Journal of Alloys and Compounds 844 (2020) 156068

Contents lists available at ScienceDirect

Journal of Alloys and Compounds

journal homepage: http://www.elsevier.com/locate/jalcom

A rational interpretation of solidification microstructures in the Mg-rich corner of the Mg–Al–La system

Manjin Kim [a, *], Stuart D. McDonald [a], Trevor B. Abbott [a, b, c, d], Mark A. Easton [b], Yahia Ali [a], David H. StJohn [a], Kazuhiro Nogita [a]

[a] School of Mechanical and Mining Engineering, University of Queensland, Brisbane, Queensland, 4072, Australia
[b] School of Engineering, RMIT University, Carlton, Victoria, 3053, Australia
[c] Department of Materials Science and Engineering, Monash University, Clayton, Victoria, 3800, Australia
[d] Magontec Ltd., Sydney, New South Wales, 2000, Australia

ARTICLE INFO

Article history:
Received 10 February 2020
Received in revised form
2 June 2020
Accepted 13 June 2020
Available online 18 June 2020

Keywords:
Magnesium
Aluminium
Lanthanum
Metals and alloys
Solidification
Ternary phase diagrams

ABSTRACT

A range of alloys in the Mg rich corner of the Mg–Al–La ternary system have been cast to experimentally analyse the solidification microstructure. Discrepancies between our experimental observations and thermodynamic liquidus projection predictions were observed and revised solidification pathways have been confirmed in this study. The range of compositions that solidify with Mg as the primary phase is significantly smaller than what has been calculated by Pandat database (Mg 2018) but quite similar to that predicted by FactSage (FTlite). The revised solidification pathways are shown to be a useful tool for practical Mg–Al–La alloy design and avoiding the presence of the $Mg_{17}Al_{12}$ phase which has been associated with poor creep resistance of Mg–Al alloys.

1. Introduction

Magnesium-aluminium based alloys such as AZ91, AM50, and AM60 are widely used in the automotive industry owing to their combination of affordability strength, castability and the opportunity they present for weight reduction. In spite of these advantages, poor creep resistance at elevated temperature limits their use in powertrain applications [1–4].

Mg–Al-RE based alloys such as AE42 and AE44 exhibit excellent creep resistance which was a critical condition for powertrain parts at the time of their development [5–9]. Previously, Ce-rich mischmetal (52–55% cerium (Ce), 23–25% lanthanum (La),16–20% neodymium (Nd) and 5–6% praseodymium (Pr)) has been used in Mg–Al-RE alloys [10]. Recently, however, the price of mischmetal has increased due to demands for Nd and Pr in magnetic applications [11]. As a result, alloying Mg with a mixture of Ce and La has become more attractive since they are relatively less expensive and more abundant.

The microstructure and the constituent phases of the Mg–Al-RE alloys significantly affect their mechanical properties [11–13]. However, there remains a lack of understanding on the microstructure and phase evolution in the Mg–Al–La and Mg–Al–Ce systems, particularly in the Mg-rich region of the phase diagram. Moreover, there are disagreements between experimental microstructure observations and the phases predicted using thermodynamic databases in ternary Mg–Al–La and Mg–Al–Ce systems [14–16]. For example, the Mg–3Al–10Ce alloy has been identified as a hypereutectic alloy while thermodynamic predictions indicate this alloy composition is hypoeutectic [17] and inconsistencies between the solidification pathway and microstructure evolution of Mg–3Al–14La alloy with thermodynamic predictions has been reported [18]. In addition, significant disagreements in the phase diagram of the Mg-rich corner of Mg–Al–La system predicted by the thermodynamic databases, FactSage (FTlite) and Pandat (Mg 2018), have been found as shown in Fig. 1.

To provide a rational basis for microstructure design, the current study aims to obtain an understanding of solidification microstructures in the Mg-rich corner of the Mg–Al–La system. A range of alloy compositions were chosen for casting and a combination of

* Corresponding author.
E-mail address: manjin.kim@uq.edu.au (M. Kim).

https://doi.org/10.1016/j.jallcom.2020.156068
0925-8388/