Soft-x-ray transmission photoelectron spectromicroscopy with the MEPHISTO system

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We complemented with data taken in transmission mode the recently described tests of the novel spectromicroscope MEPHISTO (Microscope à Emission de Photoélectrons par Illumination Synchrotronique de type Onduleur). Transmitted x rays were converted by a photocathode into photoelectrons, which were subsequently electron-optically processed by the spectromicroscope producing submicron-resolution images. Test images demonstrated excellent contrast. © *1998 American Institute of Physics.* [S0034-6748(98)02409-5]

In a recent article,[1] we reported the first tests of the MEPHISTO (from the French acronym ''Microscope à Emission de Photoélectrons par Illumination Synchrotronique de type Onduleur'') synchrotron spectromicroscope,[2] which achieved spatial resolution values of 50 nm. We extended the tests to a new application of the same instrument: spectromicroscopy in the transmission mode.[3,4] Synchrotron radiation x rays transmitted through the specimen cause the emission of photoelectrons from a photocathode, which are accelerated and processed by the magnifying optics of MEPHISTO. The photoelectron beam, whose intensity is enhanced by a pair of microchannel plates, is converted by a phosphor screen to a visible image, which is captured by a computer-controlled video system. Such additional tests are particularly important[4] because charging problems which severely affect other types of photoelectron-based spectromicroscopies do not play any role in the transmission approach. Successful tests performed on different types of specimens demonstrated the performance of the instrument in the transmission mode.

Figure 1 shows a schematic of the apparatus for the transmission mode tests. The x-ray beam was produced by the Aladdin storage ring at the Wisconsin Synchrotron Radiation Center, and monochromatized by a Mark II ''Grasshopper'' monochromator or a 6 m toroidal grating monochromator. Figures 2 and 3 refer to the first successful tests. Figure 2 refers to a Fresnel zone plate (FZP) made of gold structures (dark areas) on a 2 μm thick silicon nitride membrane. Soft x rays were completely absorbed by the thick substrate; the image of Fig. 2 was taken with zero-order pho-

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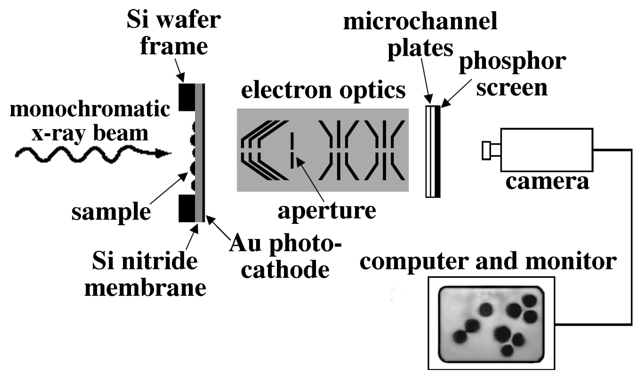

FIG. 1. Schematic diagram of MEPHISTO in the x-ray transmission mode.

tons from the monochromator, and is primarily produced by the ultraviolet component of the radiation. The test structures were patterned down to 0.12 μm, so that more than 100 lines are present in that area; some of the central and wider structures are resolved, but the finer lines are not. This can be attributed to the fact that the 2 μm membrane introduces severe blurring in the ultraviolet (UV) photons transmitted by the FZP, on the order of 0.7 μm for UV radiation of 250 nm wavelength. The results demonstrate that the imaging method is suitable for inspecting this kind of device, but also that harder x rays (or thinner silicon nitride membranes) will be needed in order to obtain higher resolution on FZPs.[5] Figure 3 shows the results of spectromicroscopy tests: x ray transmission image and spectrum of thin borocaptate ($B_{12}H_{11}SH$, or BSH) crystals on a 200 nm thick Si_3N_4 membrane. For comparison the photoelectron total yield spectrum of BSH is reported in the same plot. This latter curve was acquired with MEPHISTO in the photoemission mode. Comparing the two curves we note that the transmission spectrum dips down when the photon energy crosses the absorption edge, whereas the photoelectron yield curve has a rise, but their line shapes are very similar. In summary, our tests demonstrate the feasibility of using the advanced MEPHISTO spectromicroscope for transmission spectromicroscopy studies. This success paves the way to the microchemical analysis of different systems including biological specimens of subcellular thickness.

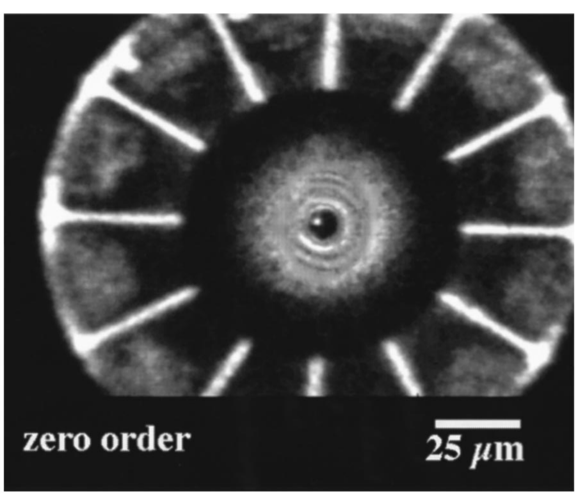

FIG. 2. X-ray transmission micrograph of a Fresnel zone plate taken with unmonochromatized photons.

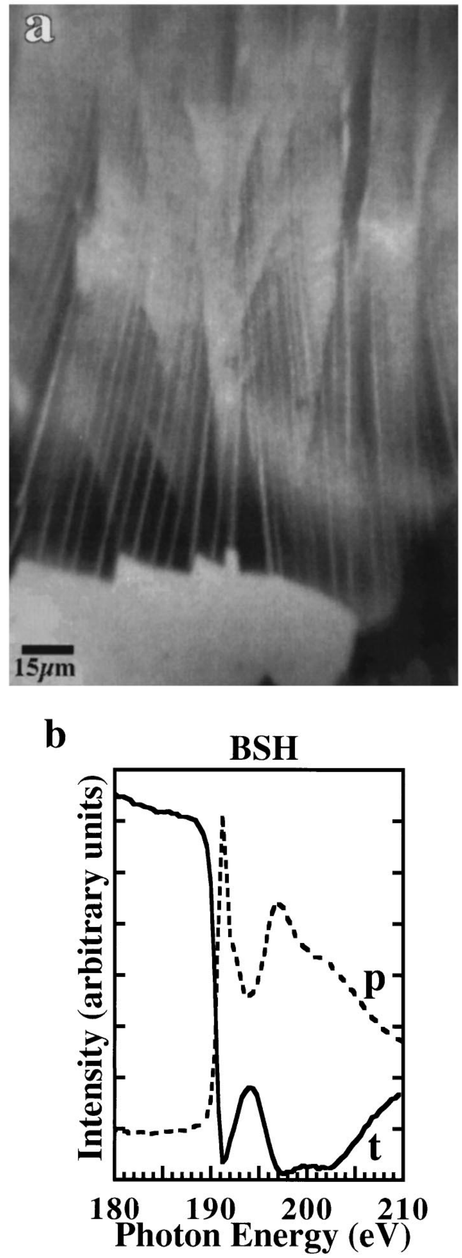

FIG. 3. (a) X-ray transmission micrograph taken at a photon energy of 450 eV, showing borocaptate (BSH) crystals over a 200 nm thick silicon nitride membrane with a 200 Å thick Au photocathode; (b) transmission x-ray absorption curve from a 10×10 μm^2 area at the center of Fig. 3(a). The transmission curve (t) corresponds to the number of photoemitted electrons (from the photocathode) per unit area, per unit time vs the photon energy. The BSH total yield curve (p) was acquired with MEPHISTO in the photoemission mode. In this case the curve represents the number of photoelectrons emitted by BSH (at 60° from the illuminating photon beam) per unit area, per unit time.

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[1] G. De Stasio, M. Capozi, G. F. Lorusso, P. A. Baudat, T. C. Droubay, P. Perfetti, G. Margaritondo, and B. P. Tonner, Rev. Sci. Instrum. **69**, 2062 (1998).

[2] B. P. Tonner, G. R. Harp, S. F. Koranda, and J. Zhang, Rev. Sci. Instrum. **63**, 564 (1992); G. De Stasio, S. Hardcastle, S. F. Koranda, B. P. Tonner, D. Mercanti, M. T. Ciotti, P. Perfetti, and G. Margaritondo, Phys. Rev. E **47**, 2117 (1993).

[3] F. Polack and S. Lowenthal, Rev. Sci. Instrum. **52**, 207 (1981); Nucl. Instrum. Methods **208,** 373 (1983); H. Seidel, A. Heuberer, and H. Baumgärtel, J. Electrochem. Soc. **137**, 3612 (1990); R. N. Watts, S. Liang, Z. H. Levine, T. B. Bucatorto, F. Polack, and M. R. Scheinfein, Rev. Sci. Instrum. **68**, 3464 (1997).

[4] G. DeStasio, G. F. Lorusso, T. Droubay, M. Kohli, P. Muralt, P. Perfetti, G. Margaritondo, T. F. Kelly, and B. P. Tonner, Rev. Sci. Instrum. **67**, 737 (1996).

[5] S. Ted Liang, F. Cerrina, and T. Lucatorto, Proc. SPIE **2723**, 211 (1996).

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