# Colloidal quasicrystals engineered with DNA

A model for the controlled synthesis of hitherto unattainable complex nanostructures is featured in a study co-led by Luis Liz-Marzán and published by *Nature Materials*

The study sheds light on the design and creation of intricate structures, and opens up a world of possibilities for advanced materials and innovative nanotechnology applications

**Donostia-San Sebastian (Basque Country). 3 November, 2023.** A team of researchers from the Center for Cooperative Research in Biomaterials CIC biomaGUNE, the Northwestern University's International Institute for Nanotechnology, and the University of Michigan has unveiled a novel methodology to engineer colloidal quasicrystals using DNA. This study, groundbreaking in the field of nanotechnology, has been published in the journal *Nature Materials* under the title "Colloidal Quasicrystals Engineered with DNA".

What characterizes quasicrystals is the fact that they are ordered yet non-repeating crystalline structures (which follow patterns similar to tiling structures) and have long puzzled the scientific community. The existence of quasicrystals remained an enigma for decades and their discovery warranted the Nobel Prize. "It is very difficult to prepare particles with this geometry in sizes of about 100 nm and with a sufficiently good size uniformity to make it possible to generate these quasicrystalline structures," explained Ikerbasque research professor Luis Liz-Marzán of CIC biomaGUNE and one of the senior researchers of the study.

"Although there are now several known examples, discovered in nature or through serendipitous routes, our research demystifies their formation and more importantly shows how we can harness the programmable nature of DNA to design and assemble quasicrystals deliberately," remarked Chad Mirkin of Northwestern University and co-author of the study.

The study emerged out of a proposal by CIC biomaGUNE's Bionanoplamonics group led by Liz-Marzán, a pioneer in the development of manufacturing methods and surface modification of nanoparticles to improve their application possibilities: "We had in fact found how to synthesize nanoparticles with decahedral geometry –ten-sided particles– that were of sufficient quality to tackle this study. Decahedral geometry is essential in this case because of the pentagonal symmetry involved. Pentagons are essential geometric elements in quasicrystals and that is what made it possible to end up with such unique materials."

The group led by Professor Sharon Glotzer of the University of Michigan had already predicted the first layered nanoparticle quasicrystal in 2009: "In our original quasicrystal simulation, the arranged of the decahedra left very small gaps between them. Here, those gaps would be filled by DNA," explains Glotzer, co-corresponding autor of the study.

**An innovative approach opening up new avenues in nanoscale design**

The study focused on the assembly of decahedral nanoparticles using DNA as a guide structure in a colloidal medium: "In other words, in a non-homogeneous medium in which the particles are suspended in a fluid," explained Liz-Marzán. By combining computer simulations with meticulous experiments, the team made a remarkable discovery: these decahedral nanoparticles can be organized to form quasicrystalline structures with intriguing pentagonal and hexagonal (penta and hexacoordinated) motifs culminating in the creation of a dodecagonal quasicrystal.

"Decahedral nanoparticles possess a distinctive five-fold symmetry that challenges the conventional periodic tiling norms," Professor Mirkin explained. By leveraging the programmable capabilities of DNA, we were able to direct the assembly of these nanoparticles into a robust quasicrystalline structure."

The research team functionalized decahedral gold nanoparticles using short, double-stranded DNA, and implemented a precisely controlled cooling process to facilitate assembly. In other words, "we attached DNA strands to the nanoparticles to guide their ordering, in a reversible way even, because it is sensitive to temperature," explained Liz-Marzán. The resulting quasicrystalline superlattices exhibited a medium-range quasiperiodic order, with rigorous structural analyses confirming the presence of a twelve-fold symmetry and a triangle-square tiling pattern, hallmark features of a dodecagonal quasicrystal.

"By engineering colloidal quasicrystals, we have achieved a significant milestone in the realm of nanoscience. Our work not only sheds light on the design and creation of intricate nanoscale structures but also opens up a world of possibilities for advanced materials and innovative nanotechnology applications," declared CIC biomaGUNE's Professor Luis Liz-Marzán.

"The implications of this breakthrough are far-reaching, as it offers a potential blueprint for the controlled synthesis of other complex structures previously considered beyond reach," said the researchers. As the scientific community delves into the boundless prospects of programmable matter, this research is paving the way for transformative advances and applications in various scientific domains.

**Bibliographical reference**

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**About CIC biomaGUNE**

The Center for Cooperative Research in Biomaterials CIC biomaGUNE, member of the Basque Research and Technology Alliance (BRTA), conducts state-of-the-art research at the interface between Chemistry, Biology and Physics, devoting particular attention to studying the properties of biological nanostructures at the molecular scale and their biomedical applications. It was recognized in 2018 as a “María de Maeztu” Unit of Excellence for meeting requirements of excellence, which are characterized by a high impact and degree of competitiveness in its field of activity on the global scientific stage.

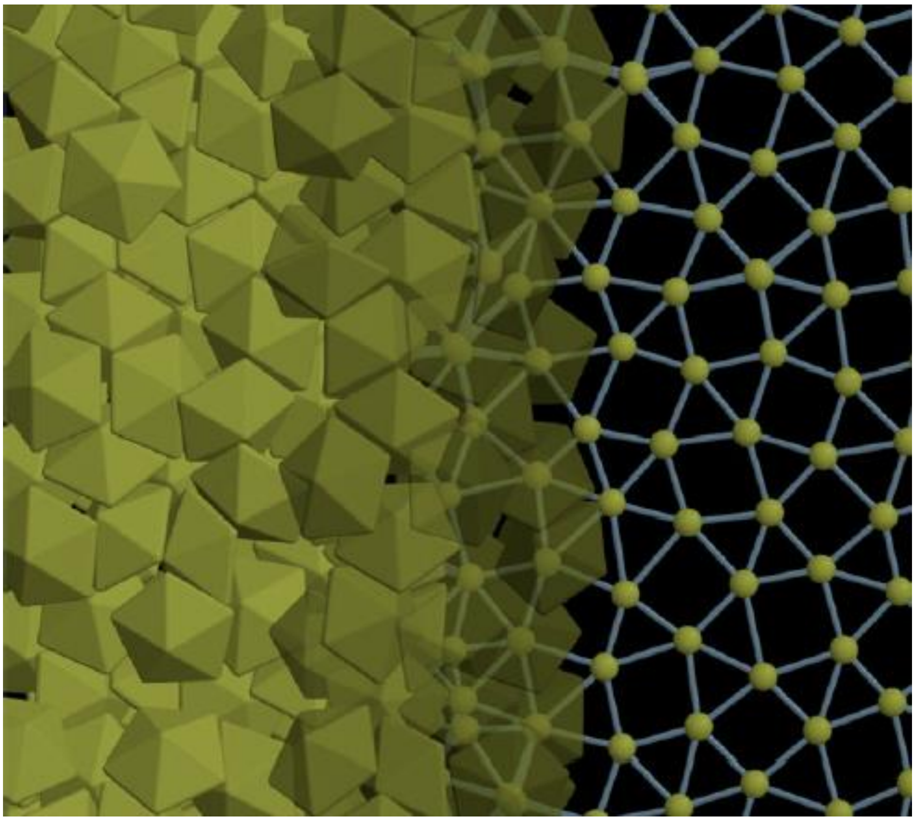

**Image caption:** Schematic illustration of a layer extracted from a DNA-functionalized decahedral quasicrystal (Source: CIC biomaGUNE, Northwestern University and the University of Michigan).