Strain measurement of 50 nm-MOSFET by nanobeam electron diffraction using HOLZ reflection

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Measuring strain in nanoscaled materials is important for developing current electronic devices. In the case of MOSFET, the gate length has become less than 50 nm by a current manufacturing technology. Nanobeam electron diffraction (NBD) can be a powerful tool for measuring strains in such nanoscaled devices [1-2]. NBD uses a narrow and parallel electron beam illuminating a nanometer-size area of a sample and provides diffraction patterns with sharp spots. So far, most of NBD studies have used zero-order Laue zone (ZOLZ) reflections around the 000 spot. In this case, the precision of the lattice parameter determination is ~0.06% error because of the short diffraction vectors. Recently, our group developed a highly precise method for the determination of lattice parameter using high-order Laue zone (HOLZ) spots. This method allowed us to achieve a high precision of a 0.02% error [3]. In the present study, we applied this technique to real MOSFET specimens.

The specimen for the NBD experiment was prepared from a CPU chip by using a focused ion beam (FIB) instrument. The NBD experiment was conducted using a TEM operated at an acceleration voltage of 200kV. The probe size of NBD was about 10 nm in diameter. NBD patterns were taken at an incidence along the $[23\bar{1}]$ orientation and recorded by a 16 bit CCD camera with 2k×2k pixels. The distortion parameters of the image forming lens system such as optical axis, radial distortion, spiral distortion and elliptical distortion were calibrated by using NBD patterns taken from an unstrained Si area in the same MOSFET specimen. Lattice parameters were determined by fitting the spot positions between a simulated NBD pattern and experimental NBD pattern. The experimental spot positions were determined as the pixels positions of the maximum intensity in each of the spot.

Fig. 1(a) shows a cross-section TEM image of the MOSFET specimen. The NBD patterns were taken along the dotted line by scanning the probe with a pitch of 15nm. Fig. 2 shows an NBD pattern taken at an incidence in the [231] orientation from the position 150 nm away from the interface. We assumed the tetragonal symmetry for the strained lattice ($a = b \neq c, \alpha = \beta = \gamma = 90°$) in the channel region from the symmetry of the MOSFET structure. We use 10 ZOLZ reflections and 20 HOLZ reflections for the determination of the lattice parameters. Fig. 1(b) shows plots of the lattice parameters of a and c determined by the NBD method. As distance decreased the interface, the lattice parameters of a and b are shrunk, whereas the lattice parameter of c is extended. At 17 nm away from the interface, there are compress strains of 0.16% in the [100] orientation, and tensile strains of 0.24% in the [001] orientation. More than 77 nm from the interface, the lattice parameters is completely relaxed.

References

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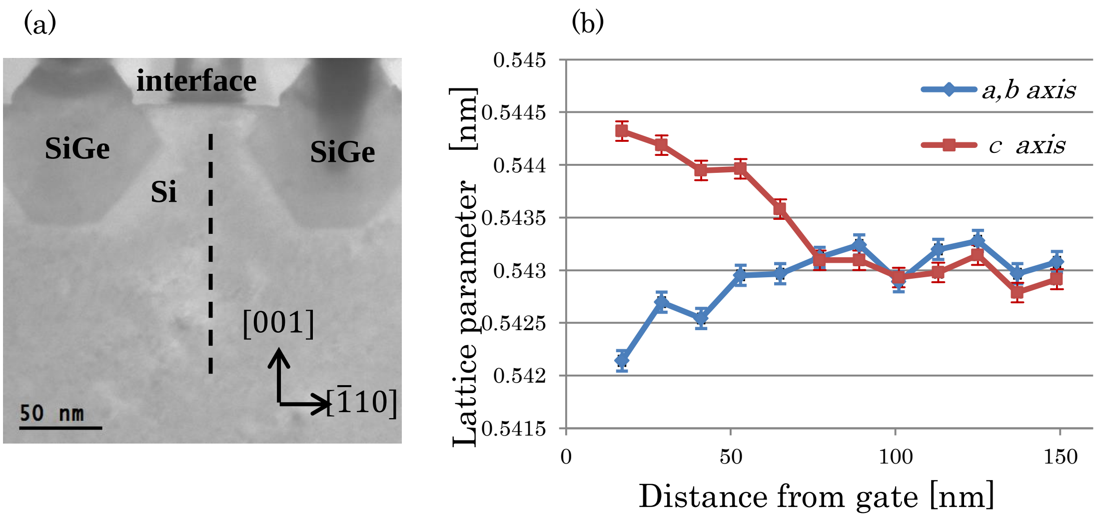

Fig. 1(a) A cross-section TEM image of MOSFET. (b)The plot of lattice parameters a, b and c along the black line in Fig. 1(a).

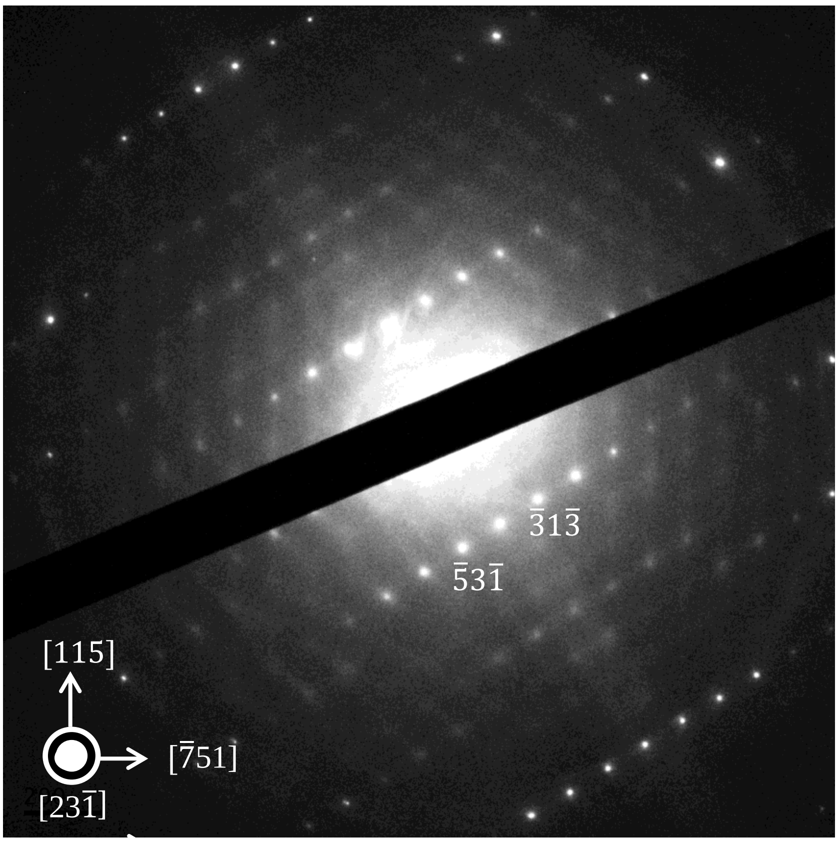

Fig. 2 [321̄]NBD pattern taken at position 150nm away from the interface.