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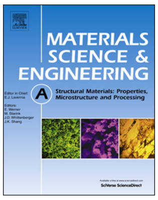

Deformation mechanisms underlying tension–compression asymmetry in magnesium alloy ZK60 revealed by acoustic emission monitoring

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ABSTRACT

This study is aimed at clarifying the microscopic mechanisms that determine a pronounced asymmetry of plastic deformation with respect to tension and compression in magnesium alloys, even having a random texture. The specific object of the present investigation is the Mg–Zn–Zr alloy ZK60. The mechanisms in question are based on a synergistic interplay between dislocation slip and deformation twinning. The details of the relative contributions of these principal processes were studied by monitoring the acoustic emission (AE) underpinned by robust AE signal classification developed recently. Through the cluster analysis of AE time series in spectral domain, the sequences of the predominant deformation mechanisms were identified for early stages of cyclic loading with opposite directions of the first loading excursion into tension or compression.

1. Introduction

Magnesium alloys are well known for their light weight and high structural efficiency which has been improved considerably due to developments of wrought alloys [1–3]. However, further development of the alloys is hindered by incomplete understanding of deformation mechanisms operative in Mg during mechanical loading [4,5].

1.1. Mechanisms of plastic deformation in magnesium at low homologous temperatures

By now, it is firmly established that due to its hexagonal close-packed (HCP) lattice magnesium has a limited number of ways to accommodate imposed plastic deformation [5–7]. As was briefly reviewed in our previous work [8], these are slip in $\langle 11\bar{2}0\rangle$ direction, or *a* slip, on basal (0001) plane, prismatic $\{10\bar{1}0\}$ planes and pyramidal I $\{10\bar{1}1\}$ planes; pyramidal slip II $\{11\bar{2}2\}\langle 11\bar{2}\,\bar{3}\rangle$, or $\langle c+a\rangle$ slip; and, finally, twinning around $\langle 1\bar{2}10\rangle$ or $\langle\bar{1}100\rangle$ zone axes [9]. The $\langle a\rangle$ slip accommodates deformation only in directions orthogonal to the *c*-axis of Mg lattice, and requires relatively low stress levels to become active. However, deformation along the *c*-axis is also required to satisfy the Taylor condition of at least five independent slip systems being operative to accommodate an arbitrary deformation [10]. Deformation along the *c*-axis can be accommodated by the pyramidal slip II $\langle c+a\rangle$ and/or twinning, but the stress level involved is much higher than that for the $\langle a\rangle$ slip. Therefore, magnesium responds anisotropically to mechanical loading, and any plastic deformation of polycrystalline Mg leads to the development of a pronounced texture.

In HCP metals, twinning has a polar nature. That is to say, a specific twinning system is favoured by only one direction of loading, i.e. tension or compression [9]. In Mg, tension along the *c*-axis is normally associated with twinning on $\{10\bar{1}2\}$ habit planes, giving rise to what is called ‘extension twins’ [7,9,11,12]. By contrast, compression along the *c*-axis is typically associated with twinning on $\{10\bar{1}1\}$, $\{10\bar{1}\,\bar{3}\}$ and $\{30\bar{3}4\}$ habit planes, resulting in ‘contraction twins’ [12–15]. Other twinning systems, although possible according to a review paper by Christian and Mahajan [9], are much more rare, and have therefore been only occasionally discussed by other researchers. At low homologous temperature, the critical resolved shear stress (CRSS) for the activation of the basal *a* slip is the lowest. CRSS for the formation of extension twins is several times larger than that, while CRSS for the activation of contraction twins is an order of magnitude larger [16]. Therefore,

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