SPECIAL PHYSICAL MATHEMATICS SEMINAR

TOPIC: CONTINUUM APPROACH TO PROFILE SCALING IN NANOSTRUCTURE DECAY BELOW THE ROUGHENING TEMPERATURE

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ABSTRACT:

Advances in the fabrication of small devices have stimulated interest in low-temperature kinetic processes on crystal surfaces. In most experimental situations, nanoscale solid structures decay in time with a lifetime that is a large power of the feature size and typically increases with decreasing temperature. Strategies for skirting the lifetime limitations involve processing at ever-lower temperatures for ever-smaller feature sizes. At temperatures below the roughening transition crystal surfaces evolve via the motion of interacting steps at the nanoscale, and may develop macroscopically flat parts known as facets. The prediction of macroscopic surface evolution at such temperatures is an open problem.

The subject of this talk is a continuum, analytical description of the morphological relaxation of crystal surfaces with a single facet below the roughening temperature by use of PDEs. For diffusion-limited (DL) and attachment-detachment limited (ADL) kinetics, the slope profile F outside the facet is described via a nonlinear, fourth-order PDE that accounts for step line-tension energy $g1$ and step-step repulsive interaction energy g3. The PDE is derived from the step-flow difference equations, which describe the motion of individual steps, and, alternatively, via a continuum surface free energy. The facet evolution is treated as a free-boundary problem recognizing that there is a region of rapid variations of F, a boundary layer, near the facet. For long times, axisymmetric shapes and $g3/g1< O(1)$, singular perturbation theory is applied for self-similar shapes close to the facet. For DL kinetics, scaling laws with $g3/g1$ are derived for the boundary-layer width, maximum F and facet radius; and a universal ODE for F is derived and solved uniquely via applying effective boundary conditions at the facet edge.

For the more intricate case of ADL kinetics a different scaling with $g3/g1$ is found for the boundary-layer width. The scaling results compare favorably with kinetic simulations. Geometries other than the axisymmetric one are discussed.

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