Revisiting the dynamics of atomic steps on crystal surfaces via nonequilibrium thermodynamics

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Abstract

We discuss the growth/sublimation of a crystal via the motion of atomic steps on its surface. We begin with a brief review of the classical Burton-Cabrera-Frank theory, with emphasis on its predictions for the stability of vicinal surfaces against step bunching and/or meandering. To resolve discrepancies between these predictions and observations made on metallic and semiconductor surfaces, we propose a thermodynamically consistent model which, under suitable assumptions, reduces to its BCF counterpart. A key feature of this model is a modified Gibbs-Thomson relation for the step chemical potential, which derives from the configurational-force balance at the steps. By altering the kinetics of adatom crystallization at steps, this relation has deep consequences on the onset of surface instabilities. We examine these consequences in relation to the coexistence of step bunching and meandering, when elastic step interactions are neglected and when they are accounted for, as well as to the stability reversals observed on silicon surfaces in the presence of adatom electromigration.