Researchers pursue blast-resistant steel using new tomograph

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Materials scientists and engineers at Northwestern University are developing a new "high-security" steel that would be resistant to bomb blasts such as the one that struck -- and nearly sank -- the USS Cole in Yemen in 2000. The researchers now have a state-of-the-art instrument that enables them to get a precise look at steel's composition on the nanoscale: a $2 million atom-probe tomograph that is only the fourth of its kind in the world.

Using the new Local-Electrode Atom-Probe (LEAP®) tomograph, researchers studying steel and other materials can -- at amazing speed -- pluck atoms off a material's surface one at a time, layer by layer over tens of thousands of layers, to better understand the entire nanostructure and chemical composition of the material, which is key to designing new materials effectively and efficiently.

The technology is similar to that used in CT (computed tomography) scans, which image body tissues for medical diagnosis. Consisting of a field-ion microscope plus a special time-of-flight mass spectrometer, an atom-probe tomograph takes multiple pictures and uses those slices to construct a detailed three-dimensional image of the material.

"We now can conduct certain experiments that would be impossible without the LEAP tomograph," said David N. Seidman, Walter P. Murphy Professor of Materials Science and Engineering, who spearheaded the effort to bring a LEAP tomograph to Northwestern, the first university in the country to secure one. The three other institutions

that have a LEAP tomograph are Oak Ridge National Laboratory, the University of Sydney and Sandia National Laboratories.

With a grant from the U.S. Office of Naval Research, Seidman is working with Morris E. Fine, professor emeritus of materials science and engineering, on the stronger steel problem. "The U.S. Navy wants a superior material for its new fleet of ships," said Seidman. "Our steel, an alloy of iron, carbon and various other elements and metals, gets its strength mainly from tiny nanosized particles of copper, which are distributed in both homogenous and heterogeneous patterns. The LEAP tomograph lets us, for the first time, view both distributions at once, which is critical to understanding the role copper plays. With in-depth knowledge of steel's structure and chemical identity, we can design a stronger material."

The LEAP tomograph has a very large field of view, analyzes significantly larger volumes of material, and collects data more than 720 times faster than its predecessor at Northwestern, a conventional 3D Atom-Probe tomograph. The LEAP tomograph collects 72 million atoms per hour while the old tomograph collects merely 100,000 atoms in the same amount of time. The specimen is held in the tomograph at cryogenic temperatures, immobilizing the nanostructure so that when atoms are removed the remaining structure is not affected. Each atom's position and chemical identity are recorded, and the data are then used to create a three-dimensional image of the material's complex atomic structure.

Researchers using the new tomograph are not focusing on steel only. The LEAP tomograph, which became operational in January and is housed in the Northwestern University Center for Atom-Probe Tomography (NUCAPT) in William A. and Gayle Cook Hall, has attracted faculty, post-doctoral fellows and graduate students working on problems ranging from semiconductor nanowires for use in new nanotechnologies to

stronger and energy efficient aluminum alloys for use at high temperatures, with applications in the airline and automotive industries. Other materials that can be studied using the LEAP tomograph are metal alloys containing ceramic particles, semiconductors and conducting polymers.

"The LEAP tomograph is a beautifully engineered and revolutionary piece of instrumentation," said Seidman, who heads NUCAPT, the second largest atom-probe tomography group in the world. "It's like going from a rotating anode X-ray tube in your lab to the synchrotron at Argonne National Laboratory. Now the rate limiting step is analyzing the data as opposed to collecting the data."

To assist Seidman and other researchers in this challenge, a post-doctoral fellow from Argonne will be involved in developing additional software to handle the large data sets. One focus will be image visualization and the display of data in a way that reveals the most useful information.

The U.S. Office of Naval Research and the National Science Foundation provided the majority of the funding for the LEAP tomograph.

Source: Northwestern University

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