Corrosion Behaviour of Mg-Alloy AZ91E with Atypical Alloying Additions

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Introduction

Magnesium is the lightest of all engineering metals however its widespread implementation is compromised by its relatively poor corrosion resistance. A number of methods have been devised in order to reduce corrosion of magnesium through coating technologies but as yet no inherently metallurgical solution has been found to produce a 'stainless' magnesium alloy. Magnesium offers many lucrative advantages over commonly used engineering metals, most important of all its it superior strength/weight ratio. This property, combined with excellent castability allows for magnesium alloys to be readily implement with low production costs and increased operating efficiency for the transport sector. The current inhibition to the use of magnesium and its alloys is the poor corrosion resistance suffered in service. This work aims to elucidate possible candidate alloying additions for the development of a stainless magnesium alloy.

Experimental Method

A range of AZ91E magnesium alloys were produced using 'in house' master alloys by melting in a mild steel crucible, under an inert atmosphere at 450°C for 24hrs to obtain a super saturated solid solution. The alloy was then cold water quenched and annealed at 200°C to achieve peak hardness and a uniform distribution of the $Mg_{17}Al_{12}$ (β) phase. These samples were then tested using a PAR potentiostat and an electrochemical flat cell. The open circuit voltage was recorded for 10mins to allow a steady-state condition to be established. Polarisation measurements were taken at 1mV/s from 100mV below OCP and stopped when a current density of $10mA/cm^2$ is achieved. SEM imaging conducted on a selection of the samples using a Phillips XL-30 Scanning Electron Microscope is Backscattered Electron (BSE) mode to observe compositional contrast.

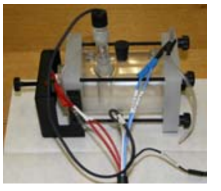


Figure 1 – Mounted Sample (above)

Figure 2 – Flat cell (left)

Results

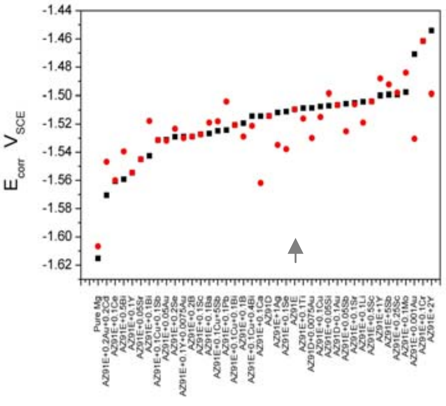


Figure 3 – Survey of E_{corr} by sample

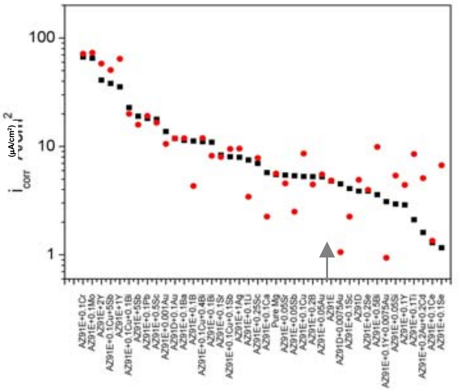


Figure 4 – Survey of I_{corr} by sample

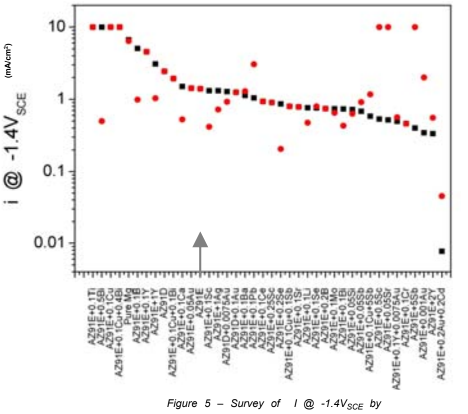


Figure 5 – Survey of I @ -1.4V_{SCE} by sample

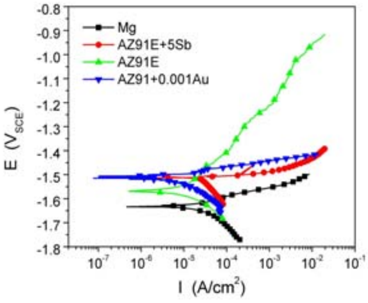


Figure 6 – Selection of alloys with relatively poor corrosion resistance

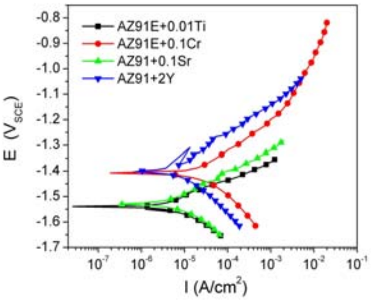
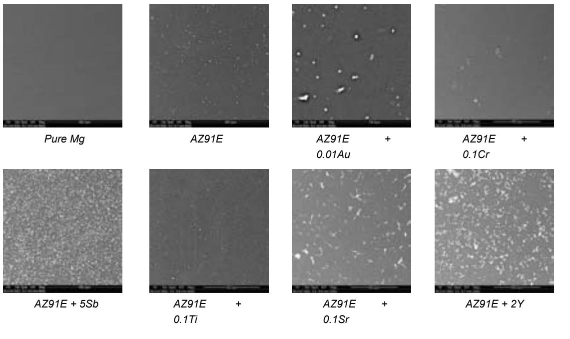


Figure 7 – Selection of alloys with relatively good corrosion resistance



Discussion

- This work represents a survey of results at this stage
- It was observed that a large number of small alloying additions can ennoble the E_{corr} value of AZ91.
- However, there were no examples of a major swing in the E_{corr} to values more positive than approximately –1.5V_{SCE}. It was noted that Y additions have a potent tendency to successfully raise E_{corr}.
- In terms of **corrosion rates measured**, these **vary significantly** between different AZ91 samples of various trace alloying additions. This variation is up to over an order of magnitude.
- This is very important to appreciate, since it reveals the sensitivity of Mg alloys to minor alloying additions that can have a disproportionate effect on corrosion response.
- For AZ91, this provides a more general sense of whether the additions described herein are to be **immediately avoided**, **tolerable**, **or possibly slightly beneficial**.
- Results will aim towards **surface engineering and alloy design**
- There is major enthusiasm for impacts in both the **auto and bio** sectors

Future Work

- Apply techniques to **Mg binary alloys** for more fundamental assessment of the improvements to corrosion resistance by single alloying additions.
- Assess corrosion behaviour of isolated individual phases present in each alloy – investigate possible coupling effects.
- Aim to develop library of corrosion information to be used as a design tool for Mg alloys.
- Develop alloys with additions of promising corrosion resistance and determine optimum amount of addition for corrosion resistance.

References

1.K.U. Kainer, ED., Magnesium Alloys and Technology. Wiley, Weheim, 2003
2.H.E. Friedrich, B.L. Mordike, Magnesium Technology; Metallurgy, Design Data, Applications. Springer, Berlin, 2006.
3.J.A. Boyer, The Corrosion of Magnesium and of the Magnesium alloys containing Manganese: Report No. 248. American Magnesium Coroporation, 1927.
4.J.D. Hanawalt, C.E. Nelson, J.A. Peloubet, Corrosion Studies of Magnesium and its Alloys, Transactions AIME, 147. 1942, p273.
5.I.J. Polmear, Light Alloys, 3rd Edn., Arnold, London 1995.
6.G. Song, Adv. Eng. Mat., 7. 2005, p.563