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Characterization of Guinier-Preston Zones in Mg-Gd-Zn Alloys by Using Transmission Electron Microscopy

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The investigation of Mg-based alloys become increasingly activated because of their attractive features such as quite low density and high strength mechanical properties, aiming at the development of a newly structural material. Especially, Mg-Gd-Zn alloys have been found to reveal remarkable age-hardening effects. It is also interesting that these materials generate a wide variety of precipitations (β'-, β1- ,LSPO[1] and Guinier-Preston zones (GP-Zones) [2]) through the aging treatment. According to a recent study about Mg-Gd-Zn alloys, the microstructures of precipitations significantly change depending on the composition of Gd/Zn and thermal history. Besides, when a composition ratio of Gd to Zn is between 1 and 1.5, GP-zone precipitation is preferentially generated. And a rather complex texture appears with an advance of aging treatment.

In this study, we focus on the GP-zone in Mg-Gd-Zn alloys and characterize their growth process. And we report results on the structural features of the GP-zones using a transmission electron microscope.

Alloys with nominal compositions of $Mg_{98}Gd_{1.0}Zn_{1.0}$, $Mg_{99}Gd_{0.5}Zn_{0.5}$ (Gd/Zn=1), and $Mg_{97.5}Gd_{1.5}Zn_{1.0}$ (Gd/Zn=1.5) were prepared by melt-mixing in carbon crucibles using an induction heating system under Ar gas atmosphere. The purities of material metals were 99.9% (Mg and Gd) and 99.95% (Zn). The alloys were annealed at 520℃ for 2 hrs and aged at 200℃ for various periods of time, and they were finally quenched in water. Thin specimens for a TEM observation were prepared by ion-milling method. STEM HAADF images were acquired by a field emission electron microscope, JEM-2100F (TEM / STEM).

Selected area electron diffraction patterns of $Mg_{97.5}Gd_{1.5}Zn_{0.5}$ alloy aged at 200˚C for 100 hours are shown in Figs..1(a) and 1(b). The incident directions for these electron diffraction patterns are [001] and [1-10] of the Mg matrix (which has a Hexagonal Closed Packed (HCP) structure). These patterns include the reflections due to GP-zones. In fact, they show that extra spots corresponding to 1/3 1/3 0-type reflections in Fig. 1(a) and streak reflections in Fig.1 (b), both of which are originated from the GP-zones present perpendicular to the c-axis of the Mg matrix.

Figure 2 shows a STEM HAADF image observed from the direction perpendicular to c-axis of $Mg_{97.5}Gd_{1.5}Zn_{0.5}$ alloy, which was annealed at 200˚C for 100 hours. Sharp bright lines (ranged between 50 and 100 nm in length) are observed. These lines correspond to the GP-Zones being parallel to the c-plane of the Mg matrix.

In Fig.3, high-resolution STEM HAADF images of the GP-zone in the Mg-Gd-Zn alloys(taken by the incident beam directions with [1-10] and [100], respectively) are shown. These results indicate that the GP-zones are arranged high-integrity with the HCP-Mg matrix and composed of such a heavy elements as Gd and/or Zn. From our other results, it is indicated that the GP-Zones in Mg-Gd-Zn alloys change their microstructures with an advance of aging in the following way; Wavy GP-Zone→Planar GP-Zone→multi-layered GP-Zones(→Stacking fault)[3].

References:

[1] M. Yamasaki et al., Acta Mater. 55 (2007) p.6798

[2] M. Nishijima et. al., Mater. Trans. 49 (2008) p.227A.

[3] K. Saito et al., J. Alloy and Comp. 509 (2011) p2031

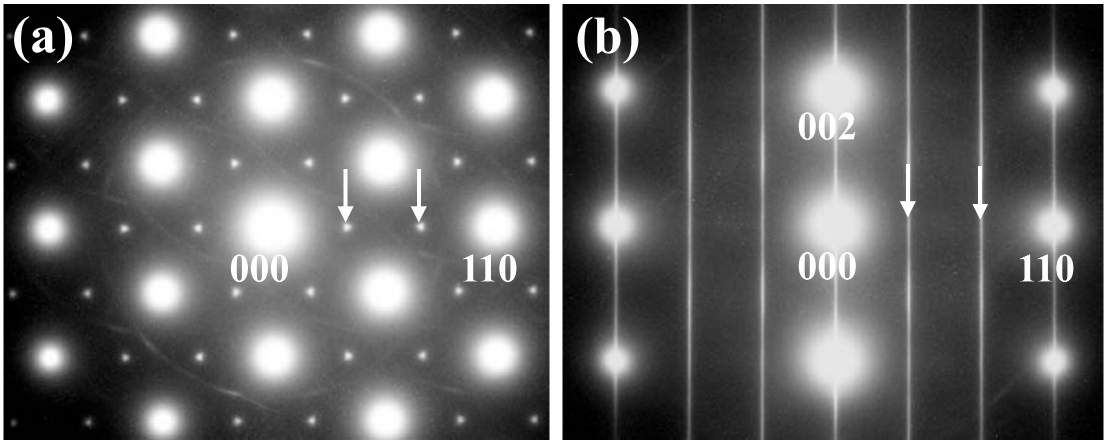

Fig.1 Selected Area Electron Diffraction Pattern of $Mg_{98}Gd_{1.5}Zn_1$ alloy annealed at 200℃ for 100hours. Each diffraction pattern (a)and (b)was recorded with the incident beam parallel to a [001] and [1-10] direction of the Mg matrix. Extra spots and steak reflections indicated by[white arrows were both originated from GP-zone.

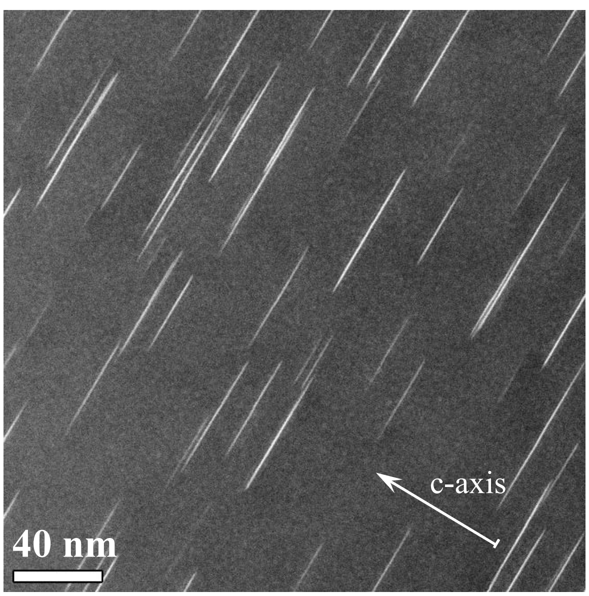

Fig.2 STEM HAADF image of $Mg_{98}Gd_{1.5}Zn_1$ alloy annealed at 200℃ for 100hours, taken with the incident beam perpendicular to a c-axis of the Mg matrix.

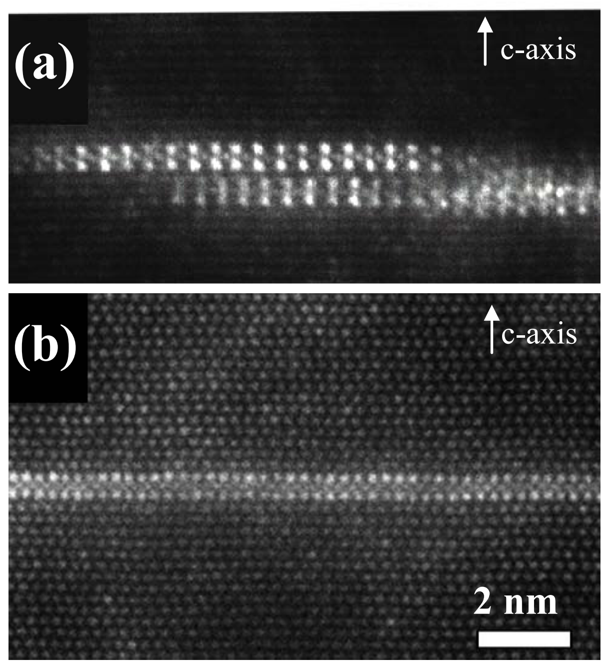

Fig.3 High-resolution STEM HAADF images of Mg-Gd-Zn alloys, taken with a incident beam parallel to the [1-10] direction (a) and [100] direction (b) of the Mg matrix.

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