Focusing properties of shaped multilayer x-ray mirrors

V. V. Aristov, S. V. Gaponov, V. M. Genkin, Yu. A. Gorbatov, A. I. Erko, V. V. Martynov, L. A. Matveev, N. N. Salashchenko, and A. A. Fraerman
Institute of Problems in Microelectronics and Highly Pure Metals Technology, Academy of Sciences of the USSR

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X rays reflected from a multilayer interference mirror with a shaped surface have been focused experimentally for the first time both for an amplitude-modulated and phase-modulated x-ray wave front.

The development of new methods in microelectronics technology in the 1980s outside the Soviet Union has made it possible to rapidly assimilate the range of electromagnetic radiation with wavelengths from 1 Å to 200 Å. The development of submicron technology and multilayer structures has made it possible to construct elements for focusing, for image transmission, and for soft x-ray spectroscopy. Research in this field paved the way for the development of high-resolution x-ray microscopes and telescopes, the photoelectronic spectroscopy scanning methods.

The development of diffraction elements for x-ray optics now has several directions. Thus, for example, the creation of translucent diffraction optics based on the Fresnel zone plates and motion-picture camera lenses[1] and the use of coherent effects for high-resolution image transmission[2,3] are closely linked with the microscopy and lithography applications. The creation of mirror dispersion elements with multilayer structures is another area of activity.[4,5] These elements can also be used for radiation focusing, but extremely stringent requirements imposed on the quality of the substrate's surface make it more difficult to obtain a small focus.

An approximately periodic relief on the surface of a multilayer mirror focuses the

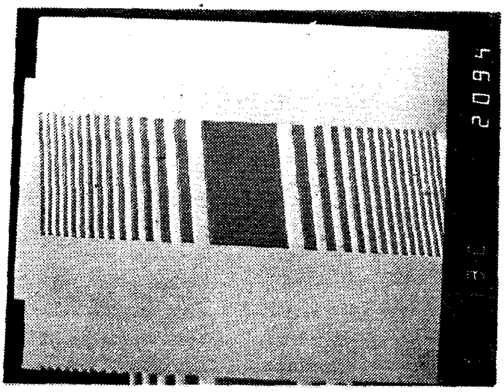
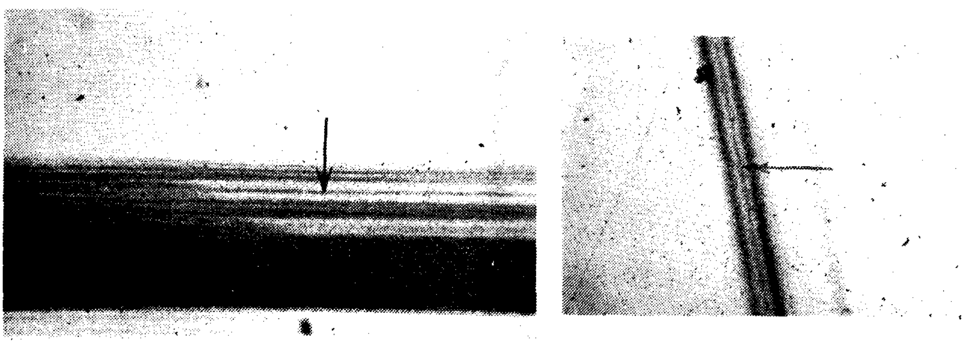


FIG. 1. Profile of the surface of a multilayer mirror.

radiation. The profile of the surface is shown in Fig. 1. As the original multilayer mirror we used a Ni–C structure.

As the x-ray source we used an x-ray tube with a linear focus and an Fe anode. The radiation from the tube is collimated with a standard slit collimator; the size of each slit is 50 μm. A mirror with a shaped surface is installed in the goniometric head 18 cm from the collimator. With a 180-μm central relief zone and angle of incidence at the mirror surface in the range 2°–2.2°, the reduced slit image is situated 1.7 cm from the focusing element. As the detector we used "Mikrat LOI-2" holographic plates with a 0.2-μm intrinsic resolution.

Figure 2 shows the images of an x-ray wave front in the region of a typical Fe$K\alpha$ spectral line obtained by (a) modulating the amplitude by forming a profile in the mirror and (b) modulating the phase by depositing ~300-Å-thick layer of gold on the mirror surface in the Fresnel zones. The slit image corresponds in size (~6 μm) to that obtained by scaling down the optical apparatus of the experiment.



a b

FIG. 2. (a) Image in the focal plane produced by modulating the amplitude of an x-ray wave front; (b) image in the focal plane produced by modulating the phase of an x-ray wave front. The arrow indicates the position of the focal line.

The results of the experiment presented above demonstrate that highly efficient focusing monochromators, operating in the soft x-ray emission range, can be built by using shaped multilayer mirrors.

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