A Soft-X-Ray Imaging Microscope Based on a Multilayer-Coated Schwarzschild Objective

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Soft x-ray microscopy has been expected to observe biological samples under wet environment in the water window region. Owing to the development of multilayer coatings, image formation by normal incidence optics has been possible in the soft x-ray region. We constructed a soft-x-ray imaging microscope based on a multilayer-coated Schwarzschild objective. In this microscope the soft x-ray emission produced at a sample with an electron beam or synchrotron soft x-rays is focused on a position-sensitive detector using a Schwarzschild objective. It provides an element-sensitive image in terms of the characteristic soft x-rays selectively reflected by the multilayer coating. It is also able to give a map of elements distributed in buried layers because of the long mean-free-path of the soft x-rays, which should be compared with photoelectrons. The Schwarzschild objective was designed to have a 50 x magnification and a numerical aperture of 0.25. From a simulation study the ideal resolution was found to be 30 μm on the optical axis. As a preliminary study we chose a Mo/Si multilayer to observe the Si *L* emission. The mirrors of the objective were coated with 41 layers in total in a uniform thickness periodicity using a magnetron sputter system. The overall throughput of the objective was estimated to be 14% at a peak wavelength of 13.3 nm. The 5-μm wide stripes of SiO_2 lithographically patterned on a Si wafer were observed under irradiation with an electron beam of 1 μA accelerated to 2.5 kV. This is the first observation of an image made by focusing the soft x-ray emission. Based on a visible light test the resolution of the microscope was confirmed to be better than 1 μm.

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