Easy Colloidal Crystallization: Building an Automated Machine and Seeding Nucleation

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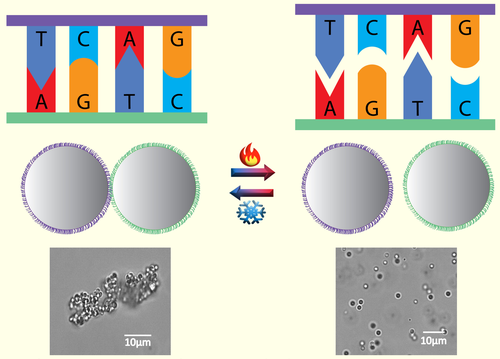
Reversible Self-Assembly via Temperature Dependent Bonds

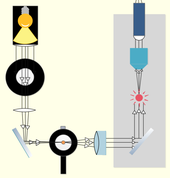


Complimentary single stranded DNA (ssDNA) strands only bind together below their melting temperature (T_m) and unbind above T_m. Polystyrene microparticles coated with complimentary ssDNA inherit this temperature dependent affinity.

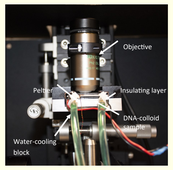
Modular Design

The machine is composed of two main components: a bright-field microscope and a heating/cooling system. All parts of the machine are assembled in-house, making them easily modifiable. This in turn expands functionality by allowing for custom built expansions and additions.

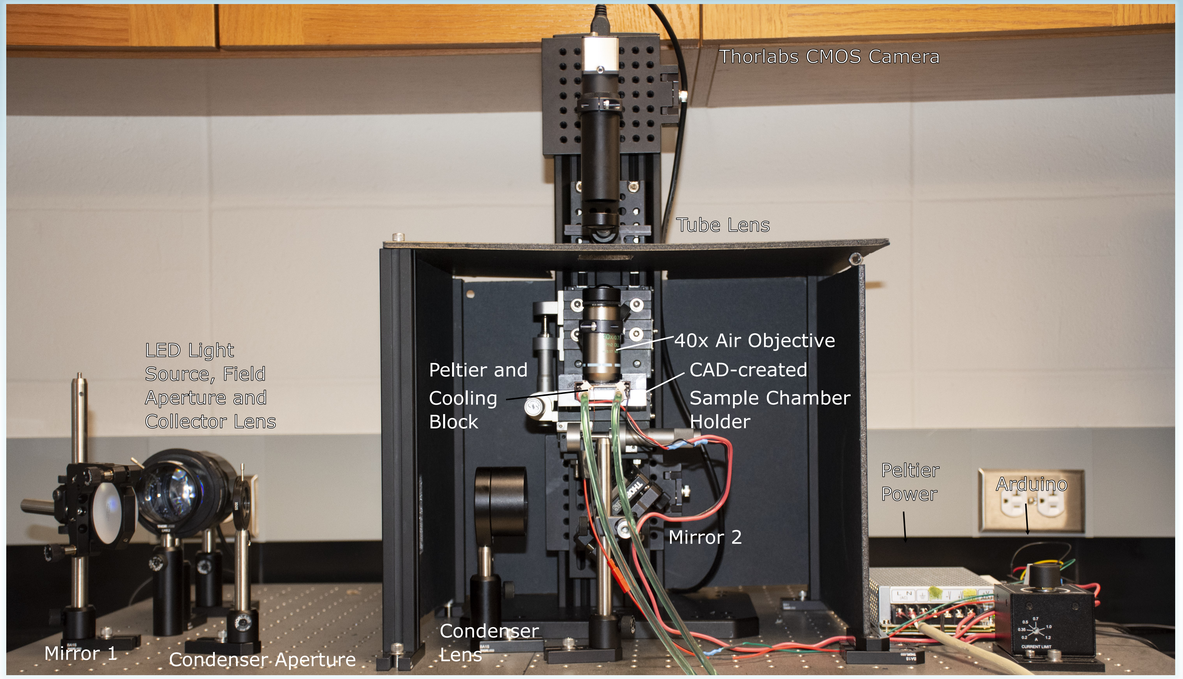
(above) 3D print design for the sample chamber attachment.
(below) close-up of the sample chamber *in situ*.



Schematic of the optical path of the brightfield mi-

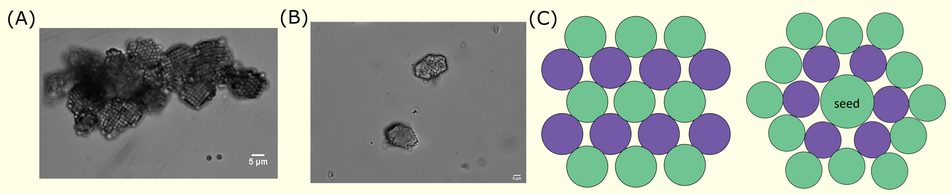


The sample chamber *in situ*.



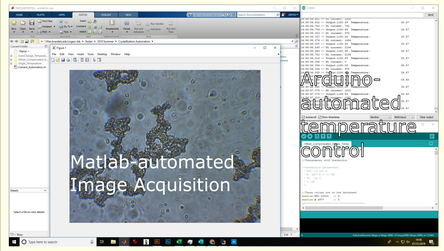
Feature	Nikon Microscope	New Machine
Interchangeable Parts	✗Removeable objectives ✗Large, enclosed build ✗Static lenses and apertures	✓Removable objectives ✓Compact, open build ✓Removable lenses, mirrors, apertures camera, and stage
Programmable Image Capture	✗Live view of sample ✗Manual image saving	✓Live view of samples ✓MATLAB-programmable automatic imaging
Programmable Temperature Control	✗Commercial "closed-system" software ✗Manual temperature adjustment	✓Arduino modifiable controller ✓Automated temperature adjustment
Upgrades and Expansions	✗Limited by microscope mounting points	✓Customizable to user's needs, regardless of source
Specialized for Crystallization	✗External heating elements ✗Incompatible stage adapted for heating	✓Insulated ✓Custom chamber dimensions to accommodate heating

Can Geometry be Further Specified?: Seeding Nucleation



Holding the sample near the lower crystallization temperatures results in rapid nucleation. This overabundance of nuclei results in the formation of polycrystals (A) instead of single crystals (B). Holding the sample near the higher crystallization temperatures results in slower nucleation. This limits the number of nuclei formed and promotes the formation of larger crystals. We intend to study the effects of artificial nuclei on the size, geometry, growth rate, and abundance of crystals. Artificial crystallization "seeds" are comprised of larger 1 μm DNA-coated particles that are complimentary to one species in a two-species sample of 600 nm particles (C).

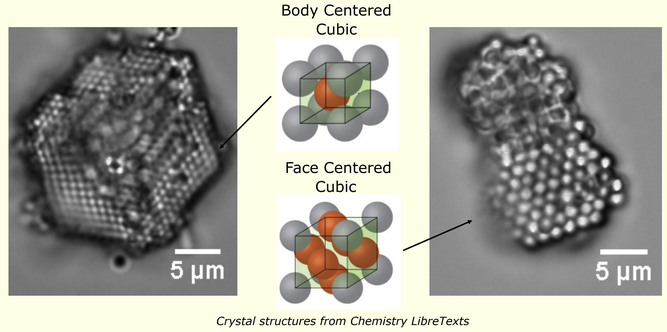
Programmable Image Acquisition



Screenshot of the computer controls during image acquisition.

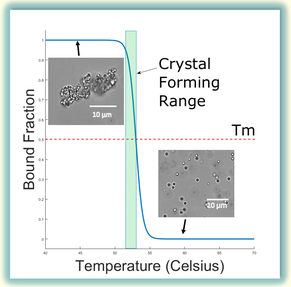
These two systems run independently furthering our goals of enhanced user control.

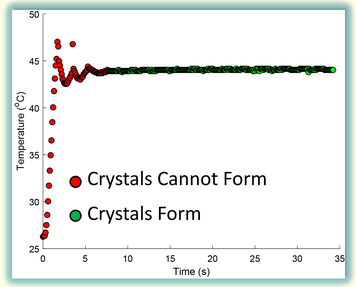
Crystals represent the most energetically favorable structures. This is because the crystalline arrangement maximizes the number of DNA-bridges formed between neighboring particles. Therefore, by examining whether the crystal structure is body-centered cubic (BCC) or face-centered cubic, we can know more about the interacting free-energies between particle species.



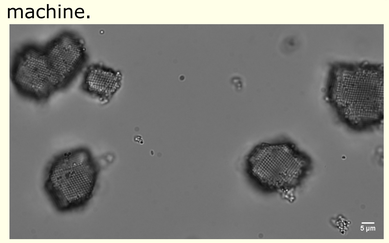
Crystal structures from Chemistry LibreTexts

Precise Temperature Control





Crystal nuclei form over a small range of temperatures slightly below T_m. Holding the sample temperature near T_m forms weak DNA bonds and allows particles to detach and migrate to more energetically favorable positions. The growth rate and abundance of nuclei can be controlled by raising or lowering the sample temperature within the crystal forming range. However, this range is very narrow (<1°C), making stable temperature control a vital component of the crystallization machine.



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This work was funded in part by the Brandeis NSF MRSEC DMR-1420382. We would like to specially thank Alexander Hensley, Simon Merminod, and the Rogers Lab for their contributions and support.

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