A new look below the surface of nanomaterials

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Scientists can now look deeper into new materials to study their structure and behavior, thanks to work by an international group of researchers led by UC Davis and the Lawrence Berkeley National Laboratory and published Aug. 14 by the journal *Nature Materials.*

The technique will enable more detailed study of new types of materials for use in electronics, energy production, chemistry and other applications.

The technique, called angle-resolved photoemission, has been used since the 1970s to study materials, especially properties such as semiconductivity, superconductivity and magnetism. But the technique allows probing to a depth of only about a nanometer beneath the surface of a material, a limit imposed by the strong inelastic scattering of the emitted electrons.

The breakthrough work of the UC Davis/LBNL team made use of the high-intensity X-ray source operated by the Japanese National Institute for Materials Sciences at the SPring8 synchrotron radiation facility in Hyogo, Japan, and allowed researchers to look far deeper into a material, providing more information and reducing surface effects.

"We can now take this to much higher energies than previously thought," said Chuck Fadley, professor of physics at UC Davis and the Lawrence Berkeley Lab, who is senior author of the paper.

The technique is based on the photoelectric effect described by Einstein in 1905: When a photon is shot into a material, it knocks out an electron. By measuring the angle, energy and perhaps the spin of the ejected electrons, scientists can learn in detail about electron motion and bonding in the material.

Previously, the technique used energies of about 10 to 150 electron-volts. Working at the Japanese facility, Fadley and his colleagues were able to boost that to as high as 6,000 electron-volts — energies that increased the probing depth up to 20-fold.

Thanks to recent advances in electron optics, the team was also able to collect accurate information using specially designed spectrometers — effectively cameras for electrons.

The spectrometer is rather like a pinhole camera, Fadley noted. It's easy to get a sharp image with a pinhole camera by keeping the entrance opening small. Open up this aperture and a lot more light is admitted, but a clear image becomes more difficult to extract. But new developments in electron optics, particularly in Sweden, have made it possible to detect sufficient electrons to carry out such experiments.

Several high-powered X-ray sources are now running or being built in Europe and Asia, although none are yet planned in the U.S., Fadley said. The new technique could be used both for basic and commercial research on new materials for electronics and technology.

Fadley noted that he had first proposed the idea of using a high-intensity X-ray source to look more deeply beneath the surface of materials around 1980, but neither the X-ray sources nor the spectrometers existed to make the experiment feasible.

Provided by University of California - Davis