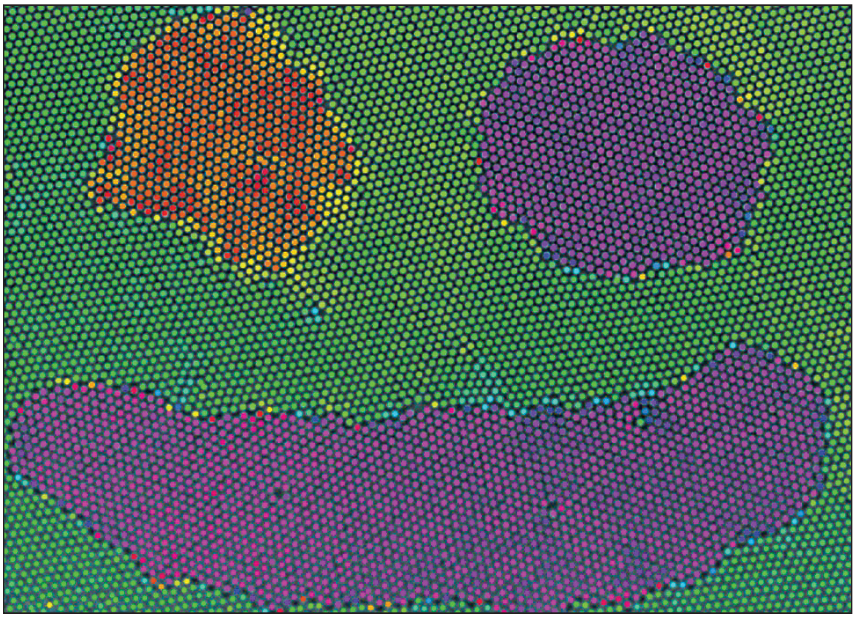
Optical blasting of polycrystals manipulates grain boundaries

In the realm of materials science and beyond, grain boundaries play a central role in defining the optoelectronic, magnetic, thermal, mechanical, and other properties of materials. Materials scientists are concerned about grain boundaries owing largely to their stochastic nature. The boundaries usually scatter charge carriers inhibiting transport, disrupt long-range crystallinity, and lead to brittleness, rendering the materials less attractive for applications. This might, however, change with a discovery made by the research group of Sharon Gerbode of Harvey Mudd College, and published recently in *Physical Review Letters* (doi:10.1103/PhysRevLett.120.018002).

Gerbode's group, consisting solely of undergraduates, has developed "optical blasting" as a unique tool to maneuver and control grain boundaries in two-dimensional (2D) polycrystal monolayer assemblies. Optical blasting is an analogue of the well-known "optical tweezers" initially reported in 1970. Whereas optical tweezers have been successfully employed to bring together and trap nanoscale and sub-nanoscale objects, as the name implies, optical blasting repels particles. It has so far only been explored by the Gerbode group.

The research team locally rastered a laser beam across silica microcrystals assembled in a liquid medium. Aided by a mismatch between the refractive indices of the microcrystals and the medium, the laser induced a repulsive force between adjacent microcrystals, locally melting the grain boundaries. Upon recrystallization, the grain boundaries were found to have moved from their original positions.



A smiley face experimentally fabricated using optical blasting. Particles are colored by the phase of the local orientational order parameter, showing grain orientation. Credit: *Physical Review Letters*.

"The boundaries can be made permanently distorted for longer laser interaction timescales," Gerbode says. Using the technique, the group was able to sculpt a variety of artificial grain shapes in the polycrystal assembly. "Interestingly, if the liquid medium is then evaporated, you can lock the crystals into a new grain boundary geometry," she says.

The researchers use light to locally melt a colloidal crystal and then watch as the grain boundaries reform in a new configuration. They also speculate that it may be possible to use this sort of method to perturb actual three-dimensional solid-state crystals. "The challenge there would be to image the grain boundary of the crystal in the first place, and then be able to make an intelligent local perturbation to that boundary," says Eric Weeks, an expert in colloidal glasses and a professor in the Department of Physics at Emory University.

The possibility of locally melting and manipulating grains and defects in materials will equip researchers with hitherto unachievable control over grain boundaries. The biggest advantage of the finding, Gerbode says, is the opportunity to internally tune various materials properties by grain manipulation. One can now envisage converting the routine, isotropic crystals into materials that exhibit direction-dependent properties, such as charge transport or elasticity. It could become possible, for example, to realize crystals with mechanical softness in a particular direction and stiffness in the other.

This discovery opens a vibrant chapter in materials research, and suggests that some of the simplest materials systems could become home to phenomena that can challenge conventional logic.

Ahmad R. Kirmani

Probing the buried interface between graphite layers

The secrets of the first few molecular layers near the surface of a material, or adjacent to buried interfaces is an underexplored area of science. Interfaces in rechargeable battery catalysts, semiconductor dielectrics, and two-dimensional materials play important roles in determining energy-conversion efficiency, device performance, and chemical and physical reactivity. X-rays with high photon energies are commonly used to "see" into materials due to their penetrating ability and small wavelength that approximates to the size of molecules and atoms. However, while most soft x-ray spectroscopy techniques can achieve chemical and elemental specificity, they are not able to offer

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