Study of Step Dynamics on Si(001) Surface

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On vicinal Si(001) surfaces, two types of monatomic step (S_A- and S_B-steps) coexist. These steps differ in formation energy, and shift inequivalently during annealing and growth. Many studies by several different techniques have been reported, but there have been still problems: (1) What is a unit of the step shifting / creating / annihilating? ; (2) How much is the accurate formation energies of each step? ; (3) How much is the step-step interaction energies between two steps? All the problems are concerning structural changes in atomic scale at high temperatures. To make clear the above problems, STM observations were done systematically at various temperatures up to 600°C.

The steps was found to thermally fluctuate and the movement was quantumized in (2x2) units. This means that the dimer is a stable structure, and the unit to create and annihilate during the fluctuation both on the upper and the lower terraces. This fact is also important when the growth or the step shifting is discussed.

The fluctuation has been found to be different between two types of steps. The S_B- step fluctuated higher in frequency and in amplitude than S_A- step. As the substrate temperature increased, the fluctuation became more frequently. From the fluctuation probability, the step formation energies were determined to be about 40 meV for S_A- step and 20 meV for S_B- step, respectively. These values are lower than those reported by Swartzentruber et al. Since they observed the surface quenched to room temperature, it was difficult to decide the temperature when the step structure was fixed. On the contrary, we can identify it accurately. Their lower energies were thought to be caused of the error from estimated temperature.

We have also observed the surface tilted 3 degree from (001) to [110]. We will extend the discussion to the step-step interactions on the basis of the results.