Creating an Electron Avalanche without Electronics

In this hunt, the needle is a small amount of iron and the haystack is a tree leaf composed of a messy mass of numerous metallic elements. Although it might be on a much smaller scale than the barnyard, the complexity of this search is the same for researchers using x-ray fluorescence experiments. Dilute elements – those with low concentrations in a material – are extremely hard to pinpoint because of their weak signals and interfering noise. Recently, though, a team of scientists from the NSLS and Southern University have tested a way to amplify these small signals, creating a signal stronger than those produced by traditionally used detectors.

X-ray fluorescence is a powerful technique used often in the environmental and geological sciences for measuring trace element concentrations in a sample. Typically, an 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 a "signal" in the form of x-rays at energies characteristic of a specific element. Conventional devices such as passivated implanted planar silicon (PIPS) and Lytle detectors are generally used in extended x-ray absorption fluorescence spectroscopy (EXAFS) experiments to pinpoint weak signals. However, neither is perfect: Lytle detectors produce noise that can further hide the already weak dilute element signals, and PIPS detectors are sensitive to light and temperature changes.

Elhag Shaban (left) at Brookhaven with Southern University students Marcus Walker and Vontrelle Collins.

"There are a lot of detectors on the market that can amplify a signal, but the trick is getting rid of the noise," said Southern University professor Elhag Shaban, the lead author of the study. "When you use electrical equipment to try to make a signal bigger for one element, you make noise that kills the other signals in the spectrum."

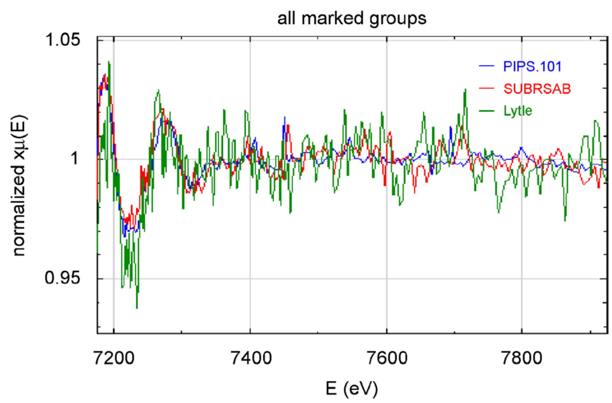

Figure: μ(E) for the detectors SUBRSAB, PIPS, and Lytle.

That's why Shaban, along with NSLS physicists Pete Siddons and Tony Kuczewski, explored the use of a detector based on a gas electron multiplier (GEM), which amplifies a signal without electronics, and therefore, virtually without noise.

"You can think of this sort of amplification as an avalanche," Shaban said. "Similar to a single chunk of snow falling down a mountain and taking more and more snow with it until it's very big, we can accelerate a small group of electrons in a field, which hit and excite other atoms and generate other electrons over and over again until the signal is very strong."

With this technique, the otherwise small signals can be made observable. Using an arbitrary tree leaf as a sample on NSLS beamline X19, the research team tested its GEM detector against the effectiveness of the PIPS and Lytle detectors in the search for the dilute element iron. They found that the GEM device resulted in an improvement in signal amplitude by a 20 and a factor of 2 when compared to the Lytle and PIPS detectors, respectively.

In addition, unlike PIPS, the GEM detector isn't affected by light and is fairly independent of temperature, Shaban said. The researchers are now exploring the possibility of adding more GEMs to the device in order to detect even more dilute elements.

Their results were published in the November 11, 2007 issue of *Nuclear Instruments and Methods in Physics Research*. This study was funded by the Office of Basic Energy Sciences within the U.S. Department of Energy's Office of Science and Southern University. The GEM was supplied by 3M Corporation.

For more information, see: E.H. Shaban, D.P. Siddons, A. Kuczewski, "Gas Electron Multiplier (GEM) Enhanced Ionization Chamber for Fluorescence Detector," Nuclear Instruments and Methods in Physics Research, 582, 185-186 (2007).

— Kendra Snyder