

# New series of icosahedral and crystal approximants in (Al, Ga, In)-Pd-(Rare earth metal) systems

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Quasicrystals are condensed matters having long-range translational order with crystallographically disallowed rotational symmetry. Since the discovery of an icosahedral phase (i-phase) in a rapidly quenched Al-Mn alloy in 1984, much effort has been devoted to searching for new alloy systems in which i-phases are formed. In the present study, we report new series of i-phases and corresponding crystal approximant phases in (Al, Ga, In)-Pd-(Rare Earth Metal) alloys.

Ternary (Al, Ga, In)-Pd-RE alloys with various compositions were prepared by Ar arc-melting. The alloys were subsequently subjected to single-roller melt spinning. The alloys were sealed in evacuated silica tubes and annealed at various temperatures. Phase formation, composition, atomic structure of the alloys were characterized by a X-ray diffraction measurement (XRD), electron diffraction measurement (ED), scanning electron microscopy equipped with energy dispersive spectroscopy (SEM-EDS) and high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM).

FIG. 1 shows XRD spectra for the  $\text{Al}_{53.6}\text{Pd}_{30.0}\text{Sc}_{16.4}$  i-phase and  $\text{Al}_{55}\text{Pd}_{30}\text{Sc}_{15}$  1/1-phase. The quasilattice constant of the i-phase was evaluated to be 0.507 nm. The i- and 1/1-phase have also been found to form in Al-Pd-RE (RE = Yb, Tm and Er), Ga-Pd-Sc and In-Pd-RE (RE = Y, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, and Tm) alloys by the substitution of Al for (Ga, In), or Sc for other RE in the constituent elements of the Al-Pd-Sc i-phase. FIG. 2 and FIG. 3 show typical examples of ED patterns of the Al-Pd-Yb i-phase and the Ga-Pd-Sc 1/1-phase, respectively. For the i- and the 1/1-phases found in this study, the valence electrons per atom ( $e/a$ ) ratio is 2.10, and the ratio of the atomic radius of the rare earth element to that of the other base elements is in the range 1.15–1.24, which is within the range of the values reported for other Tsai-type i-phases [1, 2]. HAADF-STEM imaging directly confirmed that the 1/1-phases have a periodic arrangement of the Tsai-type icosahedral cluster.

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## References

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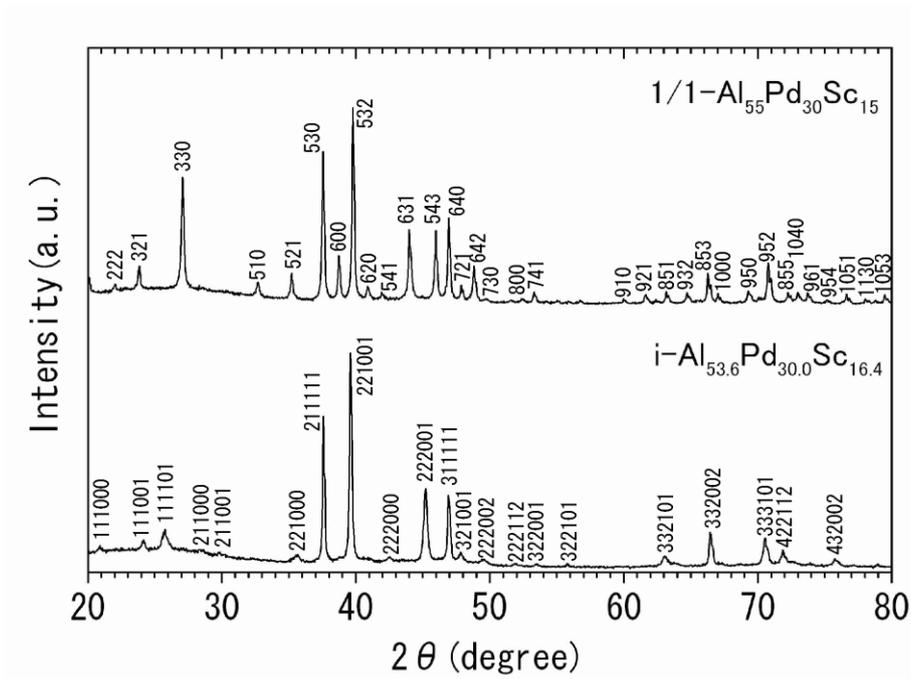


FIG. 1. X-ray diffraction spectra for Al-Pd-Sc icosahedral and 1/1-approximant phases.

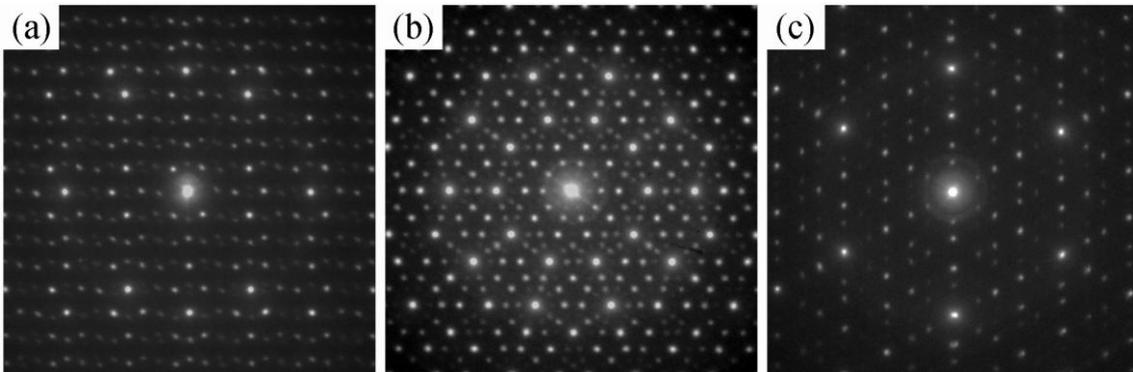


FIG. 2. Electron diffraction patterns of  $\text{Al}_{54}\text{Pd}_{30}\text{Yb}_{16}$  icosahedral quasicrystal taken along (a) 2-fold, (b) 5-fold and (c) 3-fold directions.

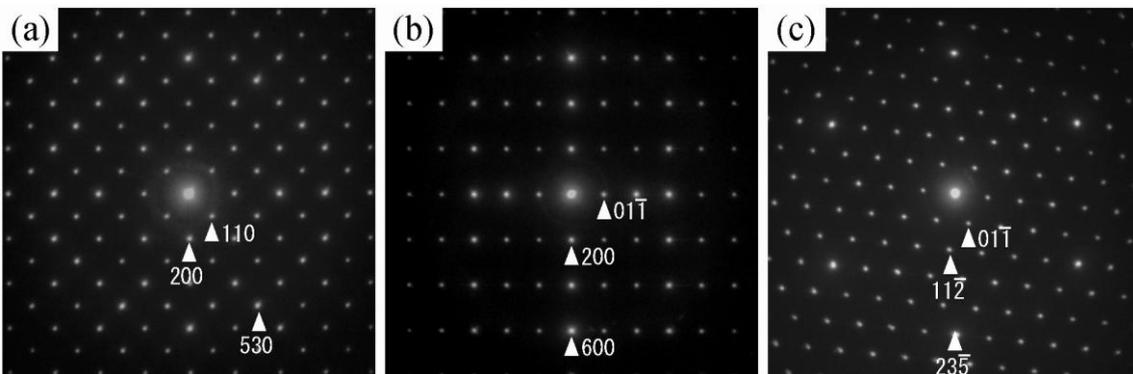


FIG. 3. Electron diffraction patterns of  $\text{Ga}_{55}\text{Pd}_{30}\text{Sc}_{15}$  1/1-approximant taken along (a)  $[001]$ , (b)  $[011]$  and (c)  $[111]$  directions.