Repurposing the Blueprint for Life Through Colloidal Crystal Engineering with DNA

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To develop functional materials with properties by design, new synthetic strategies are needed to independently tune material composition and structure. However, it is exceedingly difficult to control complex interactions between atomic and molecular species in such a manner. Nanoscale building blocks, in contrast, can be encoded with programmable interactions through the ligands attached to their surface in a manner independent of the nanoparticle structure and composition. In our research, we have repurposed DNA from the genetic "blueprint for life" as a powerful programmable tool to use as a structure-directing agent and a structural material for materials assembly. Nanoparticle building block "atoms" can be densely functionalized with a shell of DNA ligands and assembled into sophisticated colloidal crystal structures with symmetries and spacings dictated by the DNA "bonds." The sequence and length tunability of nucleic acid bonds has allowed us to define a powerful set of design rules for the construction of colloidal crystals with more than 78 unique lattice symmetries, interparticle distances spanning 7 nm to over 1 μm, eight well-defined crystal habits, and several phases that have no known mineral equivalent. We have recently expanded the scope of building blocks to hollow nanoframes, which enable the assembly of open-channel lattices with controlled pore geometry and size ranging from 10-1000 nm. Notably, colloidal crystals engineered using this approach exhibit emergent properties distinct from the nanoparticle and DNA building blocks. We have also shown that the DNA bonding elements impart remarkable shape memory properties, with full recovery of crystallinity and habit after 90% compression and loss of crystallinity upon dehydration. Finally, this unique genetic approach to materials design affords functional nanoparticle architectures with properties such as shape memory, pore size, and optical properties including wavelength dependent reflection, second harmonic generation, and negative refractive index.

Biography

Chad A. Mirkin, PhD is the Director of the International Institute for Nanotechnology and the Rathmann Professor of Chemistry and Medicine at Northwestern University. He is known for his invention and development of spherical nucleic acids and Dip-Pen Nanolithography and related cantilever-free nanopatterning and materials discovery methodologies. He has authored >865 papers and >1,200 patents worldwide (>410 issued) and founded ten companies. Prof. Mirkin has been recognized with over 250 national and international awards including the Wilhelm Exner Medal, the Dan David Prize, the National Academy of Sciences Sackler Prize in Convergence Research, and the King Faisal Prize from the Kingdom of Saudi Arabia. He served for eight years on the President's Council of Advisors on Science & Technology, and he is one of very few scientists to be elected to all three US National Academies. Mirkin has served on the Editorial Advisory Boards of over 30 scholarly journals, is the founding editor of the journal Small, and is a Proc. Natl. Acad. Sci. USA Editorial Board Member. He has given >900 invited lectures and educated >320 graduate students and postdocs.