Strain analysis of 3D structured semiconductor device by STEM moiré method

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Strain analysis of 3D structured devices is requested, since strain technology is an essential key for modern device technology. The strained device is utilized for the low power consumption and high switching speed. It is important to measure of the strain of the channel in a finFET, which is the most popular 3D structured device. However, it is hard to measure, since the channel is sandwiched with top and bottom gates. And the sample thickness must be < 100 nm to avoid strain release. In spite of these difficulties, we have recently succeeded in measuring a strain using moiré fringes in scanning transmission electron microscopy (STEM), so called STEM moiré method, which utilizes moiré fringes appear as a result of interference between lattice fringes and the raster of STEM [1-3]. In this paper, we report experimental setup and results for strain measurement of the finFET by the method.

The strain was measured with an aberration corrected microscope (JEM-ARM200F, JEOL) at 200 kV to have better contrast of the lattice fringes. The sample was fabricated by focused ion beam (FIB) to be as thin as 150 nm. The lamella was cut along the X direction (channel direction) so that we can observe the strained channel between Si/Ge stressors. The moiré fringe we used was formed by the Si (220) lattice fringe and STEM raster. The moiré method can extract only the target lattice (Si [220]) in the Si channel, since it works as a real space frequency filter.
Figure 1 shows a measured strain map of the sample of a finFET device and its line profile of strain. The moiré fringe was invisible under the W electrode, since heavy W grossly absorbs and/or scatters electrons. Therefore, we measured the strain from the area neighboring the W wire. The strain shown in the map is of the (220) lattice, which is ε_{xx}. The line profile was shown in the Figure is sampled from the indicated area by a yellow rectangle in the strain map. Finally, the compressive strain ε_{xx} of the channel between the Si/Ge stressors was successfully measured to be - 0.7 to 0.8%.

In summary, we could measure the strain of a Si channel by the STEM moiré method for the 3D device, finFET, even when the channel is sandwiched with top and bottom gates. This is because the STEM moiré fringes act as a real space spatial filter and can extract only the lattice of Si channel. This advantage of this method can generally be applied to measure the strain of the other types of 3D devices like gate-all-around FET and nanowire FET devices.

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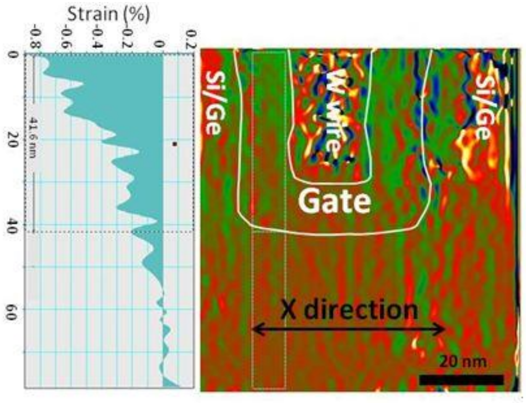

Figure 1. Strain map of a finFET device (right), and line profile of compressive strain ε_{xx} along a yellow rectangle area in the map (left).