The critical factor for the iron tolerance limit in magnesium

L. Yang, T. Hashimoto, J. Yu, X. Zhou, G.E. Thompson, G.M. Scamans and Z. Fan

For magnesium and its alloys, a major deficiency is its inadequate corrosion resistance under service conditions, particularly when Fe, Ni, Cu, or Co is present, since their low over-potential (or high exchange current density) for hydrogen evolution has detrimental effects on the corrosion resistance due to increase in the hydrogen reduction rate.

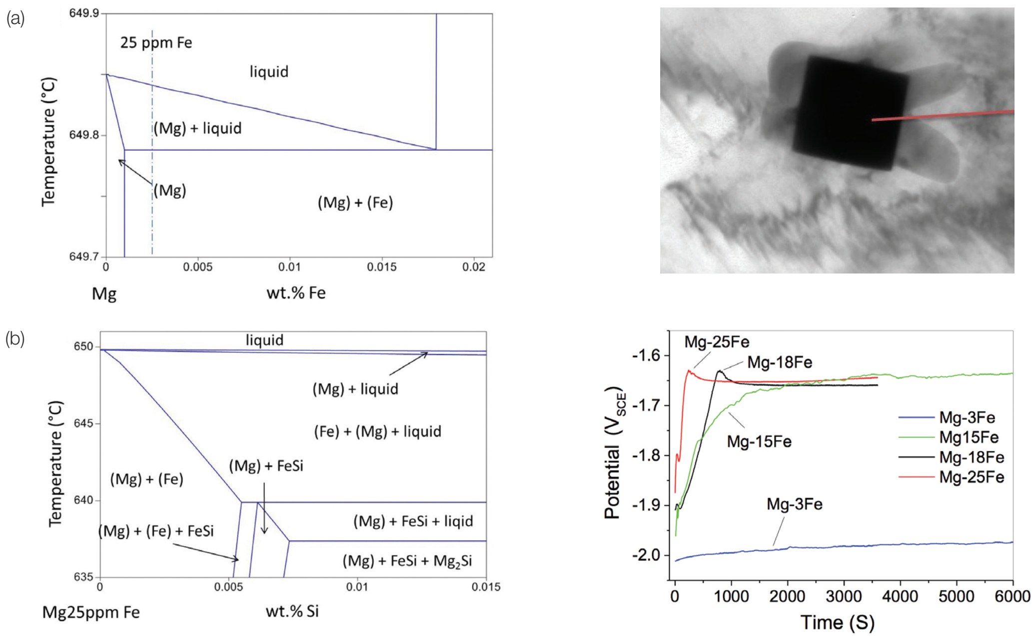

FIGURE 1. (a) The solidification interval of Mg-Fe phase diagram, (b) the ternary Mg-Fe-Si phase diagram at constant 25 ppm Fe showing an enlarged solidification interval, (c) TEM images of a typical Fe-rich particle and (d) open circuit potential as a function of immersion time, revealing the surface film breakdown potential that is controlled by the cathodic reaction at Fe-rich particle.

Iron is one of the most common impurities, which are introduced during alloy production, particularly for recycled alloys. The corrosion rate of Mg is usually insignificant (< 1 mm/year) if the content of Fe is below a critical value, whereas the corrosion rate substantially increases when the Fe content exceeds the critical value. This critical value is referred to as iron tolerance limit. However, significantly different values of iron tolerance limit have been reported. This presented study is focused on determining the critical factors that control iron tolerance limit in magnesium, with a particular focus on the solidification behaviour of Fe-rich phases.

It is found that the critical factor for the tolerance limit of iron in magnesium is corrosion potential, which is determined by the cathodic and anodic reactions and their kinetics that are controlled by the size and population of Fe-rich particles. Further, the iron tolerance limit is significantly affected by the presence of other alloying elements or impurities. Silicon, a common impurity in magnesium, even at the low ppm level, can significantly influence the solidification behaviour of the (Fe) phase in Mg-Fe alloys through introducing a solidification interval and, consequently, promoting the formation and growth of (Fe) particles that contain silicon. This reduces the corrosion tolerance limit of Fe in magnesium.

In summary, the critical factor for iron tolerance limit in magnesium is corrosion potential, which can be controlled by the distribution of iron. The iron tolerance limit in magnesium can be increased by controlling the formation of Fe-rich particles.

Future research will focus on how to promote the formation of iron-rich particles that have relatively high over-potential and low exchange current for hydrogen reduction so that the iron tolerance limit in magnesium can be increased.