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Application of lattice strain analysis of semiconductor device by nano-beam diffraction using the 300 kV Cold-FE TEM

T. Sato*, H. Matsumoto*, M. Konno*, M. Fukui*, I. Nagaoki** and Y. Taniguchi**

* Hitachi High-Technologies Corp., 11-1 Ishikawa-cho, Hitachinaka, Ibaraki, 312-0057 Japan
** Hitachi High-Technologies Corp., 882 Ichige, Hitachinaka, Ibaraki, 312-8504 Japan

The evaluation of lattice strain is important to control the electrical characteristic of semiconductor devices. We investigated the lattice strain of the device by nano-beam diffraction (NBD [1-3]) using the HF-3300 Cold FE-TEM [4] with the acceleration voltage of 300 kV. As a result, the rate of the lattice strain in device increased with changing specimen thickness. The effective alteration of the lattice strain in device could be observed more than 300 nm specimen thickness by the NBD.

The degree of lattice strain is affected by the specimen thickness, in which thin specimen becomes weaker lattice strain. Therefore, in this study, we prepared the specimen thickness of 500 nm, 300 nm, 200 nm and 100 nm by the FIB system with the FIB micro-sampling mechanism [5]. Figure 1 shows the TEM image of P-MOS structure by the FIB. Figure 2 shows the magnified image of a rectangle region in Fig. 1. Dotted circles indicate the NBD measurement position. We measured the NBD pattern on the position of the five points from the gate, as indicated circles in Fig. 2.

Figure 3 shows the measurement conditions of the NBD. Figure 3(a) shows the TEM image of focused probe on Si(110) plane. Lattice image of the Si(111) can be clearly observed, as shown in Fig. 3(a). In this experiment, we used that the probe size with the NBD is the 10 nm with the intensity profile, as shown in Fig. 3(b). Figure 3(c) shows the NBD pattern on this probe condition. The distance between Si(022) diffraction spots, i.e., lattice strain of the horizontal direction against the gate was measured using the diffraction analysis function on the Hitachi EMIP software. The electron diffraction pattern of the reference was assumed the diffraction pattern of a place left from the gate by 1 μm.

Figure 4 shows the change in the strain rate by the difference of the specimen thickness in the P-MOS device. The strain rate decreases corresponding in the specimen thickness, as shown in Fig. 4(A). In the specimen thickness of 300 nm, the increase of the strain rate can be confirmed to the region at the 35 nm from the gate. This change of the strain rate is remarkable in the specimen thickness of 500 nm, as shown in the square dotted line in the Fig. 4(A). These results indicate the reflection of the stress strain in the bulky state. Figure 4(B) is showing of the strain rate of P-MOS and N-MOS devices in the 300 nm thick specimen, in which from the result of Fig. 4(B), an effective changing of the strain rate of N-MOS was not observed.

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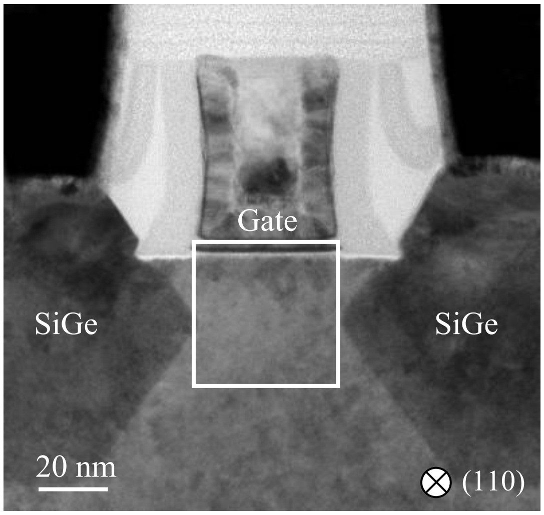

Fig. 1. TEM image of the prepared by FIB system.

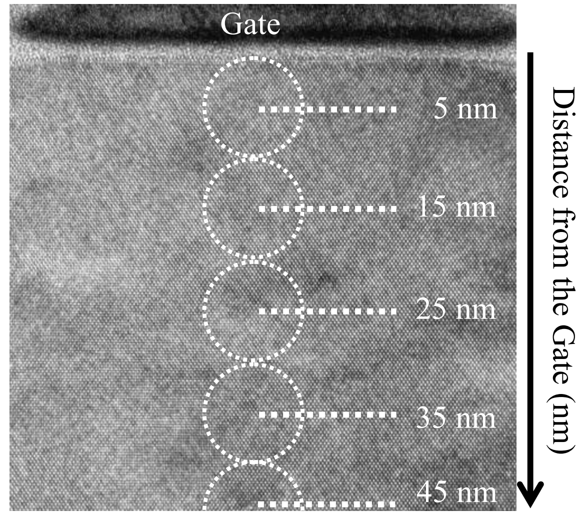

Fig. 2. TEM image indicated the measurement position of nano-beam diffraction.

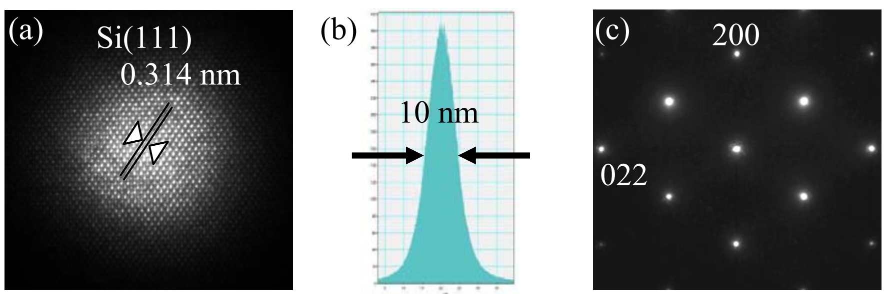

Fig. 3. Measurement condition of nano-beam diffraction. (a) TEM image of focused probe on Si(110) plane. (b) Intensity profile of the probe. (c) Nano-beam diffraction pattern on this condition.

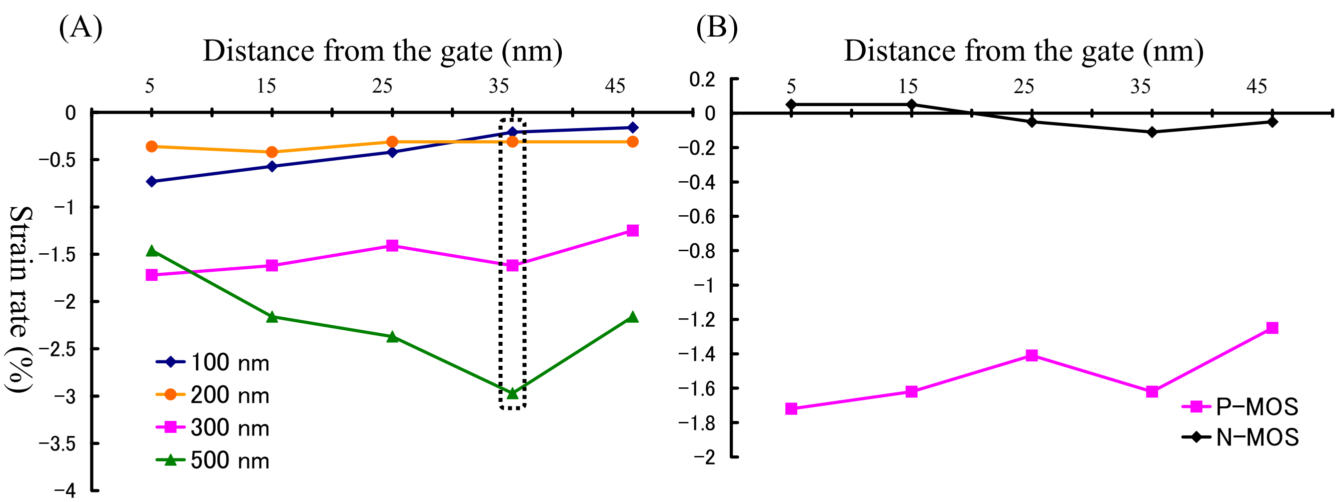

Fig. 4. (A) The strain rate of the different thick measured at several points. (B) The strain rate of P-MOS and N-MOS devices on the 300 nm specimen thickness.

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