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Soft Quasicrystals - a D11 discovery

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Quasicrystals are a peculiar state of order, which is fundamentally different from classical ordered crystalline states. Discovered in 1982 for MnAl-alloys, it has since then been found for more than 100 different metal alloys.

In a 2009 D11 summer nightshift we discovered a micellar phase showing an unusual SANS-pattern with 12-fold rotational symmetry. When published in 2011, it was the third ever reported non-metallic dodecagonal quasicrystalline phase. Non-metallic quasicrystals have since then been found also for block copolymers, nanoparticles, colloids, or fullerenes. This indicates that quasicrystals are a quite common state of matter.

We have since then shown by X-ray and neutron scattering experiments as well as MD-simulations that particles with soft repulsive interactions form a distinct set of two- and three-dimensional quasicrystalline states with 8-, 10- and 12-fold rotational symmetry. We investigated quasicrystals formed by block copolymers, nanoparticles and colloids covering length scales from 10 nm to 500 µm. We observe surprisingly good agreement between the predicted and observed quasicrystalline structures and their stability regions in 2D- and 3D-phase diagrams. We further show that all so far reported non-metallic quasicrystals including dendrons, star and block copolymers, nanoparticles, polymer-grafted nanoparticles, colloids, mesoporous silica as well as BaTiO3-, fullerene, and organo-framework monolayers can be derived from this set of quasicrystalline structures. Furthermore, we demonstrate a direct link between non-metallic quasicrystals derived from repulsive potentials and metallic quasicrystals derived from attractive potentials. We show that the existence of two intrinsic length scales is essential for the formation of both non-metallic and metallic quasicrystals, facilitating locally high coordination and thereby optimizing sphere packing.

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