CSU PHYSICS COLLOQUIUM

Nanoscale Surface Patterning by Non-Equilibrium Self-Assembly of Ion-Induced Cacancies and Ad-Atoms

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Abstract

Various self-organized nanoscale surface patterns can be produced by low- and medium-energy ion beam irradiation [1], depending on the irradiation conditions. Hexagonally ordered dot or pit patterns, checkerboard patterns, as well as periodic ripple patterns oriented perpendicular or parallel to the ion beam direction are formed spontaneously during the continuous surface erosion by ion sputtering. On amorphous surfaces, the formation of these patterns results from an interplay of different roughening mechanisms, e.g. curvature dependent sputtering, ballistic mass redistribution, or altered surface stoichiometry on binary materials, and smoothing mechanisms, e.g. surface diffusion or surface viscous flow.

An additional surface instability arises above the recrystallization temperature of the material. In this case, ion induced bulk defects are dynamically annealed and amorphization is prevented. The diffusion of ion-induced vacancies and ad-atoms on the crystalline surface is now affected by the Ehrlich-Schwoebel (ES) barrier, i.e. an additional diffusion barrier to cross terrace steps. Vacancies and ad-atoms are trapped on terraces and can nucleate to form new extended pits or terraces, respectively [2].

For the mathematical description of the pattern formation and evolution in the reverse epitaxy regime, a continuum equation can be used which combines the ballistic effects of ion irradiation and effective diffusion currents due to the ES barrier on the crystalline surface. By comparison with experimental studies of pattern formation on Ge and GaAs surfaces at different angles and temperatures, we will show that the pattern evolution is determined by the surface instability due to the ES barrier, surface diffusion, and ballistic effects of ion irradiation.

[1] A. Keller and S. Facsko, Materials 3, 4811 (2010).
[2] X. Ou, K.-H. Heinig, R. Hübner, J. Grenzer, X. Wang, M. Helm, J. Fassbender, and S. Facsko, Nanoscale 7, 18928 (2015).