Atomic-scale HAADF-STEM Study of Symmetrical Tilt Boundaries in a Mg-Gd Alloy

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Magnesium (Mg) is the lightest structural metal that has tremendous potential to improve energy efficiency and system performance in automotive, aerospace and electronics industries, as well as for rechargeable batteries and biomedical applications. The addition of minor amounts of rare-earth (RE) alloying elements can produce appreciable effects on formability and mechanical properties of Mg. However, the related atomic-scale mechanisms remain poorly understood, restricting the attempt to further improve the performance of existing magnesium alloys, and to develop new alloys. The high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM) has been proved to be a powerful technique in the study of Mg alloys. Especially, it can reveal the occurrence of a periodic segregation of solute atoms in fully-coherent twin boundaries of $\{10\bar{1}1\}_\alpha$, $\{10\bar{1}2\}_\alpha$and $\{10\bar{1}3\}_\alpha$[1].

This work reports our recent findings on the study of microstructures in a deformed and annealed Mg"Gd solid solution single phase alloy using atomic-resolution HAAD-STEM imaging. It is found that the deformed microstructure of a dilute Mg-Gd alloy contains many nano-sized grains [2]. These nanograins exhibit strong texture: most of them have their $\langle 1\bar{2}10\rangle$ parallel to each other. A range of tilt boundaries are detected between these nanograins, and they can be produced by basal-plane tilt or prismatic-plane tilt about the $\langle 1\bar{2}10\rangle$ axis. Segregation of Gd atoms occurs in the tilt boundaries after annealing of the cold deformed sample. The segregated Gd atoms form a range of unique, chemically ordered patterns specific to tilt boundaries. In addition, as a special type of tilt boundary, the $\{10\bar{1}1\}$ twin boundary with distinct interfacial structures is displayed [3]. The end interface of the $\{10\bar{1}1\}$ twin boundary is found to be an asymmetric tilt boundary decorated by a periodic array of clusters comprising ordered Gd-rich columns. The broad interface of the $\{10\bar{1}1\}$ twin boundary involves coherent $\{10\bar{1}1\}$twin boundaries that are disconnected by various steps and basal/pyramidal (BPy) facets, which all contain characteristic Gd segregation.

References

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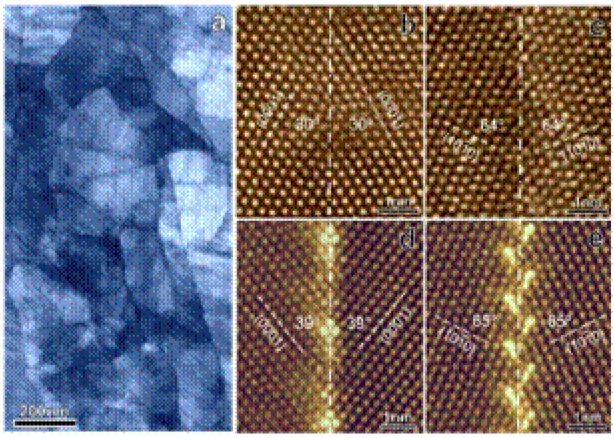

Fig. 1 (a) A low-magnification STEM image showing a region containing many nano-sized grains, (b-c) Atomic-scale HAADF-STEM images showing the basal-plane and prismatic-plane tilt boundaries respectively, (d-e) HAADF-STEM image showing segregation of Gd atoms in basal-plane and prismatic-plane tilt boundaries respectively.

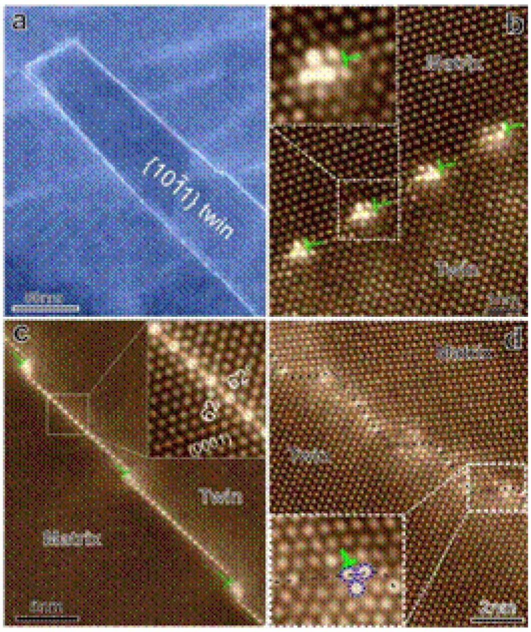

Fig. 2 (a) A low-magification HAADF-STEM image showing a $\{10\bar{1}1\}$ deformation twin, (b) atomic structure of the end interface of the $\{10\bar{1}1\}$ twin, (c-d) atomic structures of the broad interface of the $\{10\bar{1}1\}$ twin.