"Self-assembly of Colloidal Diamond for Photonics"

Abstract

Self-assembling colloidal cubic diamond been a longstanding goal because of its potential for making materials with a photonic band gap. These materials suppress spontaneous emission of light and are valued for their applications as optical waveguides, filters, and laser resonators, for improving light-harvesting technologies, and for other applications. Cubic diamond is preferred over more easily self-assembled structures such as face-centered cubic (FCC) because diamond has a much wider band gap and is less sensitive to imperfections. The band gap in diamond crystals opens up for a refractive index contrast of about 2.0, which means that a photonic band gap could be achieved using known materials at optical frequencies, which appears not to be possible for FCC crystals. Nevertheless, self-assembled colloidal diamond has not previously been realized. Because particles in a diamond lattice are tetrahedrally coordinated, one approach has been to self-assemble spherical particles with tetrahedral sticky patches. Difficulties persist, however, because patchy spheres possess no mechanism to select the proper staggered orientation of tetrahedral bonds on nearest-neighbor particles, a requirement for cubic diamond. We show that by using partially compressed tetrahedral clusters with retracted sticky patches, colloidal cubic diamond can be self-assembled using patch-patch adhesion in combination with a steric interlock mechanism that selects the proper staggered bond orientation. Colloidal particles in the self-assembled cubic diamond structure are highly constrained and mechanically stable, which make it possible to dry the suspension and retain the diamond structure. This makes these structures suitable as templates for forming high-dielectric-contrast photonic crystals with cubic diamond symmetry. Photonic band structure calculations reveal that the direct and inverse lattices exhibit promising optical properties, including a wide complete photonic band gap.

Brief Bio

David Pine is the Julius, Roslyn, & Enid Silver Professor at New York University, with appointments in the Physics Department and the Chemical & Biomolecular Engineering Department. He received his PhD in Physics from Cornell University in 1982. Prior to assuming his appointment at NYU, he was Professor and Chair of Chemical Engineering and Professor of Materials at UCSB. Before that, he was a Staff Physicist at Exxon Corporate Research and an Assistant Professor at Haverford College. He is broadly interested in soft materials, light scattering, and optical materials. Current research interests include non-equilibrium phase transitions, self-assembly of colloids and emulsions, DNA-coated particles, colloids with directional interactions, and photonic materials. He is a Fellow of the American Academy of Arts and Sciences, the American Association for the Advancement of Science, and the American Physical Society.