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Stress-driven nonlinear dynamics of ion-induced surface nanopatterns

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Abstract- For many solid targets, like semiconductors, that become amorphous under irradiation by energetic ions, the outermost surface layer displays formation of asymmetric nanoscale ripples in macroscopic timescales. In contrast to the well-known macroscopic case of an incompressible thin fluid film spreading down an incline, in which the morphological instability is controlled by gravity, here we prove that residual stress induced by the ions is responsible for pattern formation and accounts for its long-time dynamics, even in absence of sputtering effects. Using a continuum framework, we derive closed nonlinear evolution equations for the depth of the irradiated layer. This description includes novel terms associated with the spatial distribution of damage that builds up through sustained bombardment, thus extending to the nanoscale classic models of macroscopic fluidflow systems, and providing detailed information on the pressure and velocity fields within the irradiated layer. Numerical simulations reproduce the main dynamical features of surface nanopatterning under the assumed conditions, elucidating the ensuing nonlinear properties on ripple amplification and transport.

Index Terms-

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