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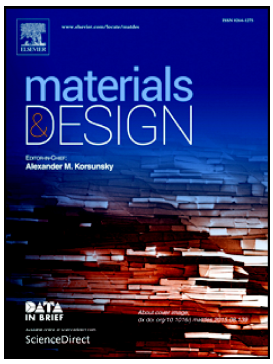

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Microalloyed Zn-Mn alloys: From extremely brittle to extraordinarily ductile at room temperature

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Abstract

Zn-0.34Mn and Zn-0.76Mn alloys transit from extremely brittle in as-cast status to extraordinarily ductile with elongations ranging from 88.8% to 94.0% at room temperature through 83.3% hot-rolling, annealing at 200 °C for 2 h and then air cooling, and finally 84% cold-rolling. Both the hot-rolling and the cold-rolling greatly refine Zn grains, while the annealing changes rolled textures into annealed textures. Grains in the as-cold-rolled alloys are smaller than 3 μm. After tensile testing, Zn grains close to the fracture are predominantly equiaxed rather than elongated. An aggregation or a long band of very fine Zn grains smaller than 1 μm is revealed in regions close to the fracture. The extraordinary ductilities of the alloys owe to fine grains before tensile testing and dynamic recrystallization during tensile testing, which helps to relieve accumulated stress.

Keywords: Zn alloys; EBSD; Ductility; Fracture; Recrystallization.

1. Introduction

Zinc and its alloys emerge as a fast developing category of biodegradable metals in recent years owing to beneficial effects of Zn for human beings [1-3]. Various biodegradable Zn alloys have been developed with wide-ranging mechanical properties [4-14]. In a conventional way, Zn alloys can also be used to make parts of plates and shells such as keyboard frame and spectrometer cover. As-cast Zn and its alloys are often brittle with limited elongations usually lower than 3%. In pure Zn with a hexagonal close-packed (HCP) crystal structure of c/a = 1.856, cleavage occurs predominantly on the basal plane, which is also its primary slip plane so that it inclines to form cleavage cracks and show brittle fracture behaviors [15-17]. If cleavage planes parallel to the basal plane in adjacent grains meet in line on the grain boundary, cleavage can transfer from grain to grain readily. If not, cleavage planes parallel to other crystal planes will form in the vicinity of the grain boundary [15].

Hot deformation processing is an effective way to make Zn and its alloys ductile. After hot extrusion or hot rolling, elongation of pure Zn can reach as high as 60% [4, 16]. However, it is also reported that hot extruded or hot rolled pure Zn only has a limited elongation below 6% [18]. Such a paradox may arise from inappropriate processing parameters and impurities in pure Zn. There is also a divergence of views as to how alloying elements affect ductility of Zn. Combined addition of two elements among Mg, Ca and Sr is reported to make the resulted Zn alloys more ductile than their