Materials Science & Engineering Doctoral Defense

Role of solid-state and non-equilibrium processing induced microstructural variation on corrosion behavior of light-weight alloys

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Abstract

Solid-state and non-equilibrium processing have drawn large attention in the material science community due to their ability to control and refine the bulk and/or surface microstructure of metallic alloys and pushes them to surpass their conventional properties limit. In this dissertation, solid-state processing, i.e., Shear Assisted Processing and Extrusion (ShAPE), and non-equilibrium processes, i.e., surface mechanical attrition (SMAT) and additive manufacturing (AM) techniques were used to process various magnesium and aluminum alloys, respectively. A synergistic investigation of processing-induced microstructural modification and its effect on corrosion resistance was performed using various ex-situ, quasi-in-situ, in-situ electrochemical, microscopy, and spectroscopy characterization techniques. To evaluate the effect of the processing condition on a range of microstructures, a variety of magnesium alloys such as AZ31B, Mg-3Si, ZK60, and pure Mg were processed using a novel solid-state processing method, namely ShAPE. Simultaneous application of loads and friction-induced temperature in ShAPE will cause a significant grain refinement, homogenized distribution of second phases, and low residual strain in magnesium alloys. In the case of aluminum alloy, surface severe plastic deformation through the continuous impact of high energy milling media in SMAT processing will create a gradient nano-grain surface layer with several other microstructural changes such as dissolution of inherent phases, accumulation of defects and vacancies, and precipitation of new phases. Similarly, laser powder-based fusion (LPBF) based reactive AM processing will generate a distinct microstructure compared to wrought alloys such as formation of metastable phases, inoculants driven refined equiaxed grains, and fine distribution of second phases due to rapid solidification. This multitude of processing-induced microstructural modifications will have significant effects on corrosion behavior. ShAPE processed AZ31B alloy showed a noble breakdown potential, stable protective film, and improved corrosion resistance compared to the parent extruded counterpart. However, with variations in composition, volume fraction, and distribution of second phases in Mg-Si and ZK60 magnesium alloy an opposite response was inferred indicating a strong dependence of corrosion on underlying microstructure compared to a processing condition. Furthermore, SMAT processed aluminum 7075 alloys illustrated a reduced anodic dissolution rate and improved film resistance, which was attributed to the thicker and composite oxide layer along with new nanoscale precipitates. Lastly, AM-induced microstructure led to an increased anodic dissolution, especially in aluminum 7050 alloy, and an overall reduction in corrosion resistance. Overall, this work helps advance the current understanding of corrosion behavior in lightweight alloys processed via novel processing techniques and aids in developing design strategies for engineering corrosion-resistant materials.

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