Search for Ga-based icosahedral quasicrystal

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Introduction

Quasicrystals are defied as a solid which has the sharp Bragg peaks as a conventional crystal but loses the lattice translational symmetry in physical space. Recently, some interesting behaviours in quasicrystals (and its related approximants) such as superconductivity [1], quantum critical phenomena [2] as well as various magnetic transitions [3] *etc.* are demonstrated. However, such properties are still limited in quasicrystals. Thus, new icosahedral quasicrystals (*i*-phases) in novel alloys may open a new research field of quasicrystal society.

Since the discovery of the stable quasicrystal in ternary Al-Cu-Fe [4] alloy, Al-transition metals (TMs)-based stable *i*-phases have been reported. These *i*-phases were discovered by the Hume–Rothery rules, which is a tendency for a specific crystal structure to form at a characteristic ratio of the number of itinerant electrons per atom (e/a) [5], as a guide. In the case of Al-TM type *i*-phases, this e/a values are known around 1.8. Recently extensively studied or discovered quasicrystals, which may be classified as Tsai-type *i*-phases, the e/a values are known around 2.0. Our motivation is to search for the Ga-based *stable i*-phase similar to those in Al-TM systems as well as number of alloy systems of Tsai-type systems.

We chose the Ga-Ru-Cu system and the Ga-Ni-(Hf, Zr, and Sc) systems to search for the Ga-based *stable i*-phase. The former is the counterpart of Al-Ru-Cu alloy, which has the widest formation range of the stable *i*-phase of all known Al-TM alloys [6]. The latter is known to form the 1/1 approximant phase in the literature [7].

To clarify the presence or absence of a stable *i*-phases (or the possibility of new intermetallic phases), we construct the isothermal section of the ternary diagram of Ga-Ru-Cu system and the Ga-Ni-(Hf, Zr, and Sc) system in experimentally.

Experimental

High-purity elements with appropriate amount were melted by an arc-melting on a water-cooled Cu hearth. The obtained mother ingot was then sealed inside a quartz tube under a pure Ar atmosphere and annealed at appropriate temperature for typically 48 – 72 hours in an electronic furnace. The phase constitutions / compositions were studied by powder X-ray diffraction (XRD) as well as scanning electron microscopy/energy dispersive X-ray spectroscopy (SEM/EDX) measurements. Some alloys were also examined by the transmission electron microscopy (TEM).

Results and discussion

Figure 1 show the ternary phase diagram of Ga-Cu-Ru system at 1073 K determined by our experiments. No *i*-phase (as well as its approximant phase) are not discovered. However, we found only one ternary phase namely τ-phase [8] with the ideal composition of $Ga_{50}Ru_{37.5}Cu_{12.5}$, which have the *C*-centered orthorhombic lattice with *a* = 11.80 Å, *b* = 6.04 Å and *c* = 3.07 Å. This intermetallic phase is strongly related to the GaRu phase.

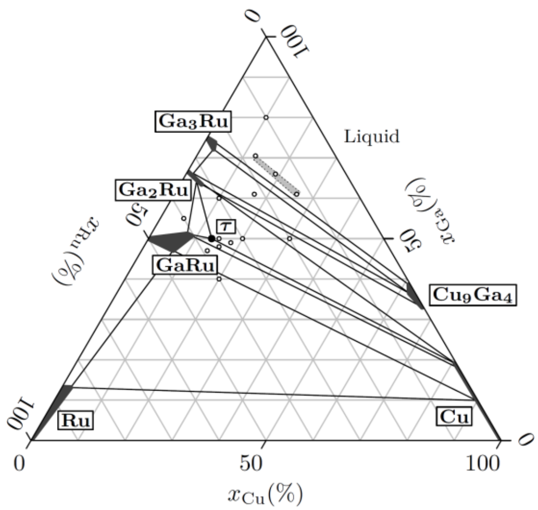

Figure 1. Ternary diagram of the Ga-Ru-Cu system at 1073 K determined by our experiments [8].

Ga-Ni-(Sc, Zr, and Hf) systems were reported to form 1/1 approximant (classified as Tsai-type approximant), however, its formation condition as well as the possibility of the formation of *i*-phase are not fully discussed. In this presentation we will demonstrate the phase diagram of Ga-Ni-(Sc, Zr, and Hf) and also discuss the possibility of *i*-phases.

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