Morphology Changes of Ni Ion Irradiated Si(111) Surface at Room Temperature

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Introduction Nickel mono-silicide (NiSi) is a promising candidate for the metal source/drain(S/D) material of the future Si-CMOS devices owing to its low parasitic resistance and low formation temperature. It has been reported that the Ni silicidation reaction preferentially occurs in the Si lattice damaged by ion irradiation[1], suggesting that the growth process of the silicide region can be controlled by the defects introduced by the ion irradiation. This study demonstrates a atom-scale observation of Ni^+ ion irradiated Si(111) surface by scanning tunneling microscopy(STM) to investigate the atom-scale mechanism of the interaction between Ni atoms and lattice defects.

Experimental Method The employed UHV-STM system is equipped with a liquid metal ion source ion gun (LMIS-IG)[2]. A sample cut from an n-type Si(111) wafer was cleaned chemically and installed in the UHV chamber. The sample was degassed at 600 ºC for 12 h and flashed repeatedly at 1200 ºC by resistive heating until the whole surface was covered with the 7×7 structure. Then the surface was irradiated with Ni^+ ion beam of 5.0keV with a dose of $3\times10^{15}cm^{-2}$, followed by quenching to room temperature. Finally, we performed in-situ STM observation. Scanning speed of STM is 40sec/image. The tip bias and tunneling current are 6.5V and 0.3nA, respectively.

Results and Discussion Figure 1 (a) show the STM image of Si(111) surfaces just after the Ni^+ ion irradiation, and Fig.1(b) shows the same surface observed 18 hours later. Vacancy islands are created on the surface, and entire surface is covered by a new periodic structure. Fig. 1 (c) is a magnified STM image of Fig.1(b), showing that the surface is covered with √19×√19 periodic structure. The structure corresponds to the Ni/Si(111)-√19×√19 reconstruction[3], suggesting the surface precipitation of implanted Ni atoms. Fig. 2 shows a schematic of the formation process of the Ni/Si(111)-√19×√19 in the present experiment. First, the vacancy islands in Fig. 1 (b) is formed by the vacancy precipitation at the surface. Next, the Ni atoms precipitate at the surface to form the Ni/Si(111)-√19×√19 structure. Thus the surface reconstruction including Ni atoms slowly proceeds at room temperature. The result suggest that the characteristic of the NiSi/Si contact is unstable, which may induce a new reliability issue of the metal S/D devices.

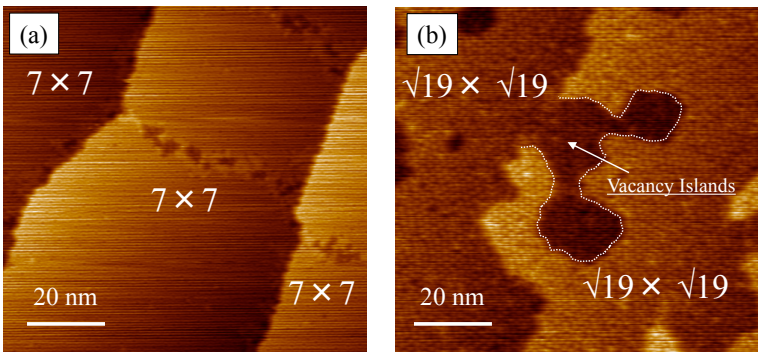

Figure 1 STM images of Si(111) surface (a) just after Ni^+ ion irradiation (b) 18hrs after the irradiation (c)magnified STM image of Ni/Si(111)-√19×√19 surface and atmistic model.

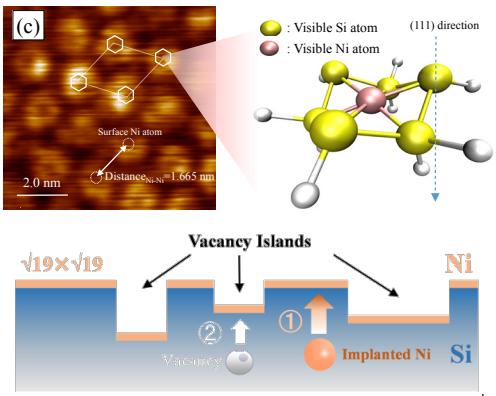

Figure 2 Formation of Ni/Si(111)-√19×√19 surface with large vacancy islands.

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Reference [1] M. Uchigasaki, et al., Rev. Sci. Instrum., **76** (2005). [2] T. Kamioka, et al., Rev. Sci. Instrum., **76.12** (2005). [3] R. J. Wilson, et al., Phys. Rev. Lett. **58**, 2575 (1987).