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Colloidal Quasi-Crystals Discovered

An international research group led by Professor Stephan Förster of the University of Bayreuth has discovered colloidal quasi-crystals for the first time. In contrast to the quasi-crystals previously documented, which can only be produced under special laboratory conditions, they are simply structured polymers that evolve through self-assembly. Due to their structural characteristics, they will probably be used in the development of innovative devices in photonics.

In the “Proceedings of the National Academy of Sciences of the United States of America (PNAS)“, the participating scientists from Bayreuth, Zurich, Hamburg and Grenoble report this discovery.

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Unusual symmetrical structures, made visible in diffraction experiments

Quasi-crystals are characterised by a very unusual alignment of atoms. In normal crystals, atoms form ordered periodical structures; i.e. they arrange themselves into a gap-free integral overall structure, whereby one single symmetrical pattern is regularly repeated. For geometrical reasons, only 1-, 2-, 3-, 4- and 6-fold symmetries are possible. This figure indicates how frequently a structure may be rotated between 0 and 360 degrees, until it is congruent with itself. Quasi-crystals behave differently. They contain ordered aperiodic structures, i.e. there are at least two different symmetrical patterns which form a gap-free integral overall structure, despite not repeating themselves regularly. Under these circumstances, 8-, 10- or 12-fold symmetries may originate.

The structural differences between crystals and quasi-crystals can be made visible in diffraction experiments, using electro-magnetic waves. This results in diffraction patterns that provide information on the structure of crystals and quasi-crystals. The discernible symmetrical structures are termed diffraction symmetries.

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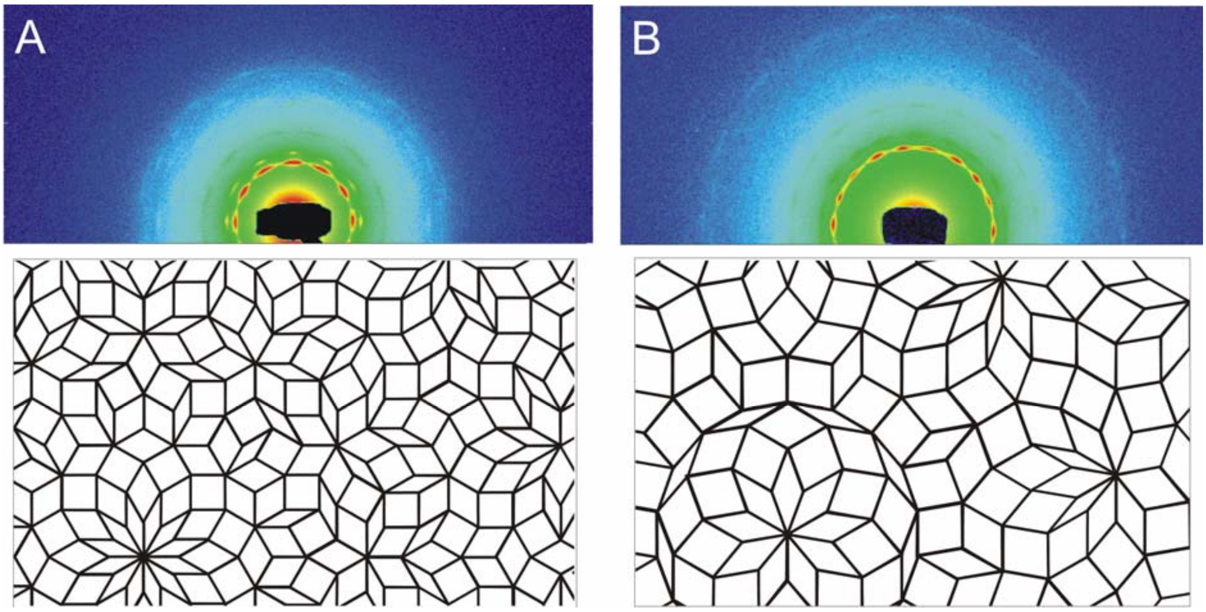

(A) Defraction image of a colloidal quasi-crystal with 12-fold symmetry; underneath the corresponding tiling / (B) Defraction image of a colloidal quasi-crystal with 18-fold symmetry; again underneath the corresponding tiling. The tilings depict the respective complete overall structures.

Colloidal quasi-crystals that evolve through self-assembly

The colloidal quasi-crystals that were discovered are hydrogels (insoluble water-containing polymers). They have a relatively simple structure and evolve by self-assembly of identical “building bricks”. Such "building bricks“ are polymer micelles: small spherical entities with a diameter ranging between 5 and 100 nanometres, which can be produced on a greater scale without any laboratory input. Therefore colloidal quasi-crystals are easily obtainable to a great number of scientists and to industry.

Professor Stephan Förster’s Bayreuth University team has been studying polymer micelles capable of forming lattice structures (i.e. on scales of up to 100 nanometres length) for a considerable period. In joint research projects with the Institute Laue-Langevin in Grenoble and the DESY in Hamburg, it was recently discovered that from such self-assembly, quasi-crystalline lattice structures may evolve. Not only was a 12-fold symmetry observed in diffraction experiments, but also an 18-fold symmetry for the very first time.

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Perspectives for innovative uses in photonics

Such experiments are under no circumstances to be considered "glass bead games" of fundamental research. Researchers in the field of photonics, a branch of physics, are interested in high-numbered diffraction symmetries applied to the development of optical technologies for the transfer and saving of information. In recent years it was shown that structures with high diffraction symmetries are characterised by the passage of light rays only in certain directions. They are a particularly suitable medium when it comes to the passage of light rays of a certain wavelength in previously defined directions. Therefore structures with high diffraction symmetries are extremely relevant to the manufacture of photonic devices.

Are the recently discovered hydrogels, with their high diffraction symmetries, suitable as “building materials” for photonics? For this to happen, one obstacle needs to be overcome: photonics requires structural characteristics of several hundred nanometres, while colloidal quasi-crystals do not extend beyond 100 nanometres. Scientists in Bayreuth, Hamburg and Grenoble are currently intensively working on the formation of quasi-crystalline larger structures, suitable for use in photonic devices, from polymer micelles. "I am optimistic that such endeavours will soon be successful“, says Professor Stephan Förster.

Quasi-crystals – no longer a laboratory curiosity

Colloidal quasi-crystals are expected to be far more suitable for uses within photonics than the approx. 100 quasi-crystalline compounds known to date. These are nearly all metal alloys that can only be produced in small amounts and under special laboratory conditions. Furthermore, these quasi-crystalline structures range in size between 0.1 and 1 nanometre. For practical use in photonics, they are first and foremost far too small. In order to produce quasi-crystalline structures for photonics, up until now very intricate electrolithographic processes were required.

The very existence of quasi-crystals was first proven in 1984 by a research team fronted by the American physicist Dan Shechtman. Afterwards, quasi-crystals were considered a laboratory curiosity for a long period, until photonics researchers were alerted to their unusual structural characteristics.

The international research team now publishing their discovery of colloidal quasi-crystals, includes Stephan Förster and his Bayreuth University team, Professor Walter Steurer and Dr Sofia Deloudi (ETH Zurich), Dr Peter Lindner (ILL Grenoble) and Dr Jan Perlich (DESY Hamburg).

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Photo page 1:
Professor Dr. Stephan Förster, University of Bayreuth; free for publication.

Diffraction images page 2:
Department of Physical Chemistry, University of Bayreuth;
free for publication when references are included.

Photo and diffraction images in high resolution for download:
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