Featured Highlights

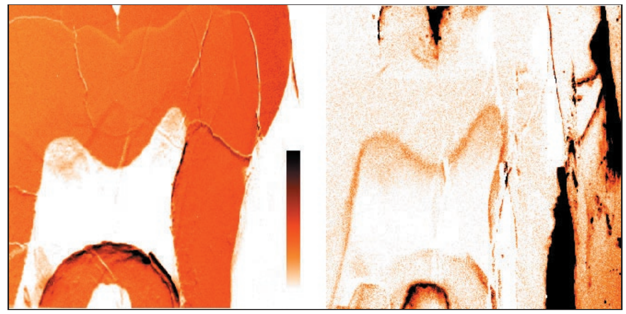
from the National Synchrotron Light Source

Boosting Speed, Precision of X-ray Fluorescence Microprobes

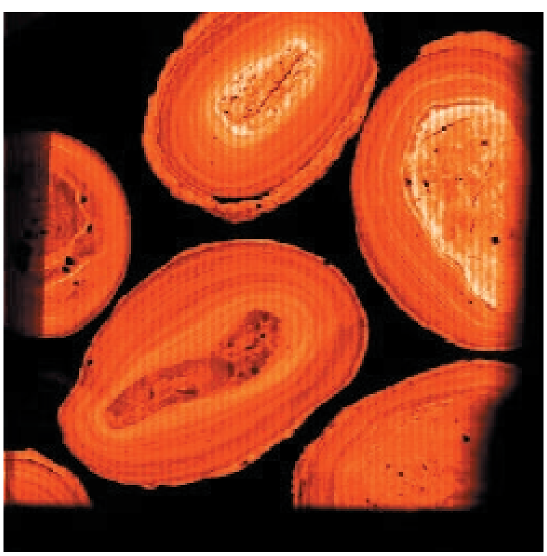
Combining large, high-resolution detector arrays with an advanced analysis technique, researchers from the NSLS, BNL's Instrumentation Department, and Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) have developed an x-ray fluorescence microprobe system that will be about 1,000 times faster than previous methods.

X-ray fluorescence is a powerful technique usually used in the environmental and geological sciences for measuring trace element concentrations in a sample. Typically, a very tiny x-ray spot is focused on a sample, which ionizes electrons from the material's atoms. These excited atoms relax, filling the vacancies, and in doing so, emit x-rays at energies characteristic of specific elements. However, scientists can only determine the elements present in the portion of the sample that's exposed to the x-ray spot. To get an idea of the entire sample's chemical composition, the spot must be manually moved from one location to another – a process that can take many hours to produce low-resolution maps of just a few thousand pixels.

"You have to stop and start and it's a pain in the neck," said NSLS physicist Peter Siddons. "So we came up with a method that would allow us to scan the scheme continuously along a line. The exposure time is just a few milliseconds at each point so, like previous 'on-the-fly' scanning systems, it never really stops moving. However, we collect full spectral data as we go. That not only makes it fast, but allows a high-quality quantitative analysis as well."



Calcium (left) and lead in a 14th century tooth imaged using the 32-element prototype detector array at NSLS beamline X27A. The color legend distinguishes high (top) from low concentrations. The tooth was supplied by Rudiger Brenn, University of Freiberg. (12x12 *mm², 2000x2000 pixels at 6ms/pixel, 6.7 hours acquisition)*



Iron-oxide nodules imaged using the 32-element prototype detector array at NSLS beamline X27A. (12x12mm², 375x375 pixels at 32ms/pixel)

The new scanning method, which has been tested at NSLS beamline X27A, also includes two other improvements upon the old technique. The first is the use of a multi-element detector, which incorporates many small detectors (32 in the test run) into one device, instead of using one large detector.

"These experiments are limited not only by mechanical speed, but also by how many photons you're detecting from the x-ray spot," Siddons said. "There are always more than enough photons in the synchrotron spectrum to excite these samples and saturate the detector. By making the detectors smaller and making more of them, we can collect more signal at each position in the map, or do it much faster."

The final pieces of the new fluorescence microprobe system are advanced data analysis techniques that can handle the increased data processing speed and map the x-ray energies in real time. Led by physicist Chris Ryan, scientists at CSIRO developed software and hardware to unfold the signals from chemical elements at up to 100 million events per second.

"The combination of large multi-element detectors, fast scan mapping, and real-time processing means we can tackle challenging new approaches in a realistic timescale," Ryan said. "Techniques such as chemical-state imaging and fluorescence tomography will now become practical tools, made possible with this massive increase in speed and throughput."

In the first demonstration of this technique, which was detailed in the *2006 Goldschmidt Conference Abstracts*, the research team produced a 4 mega pixel image of a 14th century tooth and looked for lead accumulation that might indicate the presence of lead poisoning hundreds of years ago.

“The image was produced in just about six hours, a task that would normally take days”, Siddons said. “No one ever did a 4 mega pixel image before because it would just take too long.”

Now, the group is building two 400-element detectors: one for the NSLS and one for the Australian Synchrotron. They are expected to produce scanning images 1,000 times faster than the traditional x-ray fluorescence technique.

Other scientists involved in the research include Gareth Moorhead, Paul Dunn, Robin Kirkham, Robert Hough, and Barbara Etschmann, all of CSIRO; and Angelo Dragone and Gianluigi De Geronimo, from BNL. This research was funded by the U.S. Department of Energy and the CSIRO Emerging Science program.

— Kendra Snyder