Atomic Scale Characterization of Crystal Defect in Epitaxial Silicon by Aberration-corrected STEM and Low Energy FIB Sample Preparation

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Aberration-corrected Scanning transmission electron microscopy (STEM) has proven to be a powerful technique to study structural and compositional information of materials at the atomic scale resolution [1-2]. In order to obtain atomic-level imaging, high quality specimens are required. Recently, low energy Focused ion beam (FIB) technique has been developed, and it can reduce the Ga ion beam damage that is a non-negligible influence on image quality[3]. FIG.1 shows the Si<110> HAADF image obtained by aberration-corrected Titan cube operating at 300kV. The sample was made by low energy FIB technique. The silicon dumbbell structures can be seen, and Fourier transform confirms less than 0.1nm information transfer. Currently, the sample preparation in this method is then also possible to obtain atomic-level images.

In this study, we looked at the surface crystal defect in epitaxial silicon layer that is serious problems in the semiconductor devices. FIG.2 shows the SEM image of surface crystal defect. This defect has a groove-like shape. We call this defect, “groove-like defect”. FIG.3 shows the cross-sectional HAADF image in FIG.1. The groove-like defect can be seen in epitaxial silicon layer. The thickness of the epitaxial silicon layer is 800nm. The HAADF images of the silicon wafer / epitaxial silicon layer interface are shown in FIG.4. The silicon dumbbell structures can be seen in wide area. The bright contrasts were identified as Ni silicide from the EDS analysis result. It is considered that the formation of Ni silicide caused by the Ni contaminations. The twin defect was also observed. This defect is generated from Ni silicide, and ends at the groove-like defect. It became apparent that the occurrence of groove-like defect was found to be growth of the twin defect that was generated from Ni silicide in epitaxial silicon process.

The site-specific sample preparation using low energy FIB technique and observation using aberration-corrected STEM could be possible to obtain HAADF images with the atomic-level resolution. We could understand the formation mechanism of the surface crystal defect in epitaxial silicon layer.

References

[1] S. J. Pennycook et al, J. Electron Microsc. 60 (2011) S213.
[2] O. L. Krivanek et al., Nature Letters 464 (2011) 571.
[3] M. Schaffer et al., Microsc. Microanal. 17 (2011) 630.

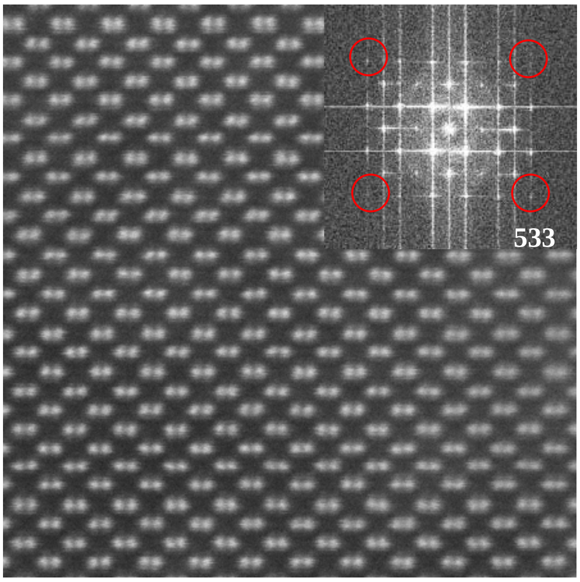

FIG.1 HAADF image of Si <110> obtained by Titan cube operating at 300 kV. ADF detector spanning 38.4–191.8 mrad.The sample has been made by FIB at low accelerating voltage 2kV. Fourier transform showing the presence of the (533) spacing at 0.083nm, confirming the less than 0.1nm information transfer.

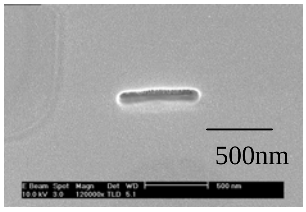

FIG.2 SEM image of surface crystal defect.

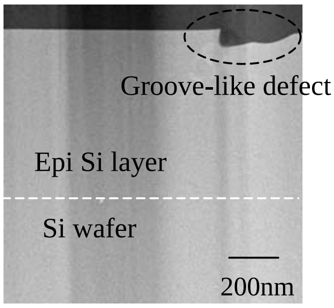

FIG.3 Cross-sectinal image of groove-like defect.

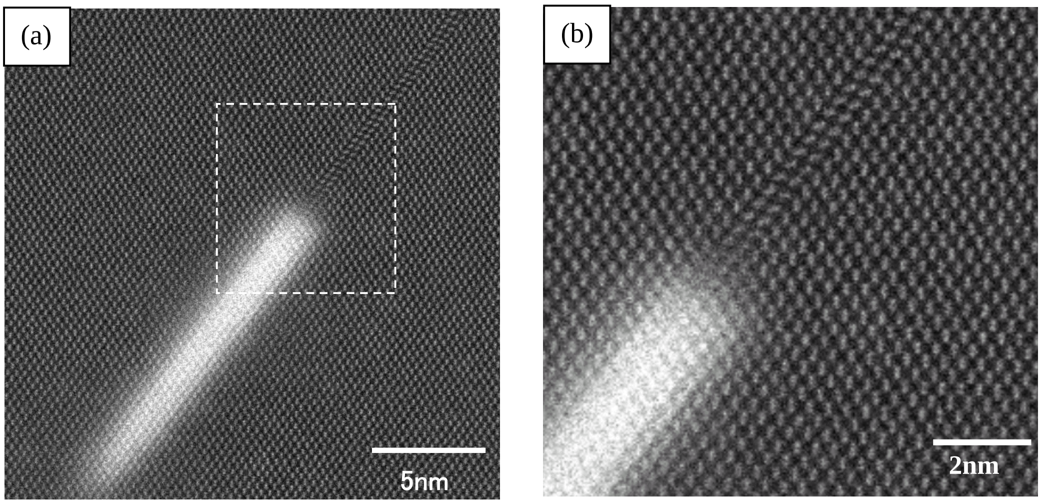

FIG.4 (a): HAADF image of the silicon wafer / epitaxial silicon layer interface. The bright contrasts are Ni silicide. The twin defect was also observed. (b): Enlarged image of dotted line area in (a). The twin defect has been generated from Ni silicide.