X-RAY FLUORESCENCE TOMOGRAPHY WITH A WOLTER MIRROR X-RAY MICROSCOPE

Because the Wolter-type grazing-incidence mirror has small coma and no chromatic aberration it can be used for simultaneous imaging of polychromatic fluorescent X-rays from multiple elements [1]. Using a Wolter mirror, an X-ray fluorescence imaging microscope was assembled at beamline **BL39XU**. 2-dimensional elemental maps of a test specimen (consisting of Cu, Co, Ni, Fe and Ti wires) and a rock specimen were obtained by subtraction between the images at different X-ray energies just above and below the absorption edges of the specific elements [2].

Using this microscope, 3-dimensional X-ray fluorescence tomography was successfully performed. The optical arrangement is shown in Fig. 1. Monochromatic X-rays in the energy range of 6 – 10 keV were used for excitation. The fluorescence image X-rays were enlarged and focused onto a CCD camera (Hamamatsu, TI, TC-215) by a Wolter mirror (magnification: 10; object-image distance: 2200 mm; grazing angle: 7 mrad; Pt-coated surface). The spatial resolution of the mirror was found to be about 10 μm [1]. The excitation area of a specimen was restricted to be about 1×1 mm^2 by adjusting the slit width. The energy profile of the fluorescent X-rays could be measured by a SSD on the image plane. A transmission image of the specimen was also recorded by another CCD camera behind a specimen. By rotating the specimen by 7.2-degree intervals, a series of X-ray fluorescence images from 50 different angles of view was recorded. The tomographic reconstruction was calculated by the filtered back projection method.

Figure 2 shows examples of maximum intensity projection of 3-dimensional reconstructed images of a test specimen (Cu: ϕ 25 μm, Ni: ϕ 25 μm, and Fe: ϕ 100 μm wires in a quartz capillary tube: ϕ 300 μm). Excitation X-ray energies of 9.00 keV (above Cu *K* absorption edge) and 8.34 keV (below Cu *K* absorption edge) were used in Fig. 2(a) and Fig. 2(b), respectively. The Cu wire can be seen in Fig. 2(a), whereas it cannot be seen in Fig. 2(b) because of the lower energy of the excitation X-rays. This result shows that this method is applicable to 3-dimensional elemental mapping of a specimen. Figure 3 shows the maximum intensity projection of the reconstructed tomographic image of the synthetic diamond. The excitation X-ray energy was 8.34 keV. The diamond contained impurities consisting of Fe, Co, and Ni. The fluorescent X-rays from the impurities was clearly observed.

To evaluate the absolute concentration of the specific elements, it is necessary to calibrate the X-ray absorption by the specimen. This technique is being developed by examining the transmission X-ray images.

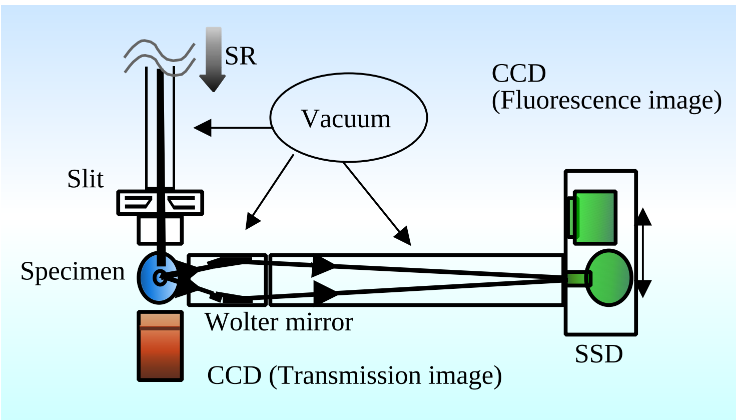

Fig. 1. Optical arrangement of the X-ray fluorescence microscope.

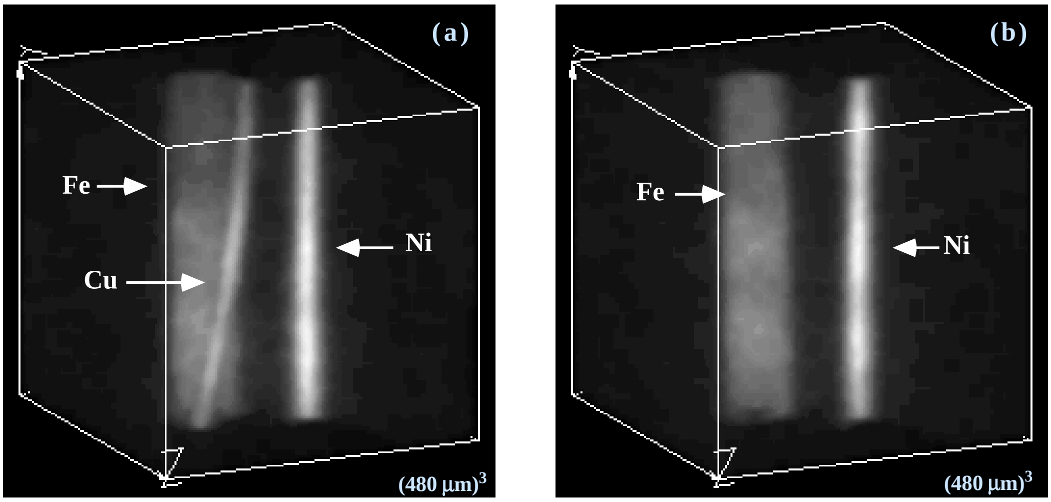

Fig. 2. 3-D reconstructed images of Cu, Ni and Fe wires at the excitation X-ray energy of ***(a)*** *9.00 keV and* ***(b)*** *8.43 keV. The (480 μm)^3 cubic volume is shown. The images were reconstructed from 50 X-ray images from different angles of view with the same interval of 7.2 degrees. The exposure time of each X-ray image was 60 s.*

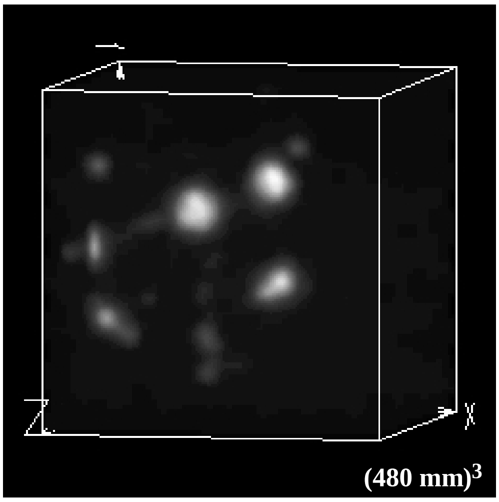

Fig. 3. 3-D reconstructed image of a synthetic diamond at an excitation X-ray energy of 8.34 keV. The images was reconstructed from 50 X-ray images from different angles of view with the same interval of 7.2 degrees. The exposure time of each X-ray image was 8 min.

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References

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[2] K. Yamamoto *et al.*, J. Synchrotron Rad. **7** (2000) 34.