Interactions of Nanoparticles with a Dewetting Solid Film

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Capillary forces at the interfaces between particles, fluids, and solid substrates lead to the self assembly of structures during liquid film evaporation. We introduce a related process that involves nanoparticle assembly during dewetting and sublimation of a solid thin film. Metal atoms evaporated onto condensed inert gas films form clusters that can be delivered to a substrate of choice by subliming the film. Warming leads to hole formation at defects or grain boundary triple points and surface tension causes hole spreading and film breakup. For Au on Xe we show that, as for liquids, the physics underlying aggregation involves capillary forces as films dewet amorphous carbon substrates. The cluster mobility reflects the dynamics of the boundary of the retreating solid film and results in the formation of nanostructures, whose sizes and densities are controlled by adjusting the film thickness. Kinetic Monte Carlo simulations reproduce the experimentally-observed shapes and distributions and provide insight into the particle assembly process. In contrast to liquid films, particle motion is limited to the dewetting front where capillary forces drive cluster aggregation. This nanoparticle assembly process is not limited to noble metals on rare gas films but occurs in a variety of systems where particles are deposited onto thin volatile films, e.g. II-VI semiconductor particles and condensed CO_2 layers.