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Surface Decorations of Al–Cu–Fe and Al–Cu–Co Single Quasicrystals

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We studied surface decorations of faceted icosahedral Al–Cu–Fe and decagonal Al–Cu–Co single quasicrystals by the scanning electron microscopy using primary and secondary electrons. Both types of single quasicrystals exhibited decorations on their facets, however the character of the decorations was totally different. Three kinds of decorations has been developed. On icosahedral $Al_{60}Cu_{26}Fe_{14}$ quasicrystals we found three kinds of decorations: cellular, cavity type and fractal-like. There was no evident difference in chemical composition between the inner dodecahedra and the decorations of all types. Surface decorations found on decagonal $Al_{73.5}Cu_{17.5}Co_{9}$ quasicrystals formed a kind of irregular dendritic stars on the separate bright islands.

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1. Introduction

The crystallization mechanism of icosahedral and decagonal quasicrystals involves a peritectic reaction. In spite of that polyhedral growth forms are commonly obtained [1–3]. Facets of single quasicrystals are not always flat having smooth surfaces; rather they exhibit fractal-like dendritic decorations [4], faceted voids or microholes [5–7]. Fractal-like dendrites on threefold facets were found to show an approximately threefold arrangement of the main decoration branches. An analogous correspondence of symmetry has been observed for fivefold facets [4]. Polygonal microvoids detected on facets of Al–Pd–Mn quasicrystals were depleted in Mn and enriched in Pd compared to the bulk [5]. Surfaces of voids created due to coalescence of vacancies exhibited decorations with fractal-like morphology [6, 7]. On the other hand, perfect, highly faceted microvoids formed by condensation of thermal vacancies have also been observed [8].

The growth of high density microvoids in Zn–Fe–Sc quasicrystals is understood as thermally activated, too [9].

The contribution reports on investigations of facet decorations formed during crystallization of polygonal single quasicrystalline ψ phase occurring in Al–Cu–Fe as well as decorations formed on flat facets of decagonal Al–Cu–Co single quasicrystals.

2. Experimental details

Polyhedral equilibrium single grains of the ψ phase were obtained by a peritectic reaction inside of ingots of an Al–Cu–Fe alloy with nominal composition of 65 at.% Al, 20 at.% Cu, and 15 at.% Fe. The specimens were synthesized in a helium atmosphere using a Bridgman–Czochralski-Growth (BCG) apparatus equipped with an induction furnace [10].

Decagonal single quasicrystals of $Al_{73.5}Cu_{17.5}Co_{9}$ have been obtained by inclined front crystallization technique [11]. The decagonal phase crystallizes also during the peritectic reaction forming a porous part of the ingot. After crushing the ingots polygonal single quasicrystals with decorated facets were detected inside the pores.

The surface topography was investigated by scanning electron microscopy (SEM) using primary and secondary electrons. In order to determine the chemical composition we also applied selected area diffraction (SAD) and energy-dispersive X-ray spectroscopy (EDX).

3. Results

Single quasicrystals of the ψ-phase exhibit icosahedral symmetry with pentagonal dodecahedral growth forms 12 faces perpendicular to the fivefold axes (Fig. 1a). The dodecahedra have irregularities and various edge lengths up to 160 μm. The faces of the dodecahedra are not perfectly smooth and show some residual flux. Some of the dodecahedra are uniformly covered by cellular type decorations (Fig. 1a) or by cavity type decorations (Fig. 1b) gradually covering almost all facets. During the next stage of the decoration process secondary fractal-like decorations appeared on the quasicrystal surfaces (Fig. 1c). There was no evident difference in chemical composition between the inner dodecahedra on one hand and the cellular decorations and the secondary fractal-like decorations on the other hand. The maximum difference in Al concentration was less than 2% and 0.4% of the Fe content.

The decorations observed on decagonal Al–Cu–Co quasicrystals have sizes up to 20 μm (Fig. 2b). They are different from those on the Al–Cu–Fe quasicrystals

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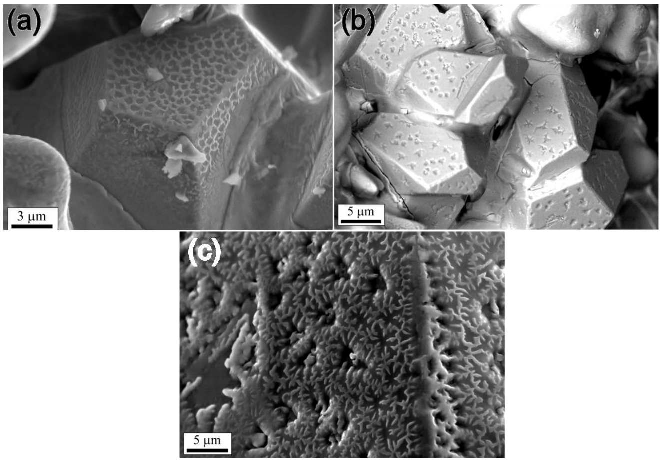

Fig. 1. Decorations on pentagonal faces of the ψ phase: (a) primary cellular decoration, (b) cavity type decorations, (c) secondary fractal-like decoration.

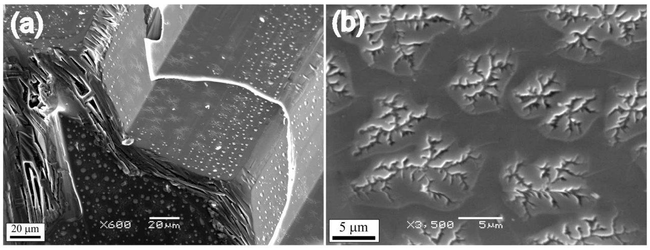

Fig. 2. Decorations on decagonal facets of Al–Cu–Co single quasicrystal: (a) decorating stars on quasicrystal facets; (b) single decorating islands with fractal cracking.

(Fig. 2a). The individual decorations have a characteristic dendritic star-like shape exhibiting black-white contrast. The stars sit on regions of brighter contrast with shapes and dimensions matching those of the stars (Fig. 2b). Additional decorations in a form of white spots are visible in the lower part of Fig. 2a. There was a noticeable difference in chemical composition between the bright islands with dendritic stars and the surrounding surface; the Al concentration was slightly higher on the islands.

4. Conclusion

The phenomenon of the decoration of quasicrystal surfaces is not completely understood. The facets of icosahedral Al–Cu–Fe dodecahedra are decorated in similar way as the fivefold facets of Al–Pd–Mn quasicrystals found by Beeli and Nissen [4]. In our case, however, there is no relationship between the symmetry of the facets and the symmetry of the dendrites.

In their systematic investigations of decorations on Al–Pd–Mn quasicrystal facets, Lück et al. [6], as well as Beeli et al. [7] conclude that the decorations consist of precipititations at the surface formed by diffusion induced local equilibrium. These authors state that the material of the decorations is poorer in Al-content.

In our observations of Al–Cu–Fe quasicrystals we have found more types of decoration morphology: cellular, cavity type and fractal-like apparently formed as a result of the precipitation process.

We assume that the different character of decorations on Al–Cu–Co decagonal facets is also a consequence of a precipitation process resulting in the formation of bright islands. A relatively thin layer of precipitate promotes cracking, thus enhancing the phenomenon of decoration. The precipitate layer on the bright islands exhibited enrichment of Al. Additional decorations randomly distributed on the Al–Cu–Co quasicrystals visible as white spots on the lower part of Fig. 2a form another type of precipitate decorations.

References

[1] T. Ishimasa, M. Mori, *Philos. Mag. Lett.* **62**, 357 (1990).

[2] T.A. Lograsso, D.W. Delaney, *J. Mater. Res.* **11**, 2125 (1996).

[3] I.R. Fisher, M.J. Kramer, Z. Islam, T.A. Wiener, A. Kracher, A.R. Ross, T.A. Lograsso, A.I. Goldman, P.C. Canfield, *Mater. Sci. Eng A* **294-296**, 10 (2000).

[4] C. Beeli, H.-U. Nissen, *Philos. Mag. B* **68**, 487 (1993).

[5] S. Suzuki, Y. Waseda, K. Urban, *Mater. Trans* **39**, 314 (1998).

[6] C. Beeli, T. Gödecke, R. Lück, in: *Proc. 6th Int. Conf. on Quasicrystals*, World Scientific, Singapore 1998, p. 421.

[7] R. Lück, T. Gödecke, C. Beeli, *MRS Symp. Proc.* **634**, K2.4.1 (2001).

[8] C. Beeli, T. Gödecke, R. Lück, *Philos. Mag. Lett.* **78**, 339 (1998).

[9] T. Ishimasa, J. Matsunagi, *Philos. Mag.* **88**, 1985 (2008).

[10] M. Surowiec, W. Bogdanowicz, J. Krawczyk, B. Formanek, M. Sozanska, *Philos. Mag.* **91**, 2458 (2011).

[11] W. Bogdanowicz, *J. Cryst. Growth* **240**, 255 (2002).