TEM Observation of the Platelets in Hydrogen Implanted Silicon

水素イオン注入により発生したシリコン結晶内プレートレットのTEM観察

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Abstract : *A damaged layer formed by high dose hydrogen implantation into a silicon wafer has been observed with cross sectional Transmission Electron Microscopy (XTEM). Hydrogen ions were implanted into n-type (100) silicon at 80keV with a dose of 1.0×10^{17} atoms/cm^2. Four kinds of major defects, i.e., (1)～(4) observed as in the following, are investigated; (1) point-like defects existing broadly between surface and projection range (Rp), (2) (100)platelets existing around the Rp, (3) (111)platelets existing in the deeper region than the Rp, (4) dislocation-like loops in the region deeper than the damaged layer. In the sample with lower implantation dose, i.e., 8.0×10^{16} atoms/cm^2, the dislocation loop was not observed. After 300℃ annealing, cracks were observed at the Rp. After 475℃ annealing, the (111)platelets disappeared. In addition, the depth profile of hydrogen distribution was measured by Secondary Ion Mass Spectroscopy (SIMS). Si-H bond condition was investigated by Fourier Transform Infrared spectroscopy (FTIR). Comparing those results with the results obtained by XTEM, it is found that the point defects and platelets contain hydrogen atoms, and (111)platelets involve Si_2-H_6 bond.*

1. Introduction

Hydrogen in silicon play an important roll in technological applications, for example, passivation of the electrical properties of shallow acceptors, donors, and other point defects. In the field of Silicon On Insulator (SOI) material technology, micro slicing process of silicon by hydrogen implantation technique has been recognized remarkably.This new process referred as Smart-cut process seems to have advantages in respect of cost and crystal quality than other process [1,2].

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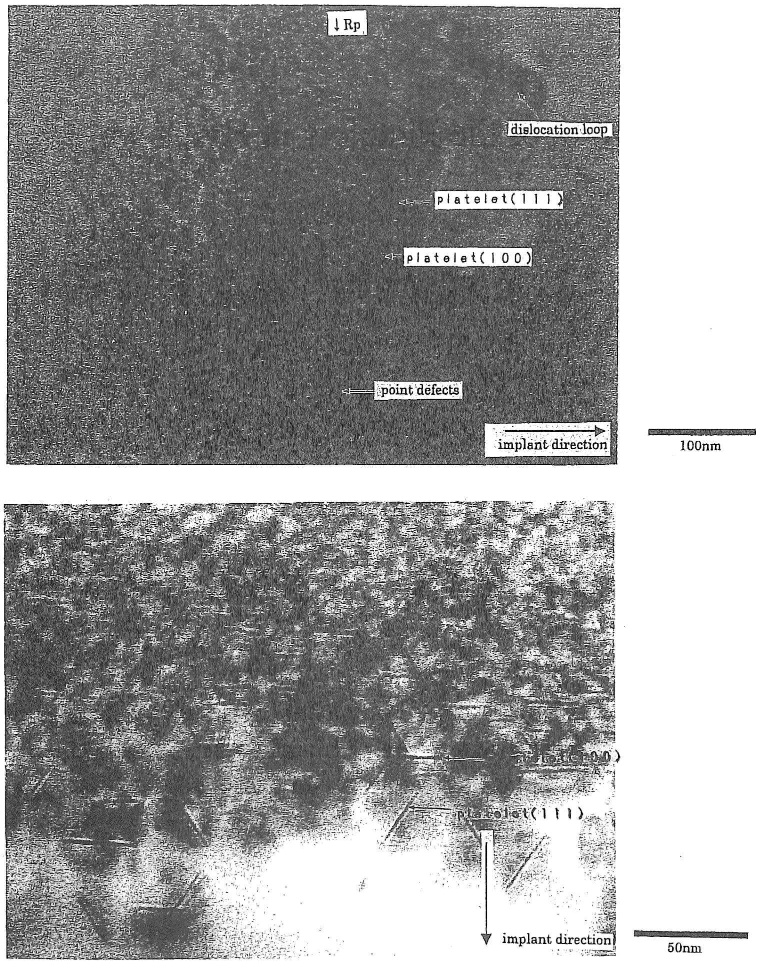

Fig.1 XTEM Bright Field image, damaged layer as 1.0×10^{17} dose implanted and defects.

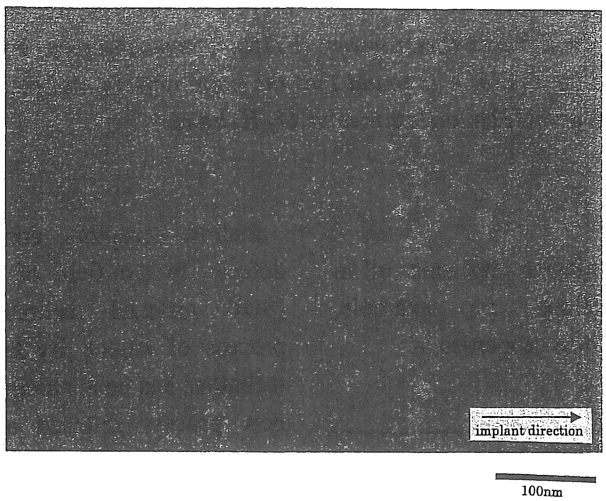

Fig.2 XTEM image, damaged layer as 8.0×10^{16}dose implanted.

The most interesting procedure in this process is as follows; after hydrogen implantation, hydrogen implantation causes many defects around the projection range (Rp). During thermal annealing, implanted hydrogen in silicon diffuses into the defects and the defects form cracks parallel to the surface, resulting in a very thin sliced silicon formation. However, the underlying mechanism is not well understood [3,4].

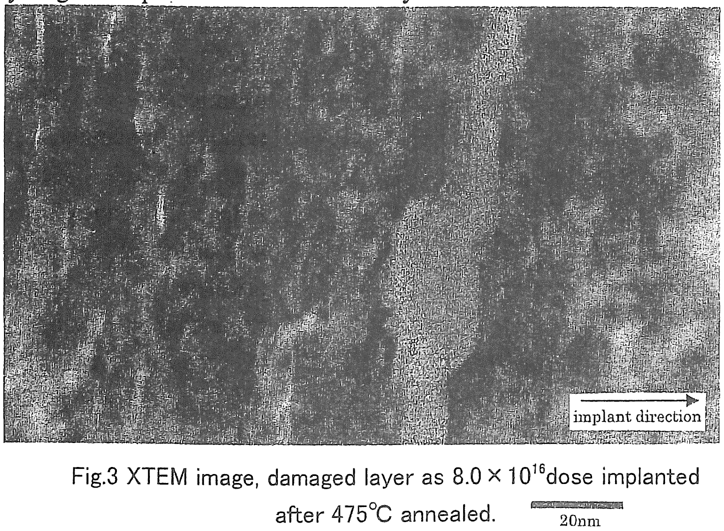

Fig.3 XTEM image, damaged layer as 8.0×10^{16}dose implanted after 475°C annealed.

In the present paper, implantation of hydrogen into silicon is made as a function of dose and temperature. The effects of hydrogen implantation on the defects have been studied using a combination of cross sectional Transmission Electron Microscopy (XTEM), Secondary Ion Mass Spectroscopy (SIMS) and Fourier Transform Infrared spectroscopy (FTIR). The changes of microstructure in the damaged layer at various annealing temperatures are also investigated.

2. Experiments

Implantation of hydrogen ions was made in (100) oriented silicon. The doses ranges from 1.0 $\times 10^{16}$ to 1.0×10^{17}Hcm^{-2}. Samples were cut into disks of 3mm in diameter and mechanically polished down. Then the disks were dimpled at the center and thinned down by argon ion milling.

The bright field images and also high resolution pictures of the damages and defects induced by hydrogen implantation were taken by XTEM. The depth profile of hydrogen in silicon was

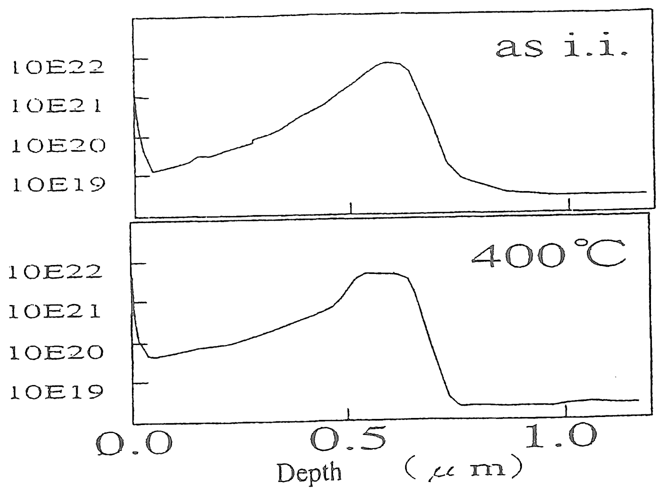

Fig.4 Hydrogen concentration obtained by SIMS.(as implanted and after 400°C annealed)

determined by SIMS. In order to examine the bonding condition between hydrogen and silicon, FTIR was utilized.

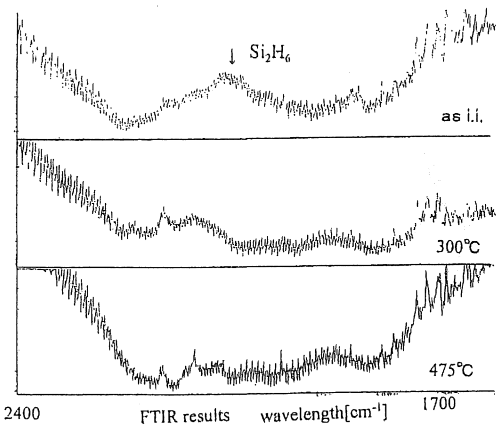

Fig.5 Si–H bonding condition obtained by FTIR
(as implanted, after 300℃ and 475℃)

3. Results and Discussion

Fig.1 shows the damaged layers examined by XTEM after $1.0x10^{17}Hcm^{-2}$ dose implantation. The depth of the layer was almost the same as the depth of theoretical Rp. Four kinds of defects (1)～(4) were observed (shown in Fig.1) around this layer. (1) (100) platelets existing parallel to the surface. (2) (111) platelets existing between the Rp and deeper region than the Rp. (3) small defects like a point defect existing in the shallow region of the layer. (4) large defects like a dislocation loop existing in the deeper region than the Rp. Fig.2 shows the damaged layers after $8.0x10^{16}Hcm^{-2}$ dose implantation. Comparing with Fig.1, the quantities of defects were obviously decreased. Especially, the large defects like a dislocation loop existing in the deeper region disappeared. Then, the samples annealed at 375℃ and 475℃ were examined. These samples implanted at a dose of $8.0x10^{16}$ Hcm^{-2}. After 375℃ annealing, it was observed that (100) platelets began expanding and changing to cracks. After the 475 ℃ annealing, the (111) platelets disappeared (shown in Fig.3).

The hydrogen concentrations were obtained from SIMS profiles (shown in Fig.4). The depth of highest concentration region was in agreement with the depth of damaged layer. It shows the defects contain hydrogen. Comparing with those implanted and annealed at 400℃, the maximum value of concentration was decreased after annealing. The thickness of high concentration region was increased. This shows hydrogen has a trend to move toward to surface. Incidentally, the FTIR results obtained with the samples of (a) as implanted, (b) after 300℃

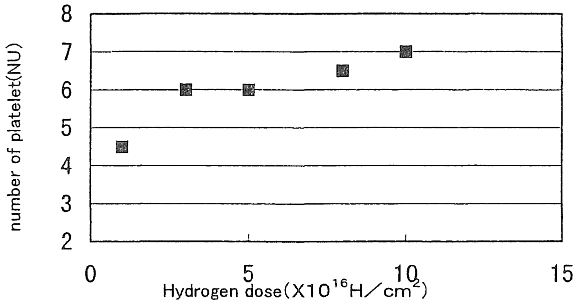

Fig.6 Platelet concentration and hydrogen dose.

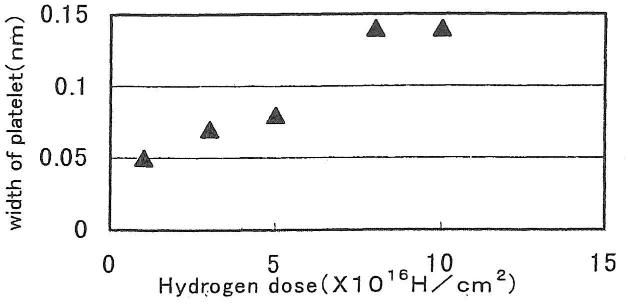

Fig.7 Platelet width and hydrogen dose.

annealed and (c) after 475℃ annealed, were shown in Fig.5. The value of peak at 2070 [cm^{-1}] in as-implanted samples decreased after 300℃ and 475℃ annealing. The peaks at 2070 [cm^{-1}] correspond to the existence of Si_2-H_6 bond. This temperature is same as the temperature of disappearance of the (111) platelets, so that it was confirmed that the (111) platelets involve Si_2-H_6 bonds. Comparing the damaged layers at various ranges of dose examined by XTEM, the number of platelet increased with dose, especially increased rapidly at the $3.0x10^{16}$ atoms/cm^2 dose or more as shown in Figure 6. The width of platelet at the damaged layer became wider with dose shown in Figure 7, but the length of platelet did not change significantly.

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