Reducing stress in multilayer laue lenses

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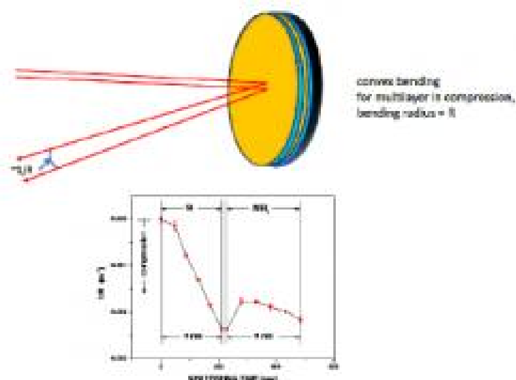

Schematic illustration of the laser-based measurement of the radius of curvature caused by the stress inherent in the sputter deposition of a multilayer. For the sake for clarity only two multilayer periods are depicted. The measured data were obtained by averaging over several periods.

Multilayer Laue lenses (MLLs) developed at the U.S. Department of Energy Office of Science's Advanced Photon Source (APS) focus high-energy x-rays so tightly they can detect objects as small as 16 nanometers in size, and are in principle capable of focusing well below 10 nanometers. As recently reported this approach doubles the resolution over existing lenses, and future advancements could increase resolution by 10 times. Furthermore, large-diameter MLLs have the potential to achieve a very high efficiency, enabling detailed studies of individual nanoparticles. Now, studies carried out by researchers at the APS reveal a simple means to reduce stress in MLLs, thereby removing a possible obstacle to maximizing the potential of these lenses.

Future MLLs with an overall growth thicknesses in excess of 50 µm will be needed to focus the full brilliance of APS x-ray beams to spot sizes of 5 nm and below. Any built-up stress, if not reduced, can limit the maximum useful thickness of the MLL. Excessive stress can cause delamination of the lenses during processing of deposited multilayers into ready-to-use lenses. However, as recently reported in Applied Physics Letters, there is a way to reduce the grown-in stress.

Since their invention at the APS, MLLs and the technology needed to make them have progressed to the point where a focus spot of 25 nm x 27 nm was recently reported in Optics Express. The deposited thicknesses for the two crossed lenses were 12.4 µm and 13.4 µm, which limited the focused flux to approximately 1% of what could ideally be obtained. Future lenses will require thicker deposits, and methods to reduce stress are needed.

Grown-in stress resulting from a newly deposited layer can be measured by monitoring the change in the radius-of-curvature of the entire wafer, as schematically shown in the top part of the accompanying figure. The formula that relates the stress to this curvature was first published by G.G. Stoney in 1909, and measurements of curvature offer a very simple and powerful means to monitor changes after only 1 nanometer of a thin film is deposited on a substrate via sputter deposition, as shown in the bottom part of the figure. The fact that stress in very thin layers can be studied is reported in *Applied Physics Letters*. The data reveal that more of the grown-in stress arises from the Si layers than from the WSi_2 layers, so that a reduction in the fraction of the multilayer period that is Si should be effective.

This simple means to reduce stress is presently an active area of research at the APS, and the preliminary results point to an effective path towards larger diameter optics.

More information: Hanfei Yan, et al., "Two dimensional hard x-ray nanofocusing with crossed multilayer Laue lenses," *Opt. Express* 19, 15069 (2011).

[2] Kimberly MacArthur, et al., "Periodic variation of stress in sputter deposited Si/WSi2 multilayers," *Appl. Phys. Lett*. 99, 081905 (2011).

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