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X-ray fluorescence holography using cooled avalanche photo diode

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Introduction

X-ray fluorescence holography (XFH) is a new experimental tool for determining a local three-dimensional atomic structure around a specified atom. Fast energy dispersive x-ray detector have been desired for recording x-ray fluorescence hologram because the fluorescent x rays from a sample can be detect with large solid angle acceptance. A cooled avalanche photo diode, which has 10 % energy resolution and fast counting system, is one of the detectors satisfied above conditions. In the present study, we collected the inverse XFH data of Ge single crystal using the cooled APD and evaluated a feasibility of our new system.

Experimental

A Ge single crystal (001), whose dimension was 10 x 10 x 0.5 mm^3, was used as the measured sample. The incident energy was 12.5 keV. The x rays emitted from the sample were checked by the Si PIN diode, and strong Ge fluorescence and scattered x rays are observed. Subsequently, these spectra are observed by the cooled APD. Fast voltage pulses from the APD were processed by a fast amplifier, discriminator and scaler. By scanning the discriminator threshold, pulse-height distribution was measured with the fast counting system. Figure 1 shows the energy spectra of x-ray fluorescence, obtained by the cooled APD. Peaks of the Ge Kα and scattered x rays are observed at 366 and 455 channels, respectively. The peak of Ge Kβ is hidden by the strong peaks of the Ge Kα and scattered x rays. These spectra include backgrounds which appear below the energy of the main peaks. As shown in Fig.2, the Ge Kα, Kβ and elastic scattering peaks and their backgrounds were fitted by Procter and Sherwood's fitting method which has been used for determinations of photoelectron peak intensities. From these fitting curves, we could determine the intensities of the Ge fluorescence and scattered x-rays. The intensities of Ge fluorescence was measured as a function of the azimuthal angle φ and polar angle θ within the range of 0° = φ = 360° and 20° = θ = 70°.

Results and Discussion

Figure 2 (a) and (b) show planes parallel to the {001} lattice planes taken at distance of z = 0 Å and 1.4 Å (≅ a/4), respectively. In Fig.4 (a), $\frac{1}{2}\ \frac{1}{2}$ 0 atom is visible, but a distance between this atom and emitter is smaller than the tabulated $\sqrt{a}$ = 4.00 Å. In Fig. 4 (b), $\frac{1}{4}\frac{1}{4}\frac{1}{4}$ is displayed at the position 2.0 Å apart from the center in agreement with the known value. In order to check the accuracy of the measurement, hologram of 185771-atom Ge cluster was calculated for 12.5 keV. The images reconstructed from the theoretical hologram are also in good agreement with that from the experimental hologram. In particular, the displacement of $\frac{1}{2}\ \frac{1}{2}$ 0 atom toward the center is observed similarly to the reconstruction of z =0 Å from theoretical hologram. The calculation shows that the shift of these atomic images mostly caused by the real-twin interference. Moreover, the far atoms such as 100 and $\frac{3}{4}\frac{1}{4}\frac{1}{4}$ atom are hardly seen in the theoretical reconstructions similarly to the experimental ones, suggesting that the disappearances of these atoms are not explained simply by a weakness of the holographic signals. It is considered that twin images affected this phenomenon. Note, however, problems of these displacement and disappearance are solved by recording the holograms at several incident energies.

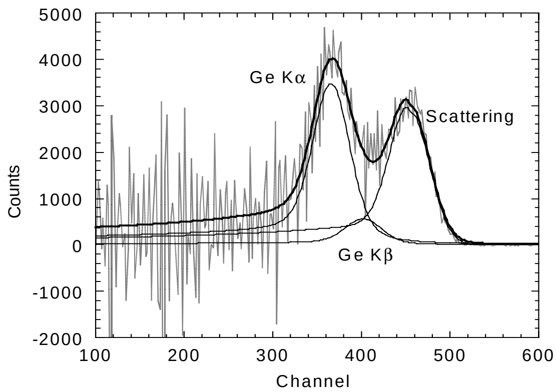

Fig.1 Energy spectra of Ge K fluorescent and scattered x rays measured with cooled APD.

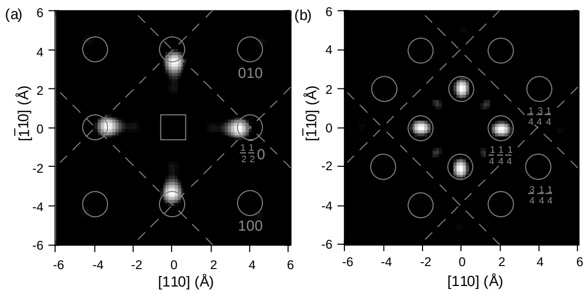

Fig.2 Holographic reconstructions. The planes parallel to the {001} lattice plane cutting through the fluorescence emitter atom and 1.4 Å above the emitter atom are displayed in (a) and (b), respectively.