Chapter 7
Space of Nanoworld

G. V. Zhizhin
Skolkovo OOO – Adamantan, Russia

M. V. Diudea
Babes-Bolyai University, Romania

ABSTRACT

In this chapter, a geometrical model to accurately describe the distribution of light points in diffraction patterns of quasicrystals is proposed. It is shown that the proposed system of parallel lines has axes of the fifth order, periodically repeating the fundamental domain of the quasicrystals. A 4D- polytope, called the golden hyperrombohedron is introduced. It consists from eight rhombohedrons densely filling the 4D space (like the regular 8-Cell). Faces of the hyperrombohedron are connected by the golden section; they can be scaled as needed. On this universal lattice of the golden hyperrombohedron, famous crystallographic lattices: Bravais, Delaunay, Voronoi, etc. can be embedded. In supporting the idea of n-dimensional domains entangled within the three-dimensional Euclidean space, in minerals or synthetic chemicals, two series of small double-shell clusters are designed by operations on maps and their topological properties discussed.

INTRODUCTION

Finding in 1982 of ordered structures deprived of translational symmetry (Shechtman et al., 1984), next called “quasicrystals”, had marked the beginning of numerous cycles of papers and books devoted to the experimental and theoretical study of these unusual materials. The main problem was to prove that the lack of translational symmetry does not contradict the existence of the crystal, even it is mandatory in the classical crystallography. It was noted (Janssen et al., 1984) that the absence of visible strict periodicity in quasicrystals does not mean randomness (i.e. disorder) of such structures. Approximants of quasicrystals can be described in terms of almost-periodic functions (Bohr, 1952). Almost-periodic (or quasi-periodic, aperiodic) functions occur when periodic functions with incommensurable periods (expressed by irrational numbers) are involved. It was shown that, in order to obtain a clear diffraction pattern, it is not necessary to have a strict periodicity of the crystal, but rather a quasi-periodicity. Moreover, the diffraction pattern retains its form by modulation of periodic structures by irrational numbers.

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However, the quasi-periodic functions do not conflict with the axes of the fifth and tenth-order diffraction patterns, observed in quasicrystals, banned in the strictly periodic structure. The presence of these axes in the diffraction patterns of quasicrystals promoted attempts to explain the structure of quasicrystals by means of convex polyhedrons with axes of the 5-th order, i.e., icosahedron and dodecahedron (Shechtman & Blech, 1985). Many studies have been devoted to the qualitative explanation of diffraction patterns of quasicrystals by Penrose tiling (Penrose, 1979). However, icosahedrons cannot fill the three-dimensional space without cracks and gaps and therefore the description of the diffraction patterns of quasicrystals using icosahedrons is impossible; also, the geometric elements of Penrose rhombic tiling in the diffraction patterns are absent. Pauling (1987) explained the diffraction patterns of icosahedron apparent symmetry by multiple twinning of cubic crystals. He based his arguments only on the radial intensity distribution of the spots of diffraction patterns. However, this model could not explain the high-resolution micrographs and diffraction patterns with the distribution of spots different from those proposed by Pauling (Gratias & Cahn, 1986). Other recent attempts (Janssen et al., 2007) also failed in reproducing the accuracy of the observed diffraction patterns.

Figure 1 illustrates the electron diffraction pattern of the cluster Al₆ Mn (Shechtman et al., 1984). The same countenance is shown by the electronic diffraction patterns of many other compounds: Al₆₋ₓFeₓW₁₀ (Mukhopadhyay et al., 1993) (Figure 3), Al₁₂ Ni₂₀ Co₈ (Eiji Abe et al., 2004) (Figure 2), Ti₅₄ Zr₂₆ Ni₂₀ (Zhang & Kelton, 1993) (Figure 4). Clearly, the diffraction patterns show, at the center, a bright spot that correspond to the crash of the electron beam on the sample. Less bright spots of various sizes form a complex geometric pattern away from the center. The diffraction patterns emanating from the center form the axis of rotation of the 10th order, which is perpendicular to the plane of diffraction patterns. In the vicinity of the central spot, the smaller ones form regular pentagons, adjacent to each other. The distance between the spots increases away from the center of the diffraction patterns along the lines passing through the center, while smaller pentagons are formed inside larger pentagons. Spot sizes and the distance between them can vary depending on the experimental conditions, the composition of matter and the used device.

Figure 1. Electron diffraction pattern compound Al₆ Mn

Figure 2. Electron diffraction pattern of Al₇₂ Ni₂₀ Co₈