Temperature Dependence of the Step Line Tension and Island Decay on the Si(111) (1x1) Surface

A. Pang[1], K.L. Man[1], T. Stasevich[2], F. Szalma[2], T. L Einstein[2] and M.S. Altman[1]

[1]*Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong*
[2]*Department of Physics, University of Maryland, College Park, Maryland. 20742, U.S.A.*

The Gibbs-Thomson (GT) relation describes the dependence of the chemical potential of an atomic surface step upon its radius of curvature. This dependence is responsible for phenomena that influence surface morphology such as island coarsening and island decay. The step line tension is a crucial element in the GT relation. A proper description of island decay and other step morphological phenomena therefore requires accurate knowledge of line tension, as well as its temperature dependence. Surprisingly, reported values for the step line tension on the widely studied Si(111) (1x1) surface vary by almost an order of magnitude, and nothing is known about its temperature dependence. Using low energy electron microscopy, we have measured the temperature dependence of the island decay rate and island edge fluctuations during decay on the Si(111) (1x1) surface. Accurate results were ensured by performing these experiments on the tops of prefabricated mounds, which serve as controllable and reproducible island sources and platforms for decay. Definitive information on the step line tension is obtained from a capillary wave analysis of island edge fluctuations. A temperature coefficient of –1.4 meV/nm·°K is determined from this analysis. This amounts to a 41% decrease of line tension in the temperature range, 1145 – 1343 K, that the island decay rate was measured. Within this temperature range, the role of desorption in island decay varies from negligible to dominant. Therefore, an extension of the existing special model of island decay that neglects desorption was made based on the solution of the diffusion equation inclusive of a desorption term. Evaluation of the experimental data with this general model referenced to the temperature dependent line tension (Fig. 1) accurately determines the sum of the adatom formation and diffusion energies $E_1 = E_{ad} + E_{dif} = 1.51$ eV and the difference of the desorption and diffusion energies $E_2 = E_{des} - E_{dif} = 2.55$ eV. The sum of these activation energies agrees with the sublimation energy that was reported previously.

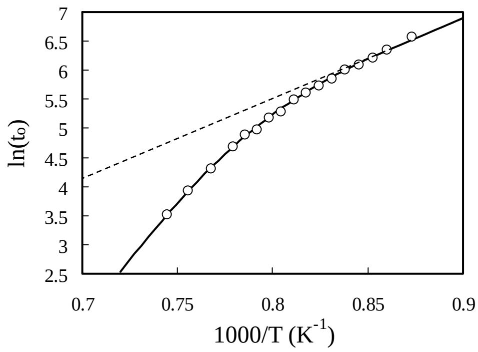

Fig. 1: The logarithm of the island decay time (O) is plotted vs. inverse temperature. The fits of the models that include desorption (solid curve) and neglect desorption (dashed curve) are shown.