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

K. Yubuta[1], A. Yasuhara[2], K. Yamamoto[3], K. Hiraga[1]

[1] *Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan*

[2] *EM Application Group, EM Business Unit, JEOL Ltd., Tokyo 196-8558, Japan*

[3] *Department of Physics, Nara Women's University, Nara 630-8506, Japan*

yubuta@imr.tohoku.ac.jp

Recent *C*s-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 (*C*s)-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).

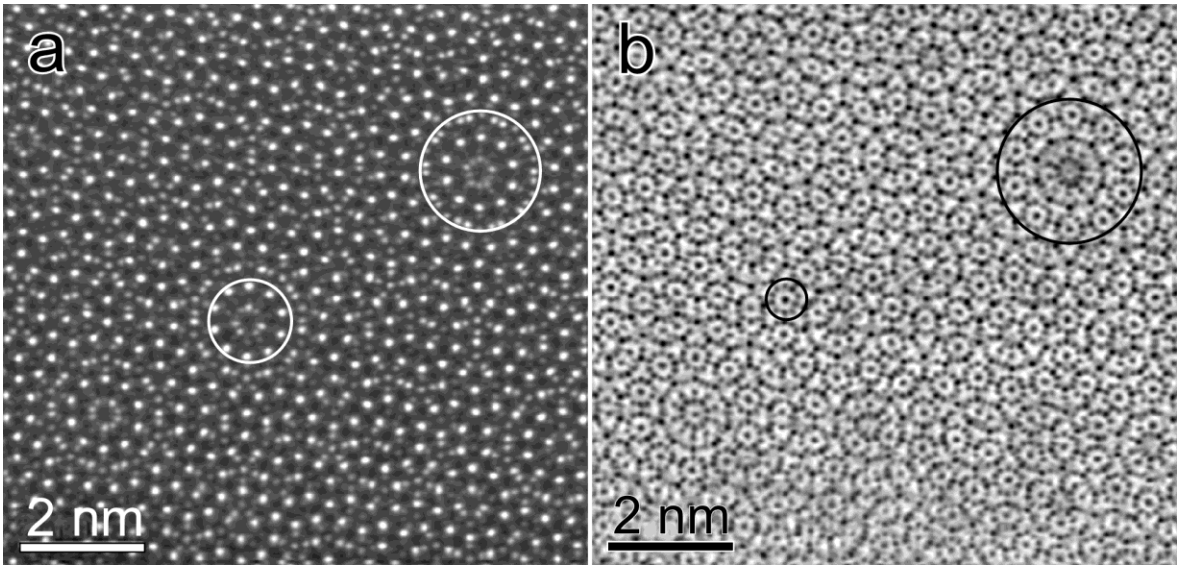

Figure 1. HAADF-STEM (a) and ABF-STEM (b) images of the Al-Rh-Cu DQC, taken with the incident beam parallel to the periodic axis. In (a), one can see concentric circles of bright dots with 1.2 nm and 2 nm in diameter, as indicated by small and large white circles, respectively, which are drawn in a size 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 ob-served 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 τ^2 (τ: golden ratio)-inflated pen-tagonal 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.

1. K. Hiraga, A. Yasuhara, K. Yamamoto, K. Yubuta, *Phil. Mag.*, **95**, (2015), 1524.

2. K. Hiraga, A. Yasuhara, *Mater. Trans.*, **54**, (2013), 493.

3. K. Hiraga, A. Yasuhara, *Mater. Trans.*, **54**, (2013), 720.

4. K. Yubuta, K. Yamamoto, A. Yasuhara, K. Hiraga, *Mater. Trans.*, **54**, (2014), 866.

5. P. Kuczera, J. Wolny, W. Steurer, *Acta Cryst.*, **B68**, (2012), 578.

Acknowledgement

This work was supported by JST CREST Grant No. JPMJCR1322.