in sequence. The plate would look dark to the human eye, but a cross-section would reveal a rainbow of colored layers piled on top of one another.

By layering the dyes, scientists hope to capture as much available light as possible — ultimately, more than can be collected with current semiconductor solar panels.

For example, a layer that appears green to the naked eye absorbs most of the spectrum except for the green wavelength, which is reflected back to the human eye to be seen. Other layers capture other portions of the spectrum and reflect back the portions that appear to the human eye as the layers' respective colors.

To a human observer looking down on the plate, very little light would be reflected back, so the plate would appear dark, or black if it were absorbing all visible wavelengths.

Researchers are using chemicals that allow them to build up layers simply by dunking the substrate into a dye solution. This low-tech, low-cost method avoids the use of potentially hazardous organic chemicals common to some thin-film deposition techniques.

The simplicity comes from the chemicals themselves.

To build up the layers, researchers coat the glass substrate with a polymer that has positively charged sites. Next, the substrate is dipped into a solution that contains negatively charged dye particle. The dye ions are attracted to the positively charged polymer layer and they stick to it.

After the dye layer is applied, another layer of polymer is added and the collector is ready for dipping into another dye solution. The process can be repeated until all dye layers are applied.

Researchers are working to perfect the first dye layer. The dye comes from a class of molecules called porphyrins — the same class of dye as the chlorophyll found in plants.

The porphyrin molecule has four negatively charged branches radiating from a central cluster of chemical rings. The Los Alamos team is experimenting with how different metal ion species added to the interior affect energy transfer. In this case, they are using porphyrins with zinc ions in the center.

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When light hits the porphyrin, the molecule absorbs a photon and moves to an electronically excited state. Since molecules like to remain at the lowest stable energy level possible, the porphyrin will try to transfer its energy to a neighboring molecule of lower energy, which in turn will try to pass energy to its neighbor and so on — like a line of people passing a bucket of water from a well to a burning barn.

The idea behind the light-harvesting multilayer film is to get the molecule to pass their energy from one molecule to the next through all the different dye layers until the energy can be passed into a "trap."

A similar mechanism occurs in plants. When a plant porphyrin captures a photon, it passes its energy around to other porphyrins that are clustered around an energy center. Like a pinball bouncing off bumpers, the energy is transferred between porphyrins until it strikes the energy center. The plant then can "digest" and use the energy.

Zinc porphyrins transfer energy well while in solution, but they behave differently on the film. Van Patten believes that part of the problem is the way in which the molecules attach themselves to the substrate. He is experimenting with the chemistry of the molecules to see if they will line up on the substrate in an orderly fashion once the substrate is dipped into the dye solution.

Researchers also are experimenting with other dyes to see how they behave on a substrate and how well they transfer energy.

If the research is successful, it may have applications beyond solar collectors. Energy-transferring films could be used in a number of applications, including devices that could use sunlight to transform toxic environmental contaminants into harmless substances.

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BRIEFLY ...

LOS ALAMOS FIRE PROTECTION SPECIALIST RICHARD PEARSON HAS BEEN NAMED "EMPLOYEE OF THE YEAR" BY CAREERS AND THE DISABLED MAGAZINE. "I never dreamed that I would be nationally recognized for what I am doing for the Deaf Community and the Laboratory," Pearson said. A Los Alamos employee for 17 years, Pearson has worked in the former Engineering Division and now works for the Fire Protection Group. Pearson, who is Deaf, has served as chair of the New Mexico Association for the Deaf and worked on numerous other state legislative committees to advocate for Deaf and Hard of Hearing individuals. He is a 1976 graduate and past president of the Alumni Association of the New Mexico School for the Deaf. Pearson also is a graduate of Seattle Central Community College where he received an associate's degree in drafting technology. Michelle Stump, coordinator of Los Alamos' Americans with Disabilities Act out of the Diversity Office, nominated Pearson for the award.

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