Colloids get creative to pave the way for next generation photonics

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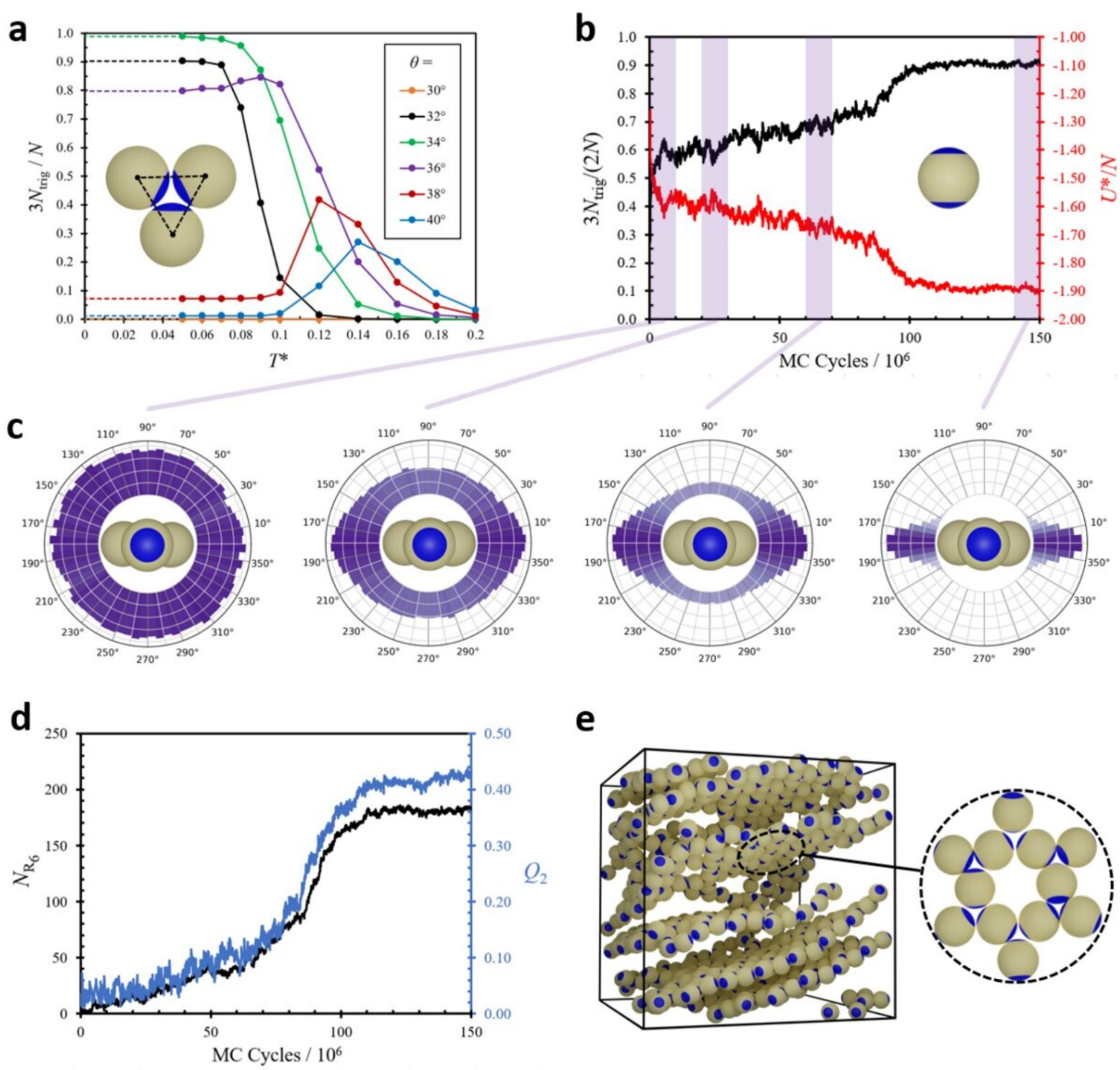

Self-assembly of stacked kagome planes. Credit: *Advanced Materials* (2023). DOI: 10.1002/adma.202211197

Scientists have devised a way of fabricating a complex structure, previously found only in nature, to open up new ways for manipulating and controlling light.

The structure, which naturally occurs in the wing scales of some species of butterfly, can function as a photonic crystal, according to a new study by researchers at the University of Birmingham. It can be used to control light in the visible range of the spectrum, for applications for lasers, sensors, and also devices for harvesting solar energy.

Their computational study, published in *Advanced Materials*, demonstrates that the complex gyroid structure can be self-assembled from designer colloidal particles in the range of hundreds of nanometers.

The gyroid is typically known as a curved surface, which divides space into two interwoven channels. Each of these channels can have a network representation of linked vertices with three-fold connectivity and corkscrews through space in a particular direction, right or left. This twist makes each network chiral—the mirror images cannot be superimposed on each other, like left and right hands. This is important because the chirality imparts additional optical properties to a photonic crystal.

The chirality is lost, however, when the two networks of opposite handedness are together in the form of the double gyroid structure. This occurs in certain synthetic systems.

In this work, the team of researchers first presents a single network gyroid structure built from colloidal spheres as a target for self-assembly —the nature's way of building architectures—before establishing the design principles for fabricating this chiral crystalline structure in computer simulations.

Dr. Angela Demetriadou, a co-author from the School of Physics and Astronomy, has said, "This is a new and exciting way to fabricate nanophotonic media with exceptional and tailored chiro-optical properties, with immense control over their properties."

So far, the focus on self-assembling colloidal photonic crystals has been mostly on diamond-structures. Self-assembly of colloidal diamond presents a number of challenges, including the requirement of selecting the cubic form over its hexagonal counterpart for their practical applications as photonic crystals in optical devices.

The new approach established in this work involves patchy spheres, which have a designer decorated surface to encode the information of the target structure—the single colloidal gyroid. The decorated parts of the surface are sticky to bring the particles together to form the network structure. In addition, the work shows that the single colloidal gyroid also has intriguing optical properties by virtue of its chirality, which is lacking in a diamond structure.

Dr. Dwaipayan Chakrabarti, the corresponding author from the School of Chemistry at the University of Birmingham, has said, "To the best of our knowledge, this is the first report of direct self-assembly of single colloidal gyroid structures from designer building blocks. We hope that our novel approach will stimulate further investigations in the field of colloidal self-assembly, especially experimental efforts to build on this exciting development."

This excitement is echoed by Professor Stefano Sacanna, a Professor at New York University with world-leading expertise in the synthesis of colloids and self-assembly of new materials, who is not involved in this study. He has said, "With their work, Chakrabarti and co-workers bring an exciting new target to the attention of the colloidal self-assembly community. Using just spheres with a clever patchy design, their bottom-up routes to colloidal gyroid structures pave the way for a new generation of experimentally achievable photonic crystals."

More information: Wesley Flavell et al, Programmed Self-Assembly of Single Colloidal Gyroid for Chiral Photonic Crystals, *Advanced Materials* (2023). DOI: 10.1002/adma.202211197

Provided by University of Birmingham