

Barrier Corrosion Properties of Amorphous Aluminum-Based Metallic Glasses

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The newly discovered Al-rich glass alloy system based on rare earth (Ce, Gd, and Y) and transition metal (Co, Fe, and Ni) compositions is a promising candidate for a multi-functional metallic cladding. Included in the functions are active corrosion inhibition, corrosion barrier properties, and sacrificial cathodic prevention. Recently, a new amorphous Al-Co-Ce-(Mo) alloy has been developed at the University of Virginia that is amorphous over a flexible range in composition from 0 to 12 Co at% and 2 to 11 Ce at%. Currently, it is unknown which alloying elements (e.g., Ce, Co, Mo) contribute to improved corrosion barrier properties, either when present in solid solution or when enriched in the oxide for a given bulk alloy composition. The optimization of the alloy's composition is necessary in order to produce a final chemistry that offers the highest degree of corrosion resistance. Therefore, an investigation into the mechanisms by which composition contributes to or governs the barrier properties of these Al-rich glass alloys (including both alkaline and acidic dissolution, as well as pitting corrosion resistance in near-neutral halide solution) is necessary to select the optimum alloy composition.

Aluminum and many of its alloys form a protective oxide layer upon exposure to air. This oxide serves as a barrier, preventing the dissolution of the underlying metal as well as providing protection from any aggressive ions that may be present in the environment (such as chlorides). Improvements that enhance barrier corrosion properties can be attributed to several properties of the oxide. These include thickness, structure and defects composition, electronic-semiconductor properties, and adsorption properties. In conventional alloys heterogeneities in the underlying alloy such as grain boundary triple points, second phase particles, and inclusions are the location of weak spots in the oxide that are most likely the sites of pit initiation. These heterogeneities can also short-circuit the breakdown process despite any beneficial oxide properties they may offer. However, it is well-known that in the absence of defects, oxide properties serve to mediate local corrosion initiation properties and it is generally believed that alloy composition controls pit stabilization. Therefore, the amorphous structure of the Al-rich glass alloys and its alloying elements offers the potential for enhanced barrier properties strictly by manipulating the oxide properties.

The oxide composition, thickness, and valence state as well as alloying content in solid solution in the underlying alloy contribute to pit initiation and stabilization resistance. Enrichment of the oxide in solute may render the oxide more resistant to acidic and alkaline dissolution, but the role of each alloying element is unknown. A variety of electrochemical methods will be used to determine both the physical barrier properties of the surface oxides that prevent pits from initiating, as well as the alloy composition and attributes that reduce the stability of the pits once they have been initiated. Included in the testing methods of the alloy's corrosion resistance are a collection of electrochemical tests conducted in 0.6M NaCl solution, as well as in a range of chloride free pH buffered

solutions. Tests performed in the aggressive chloride solution involve a far-spaced electrode array to determine the E_{pit} and E_{tp} values for various alloy and oxide compositions with statistical accuracy. The experiments conducted in chloride free solutions serve to characterize the rate of dissolution of the material at various potentials in a variety of pH environments. Data for a variety of oxide compositions will be analyzed using multiple regression analysis to determine with statistical accuracy the influence of each alloying element on corrosion behavior. In addition, specific characterization techniques such as X-ray Photoelectron Spectroscopy (XPS) will be used to determine the properties of the oxide layer including its thickness and composition. Oxide thickness and composition will be correlated with metrics that define barrier corrosion properties. By performing this collection of experiments, a more complete understanding of the corrosion barrier properties offered by this alloy system will be developed and a more complete understanding of optimal alloy composition will be achieved.

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Further Reading

Sweitzer, J.E.; Shiflet, G.J.; Scully, J.R.; *Electrochimica Acta*