Melting and Freezing of Colloidal Crystals on Patterned Surfaces

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Abstract:
The dynamics of colloidal crystal growth and melting are studied in the presence of patterned substrates created using photolithography and reactive ion etching fabrication techniques. Island growth is observed on patterned lattices of square and triangular symmetry for both commensurate and incommensurate underlying lattices. The underlying lattice symmetry and strain are found to alter the growth/melting dynamics, including the diffusion of adatoms in growing islands and the melting rate of individual islands.

Summary:
In recent years of colloidal crystallization studies, microfabricated templates have been successfully used to template the growth of sedimented colloidal particles into self-assembled structures [1]. This technique allows for accelerated colloidal crystallization, which has been exploited to study the effects of various boundary conditions, including stretched templates [2] and surfaces with embedded grain boundaries [3]. In our current research project, we fabricate polymethylmethacrylate (PMMA) templates on silica glass substrates. A suspension of 1.3 µm diameter charge-stabilized polystyrene colloidal particles are sedimented onto the patterned surface, whose 1.3 µm diameter holes trap a monolayer of particles, forcing them to assume the underlying symmetry. The growth, and hence melting, of a single layer directly above the trapped layer is studied using an inverted microscope. The dynamics of crystallization of this single layer of colloidal particles can then be directly observed with single particle resolution in real time. The fabrication process utilizes electron beam lithography to pattern periodic arrays of 1.3 µm holes in a 500 nm thick layer of PMMA. Two specific underlying array symmetries are created on the templates to probe the dynamics of the colloidal particles. A square lattice of micron-size holes (Figure 1) may be used to grow a face-centered cubic crystal along the (100) face—by tuning the lattice constant of the array, we can probe both commensurate and incommensurate lattice matches. Alternatively, we pattern triangular lattices (Figure 2) to explore the (111) face.

In combination with a temperature dependent attractive interaction [4], we are able to observe the dynamics of both island growth and melting. An initial layer of colloidal particles, which form within the template holes, Figure 1: Picture of 1.3 µm polystyrene colloidal particles forming two layers on a PMMA template with imposed square symmetry. The experiment entails studying the dynamics of growth and melting of island in the top layer (white particles). Particles in the bottom layer sit in the template hole and assume the underlying symmetry imposed by the template. Due to the attractive interaction in the system, only the top layer of particles tend to move when the temperature is changed and the interaction is weakened, causing melting of the top layer.
self-assemble due to the attractive interaction which occurs between both individual particles and individual particles with the substrate. Island growth occurs atop the initial layer of colloidal particles with the same symmetry as the underlying lattice. Small changes in temperature cause the interaction to weaken, leading the islands to melt (Figure 3). The rate of melting is found to vary dramatically depending on the underlying lattice symmetry (Figure 4).

References:


