Ge 選択成長における SiO_2 マスク上への横方向成長促進

Enhancement of Ge lateral overgrowth over SiO_2 mask

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[Introduction] Ge is a promising material for photo-detectors (PD) on Si because of its direct bandgap corresponding to 0.8eV (1.55μm) and its process compatibility with CMOS. The lattice constant mismatch between Ge and Si causes, however, threading dislocations (~10^9 cm^{-2}) which increase the reverse leakage current [1]. Thus the reduction of threading dislocations is an important goal of device research. It has been reported that Ge laterally overgrows on SiO_2 selective epitaxial growth (SEG) masks and the overgrown Ge shows a low density of threading dislocations (~10^6 cm^{-2}) [2, 3].

[Experimental] SiO_2 layers of ~20 nm thick were prepared by thermal oxidation of (100) Si wafers at 900 ˚C for 2 hours and were locally etched by a buffered-HF solution to expose Si for the SEG windows. The width of the SEG windows (W_{Ge}) and the SiO_2 layers (W_{SiO2}) between the windows were 0.5 ~ 2.0 μm and 0.1 ~ 2.0 μm wide. Ge was grown on the patterned wafer by 2 step growth using Ultra High Vacuum CVD with GeH_4/Ar gas: a buffer layer was grown at 370 ˚C and then a high quality (main) Ge layer at 600 ˚C. Temperature effect was observed with 150 nm thick SEG SiO_2 mask by changing main Ge layer growth temperature for 500 and 600˚C.

[Results & Discussions] Figure 1 shows cross-section of grown Ge. The actual width of Ge is 0.128 μm wider than W_{Ge} (2.0μm). Thus, the Ge layer laterally overgrown on SiO_2 mask is 0.064μm wide. The width of overgrown Ge and the height of Ge peak on Si (referred to as Ge thickness) are plotted in Fig. 2. When $W_{Ge} \geq 0.7$ μm, it is clear that:

i) the overgrown Ge is wider as W_{Ge} is narrower,

ii) Ge on Si is thinner as W_{Ge} is narrower.

These results can be explained considering the difference of growth rates on (311) facets and (100) plane. At first, (311) facets are separated by (100) top plane, and finally (311) facets come together leaving no (100) plane. Ge growth rate of the (311) facet is slower than that of (100) plane, and the (100) plane disappears faster as W_{Ge} get narrower. It is concluded that narrow W_{Ge} enhance the overgrowth of Ge. Half of Ge atoms migrate on (311) facets are trapped by (100) plane before (100) plane disappears and does not contribute to Ge growth on SiO_2 mask. All Ge atoms migrate on (311) facets settle down to the bottom of (311) facets after the (100) plane disappearance, and enhance the lateral overgrowth. In narrower W_{Ge} region of 0.5 and 0.6 μm, the (311) facets are not formed and migration on the facets is not expected, then overgrowth width is narrower. SEM image of main Ge layer grown at 500˚C (Fig. 3, W_{Ge}=0.6μm) indicates that low temperature growth help (311) facet formation: suitable for lateral overgrowth.

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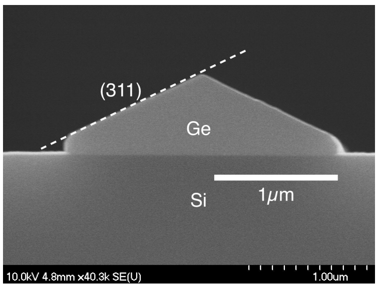

Fig.1. Cross-section image of Ge

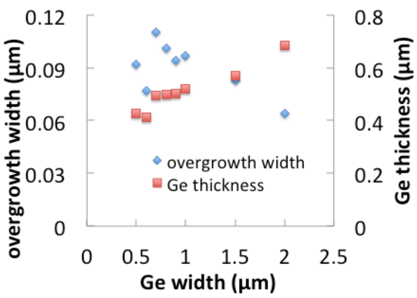

Fig. 2. W_{Ge} vs. overgrowth width and thickness

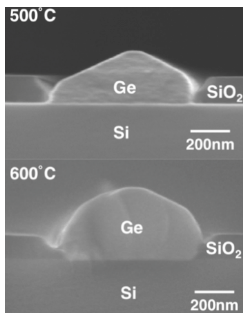

Fig.3 Temperature effect on SEG Ge shape

[References]

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