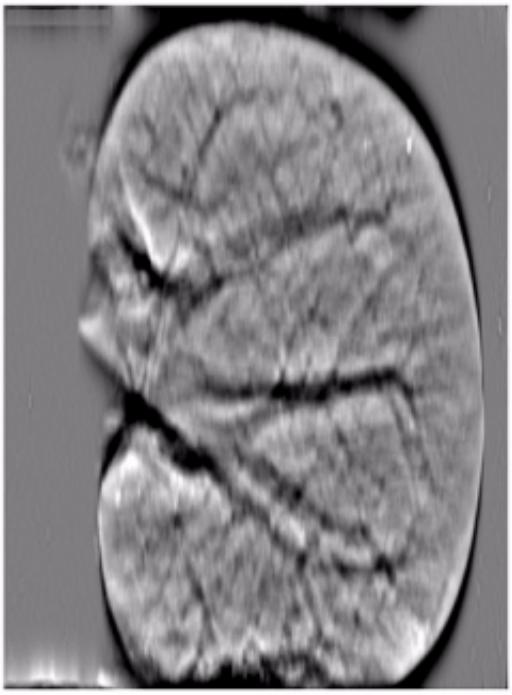
A new multilayer-based grating for hard X-ray grating interferometry

November 22 2013, by Chian Liu



An image of the phase shift in the mouse kidney from a Bonse-Hart interferometer built utilizing the new micro-multilayer grating provides a projection view of the blood vessels.

(Phys.org) —A new kind of x-ray multilayer grating that could open a pathway for high-sensitivity, hard x-ray phase contrast full-field imaging of large samples has been developed by researchers at the National Institutes of Health, the U.S. Department of Energy Office's (DOE's) Argonne National Laboratory, and Penn State University. In tests at the

DOE Office of Science's Advanced Photon Source at Argonne, the device produced phase-contrast images of vascular structures in a mouse kidney specimen that rival those obtained with magnetic resonance imaging. Such soft-tissue structures were previously invisible to conventional attenuation-based x-ray imaging methods.

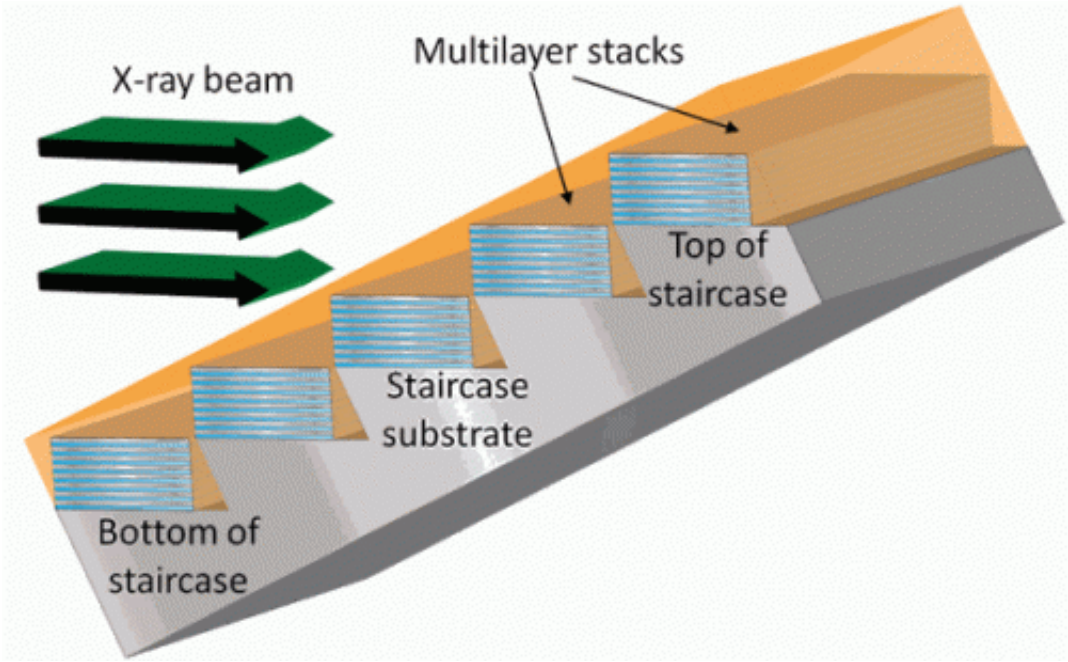
The new grating, with an ultra-small period and theoretically unlimited depth-to-period ratios, is based on a multilayer thin-film-deposition technique utilizing an anisotropic wet-etched staircase on an off-cut silicon (Si) wafer as the substrate. It has a very small grating period that is equal to the bilayer thickness of the multilayer. It also features a large area of the whole staircase with thousands of steps.

Details of fabrication processes were published in the *Journal of Micromechanics and Microengineering* . The paper has been selected for inclusion in the Highlights 2012 collection of the journal, based on referee endorsement, novelty, scientific impact, and broad appeal.

Grating-based interferometry for x-ray phase-contrast imaging has advanced rapidly thanks to its potential for better image contrast and lower radiation dose over conventional absorption radiography and computed tomography. Phase-contrast imaging is hundreds of times more sensitive than conventional x-ray imaging techniques based solely on absorption contrast. It is especially useful for imaging soft tissue with hard x-rays from synchrotron light sources like the Advanced Photon Source.

Gratings are used to diffract an incident x-ray beam into two beams that pass through a sample and produce an interference pattern at the detector plane. Variations of the refractive index in the sample lead to a relative difference in the path length, or phase delay, between the interfering beams, which is detectable as a shift of the fringe pattern. Additionally, random scattering of the beams in the sample reduces their

mutual coherence, resulting in decreased amplitudes of the interference fringes. A grating interferometer is thus able to detect both x-ray refraction and diffraction in the sample.



The multilayer grating consists of an array of micro-gratings of multilayer sitting on the floor of steps of a staircase Si substrate. The grating period equals the bilayer thickness, and the grating area covers the whole staircase with thousands of steps.

A small grating period, which splits and diffracts light into several beams travelling in different directions, will lead to a larger separation between the diffracted beams and thus higher interferometer sensitivity.

Hard x-rays have great penetration power. The interferometer gratings require a sufficient thickness to produce the desired phase shift and absorption. Traditional hard x-ray gratings are fabricated using lithography processes; the grating period is relatively large, and the

attainable aspect ratio of the grating is limited.

Multilayer gratings can easily solve the aspect ratio problem. The layers can be as thin as a few nanometers, and the grating can be sliced to many millimeters. However, if a flat substrate is used, the limited height of a single multilayer stack (