Decagonal Quasicrystals and Approximants - 2D or 3D Solids

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Decagonal quasicrystals (d-QCs) and their periodic approximants are traditionally described as a periodic stacking of atomic planes with either quasiperiodic atomic order in one plane in the case of d-QCs, or translationally periodic order in three directions in the case of the approximants. Consequently, d-QCs are considered to be two-dimensional (2D) quasicrystals, whereas they are periodic crystals in the third dimension. Examples of the stacked-layers d-QC structures are d-Al-Ni-Co with two atomic layers within the periodicity length of about 0.4 nm along the stacking tenfold direction, d-Al-Ni, and d-Al-Si-Cu-Co with four layers within the periodicity length of about 0.8 nm, d-Al-Mn, and d-Al-Mn-Pd with six layers within the periodicity length of about 1.2 nm and d-Al-Pd and d-Al-Cu-Fe with eight layers within the periodicity length of 1.6 nm. Decagonal approximant phases are characterized by large unit cells but preserve the stacked-layer structure with the periodicity lengths along the stacking direction almost identical to those of the d-QCs. Decagonal approximant, known as the Y phase of Al-Ni-Co, comprises two atomic layers within one periodic unit. The other Al13TM4 (TM=transition metal) family with TM = Co, Fe, ... , represents four-layer approximant phases, whereas the Al4TM phases, and Taylor-phase T-Al3Mn represent six-layer approximant. In order to see whether this pseudo-2D description is justified also from the chemical bonding scheme, or the compounds are true 3D solids, we performed transport and a 27Al NMR spectroscopic studies of single crystals the members of the Al13TM4 family. From the structural and the physical-property points of view, the Al13M4 decagonal approximants are true 3D solids. Their description in terms of 2D atomic layers stacked along the pseudotenfold direction is a convenient geometrical approach to describe and visualize their complex structures but is not appropriate for the description of their physical properties, which should be analyzed by taking into account the full 3D nature of the chemical bonding framework.