

The In-situ Analysis of Precipitates in Some Mg-Rare Earth Alloys

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High strength magnesium casting alloys based on the Mg-Y-Nd system are the basis of the successful commercial alloy WE43 (Mg-4wt%Y-2.25wt%Nd-1wt%HRE-0.6wt%Zr) [1]. The alloy is precipitation hardened and exhibits a complex precipitation sequence[2]: Mg(SSSS)→β''→β'→β₁→β. For cost reasons, the heavy rare earth additions (HRE) are usually added in the form of a 'Misch Metal' which contains a number of rare earths and reflects the geological origin of the HRE ore. Work in Russia[3] has indicated that the additions of single rare earth elements can result in enhanced tensile properties. The current research was undertaken to investigate the effect of additions of Gd and Dy. Four alloys were investigated: WE43, WN42 (Mg-4%Y-2.25%Nd-0.6%Zr), DN72 (Mg-7%Dy-2.25%Nd-0.6%Zr) and GN72 (Mg-7%Gd-2.25%Nd-0.6%Zr).

The three alloys were sand-cast and solution treated (for 8 hrs at 525°C) by Magnesium Elektron (MEL). Samples for TEM analysis were electropolished and, immediately prior to analysis, were given a thirty minute "ion beam wipe" in a Gatan PIPS ion beam polisher with a gun potential of 3.7kV and beam current of the order of 10μA. Examination was carried out in a Philips CM20 TEM operating at 200kV.

Quantitative energy dispersive spectroscopy of thin foils was carried out following the method developed by Cliff and Lorimer [4]. A variety of theoretical models for k_{AB} factors are available, however, these were found to be unreliable when dealing with the rare earth elements. For this study, experimental k_{AB} values were determined for yttrium and the rare earth elements using the matrices of the solution treated alloys as TEM standards. Bulk electron probe microanalysis (EPMA) showed a uniform composition in the matrix of the solution treated alloys, and good agreement with the mass spectroscopy analyses carried out during alloy production. k_{AB} factors were determined from subsequent EDX analyses of these samples in the TEM. The k_{AB} factors determined experimentally were: k_{MgNd} (Nd L) = 3.5, k_{MgY} (Y K) = 2.1, k_{MgDy} (Dy L) = 3.6 and k_{MgGd} (Gd L) = 3.5.

In Fig. 1 results are presented for the examination of the β₁ precipitates which were formed in the four alloys after solution treatment at 525 °C for 8 h, hot water quenching and ageing at 300 °C for 30 minutes. A typical microstructure showing the β₁ precipitates in alloy GN72 is shown in Fig. 1(a). Electron diffraction indicated that in all alloys the β₁ precipitates had the same FCC lattice with a~0.74 nm. The activated volume for the analyses of the precipitates included the surrounding matrix and results are presented using the extrapolation technique described by Lorimer *et al* [5].

The results in Fig.1(b)-(e) show that in alloy GN72 the Gd concentration in the β₁ precipitates is higher than Nd while in alloys DN72, WN42 and WE43 the β₁ precipitates are rich in Nd.

References

- [1] J.F. King J.F. in Adv. Mat. Tech. Inter.. Ed.G. B Brook Ed. (1990) 12.
- [2] L. L.Rokhlin, in Advanced Light Alloys and Composites, Proceedings of NATO Advanced Study Institute. Kluwer, (1998) 443.
- [3] J. F. Nie and B.C. Muddle, Acta Mat. 48 (2000) 1691.
- [4] G. Cliff and G. W. Lorimer, J.Microsc. 103 (1975) 203.
- [5] G.W. Lorimer et al. in Analytical Electron Microscopy. Eds. Williams DB, Joy DC. San Francisco Press, (1984.)153.
- [6] This work was supported by the EPSRC and Magnesium Elektron Ltd.

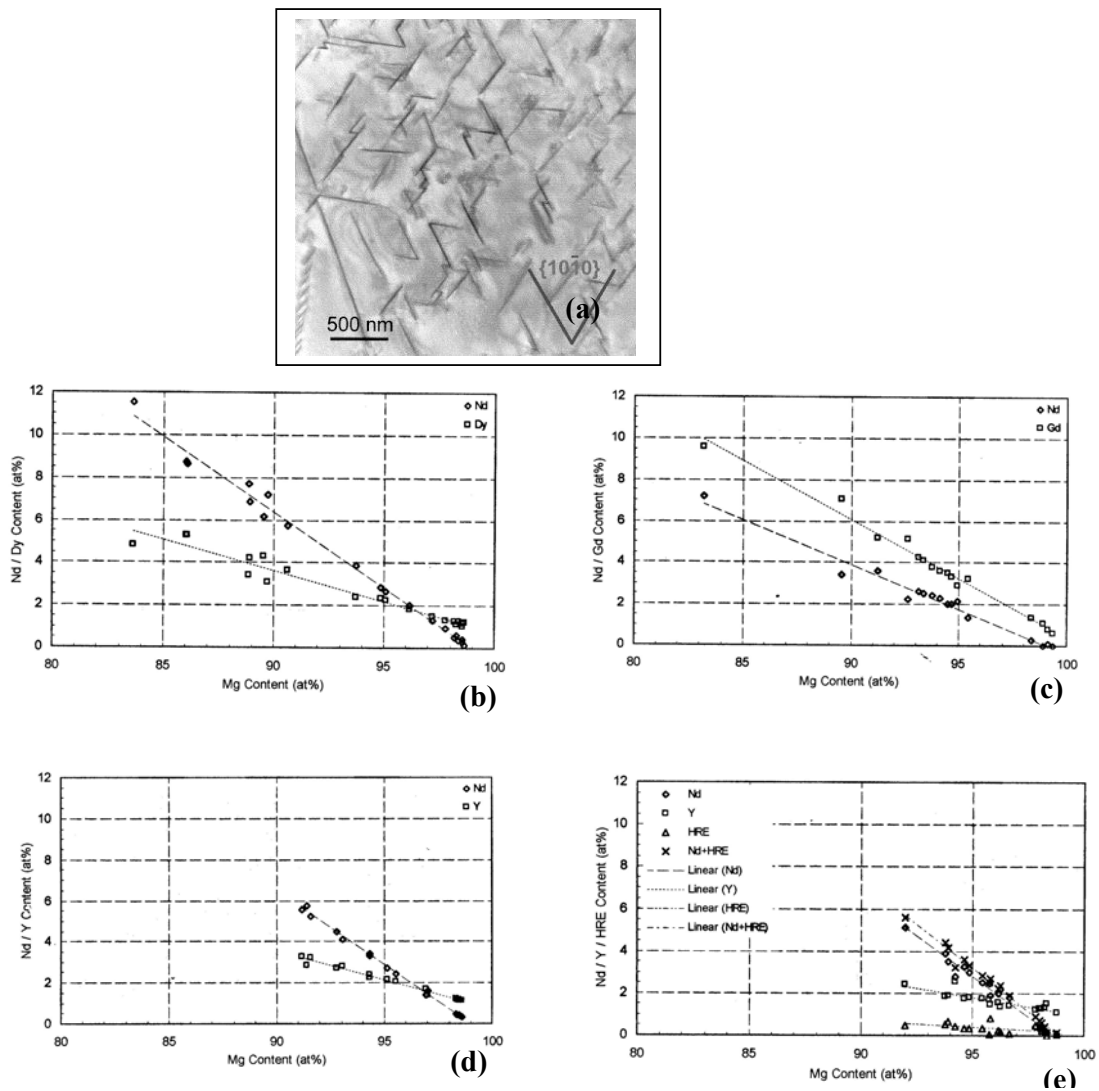


Fig.1 (a) Microstructure of GN72 viewed along $[0001]_{Mg}$ showing plate-shaped precipitates of β_1 on the prism planes. In-situ analyses of β_1 precipitates in alloys (b) DN 72, (c) GD 72, (d) WN 42 and (e) WE 43.