Atomic arrangement of Al-Rh-Cu decagonal quasicrystal investigated by Cs-corrected scanning transmission electron microscopy

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Atomic arrangement of Al-Rh-Cu decagonal quasicrystal investigated by Cs-corrected scanning transmission electron microscopy

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Recent Cs-corrected STEM has an enough resolution to reproduce separately individual transition-metal atoms in projected structures of DQCs along the periodic axis, and so arrangements of transition-metal atoms can be directly determined from observed HAADF-STEM images. By spherical aberration (Cs)-corrected high-angle annular detector dark-field (HAADF)- and annular bright-field (ABF)-scanning transmission electron microscopy (STEM), the atomic arrangement of an Al-Rh-Cu decagonal quasicrystal (DQC) formed with two quasiperiodic planes along the periodic axis in an Al$_{63}$Rh$_{18.5}$Cu$_{18.5}$ alloy has been investigated [1].

Heavy atoms of Rh, and mixed sites (MSs) of Al and Cu atoms projected along the periodic axis can be clearly represented as separate bright dots in observed HAADF-STEM images, and consequently arrangements of Rh atoms and MSs on the two quasiperiodic planes can be directly determined from those of bright dots in the observed HAADF-STEM image in Fig. 1(a).

Figure 1. HAADF-STEM (a) and ABF-STEM (b) images of the Al-Rh-Cu DQC, taken with the incident beam parallel to the periodic axis. In (a), one can see concentric circles of bright dots with 1.2 nm and 2 nm in diameter, as indicated by small and large white circles, respectively, which are drawn in a size larger so that arrangements of bright dots in those circles can be easily seen. In (b), ring contrasts indicated by a small circle are observed. The ring contrasts are arranged with a constant interval of 0.66 nm, and large clusters formed with ten ring contrasts arranged by ten-fold rotational symmetry are observed at some places, as indicated by a large circle.
The Rh atoms are arranged in pentagonal tiling formed with pentagonal and star-shaped pentagonal tiles with an edge-length of 0.76 nm, and also MSs with a pentagonal arrangement are located in the pentagonal tiles with definite orientations. The star-shaped pentagonal tiles in the pentagonal tiling are arranged in $\tau^2$ ($\tau$: golden ratio)-inflated pentagonal tiling with a bond-length of 2 nm.

From arrangements of Rh atoms placed in pentagonal tilings with a bond-length of 2 nm, which are generated by the projection of a five-dimensional hyper-cubic lattice, occupation domains in the perpendicular space are derived. Al atoms as well as Rh atoms and MSs are represented as dark dots in an observed ABF-STEM image as shown in Fig.1(b).

Observed ABF- and HAADF-STEM images clearly show the existence of bond-orientational order (BOO) for the atomic arrangement [2-4]. The present model of the Al-Rh-Cu DQC is basically different from the structure proposed by single-crystal X-ray diffraction [5], in respect of the presence of the 0.76 nm pentagonal tiling of Rh atoms and MSs of Al and Cu atoms.


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