Direct observation of defect formation and diffusion in colloidal crystals

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In any crystal structure, defects, structural imperfections in the crystal lattice, are thermodynamically bound to occur. Defects crucially influence the mechanical, structural and optical properties of materials. While defects can have desirable effects, such as doping in semiconductors, their effects can also be undesirable, such as metal fatigue, or the softening of nanocrystalline metals. Because of their importance, defects have been studied in many materials, but their diffusion and interactions are still not well understood. Especially point defects, vacancies (missing particles) and interstitials (additional particles), are not well understood, even though these play a crucial role in diffusion creep and radiation shielding material degradation.

To gain insight into fundamental phenomena colloids, small particles with a size between 1-1000 nm, have played a central role as model systems for crystallization. When dispersed in a liquid, colloids display thermal (Brownian) motion and form equilibrium phases similar to atoms and molecules, i.e. fluids, crystals and glasses. Due to their size, however, colloids are easily observable on single-particle levels using optical microscopy and provide a model system to study crystal defects. Different types of defects have already been studied in colloidal crystals such as planar defects (2D) and volume defects (3D). Point defect (1D), however, have been mostly investigated by simulations because experimentally their concentrations are typically low in colloidal crystals.

Recent advances in colloidal synthesis now provide colloidal systems that can be tuned with external parameters, such as temperature, and open up new ways to study defects. The aim of this project is to induce and study point defects in colloidal crystals using colloids that can change their size in response to temperature. Figure 1 shows a schematic of how this tunability can lead to the creation of vacancies and interstitials. The colloidal crystals will be studied on a single particle level using confocal microscopy. By employing image analysis methods to track and trace the positions of all particles, crystals and defects, will be visualized. Further investigations will include more advanced image analysis methods to investigate strain and stress fields around the defects. Additionally, a second system of particles with tuneable interactions can be used.

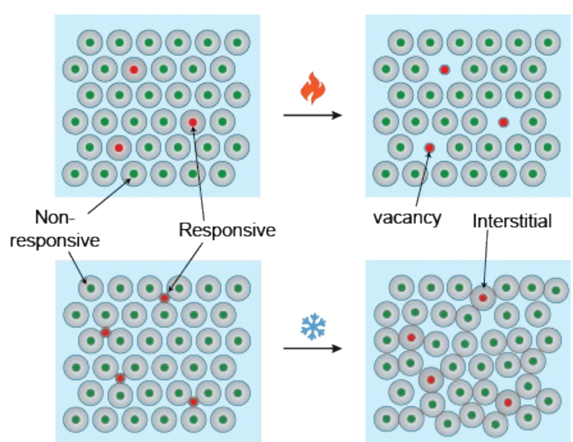

Figure 1. Schematic representations of the formation of vacancy and interstitial defects using thermo-responsive colloids embedded in a crystal of non-responsive colloids.