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Strain Measurement in FinFET Structures with Epitaxially Grown SiGe on Source/Drain Region by Nano Beam Diffraction (NBD) Method

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As conventional methods for scaling down have reached its limit, an alternative route has recently gained much attention: device performance improvement via channel strain engineering. The integral part of channel strain engineering is incorporating a stress-inducing structure into the transistor structure. For p-channel transistors, a widely adopted approach is growing epitaxial $Si_{1-x}Ge_x$ layers in the source and drain (S/D) regions to introduce compressive strain in the Si channel [1]. At sub-22nm nodes, fundamental change to transistor structure is required: from the 2D planar transistor structures to the 3D structures such as tri-gate transistor or FinFET structures [2]. To apply the strain engineering to the FinFET structures, however, has limitations in increasing the channel strain to an extent large enough to significantly influence the hole mobility, and there is a lack of direct strain measurement method in such a nanoscale structures. Thus, we applied selective epitaxial growth (SEG) of SiGe layer around the S/D region, and the channel strain was measured by using nano beam diffraction (NBD) method [3,4].

9nm-thickness $Si_{1-X}Ge_X$ (x=0.2) layer was grown on source/drain region using SEG process by ultra-high vacuum chemical vapor deposition(UHV-CVD) at 550°C, Si_2H_6 and GeH_4 were used as a precursor for Si and Ge, respectively. Micro-structural analysis of SiGe layer and Ge concentration were measured by JEM-2100F field emission electron microscope at 200 kV and EDS analysis. TEM samples were made using FEI NOVA 600 FIB system for NBD analysis. NBD was done with a 5 nm diameter probe size and 0.1% strain sensitivity.

Figure 1 shows SEM images of FinFET structures used in this study with 50nm fin width and 200nm fin length. The pitch between the fin structures is 200nm and the gate length is 100nm. TEM sample was made by using FIB parallel to the fin direction as shown in inset of Fig. 2(a). Figure 2(a) is a TEM images of FinFET structure after SiGe deposition on S/D region. The enlarged TEM image and EDS profiles indicate that 20% SiGe epi-layer was successfully grown on Si fin structure. And Figure 2(b) shows the channel strain profile from selected points in Fig. 2(a). The profile of ε_{xx} at the channel center along the vertical direction shows compressive strain increases near the top of the channel. Also, after the SiGe layer deposition, there was a distinct increase in compressive strain. The profile of ε_{xx} along the channel direction exhibits similar trends.

In summary, we investigated the strain distribution in Si fin structure using SEG of SiGe structure and nano beam diffraction (NBD) method. Our results showed that the epitaxially grown SiGe on S/D region induced the compressive channel strain effectively and NBD method can measure the strain variation in FinFET structures.

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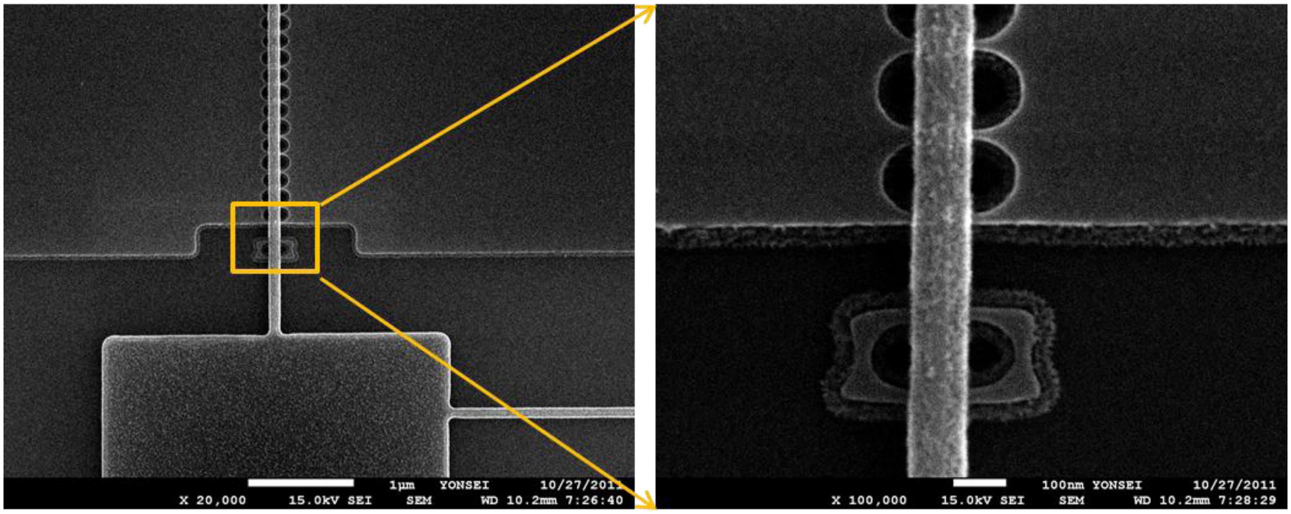

Figure 1. SEM image of FinFET structures with 50nm fin width and 200nm fin length.

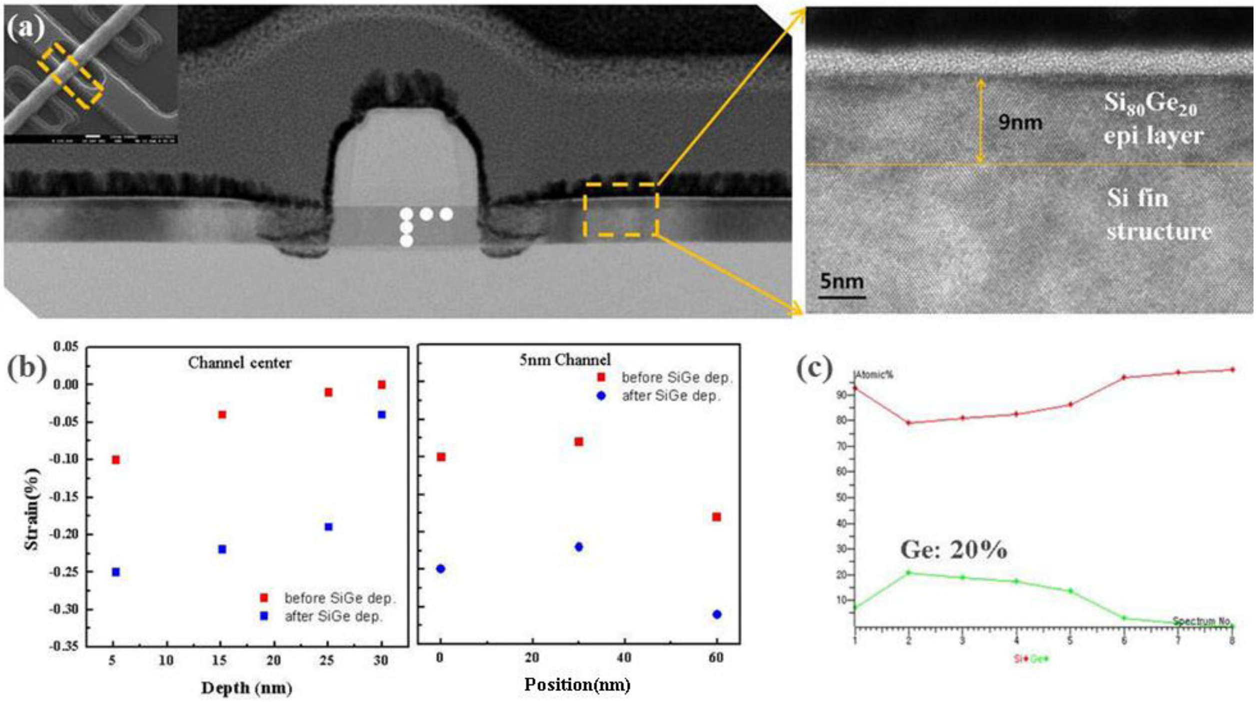

Figure 2 (a) TEM images of FinFET structure with $Si_{0.8}Ge_{0.2}$ layer on source/drain region and enlarged HRTEM image of selected region. (b) Strain profiles of the channel strain measured by NBD, and (c) STEM EDS data from SiGe epi layer.

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