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Advacancy-mediated atomic steps kinetics and two-dimensional negative island nucleation on ultra-flat Si(111) surface

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Abstract

We have investigated Si(111) surface morphology transformations during high-temperature sublimation and oxygen treatments by means of *in situ* ultrahigh vacuum reflection electron microscopy. By analyzing atomic steps kinetics and two-dimensional negative (vacancy) islands nucleation on ultra-flat Si(111) surface with extremely wide (up to 120 μm in size) terraces we have estimated the activation energy associated with the surface-bulk vacancy exchange processes. We show that atomic steps motion and negative islands nucleation kinetics at temperatures above 1180 °C can be described by the step-flow model of Burton, Cabrera and Frank taking into account advacancies formation. By comparing experimental results with predictions of model we conclude that the surface mass transport at temperatures above 1180°C is governed by surface vacancies nucleation and interaction with atomic steps rather than via adatoms surface diffusion.

Keywords: A1.Surface processes, A1. Mass transfer, A1.Diffusion, B2. Semiconducting silicon

1. Introduction

Surface morphology evolution is an important topic of the investigations in crystal growth and molecular beam epitaxy because of its fundamental significance and technological applications. Atomic mechanisms of mass transport involving two-dimensional island nucleation and atomic steps motion determine the morphology of the surfaces. Hence, understanding the atomic mechanisms and processes governing the formation of crystal surface morphologies is of crucial for low-dimensional systems and nanoscale objects formation during epitaxy, gas reactions and sublimation.

According to the classical theory developed in 1951 by Burton, Cabrera and Frank (BCF) [1], evolution of the stepped surface during crystal growth can be described in terms of adsorbed atoms (adatoms) formation, diffusion and interaction with surface sinks. Later Pimpinelli and Villain [2] extended the original BCF theory to the case of evaporation considering vacancy and adatom diffusion at crystal surface in near equilibrium conditions. The key predictions of BCF theory have been successfully approved by large variety of experimental studies performed at relatively low temperatures (below 1000°C) with the help of scanning tunneling microscopy (STM) [3, 4], low energy electron microscopy (LEEM) [5, 6], scanning electron microscopy (SEM) [7], reflection electron microscopy (REM) [8]. However, there is lack of experimental data on the characterization of the atomic processes and diffusion

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