Generalized Quasiperiodic Structures

Intermetallic quasicrystals. Locally, their structures do not differ essentially from other complex intermetallics and the same is true for most of their physical properties. Fundamentally different, however, is the quasiperiodic long-range order of their structures and peculiar are the physical properties that depend on the kind of long-range order. These are, in the first place, properties based on the propagation of electrons, phonons, and, to some extent, also of dislocations. Fundamentally different is also their noncrystallographic point-group symmetry with its implications on physical properties. For instance, icosahedral quasicrystals have fully isotropic elastic properties such as amorphous materials. The elasticity tensor of $i$-QC has only two independent coefficients while one of the cubic crystals has three. However, despite these new options, their are no real unique applications for quasicrystals up to date.

Soft quasicrystals. Recently, quasiperiodic ordering on a mesoscopic scale has been observed in several nonmetallic materials such as micellar liquid crystals and star block copolymers. The building blocks, on the scale of a few nanometers to tenths of nanometers, order to quasicrystalline domains up to micrometers. The symmetry of these soft quasicrystals is, at least on average, dodecagonal. A short overview will be given in Sect. 11.1, for a review see [7].

Artificial quasicrystals. The peculiar propagation of waves in quasiperiodic structures can lead to band gaps in a similar way as it is known for periodic structures. Combined with arbitrarily high rotational symmetry, fully isotropic band gaps can result. Materials of this kind would easily find application in all kinds of devices for the manipulation of electromagnetic waves, from microwaves to light waves. The same is true of the manipulation of elastic waves, from acoustic to ultrasonic waves. This is the reason for the recent boom in the development of quasiperiodic photonic and phononic crystals (for a review see [15]). A short introduction into the basics will be given in Sect. 11.2.
11.1 Soft Quasicrystals

The factors governing the formation of soft quasicrystals are largely different from those controlling formation and stability of intermetallic quasicrystals. In the latter case, electrons play a decisive role although this may not apply in the same way to the dodecagonal tantalum tellurides (see Sect. 8.4). Remarkably, self-organized soft quasicrystals have been observed with dodecagonal symmetry only. The origin of this behavior has been ascribed to the existence of two different length scales and three-body interactions\(^1\) [7].

Particular micellar systems, where the supramolecular micelles are built up of wedge- or cone-shaped mesomorphic dendrons, can form solvent-free liquid dodecagonal quasicrystals [24] (Fig. 11.1). As a function of temperature, the originally columnar hexagonal close packed structure transforms into the dodecagonal liquid quasicrystal \(d\)-LQC. A further increase in temperature leads to the phase sequence \(d\)-LQC \(\Rightarrow Pm\bar{3}n \Rightarrow P4_2/mnm \Rightarrow bcc\).

The other class of soft quasicrystals known so far are three-component polymeric quasicrystals. ABC star-shaped terpolymers, consisting of polyisoprene \((I)\), polystyrene \((S)\) and poly(2-vinylpyridine) \((P)\), form cylinder

![Fig. 11.1. Self-assembly of wedge- or cone-shaped tree-like molecules (dendrimers). The wedge-shape leads to cylindrical columns, which mostly assemble to hexagonal cylinder packings. If the chains need more space at higher temperature, the now cone-shaped molecules assemble to sphere-like micelles. These can adopt different structures as a function of temperature. In case of the molecule named dendron I, the dodecagonal liquid quasicrystal forms. The edge length and periodicity along the 12-fold axis of the structure model shown amounts to 81.4 Å [24] \(^1\) The ultra-soft repulsion of the building blocks and the resulting strong overlapping of their coronas lead to significant triplet interactions [19].]