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TEM and APT characterization of solute clustering and precipitation process in a novel Mg-Nd-Gd-Zn-Zr alloy

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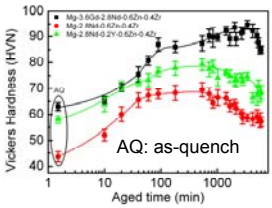
INTRODUCTION:

Magnesium alloys have important applications in the automotive and aerospace industries because of their high specific strength for weight reduction and better fuel economy. Rare-earth (RE) elements have been found to be effective to promote precipitation hardening and to improve the high temperature performance of Mg alloys. The improvement of mechanical properties in Mg-RE alloy can be mainly attributed to the precipitation strengthening. Transmission electron microscopy (TEM) and atom probe tomography (APT) characterization of solute clustering and the precipitation process during the early stage of ageing in Mg-RE alloy is of great importance to further improve the existing Mg alloys and design new Mg alloys with excellent mechanical properties for a wider application at elevated temperature.

This work is on TEM and APT characterization of a novel Mg-Nd-Gd-Zn-Zr (NG) alloy. It was carried out at Australian Centre of Microscopy and Microanalysis, the University of Sydney, Australia and State Key Laboratory of Solidification Processing, Northwestern Polytechnical University, China.

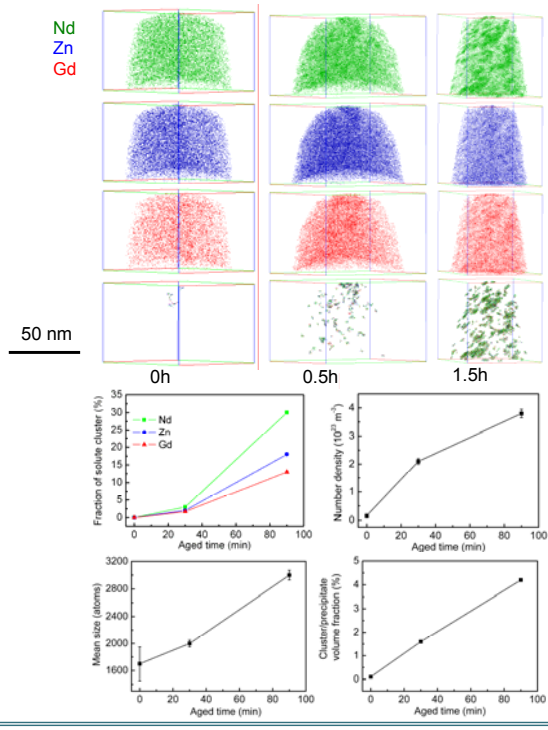
RESULTS:

1. Fast ageing hardening behaviour of three alloys aged at 200°C up to 100h

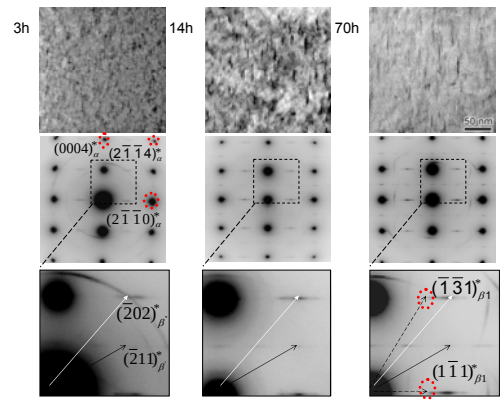


The NG alloy (black line) shows an increased ageing hardening effect.

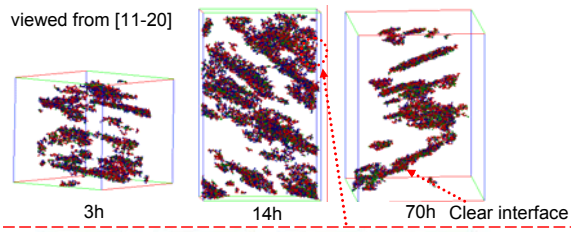
2. APT of the solute clustering of NG alloy aged at 200°C up to 1.5h



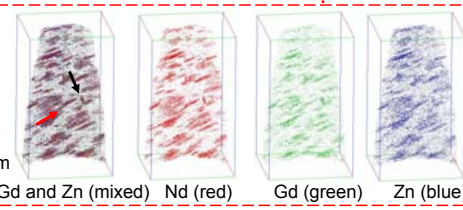
3. TEM characterization of the precipitates in NG alloy aged at 200°C from 3h to 70h



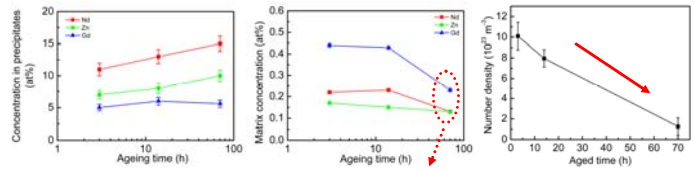
4. APT characterization of the precipitates in NG alloy aged at 200°C from 3h to 70h



ϒ precipitate (black arrow) and β precipitate (red arrow)
Box size: 100x100x170 nm



Nd, Zn and Gd partitioned significantly into the precipitates



Nd , less than 0.13 at %, Gd, lower than 0.23 at %.
This result is consistent with the phase diagram.

CONCLUSION:

1. APT characterization, for the first time, confirmed that the rapid formation of small features enriched with Nd, Gd and Zn was responsible for the fast ageing hardening effect observed during the first stage of ageing.

2. TEM characterization confirmed the precipitation sequence of NG alloy at 200° C: Supersaturated Solid Solution (SSSS) →β″ (D019) →β′ (bco) → β1(fcc) →β(fcc).

3. APT characterization revealed that not only β precipitate phases, including β″, β′ and β_1, but also ϒ precipitate phases formed on the (0001)α-Mg plane.

4. APT characterization revealed that the solute elements Nd, Zn and Gd partitioned significantly into these precipitates during ageing. With increasing ageing time, the Nd and Zn solute concentrations in the precipitates increased, while the Gd had remained unchanged.