15C/2000G200

Quantitative evaluation of Strain near reconstructed Si surface

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Introduction

It is believed that surface structure affects thin-film growth. Some experimental investigations were carried out to measure the strain field near reconstructed Si surfaces.

We developed a strain sensitive X-ray diffraction technique [1]. This technique makes strain observation possible by measuring the rocking curve of bulk reflection under grazing incidence condition. We observed the strain field near Si(111) 7×7, Si(111) √3×√3-Ag, and Si(111) √3×√3-Al surfaces using this technique [2]. We found that the experimental rocking curve of Si 113 reflection are different from each surface structure in the peak intensity and the peak width. With respect to the curve for the curve for 7×7 surface, the curve for √3-Ag surface has large peak intensity and sharp width. The curve for √3-Al surface has smaller peak intensity and wider width than that for the 7×7 surface. Comparing the experimental curves with the calculated curve for a distorted crystal model, it was concluded that, in qualitatively, the √3-Ag surface compresses the {113} spacing as compared with the 7×7 surface and the √3-Al surface extends the {113} spacing as compared with the 7×7 surface.

In this paper, we report the results of quantitative evaluation of the strain field for each surface.

Experimental

A series of undoped-Si(111) wafers gotten by the floating zone method was used as sample. The wafer size is 2-inch in diameter and 350 μm in thickness. The experiments were done at beam line 15C. The X-rays were extracted by using a monochromator, then impinged on a specimen in an ultra high vacuum (UHV) chamber whose base pressure was 6×10^{-10} Torr, through a collimator. The incident X-rays were monitored by using an ionization chamber. The UHV chamber was equipped with a reflection high energy electron diffraction (RHEED) system to observe the surface structure.

We observed the sharp 7×7 pattern for annealing surface at about 1000 °C. The √3-Al and √3-Ag surfaces were made by the annealing the substrate around 600-800 °C after Al or Ag deposition on to the 7×7 surface at room temperature. In both case, the √3×√3 patterns were observed. The rocking curves of Si 113 reflection for the 7×7, √3-Al, and √3-Ag surfaces were measured in-situ after the RHEED observations. In order to minimize contribution of a warp of the wafer due to annealing processes, an indirect annealing method was adopted and a slit of few mm width was set in front of the scintillation counter.

Results and Discussion

In the first, we evaluated the effect of surface structure to Si 113 rocking curve. The dynamical calculation method considering the surface structure was given by Takahashi et al [3]. We applied this method for the stress evaluation. Comparing the calculated curves with the experimental ones, we found it is difficult to explain the experimental results by the differences of the surface structures. So we consider a distorted layer between a surface region and a semi-infinity perfect crystal region.

In distorted layer, one-dimensional strain along the surface normal direction was assumed as follows; (1) a maximum strain value (ε_0) exists at an interface between the surface region and the distorted layer, (2) a strain amplitude decreases like a Gaussian curve and converged to a strain amplitude of 10^{-10} at the certain depth (H) from the interface. We carried out nonlinear least square fitting for experimental and calculated rocking curves. Instead of the decision of the minimum points, we decided the areas as shown in Fig. 1.

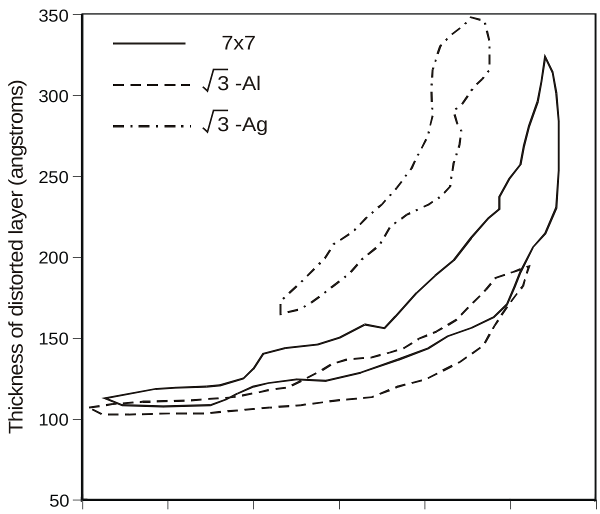

Fig.1 The ε_0 -H areas for each surface structure.

References

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