VI-F Synchrotron Radiation Stimulated Surface Reaction and Application to Nanoscience

Study of synchrotron radiation (SR) stimulated surface reaction is a promising topic both in fundamental and applied science. Dynamical process induced by the photostimulated coreelectron excitations on surfaces is attracting considerable attention in the surface science field. Semiconductor nano-structure fabrication by SR stimulated etching and thin film growth is considered to find an important application in the future devices such as molecular devices and molecular bioelectronics

VI-F-1 SR-Stimulated Etching and OMVPE Growth for Semiconductor Nanostructure Fabrication

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Synchrotron radiation- (SR-) stimulated etching and selective area growth by organometallic vapor phase epitaxy were performed to form ordered array of InP crystals on SiO_2-patterned InP (001) substrate. The SR-stimulated etching was used to pattern the SiO_2 film, because photochemical reaction using SR was expected to provide smooth surfaces, vertical side walls and fine patterning. In the first place, we investigated basic properties of the SR-stimulated etching by using mm-size pattern of SiO_2 mask. The etched depth was observed to increase linearly with the irradiation dose. It was found that the etching depth was controlled very accurately. Next, we used µm-size patterns of SiO_2 masks for fabricating the ordered array of InP crystals. In a atomic force microscope image of the sample after the etching, a steep side wall was observed. However, the etched surface was not smooth, against our expectation. Moreover, some dusts were observed on the surface. By these dusts, it was found that the SR-stimulated etching had a resolution of ≤ 100 nm at most.

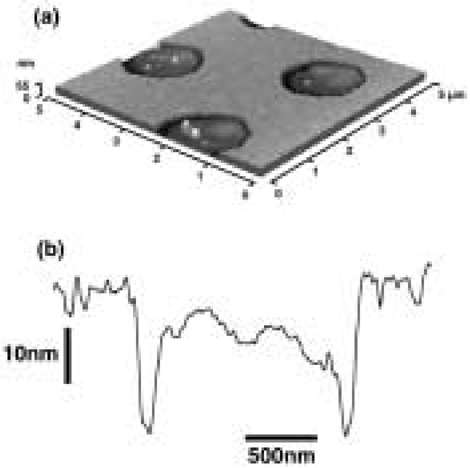

Figure 1. AFM observation of SiO_2 mask prepared by SR-stimulated etching. In (a) it is shown as a bird view image, and in (b) line profile near circular opening. Steep side wall is observed. However, surface is not smooth, against our expectation.

VI-F-2 Aligned Island Formation Using Step-Band Networks on Si(111)

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[*J. Appl. Phys.* **86**, 3083 (1999)]

We have achieved control of island formation using a patterned Si(111) surface with a periodic array of atomic-step bands and holes. Liquid metals, Au-Si or Ga, migrate on the patterned surface by annealing and form an island at a particular position in each pattern unit. The islands show highly uniform positions and narrow size distributions. To obtain such good uniformity, the diffusion length of surface atoms should be comparable with the pattern period. High mobility on step bands is also necessary factor. Periodic arrays of Au islands are used as seeds for selective growth using a vapor-liquid-solid reaction (VLS). Figure 1 shows VLS Si pillars grown on a Au-island arranged substrate using disilane gas. All Si pillars grow at the positions where Au islands were located.

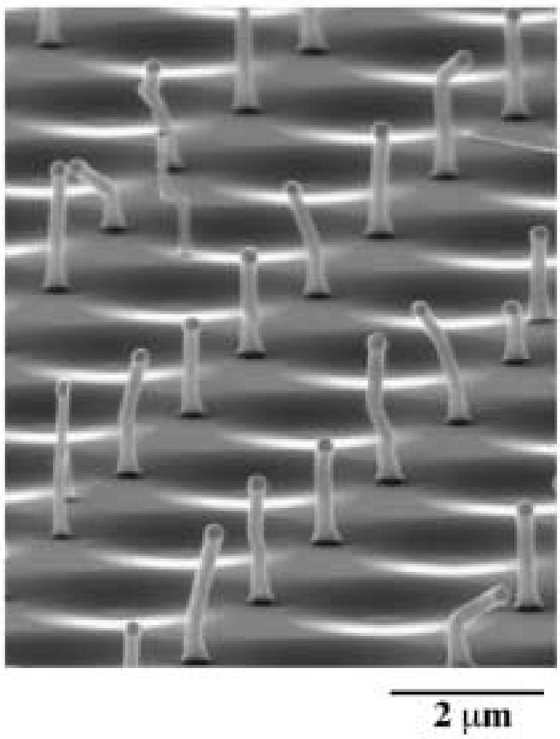

Figure 1. SEM image of Si pillars grown on Au-island arranged Si(111) substrates. The substrate was exposed to disilane gas of 1×10^{-2} Torr for 5 min at 620 °C. The angle of the electron beam incidence was 75°.

VI-F-3 Scanning Tunneling Microscopy Study of Surface Morphology of Si(111) after Synchrotron Radiation Stimulated Desorption of SiO_2

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[*J. Vac. Sci. Technol., A* **18**, 1153 (2000)]

The surface morphology of Si(111) was investigated using scanning tunneling microscopy after desorption of surface SiO_2 by synchrotron radiation (SR) illumination. The surface shows large regions of atomically flat Si(111)-7×7 structure, and is characterized by the formation of single bilayer steps nicely registered to the crystal structure. This is in sharp contrast to Si(111) surfaces after thermal desorption of SiO_2 at temperatures 880 °C and above, where the surface steps are much more irregular. X-ray photoemission spectroscopy is also applied to investigate the process of the synchrotron radiation stimulated desorption.

VI-F-4 Assignments of Bending and Stretching Vibrational Spectra and Mechanisms of Thermal Decomposition of SiH_2 on Si(100) Surfaces

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[*Chem. Phys. Lett.* **326**, 163 (2000)]

Vibrations of hydrogen-chemisorbed Si(100) surfaces with 3×1 and 1×1 structures were studied by buried metal layer-infrared reflection absorption spectroscopy. The SiH_2 bend scissors mode was found to split into two distinct peaks at 902 and 913 cm^{-1}; they were assigned to isolated dihydride (ID) and adjacent dihydride (AD), respectively. The observed differences in the dependence on annealing temperature showed that the small peak near 2090 cm^{-1} and the 2107 cm^{-1} peak were assignable to the symmetric stretching mode of ID and less stable AD, respectively. These observations have enabled discussion on the mechanisms of the thermal decomposition of dihydride species. It has been found that AD is slightly less stable than ID and that both AD and ID produce coupled monohydride by thermal decomposition.

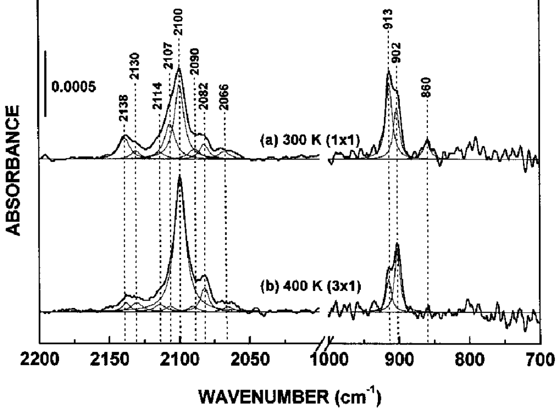

Figure 1. p-Polarized BML-IRRAS spectra associated with H/Si(100) surfaces with (a) 1×1 (b) 3×1. Narrow lines show peak-resolved spectra calculated assuming that the shape of each peak is Lorentzian.

VI-F-5 Control of Surface Composition on Ge/Si(001) by Atomic Hydrogen Irradiation

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The surface composition of Ge/Si(001)2×1 surfaces after atomic hydrogen (H) irradiation was investigated using IR reflection spectroscopy in ultrahigh-vacuum. It was confirmed that an extremely high dose of H at room temperature causes an etching reaction of the surface Ge layer. However, when H is irradiated at a temperature higher than 150 °C, the etching reaction dose not occur; instead, Ge segregated at the surface is observed to move into a subsurface and Si tends to exist on the topmost surface as a hydride in mixed Ge–Si and pure Si–Si dimers. This is in remarkable contrast to the Ge/Si(001) surface in the absence of hydrogen, where Ge is segregated at the surface and forms Ge–Ge pure dimers. The phenomenon of ‘reverse segregation’ by H irradiation may be understood by the thermochemical consideration that Si–H bonds are much more stable than Ge–H bonds. The result of first-principles total energy calculations in which the presence of hydrogen changes the stable composition at the surface from Ge to Si is also consistent with the phenomenon.

VI-F-6 Reconstruction of BL4A Beam Line and Infrared Reflection Absorption Spectroscopy System

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Re-arrangement of the beam line at BL4A has already started this year. Now it is still under construction. The IRRAS (Infrared Reflection Absorption Spectroscopy) system has been moved from BL4B to BL4A2. The reaction gas lines have been reconstructed connecting with new interlock system. The reaction chamber for IRRAS measurement was also reconstructed. The new system only use one chamber instead of formal two for the sample transfer to the measurement chamber to make the transfer more easy and efficient. The interlock system connecting these chambers and turbo molecular pumps also has been changed to the more simple and practical one.

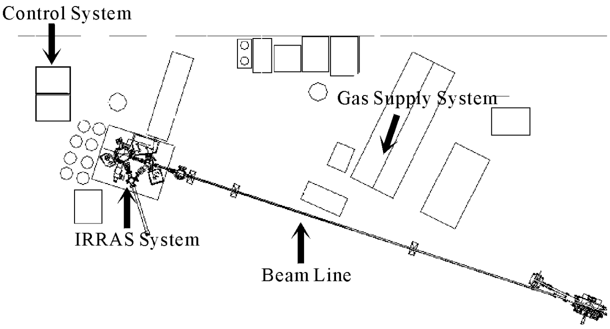

Figure 1. Schematic drawing of the BL4A2 beam line with the IRRAS system.