Control of Twinning in Magnesium Alloys Using Precipitates

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Poor low temperature formability and tension/compression asymmetry are often observed in wrought magnesium products and are detrimental to performance. The origin of these effects is now well understood, and is due to the large differences in critical resolved shear stress (CRSS) for the deformation systems operating in the hexagonal crystal. As a result the strength in directions in which easy deformation modes (basal slip and {10-12} c-axis tension twinning) can be activated is low compared to strength in directions where the resolved shear stress for these systems is low.

One potential method to reduce asymmetry and increase formability is to directly suppress twinning by strengthening this deformation mode, whilst promoting alternative slip deformation modes. The current work explores the potential to use precipitates to achieve this objective. On a fundamental level it also aims to better understand the interactions between precipitation and twinning in hexagonal (hcp) metals, a subject that has to date received little attention in the literature but is critical to the performance of most commercial hcp alloys.

In this work, magnesium alloys known to form precipitates of different shape and habit were tested before and after precipitation treatment to study the effect of precipitation on asymmetry and explore in detail how precipitates and twins interact. It was shown (Figure 1) that precipitation in some alloys (e.g. AZ91) leads to a reduction in asymmetry, whereas in other alloys (e.g. Z5) precipitation increases asymmetry. Detailed microscopy was used to explore how precipitates inhibit twin growth Figure 2 shows an example of a basal plate precipitate in AZ91 entering a twin and becoming elastically bent, which introduces an additional back stress inhibiting propagation of the twin.

Based on this understanding a model was developed to predict which precipitates are most effective at reducing asymmetry whilst also increasing alloy strength. The model can be used to produce strengthening maps (e.g. Figure 3) that can be used to predict the precipitate balance needed to meet given property goals.

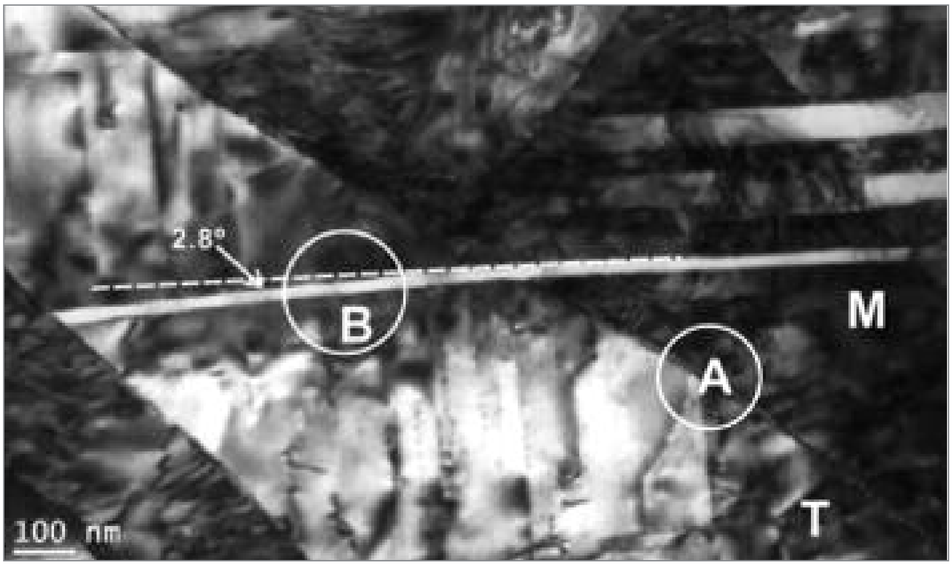

Fig. 1 TEM micrograph showing a plate shaped precipitate in the matrix (M) entering a twin (T) and becoming deflected due to the imposed shear.

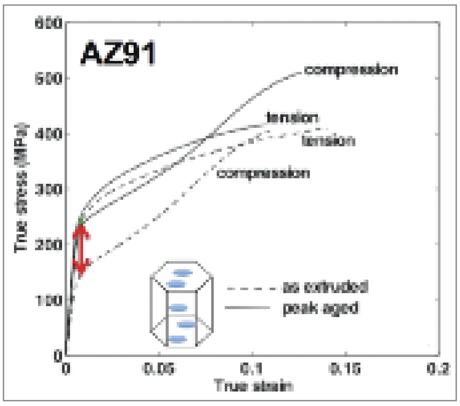

Fig. 2 Stress-strain curves of AZ91 extrusion tested in compression and tension. In the precipitate free case, the compressive strength is low due to twinning leading to a high level of mechanical asymmetry. After precipitation, twinning is suppressed and asymmetry reduced.

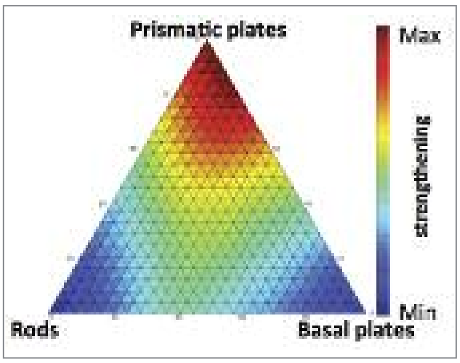

Fig. 3 Model predicted strengthening map showing the effect of different mixtures of the three main precipitate types observed in magnesium

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