Dynamics of Dislocations and Surface Instabilities in Misfitting Heteroepitaxial Films

Mikko Haataja (1), Judith Müller (2), A. D. Rutenberg (3), and Martin Grant (4)
(1) Department of Mechanical and Aerospace Engineering
and Princeton Materials Institute, Princeton University, Princeton, NJ-08544
(2) Instituut-Lorentz for Theoretical Physics, University of
Leiden, P.O. Box 9506, NL-2300 RA Leiden, The Netherlands
(3) Department of Physics, Dalhousie University,
Halifax, Nova Scotia B3H 3J5, Canada
(4) Centre for the Physics of Materials, Department of Physics, McGill University,
Rutherford Building, 3600 rue University, Montreal, Quebec H3A 2T8, Canada
mhaataja@princeton.edu

We introduce a continuum model of elasticity in a nonequilibrium multiphase system — including smooth and singular strains, as well as their coupling to free surfaces — and apply it to the dynamics of misfitting heteroepitaxial films. Above a critical thickness dislocations relieve strain, competing with an instability at the interface. At early times, the initial untable growth of interface fluctuations is driven by an effective misfit strain which in turn depends on the dislocation mobility and density. At late times, our results show that the interaction between singular and smooth strains leads to complicated morphologies. Depending on their mobility, dislocations can screen stress by building up at large-curvature groove tips, leading to high ductility, or they can be "outrun" by the tips, leading to brittleness.