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Radial distribution measurement of high-k thin films by grazing incidence x-ray scattering

***Momoko Takemura (3152)[1], Masahiko Yoshiki (4423)[1], Nobutaka Sato (15207)[2] and Ichiro Hirosawa (2088)[3]**

[1]Corporate Research & Development Center, Toshiba Corporation
[2] Toshiba Nanoanalysis Corporation
[3]Japan Synchrotron Radiation Research Institute

Nitrogen incorporated Hf silicate (HfSiON) has been considered to be a promising alternative gate insulator for next-generation LSIs. Nitrogen incorporation prevents crystallization and phase separation of Hf silicate film when it is heated as part of the device manufacturing process. We investigated HfSiON structure by Hf L-EXAFS[1)]. However, in the EXAFS analysis, the structural information for the 2nd nearest neighbor and beyond lacks clarity.

The structure of such amorphous films as high-k films can be described by a radial distribution function derived from x-ray scattering profiles[2)]. We applied grazing incidence x-ray scattering (GIXS) to characterize HfSiON films of 5 ~ 10 nm thickness.

The Hf content (Hf/(Hf+Si)) was 80 at%. The N content was 10 or 20 at%. Films were deposited on Si (100) wafers by co-sputtering of Hf and Si targets.

A GIXS experiment has been performed with the incident x-ray of 15 keV, using a multi-axis diffractometer at BL46XU.

As Fig.1 shows, a profile of 2 θ scan for a 5 nm film coincides with that for a 10 nm film, that is, the GIXS method can be applied to films thinner than 10 nm. Fig.2 shows Fourier transform of the GIXS oscillation for HfSiON film of 10 nm thickness. At least, the 4th nearest neighbor has been observed.

Ref. 1) SPring-8 User Experiment Report No.12 (2003B), C03B16B2-4012-N.
2) Ibid. No.13 (2004A), 2004A0540-NI-np-TU.

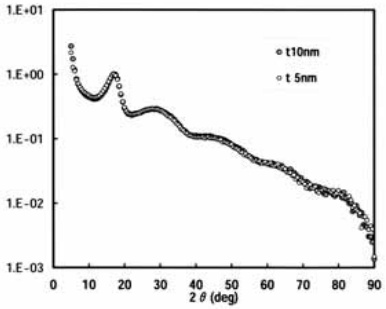

Fig.1 Comparison of 2 θ scan profiles for a HfSiON film of 10nm thickness and a film of 5nm thickness.

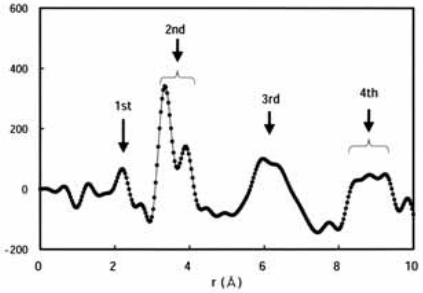

Fig.2 FT of the oscillation measured for a HfSiON film of 10nm thickness.

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Detection of local strain distribution in strained Si/SiGe/Si hetero structures using X-ray microdiffraction

Akira Sakai (15182)*, Osamu Nakatsuka (14728)[1], Noriyuki Taoka, Shogo Mochizuki (15208), Shigeru Kimura (4124)[2], Shingo Takeda (3538)[2], Masaki Ogawa[1], Shigeaki Zaima

Graduate School of Engineering, Nagoya University, [1]Ecotopia Science Insitute, Nagoya University, [2]JASRI

X-ray microdiffraction systems using a zone plate (ZP) with narrow slits are effective in characterizing strain field and its distribution locally existing in materials. In this study, we achieve the detection of local strain distribution in strain-relaxed SiGe epitaxial films on Si(001) substrates which have been recently attractive as buffer layers for high mobility strained Si channel electronic devices.

The measurements were performed at the BL46XU of the SPring-8. The area of the focused beam was 1.3×1.8 μm^2. Two types of samples were analyzed. The sample A was formed by the two-step strain relaxation procedure and consisted of a totally 125-nm-thick $Si_{0.7}Ge_{0.3}$ layer on a Si(001) substrate. Previous transmission electron microscopy revealed that the SiGe layer in the sample A is predominantly strain-relaxed with 60° misfit dislocations at the SiGe/Si(001) interface. The sample B had a 73-nm-thick SiGe layer on a Si(001) substrate which is mainly strain-relaxed with a pure-edge dislocation network.

Figures 1(a) and 1(b) show contour maps of 004-reflection intensity in a series of the X-ray rocking curves taken from the SiGe film in the samples A and B, respectively. A focused beam was scanned along the in-plane [110] direction. All rocking curves in the sample A had a wide width and the peak profile varied with the positions. This indicates the existence of the lattice tilt variation in the observed area and reflects the mosaicity in the SiGe film, which is possibly due to the non-uniformity of the strain induced by the 60° dislocations. On the other hand, peak profiles with a narrow width were observed in the sample B. Furthermore, the shape of the peak profiles is approximately independent of the positions. This result clearly demonstrates the introduction of the pure-edge dislocation network is effective in suppressing the mosaicity in micrometer-scale regions in the strain-relaxed SiGe film.

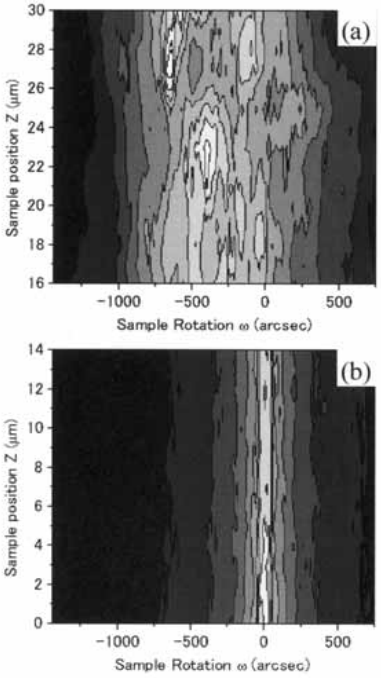

Fig. 1. Contour maps of 004-reflection intensity in a series of the X-ray rocking curves taken from SiGe films in the sample (a) A and (b) B.