Crystal Structure Analysis Beamline

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1. Introduction

Advantages produced by a third generation synchrotron source are not always realized by each experimental proposal straightforwardly. For example, when we observe x-ray diffuse scattering relating to a phase transition phenomenon, we need an optical system with intense radiation rather than a high resolution measurement system. Noda *et al.* pointed out that the measurement system with intense beam was especially required for a high-energy structural analysis[1]. Angular divergence of the beam from the bending-magnet source at SPring-8 will be 0.1mrad in the vertical direction. In our station, x-rays are focused by monochromators and mirrors and shaped by slits into 1mmx1mm at the sample position. If it is 70m apart from the take-off point of the beam, the net divergent angle is 14 μrad and is comparable with the width of (111) reflection of the perfect Si single-crystal, such as 13 μrad at the energy of 20 keV. This means that we have no choice to increase the mosaic spread of the monochromator to gain the beam intensity. One of the idea for obtaining intense radiation suitable for the ordinal diffraction experiments is to use the monochromator with 'gradient' d-spacing. It will supply a beam with an optimized energy width without a loss of the spatial divergence. The superlattice of Ge/Si system might be a good candidate for this purpose, because similar treatment for cooling process can be used. Our aim of the present research is to make a trial fabrication of the superlattice epitaxial film utilizing InGaAs instead of Ge/Si and to demonstrate the advantage of the new type gradient monochromator.

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2. Experimental and Discussions

Epitaxial films of $InxGa_{1-x}As$ with a gradient concentration were grown using molecular beam epitaxy method. The base pressure of the growth chamber was the order of 10^{-11} Torr. A GaAs (001) wafer was used as a substrate. The lattice parameter of the solid solution of GaAs (a=5.653 Å) and InAs (6.058 Å) are followed by the Vegard's law, that is,

$$a_{\mathrm{InxGa1\text{-}xAs}} = x \cdot a_{\mathrm{InAs}} + (1-x) \cdot a_{\mathrm{GaAs}}$$

where x is a content of InAs and a_n (n = InGaAs, GaAs and InAs) is a lattice constant of each material. The averaged d-spacing of the film was set to be slightly different from that of the substrate to avoid superposing of the reflection from the substrate. As the preliminary experiment, we chose intentionally wide-gradient d-spacing in the film to detect it by a laboratory X-ray diffraction system. Graded concentration of indium from 0.06 to 0.13 was achieved by heating the indium cell at a rate of 0.17 deg/min (and the cell temperature was controlled within 0.03 deg). Total thickness of the film fabricated was 2.8 μm. Figure 1 shows the x-ray diffraction (out-of-plane) profile of the film with a laboratory low-resolution setting using Cu-Kα radiation. The schematic illustration of the epitaxial film and the scattering geometry are shown in the inset. The most intense peak is the 004 reflection of GaAs used as a substrate. The broad peak on the lower angle side of the Bragg peak is coming from the fabricated film with d-spacing spread in the graded-concentration $In_xGa_{1-x}As$. Even this preliminary specimen, the integral intensity of the diffracted beam is enhanced. The line beneath the observed profile shows the calculated intensity based on the simple step model[2]. The observed profile is wider than the calculated one. The origin of the discrepancy between the observed and calculated results is owing to the Poisson's effect caused by the lattice mismatch between the film and the substrate. Namely, the designed averaged d-spacing of the film was too far from that of the substrate. The epitaxial film having the similar lattice parameter grows psuedomorphic, that is the films is suffered from the coherency strain. Kamigaki *et al.* showed the lattice parameter of the $In_xGa_{1-x}As$ film grown on the GaAs substrate as a function of the indium content[3]. For the film with thickness of 2000 Å, the film whose indium content x was less than 0.1 did not relax by misfit dislocations. Another discrepancy is that the intensity of the lower angle side of the profile is weak compared with the higher one. This indicates that the large lattice mismatch degrades the crystal quality.

We are planing to measure the efficiency of the sample using a collimated white radiation and to evaluate heat resistance of the superlattice. Final form of the gradient monochromator will be made of Ge/Si epitaxial film.

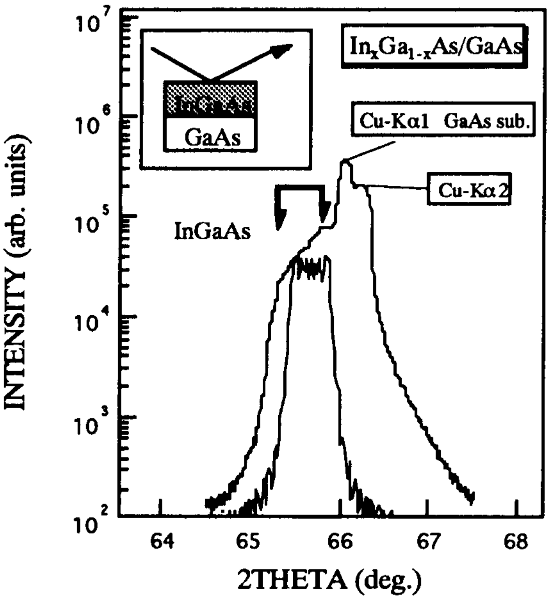

Fig.1 X-ray profile of the $In_xGa_{1-x}As$ gradient concentration film using Cu-Ka radiation. Two strong peaks are from the substrate. Observed and simulated profiles are shown , respectively. Experimental geometry is given in the inset.

References

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