Fabrication of a Condenser Mirror for a Soft X-Ray Microscope

Kwon Su Chon,[a,b] Yoshiharu Namba,[a] and Kwon-Ha Yoon[b]

[a] *Department of Mechanical Engineering, Chubu University, 1200 Matsumotocho, Kasugai, Aichi 487-8501, Japan*
[b] *Institute for Radiological Imaging Science, Wonkwang University, 344-2 Sinyong-dong, Iksan, Jeonbuk 570-711, Korea*

There have been many attempts to investigate nanometer-scale fine structure. A soft X-ray microscope can be used to investigate hydrated specimens, particularly living cells, with a resolution several times better than that possible with visible light microscopes. The reflecting optics used in a soft X-ray microscope require supersmooth surfaces and a highly accurate figure. We consider a Wolter type I microscope mirror as a condenser optic. This consists of two axially symmetric confocal surfaces of revolution: an ellipsoid and a hyperboloid.

We have optimized the design of the Wolter type I mirror for observing living cells at a wavelength of 2.3 nm in a laboratory prototype. The condenser mirror of 1/4 X magnification was chosen. The effective solid angle, which is defined as the product of the geometrical solid angle of the mirror and the reflectivity after two reflections, showed a maximum at the desired 2.3 nm wavelength.

Since the grazing angle of incidence is about 2 degrees, the mirror has a small diameter and a long length. It is not easy to fabricate such a mirror by direct machining and polishing because of the internal reflecting surfaces. As an alternative, a replication method was chosen. Machining of the master mandrel is very important because the quality of the replicated mirrors critically depends on the surface roughness and figure of the master mandrel. We first prepared the master mandrel by single-point diamond turning electroless nickel that was plated onto an aluminum alloy. The surface of the master mandrel was then polished. Finally, we fabricated Wolter type I mirrors using an epoxy replication technique. A thin gold layer, 300 nm in thickness, coated onto the master mandrel plays an important role as a parting agent to separate the master mandrel and the mirror substrate with a gold reflecting surface. The gold-coated mirrors replicated the master mandrel very well, although there were minor variations in the surface roughness and figure. After separation there was no surface degradation and figure change on the master mandrel, and several mirrors could be successfully made from one master mandrel. The surface roughness and figure error of the replicated gold mirror were 1.2 nm rms and 160 nm PV, respectively.