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Effect of calcium addition on the corrosion behavior of Mg–5Al alloy

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ABSTRACT

The corrosion behavior of four Mg–5Al–xCa alloys ($x = 0.0$ to 2.0 wt.%) was evaluated in an alkaline NaCl solution. Surface analyses indicated that the benefits of Ca addition are the refinement of the precipitates and a decrease in grain size. Furthermore, the refinement of the precipitates (Mg_2Ca, Al_2Ca) became more complete with increasing of Ca content. The electrochemical tests revealed that the pitting resistance was improved in Ca-containing specimens. In addition, the polarization resistance of the Mg–5Al specimens increased with increasing Ca content. This is due to the fact that precipitation which is expected to act as a barrier is more continuous over the Mg matrix with a smaller grain size and higher precipitation density.

1. Introduction

Magnesium and its alloys have excellent mechanical properties owing to their low density, high specific strength to weight ratio and high specific toughness [1,2]. Mg alloys are currently used as engineering materials in a range of parts, such as panels, intake manifold, steering wheels, and aerospace vehicle parts that require lightweight materials [3–6]. Among the many Mg alloys available, Mg–Al based alloys have been applied widely in a range of industries because of the enhanced castability of the alloy and high strength by precipitation of the intermetallic β-$Mg_{17}Al_{12}$ phases [7,8]. Generally, the β phase that increases the Al concentration in Mg–Al alloys has a positive effect on the corrosion behavior in chloride solutions [9–11]. In addition, the surface film of Al-containing alloys contain a mixture of MgO and Al_2O_3 or $Mg(OH)_2$ and $Al(OH)_3$. The Al in the passive layer ameliorates its protective behavior. Al improves the corrosion resistance of Mg alloys due to the homogeneity of the microstructure afforded by the intermetallic Mg and Al compound, $Mg_{17}Al_{12}$ [12,13]. Rosalbino [14] and Zhang [15] reported that an increase in the Al concentrations in magnesium alloys, such as the AM series (AM50, AM60), reduces the corrosion rate due to a decrease in the impurity level with increasing Al addition. In particular, aluminum is formed as a solid solution and is precipitated in the form of $Mg_{17}Al_{12}$ along the grain

Table 1
Nominal composition (in weight percent) of the alloys investigated.

Samples	Composition (wt.%)
# 1	5 Al, 0.0 Ca. bal Mg
# 2	5 Al, 1.0 Ca, bal Mg
# 3	5 Al, 1.5 Ca, bal Mg
# 4	5 Al, 2.0 Ca, bal Mg

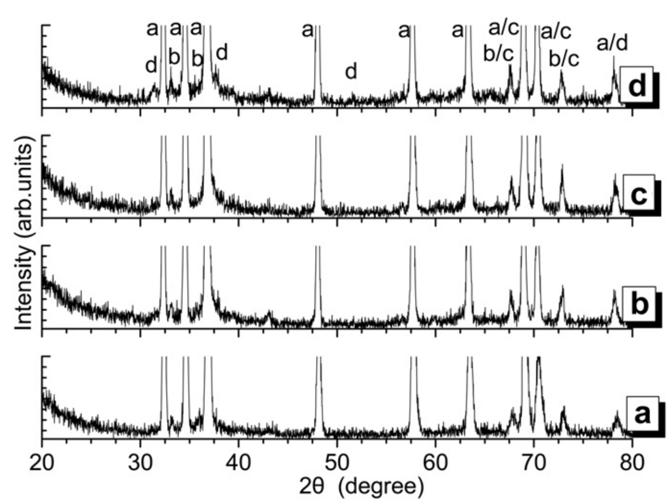

Fig. 1. XRD patterns of the Mg–5Al alloys: (a) Mg–5Al, (b) Mg–5Al–1.0Ca, (c) Mg–5Al–1.5Ca, and (d) Mg–5Al–2.0Ca: a; α-Mg, b; $Mg_{17}Al_{12}$, c; Mg_2Ca, and d; Al_2Ca.

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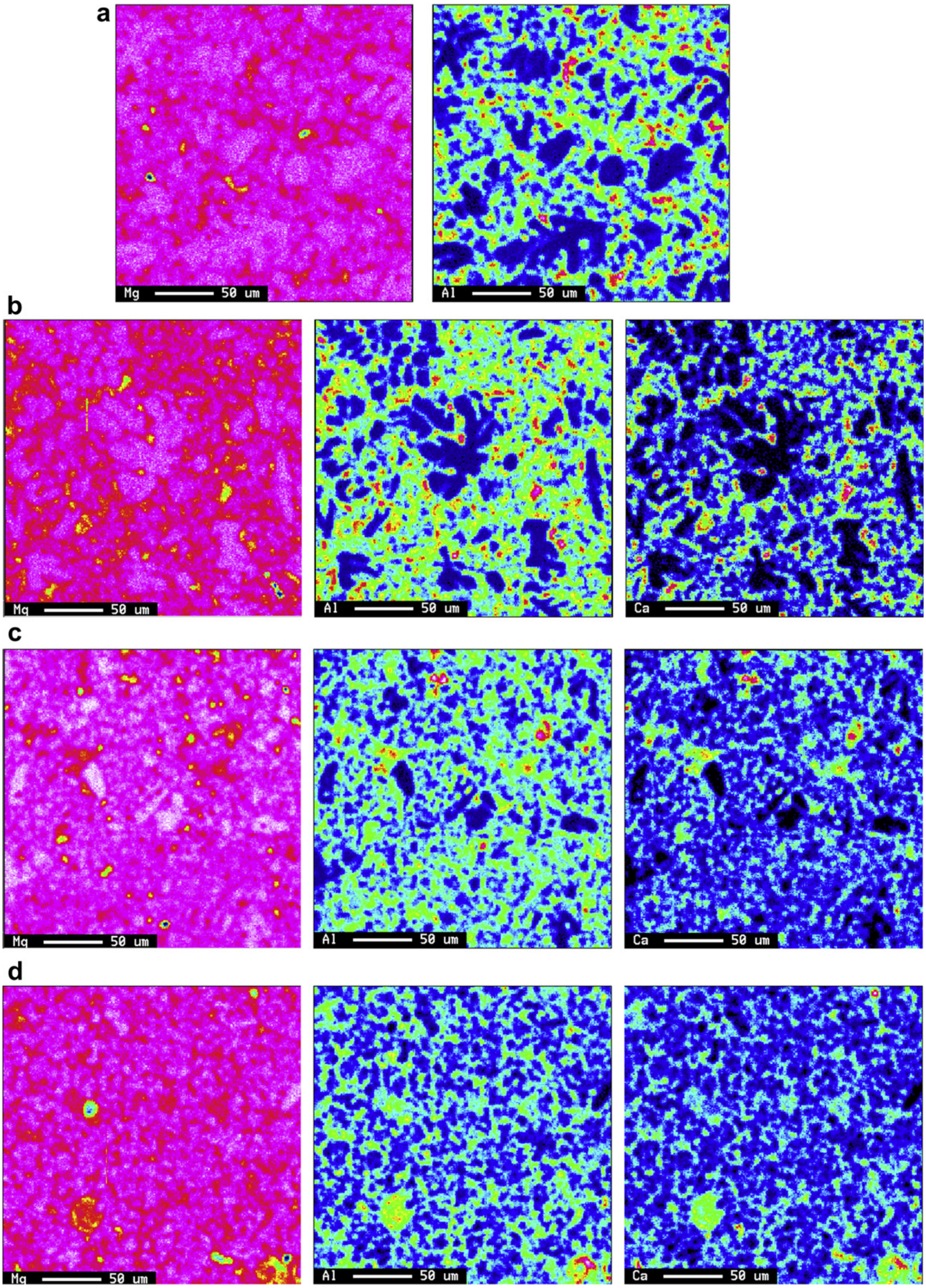

Fig. 2. EPMA mapping of the alloying elements on the specimen surface: (a) Mg–5Al, (b) Mg–5Al–1.0Ca, (c) Mg–5Al–1.5Ca, and (d) Mg–5Al–2.0Ca.

boundaries as a continuous phase and a lamellar structure [16]. In addition, $Mg_{17}Al_{12}$ exhibits more passive behavior in the high pH range than aluminum or magnesium [15–18]. However, Al improves the corrosion resistance of Mg alloys only at large concentrations. Therefore, the effect of a small amount (such as 5 wt.%) of aluminum in the Mg alloy is still questionable.

The enhanced corrosion resistance of Mg–Al alloys depends on the morphology and distribution of the $Mg_{17}Al_{12}$ phase [19].