Bespoke Crystals: Bio-Inspired Control over the Structure and Properties of Crystals

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Crystallization is a phenomenon that touches every person, each day of their lives. It underpins a vast range of technological processes including the production of nanomaterials, ceramics, and pharmaceuticals, biological processes including the generation of bones, teeth and seashells, environmental issues such as weathering and ice formation in the atmosphere, and unwanted crystallisation such as the formation of scale in kettles and oil-wells. Thanks to the aesthetic appeal of crystals, and the fundamental nature of phase transformations, it is also a subject that has fascinated for centuries. Understanding the mechanisms that govern crystallisation therefore promises the ability to inhibit or promote crystallisation as desired, and to tailor the properties of crystalline materials to a huge range of applications.

This talk will describe strategies for achieving control over crystal nucleation and growth, such that crystalline materials – with tailor-made properties – can be constructed by design. Particular inspiration is taken from biomineralisation processes, in which organisms achieve control unparalleled by synthetic systems. Crystals with complex morphologies – comparable to those of biominerals – can be generated using simple templating approaches, while microfluidic systems provide opportunities to interact with growing crystals and gain superior control. The biogenic demonstration that even single crystal biominerals are composites in which organic macromolecules are associated with the inorganic phase is then used as an inspiration to generate single crystal nanocomposites. Occlusion-species ranging from micron-scale particles, to organic and inorganic nanoparticles, to small molecules have been incorporated within calcite single crystals using a simple one-pot method. The incorporation of 20 nm anionic diblock copolymer micelles results in “artificial biominerals” with structures and mechanical properties comparable to those of biominerals. Considering then additives an order of magnitude smaller in size, amino acids could also be occluded within calcite, providing significant insight into the origin of the superior mechanical properties of many biominerals. This strategy is then extended to generate nanocomposites in which inorganic nanoparticles are uniformly distributed throughout a crystal matrix with true nanoscale mixing. Finally, I will address the most challenging topic of all – control over nucleation – and show that surface topography can provide a highly effective route for promoting nucleation.