Nano, photonic research gets boost from new 3-D visualization technology

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For the first time X-ray scientists have combined high-resolution imaging with 3-D viewing of the surface layer of material using X-ray vision in a way that does not damage the sample.

This new technique expands the range of X-ray research possible for biology and many aspects of nanotechnology, particularly nanofilms, photonics, and micro- and nano-electronics. This new technique also reduces "guesswork" by eliminating the need for modeling-dependent structural simulation often used in X-ray analysis.

Scientists from the Advanced Photon Source and Center for Nanoscale Materials at the U.S. Department of Energy's (DOE) Argonne National Laboratory have blended the advantages of 3-D surface viewing from grazing-incident geometry scattering with the high-resolution capabilities of lensless X-ray coherent diffraction imaging (CDI). The new technique, an adaptation of existing detector technology, is expected to work at all X-ray light sources.

"This is the future of how we will visualize structure of surfaces and interface structures in materials science with X-rays," said Argonne scientist Jin Wang, the lead author of "Three-Dimensional Coherent X-ray Surface Scattering Imaging near Total External Reflection" published on-line August 12, 2012, in the journal Nature Photonics.

By adjusting the angle with which the X-rays scatter off the sample, Wang and fellow Argonne scientists brought the 3-D power of the new imaging technique to the surface layers of the sample. In nanotechnology, most of the atomic interactions that control the functionality and efficiency of a product, such as a semiconductor or self-assembled nanostructure, occur at or just below the surface. Without a direct 3-D viewing capability, scientists have to rely on models rather than direct measurement to estimate a surface structure's thickness and form, which weakens confidence in the estimate's accuracy.

Using grazing-incidence geometry, rather than traditional CDI transmission geometry, scientists eliminated the need for modeling by using the scattering pattern to directly reconstruct the image in three dimensions.

Conventional X-ray imaging techniques allow for 3-D structural rendering, but they have lower image resolution and, therefore, greater uncertainty. Plus, in some cases, the X-rays' intensity destroys the sample. This new APS-designed technique potentially can image a sample with a single X-ray shot, making it non-destructive, a desirable quality for research on biological cells and features formed by organic materials.

Another benefit is the ability to expand CDI viewing from the nanometer to the millimeter scale when the X-ray beamline impinges on the sample at a glancing angle. This innovation allows scientists to relate the behavior of a bundle of atoms or molecules to that of an entire device. This area—the mesoscale, between nanoresearch and applied technology—has been a particularly difficult area for scientists to access. In nanotechnology, this area is thought to hold promise for making stronger, more flexible and more efficient materials. In biology, it connects intercellular behavior with the activity of individual cells and the larger organism.

"Hopefully this technique will be applied to research in biology, microelectronics and photonics" said Tao Sun, a postdoctoral research fellow working at the APS and the first author on the research. "This technique holds great promise because the resolution we can reach is only limited by wavelength, a fraction of a nanometer. So the APS upgrade and other advances in light source and detector technology will easily provide even higher-resolution images than we have achieved in this work."

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