PHOTOEMISSION STUDY OF THE Si, Ge EPITAXIAL GROWTH PROCESS USING SURFACTANTS

XIAOYU YANG, RENYU CAO, JEFF TERRY, AND PIERO PIANETTA
Stanford Synchrotron Radiation Laboratory, Stanford University, Stanford, CA94309

ABSTRACT

Heteroepitaxial growth of Ge on Si(100) and Si on Ge(100) surfaces with Sb as a surfactant has been investigated by in situ high resolution photoemission and low energy electron diffraction (LEED). Our results show that an ordered monolayer of Sb atoms saturate the surface dangling bonds and consequently lower the surface free energy. Deposition of Ge or Si on the Sb/Si(100) or Sb/Ge(100) surfaces either at room temperature, followed by mild annealing or deposition at elevated temperature, result in an epitaxial layer of Ge or Si on the substrate, respectively. We provide clear experimental evidence that the deposited Ge or Si atoms changes position with the surface Sb atoms in this process. Ge or Si atoms occupy the epitaxial sites previously occupied by the Sb atoms. The Sb atoms in turn segregate to the surface and form a new ordered layer. The Bi-assisted growth process is also discussed.

I. Introduction

High quality heteroepitaxial growth of Ge on Si substrate as well as Si on Ge substrate is of great interest in fundamental semiconductor physics and of importance in future device applications [1, 2]. It is however difficult to achieve epitaxial growth because of the large lattice mismatch. It has been shown that growth mode of Ge on a Si substrate is of the Stranski-Krastanov type (i.e. a few uniform layer followed by island formation) due to large lattice mismatch (4%), and that the growth of Si on Ge(100) begins with islanding. Recently, Copel et al. have grown Ge on Si(100) and Si on Ge/Si(100) with As as a surfactant [3,4]. The As atoms change the growth mode to layer-by-layer by altering the surface free energy. Higuchi et al demonstrated that Te also can assist the growth of Ge on Si(100) in the same way [5]. The kinetics of the surfactant-assisted growth are not yet fully understood. In this work, we have investigated heteroepitaxial growth of Ge on Si(100) and Si on Ge(100) using both Sb and Bi as surfactants layer by layer. High resolution core level photoemission, angle resolved photoemission and low energy electron diffraction (LEED) have been applied to characterize the growth process as well as the grown epitaxial layered structure. Photoemission is an ideal tool to study the initial stage of growth process because both the intensity and the line shape of the core level photoemission spectra are very sensitive to the surface chemical environment [6].

II. Experiment

The photoemission experiments were performed in an ultra-high vacuum chamber (UHV) with a Vacuum Generators (VG) ADES-400 angle-resolved spectrometer at the Stanford Synchrotron Radiation Laboratory. The epitaxial growth of Ge and Si was performed in the same chamber. The overall instrumental resolution (monochromator and spectrometer) for the photoemission studies is between 0.2 to 0.25 eV. The chamber had a base pressure of less than $1x10^{-10}$ Torr. The Sb, Bi and Ge were thermally evaporated. Si was evaporated by electron-beam. The thicknesses of the deposited films were measured by an in situ quartz-crystal thickness monitor.

Clean Si(100) surfaces were prepared in the following manner. N type Si wafers were chemically precleaned and etched with HF before being introduced into the UHV chamber. The sample was pre-baked at 600°C for an hour before being heated to 950°C. The temperature was ramped up slowly in order to keep the chamber pressure in the 10^{-10} torr range during the heating process to minimize contamination. After cleaning, the Si(100) wafer

Mat. Res. Soc. Symp. Proc. Vol. 259. ©1992 Materials Research Society