CornellResearch

A Pioneer of Scientific Tools

Sol Gruner, known for developing x-ray detectors, is a toolmaker, tackling scientific problems and exploring the unknown.

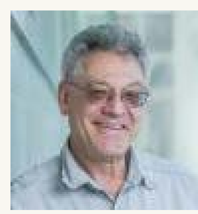
Jesse Winter

by Jackie Swift

“Most scientists focus on a very specific area, but I do many different things,” says Sol Gruner, Physics. “I’m a research mutt. Mainly, I develop tools to attack scientific problems people haven’t looked at yet, largely because the tools needed to solve those problems haven’t existed.”

Gruner’s tool-making expertise has resulted in an array of scientific breakthroughs and developments over the years. One area of research he is well-known for involves the development of new kinds of x-ray detectors for use at synchrotron facilities. X-ray detectors are crucial tools that use x-ray fraction to examine how materials change during experiments, and for several decades, Gruner’s has been one of the foremost groups working in this field. Sol Gruner, known for developing x-ray detectors, is a toolmaker for tackling scientific problems and exploring the unknown.

Featured



Sol M. Gruner
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Highlights

What’s Happening Inside Materials at the Atomic Level?

How Does Extreme Pressure Affect Biomolecules?

The Gruner group developed the first pixel array detectors (PADs)—which directly capture x-rays and process the resultant signals in integrated circuit chips—for use in very fast, time-resolved synchrotron science experiments, both at storage ring sources, such as the Cornell High Energy Synchrotron Sources (CHESS), and at x-ray free electron lasers. For example, his group designed the detectors in use at the Linac Coherent Light Source, the world's first high-energy x-ray free electron laser now operating near Stanford University in California. They allow researchers to look at matter in time scales of femtoseconds (one millionth of one billionth of a second).

What's Happening Inside Materials at the Atomic Level?

To explore these new detectors' capabilities, Gruner and his colleagues have begun a series of experiments. In one, they subject materials to extremely fast deformations by firing a gas gun at the material, crushing it in a couple of microseconds. "Our goal is to examine what happens at the atomic level by shooting x-rays through the material as it is crushed," says Gruner. "We want to break that microsecond process into bits where, for each time bit, you're getting an x-ray picture of the atomic structure as it evolves."

Information on the rapid evolution of the atomic structure of materials can be applied in a variety of ways. For instance, understanding what causes materials failure can lead to both greater safety and huge savings in the airline industry. Currently, airplanes are overhauled and rebuilt at an extremely early point in their projected lifespan in order to avoid a catastrophic materials failure. "When you pound on metals and composites they will eventually fail," says Gruner. "What is happening at the molecular level with each blow and what are the consequences of that? If we had some way of knowing when whatever is happening inside the material has accumulated to the point where it's about to fail, and could diagnose that, there would be huge practical consequences for airlines. They would no longer have to be ultra-conservative and replace material after a given number of hours. They would know exactly when it needed replacement."

How Does Extreme Pressure Affect Biomolecules?

In another line of research, Gruner has been looking at high-pressure protein crystallography, which examines the effect of pressure on soft matter. This area of inquiry is relevant to a huge portion of the biosphere says Gruner. While we, humans, live at one atmosphere pressure, most of the volume of the biosphere is at hundreds of atmosphere pressure—up to over a thousand atmospheres at the bottom of the deepest ocean trenches. Organisms live throughout the earth's crust at these extreme pressures and have adapted their life processes accordingly. How do they do it, and what are the consequences?

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"There've been many hundreds of papers written trying to understand the effects of pressure on biomolecules," says Gruner. "How do proteins and enzymes change their reaction rates, for instance? The work has been largely descriptive; they've seen huge effects, but there's very little understanding of these effects."

One of the reasons for the lack of understanding is that, until recently, biologists didn't have the tools to study this phenomenon. At the same time, high-pressure physicists, who very typically build the tools, were more interested in the effects of a million atmospheres pressure than a few hundred. "A lot of time our knowledge of the world or the universe is limited by the way scientists organize themselves," Gruner says. "By looking at places between disciplines or fields—which is another characteristic of the work my group does—you can find things that are really interesting and in many instances totally untouched."

In this case, the Gruner Group took on the biologists' dilemma and developed x-ray techniques to determine macromolecular structure at high pressure. "When we started 15 years ago there were thousands of protein structures in the Protein Data Bank," Gruner says, referring to the international crystallographic database repository for three-dimensional structural data of large biological molecules. "The structure of only one of these proteins had been solved at a pressure of a thousand atmospheres. Now, using our techniques, we routinely do high-pressure protein crystallography to examine these structures."

A Collaboration for Creating Superconductors with Novel Properties

An on-going aspect of Gruner's work is his collaboration with Ulrich Wiesner, in Cornell's Materials Science and Engineering Department, on the structure and properties of block copolymer-based synthesis of complex morphologies. Over the last 20 years, the two have published more than 30 papers together, along with various other team members. Recently they succeeded in creating the first self-assembled, three-dimensional superconductor made using these techniques. Made of niobium nitride, the gyroidal structure has opened the door for further research into superconductivity, a state in which electrons can move around without resistance and, thus, without losing energy to their environment.

While superconductors have applications today—Magnetic Resonance Imaging (MRI) scanners, for instance—they are limited by the need to cool them during operation to near absolute zero (-459.67 degrees). The hunt is currently on for superconductors that can perform at higher temperatures and have interesting properties. Gruner and Wiesner's superconductor is a new step in this direction.

"Uli and I have been dreaming for decades about creating a gyroidal superconductor," Gruner says. "This one we made has a totally new type of nanoscopic structure, and we're anxious to explore it. There are some very straight forward physics questions we could ask, such as, what is the magnetization curve for such a material and can it be put to use?"

Whatever the new superconductor leads to, one thing is sure: Gruner will continue making new tools and creating new techniques to tackle the many scientific problems still waiting to be solved. "I'm a physicist and a tool builder by nature," he says. "That's what physicists do: we make stuff."