Effects of 0.5 wt.% Ce addition on microstructures and mechanical properties of a wrought Mg–8Gd–1.2Zn–0.5Zr alloy

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1. Abstract

Effects of 0.5 wt.% cerium (Ce) addition on microstructures and mechanical properties of a wrought Mg–8Gd–1.2Zn–0.5Zr alloy were thoroughly investigated in this work. The results indicate that 0.5 wt.% Ce addition has slight refinement on the as-cast grains and results in a lattice expansion of Mg_3RE phase due to Ce segregation in it. After extrusion, 0.5 wt.% Ce addition leads to finer dynamic recrystallization grains and non-recrystallization regions, and changes the dynamic precipitates on the DRX grain boundaries from Mg_5Gd to $Mg_{12}RE$. Under peak-aging condition, 0.5 wt.% Ce addition significantly changes the precipitates in the dynamic recrystallization grains from basal plate-shaped γ′ precipitate to prismatic β′ precipitate. As a result, the as-extruded Mg–8Gd–1.2Zn–0.5Zr alloy with 0.5 wt.% Ce addition owns higher strength at both room temperature and high temperatures and has more obvious precipitation hardening response, compared with that with free Ce addition.

2. Experimental Details

♣Material preparation

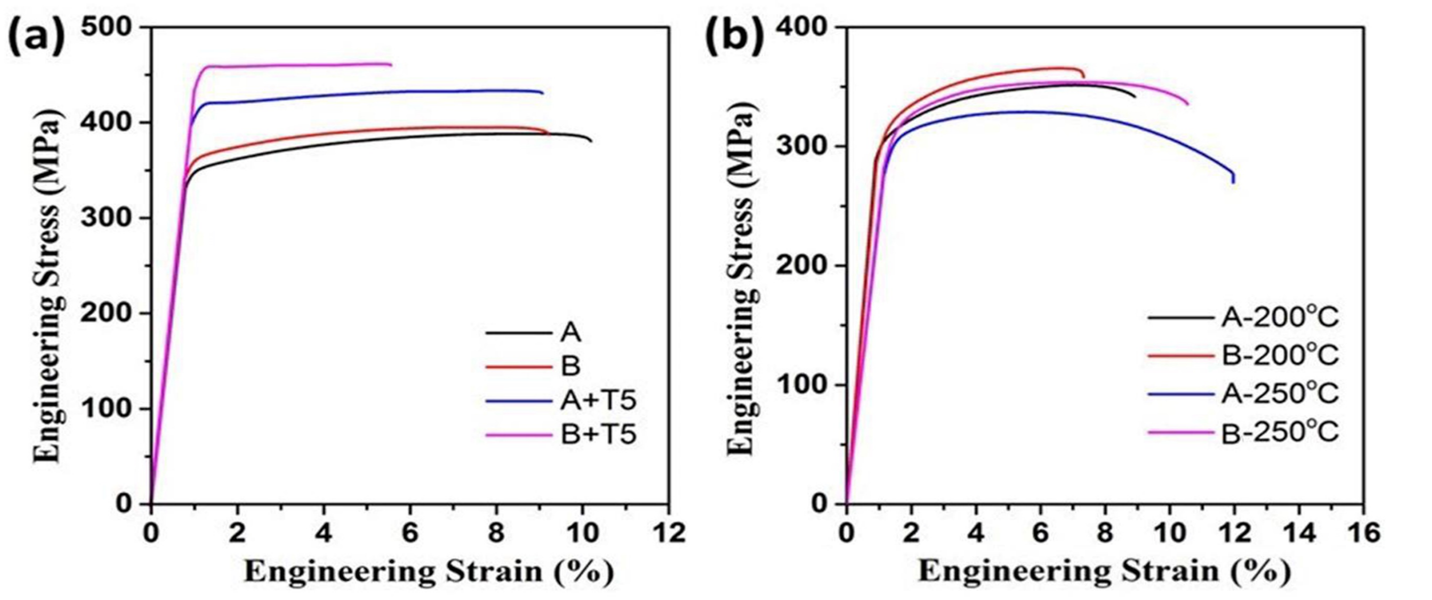
The investigated alloys (Mg–8Gd–1.2Zn–0.5Zr (A) and Mg–8Gd–1.2Zn– 0.5Zr–0.5Ce (B)) were prepared by melting pure Mg and Zn at750°C in an electric resistance furnace under a mixed atmosphere of carbon dioxide and sulfur hexafluoride. The additions of other elements were carried out using Mg–20Ce(wt%), Mg–20Gd(wt%) and Mg–30Zr(wt%) master alloys. After melting and stirring, the melt was poured into a water-cooled cylindrical iron mold with a diameter of 90 mm at 710°C. And then machined into the round bars with a diameter of 82 mm for the subsequent extrusion. These bars were preheated at 360°C for 2h, and then extruded at the same temperature with an extrusion ratio of 8:1.

♣ Characterizations

The microstructures and intermetallic phases of the studied alloy were characterized using optical microscopy (OM), X-ray diffraction (XRD) with Cu Kα radiation (λ=1.5418Å), scanning electron microscopy (SEM), and transmission electron microscopy (TEM) equipped with an energy dispersive spectrometer (EDS). The foils for TEM observations were prepared by low-energy ion beam thinning equipped with cooling system by liquid nitrogen.

3. Results and Discussions

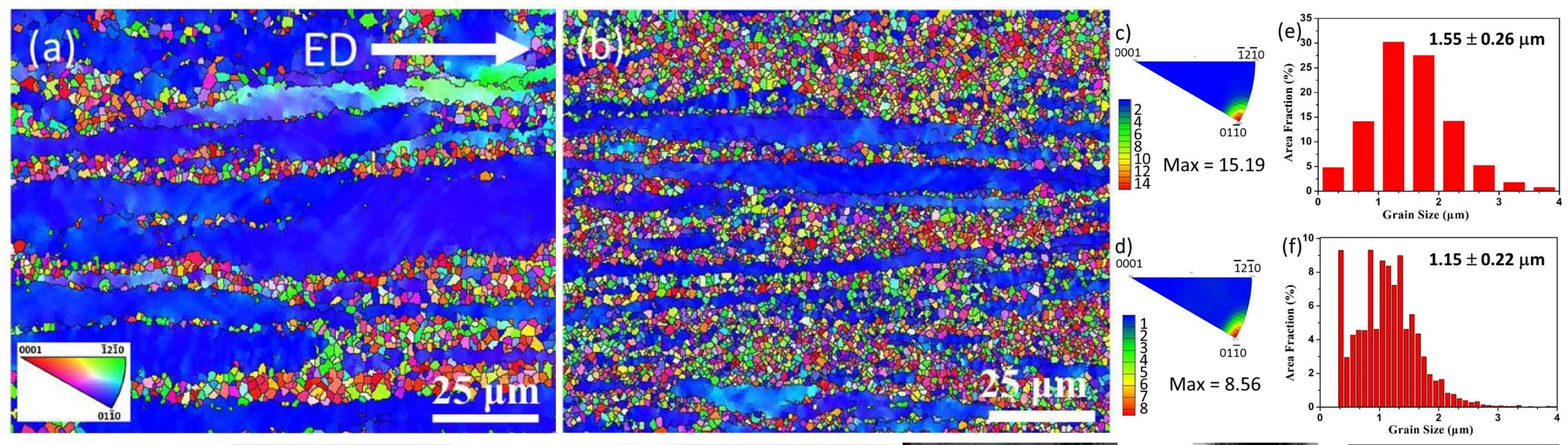
♣Tensile properties of the as-extruded alloys

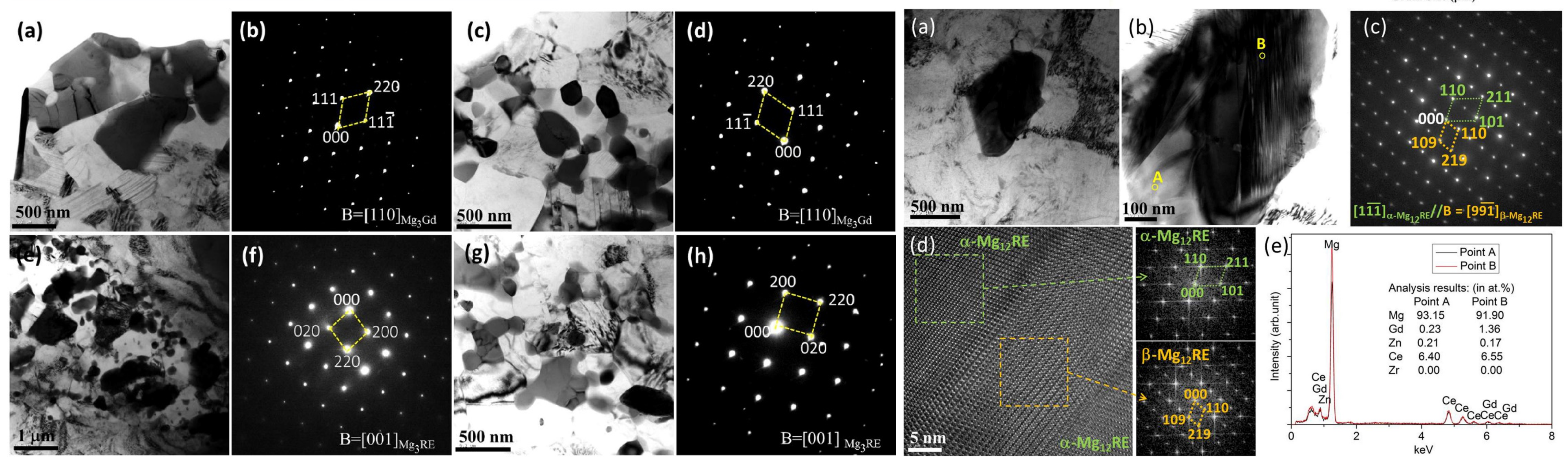


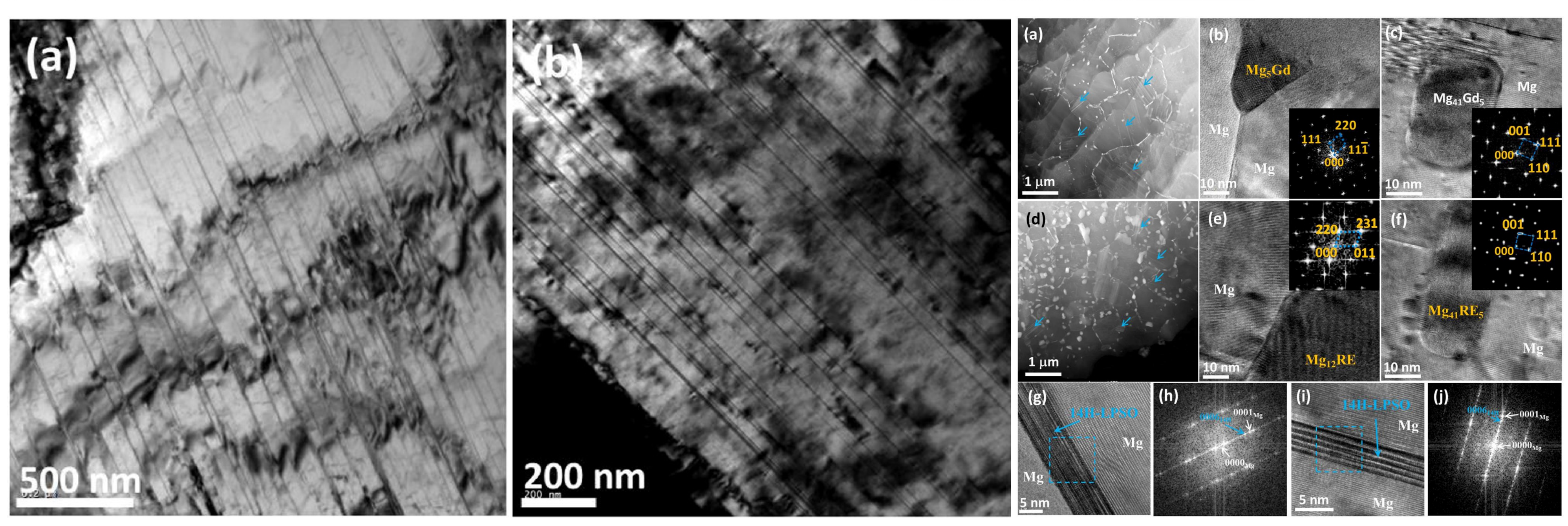
Alloy	Process state	Testing temp.	UTS(MPa)	YS(MPa)	ε(%)
A	Extrusion	RT	388 ± 5	352 ± 2	9.8 ± 1.2
	Extrusion+T5	RT	434 ± 6	421 ± 3	9.0 ± 0.9
	Extrusion	200 °C	351 ± 3	313 ± 2	8.4 ± 0.8
	Extrusion	250 °C	329 ± 4	309 ± 2	11.8 ± 1.3

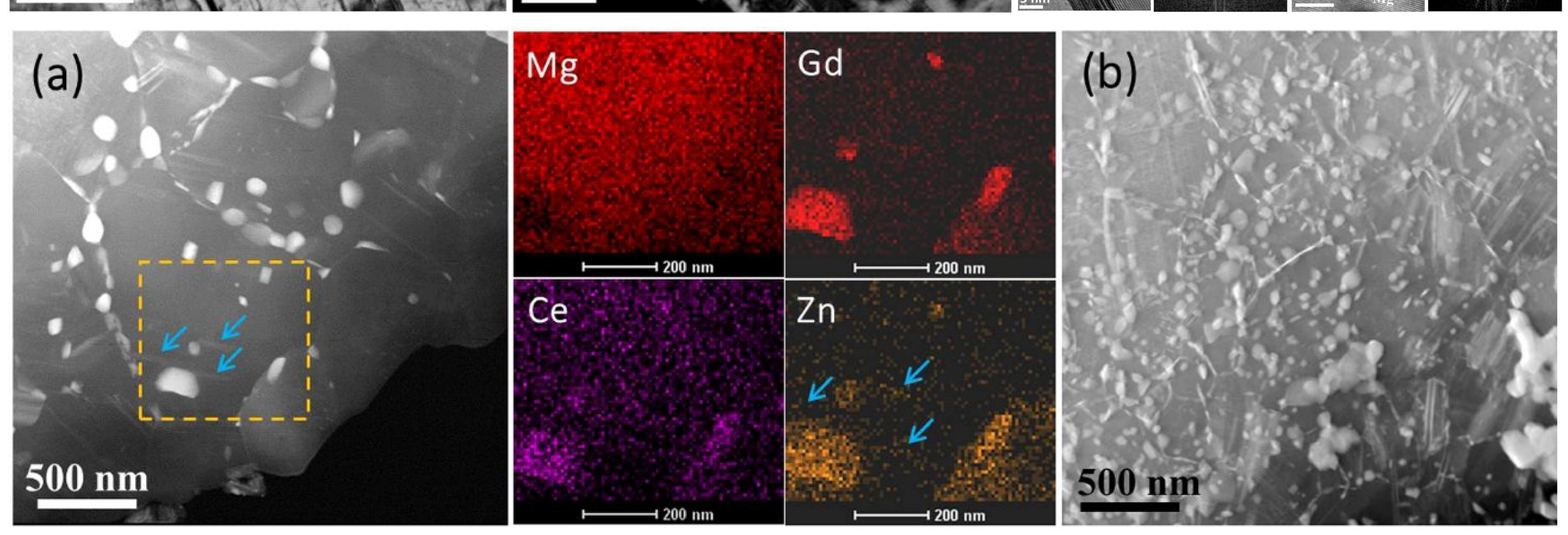
Alloy	Process state	Testing temp.	UTS(MPa)	YS(MPa)	ε(%)
B	Extrusion	RT	395 ± 6	365 ± 3	9.0±1.1
	Extrusion+T5	RT	461 ± 7	458 ± 3	5.5 ± 0.7
	Extrusion	200 °C	365 ± 4	329 ± 2	7.1 ± 0.9
	Extrusion	250 °C	354 ± 4	322 ± 2	9.9 ± 1.1

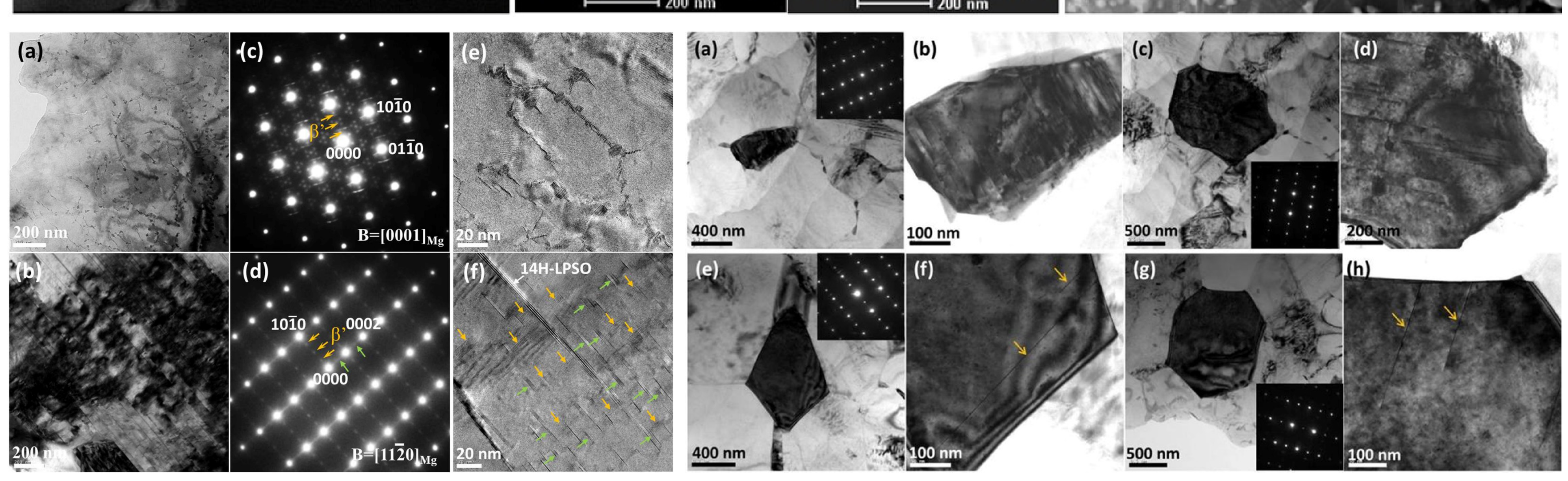
♣Microstructures of the as-extruded alloys

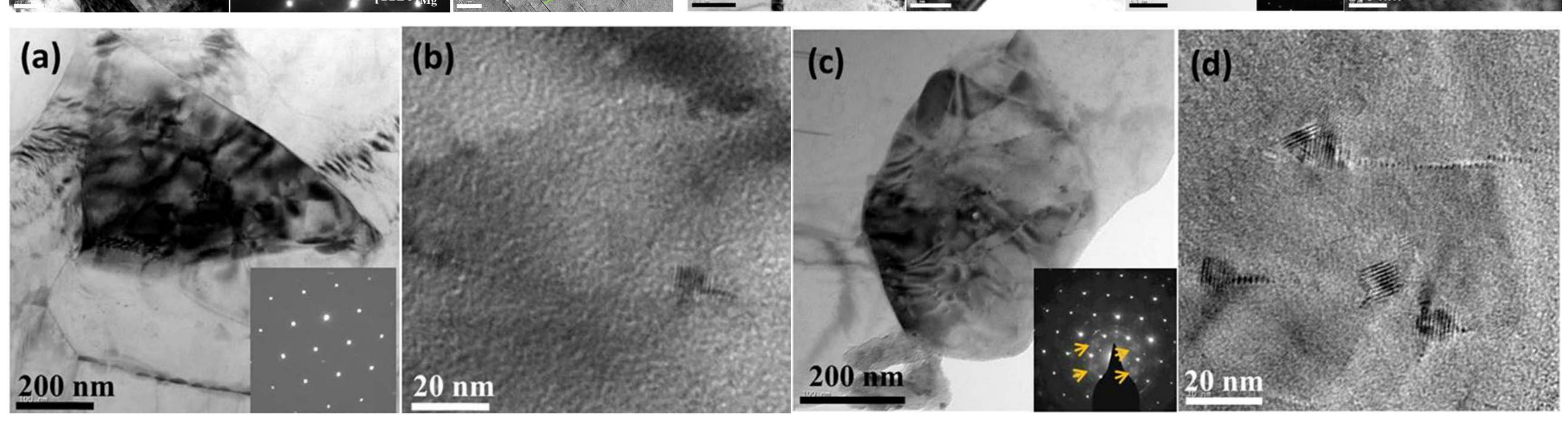












4. Summary

1. **Trace Ce addition into an as-cast Mg–8Gd–1.2Zn–0.5Zr alloy has slight grain refinement and results in a lattice expansion of the dominant intermetallic phase of Mg_3RE due to Ce segregation.**
2. **With respect to the as-extruded Mg–8Gd–1.2Zn–0.5Zr alloy, trace Ce addition leads to refining of both DRX grains and non-recrystallization regions and changes the dynamic precipitates on DRX grain boundaries from Mg_5Gd to $Mg_{12}RE$. However, it has no discernable influence on structure, morphologies, sizes and distribution of the dynamic precipitates in DRX grains and the LPSO plates in both DRX grains and non-recrystallization regions.**
3. **Trace Ce addition significantly changes the precipitates in the DRX grains of the peak-aged Mg–8Gd–1.2Zn–0.5Zr alloy, from basal plate-shaped γ′ precipitate to prismatic β′ precipitate while both of these two precipitates coexist with LPSO plates in the non-recrystallization regions and no discernable differences were observed.**
4. **Trace Ce addition clearly further improves the strength of the as-extruded Mg–8Gd–1.2Zn–0.5Zr alloy at both RT and high temperatures (200 °C and 250 °C), and obviously enhances the precipitation hardening response. The underlying strengthening mechanisms were revealed to be the finer DRX grains and non-recrystallization regions under as-extrusion state and the precipitation of the prismatic β′ precipitate in the DRX grain under peak-aging state.**