Nanoscale Patterns Produced by Ion Bombardment of Solid Surfaces: Nonlinear Effects

R. Mark Bradley

Departments of Physics and Mathematics, Colorado State University

Abstract

Bombarding a solid surface with a broad ion beam can produce a remarkable variety of nanoscale patterns. Oblique-incidence bombardment, for example, can lead to the formation of surface ripples with wavelengths as short as 10 nanometers. The anisotropic Kuramoto-Sivashinsky (AKS) equation has traditionally been used to model the formation of these ripples.

The equation of motion for the surface can be rigorously derived for angles of ion incidence just above the threshold angle for ripple formation. In the case of two diametrically opposed, obliquely-incident ion beams, the equation of motion close to threshold and at long times is a simplified version of the AKS equation, and the ripples that form are disordered. In contrast, if the surface is bombarded with a single obliquely-incident beam, the behavior is dramatically different: highly ordered ripples can emerge at sufficiently long times. This order results from the combined effect of the nonlinearity and strong linear dispersion.

Experiments show that nanoscale patterns can also form if a solid is bombarded with ions that have an energy too low to produce sputtering. If the solid is bombarded with two diametrically opposed, obliquely-incident beams of this kind, highly ordered, faceted ripples emerge for angles of incidence just above threshold. The equation of motion in this case is a generalized, anisotropic version of the Cahn-Hilliard equation.