Nucleation in Solid-solid Transitions of Colloidal Crystals

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Solid-solid (s-s) phase transitions between different crystalline structures are ubiquitous in nature, but their kinetic pathways and mechanisms are poorly understood. We directly imaged the solid-solid transitions in colloidal thin films composed of diameter-tunable NIPA microspheres with single-particle resolution by video microscopy. The superheated square lattices transformed into triangular lattices along a novel two-step nucleation pathway via intermediate liquid state nuclei both inside domains and on grain boundaries. This pathway is favored, because the solid-solid interfaces are energetically more costly than solid-liquid interface (fig. 1A). This simple mechanism indicates that the two-step nucleation "parent crystal $\rightarrow$ liquid nucleus $\rightarrow$ product crystal nucleus" should widely exist in many solid-solid transitions, such as most metals and alloys. Further, the liquid nucleus precursors were revealed to arise via particle-swapping loops rather than from newly generated defects, and the coherent and incoherent facets of the evolving nuclei exhibit different energies and growth rates which can dramatically alter nucleation kinetics. Applying a small anisotropic strain can reduces the liquid nucleus size. Above a threshold of the applied strain, the intermediate liquid nuclei vanished. Instead, a few pairs of dislocations were first generated from the square lattices, which triggered tens of particles to collectively transform to a triangular-lattice nucleus and then grew diffusively. This martensitic transformation at the early stage and the diffusive nucleation at the later stage is another novel type of kinetic pathway in solid-solid transition.

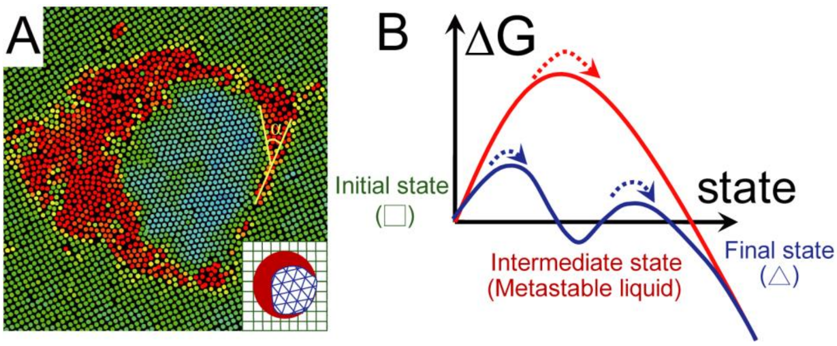

Figure 1. (a) A triangular-lattice nucleus grows from a large liquid nucleus. The contact angle indicates that the $\triangle$ lattice does not wet the $\square$ lattice. (b) Ostwald's step rule for the two-step nucleation.