Near-atomic-scale study of corrosion oxide film on grain boundary of Al-Mg alloys at the initial stage of corrosion

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Abstract Intergranular corrosion trigged by sensitization is the main reason for the failure of Al-Mg alloys with the Mg content > 3wt%[1-3]. The early stage of corrosion occurred at GBs control the evolution of the Al-Mg alloy's degradation process[4,5]. However, corrosion initiation and the oxide film formation on GBs before and after sensitization remain unsolved questions. Here, the early stage corrosion of GBs of 5083 Al-Mg alloy before and after sensitization were investigated by using quasi in-situ transmission-electron microscopy (TEM) and focus ion beam (FIB) TEM. Sensitization caused the decrease of corrosion resistance due to the precipitation of Al-Mg phase on GBs. For the GBs of both unsensitized and sensitized alloys, the oxide film on GBs showed a deeper penetration into the alloy matrix compared with the neighboring grains. In addition, Mg segregation on the GB of the sensitized alloy led to the formation of a thicker and Mg-enriched oxide film on the GB surface. Density-functional theory (DFT) calculations suggest that the local electron accumulation at interface of the oxide and the sub-surface Al atoms provided possible sites for O adsorption and oxide film formation. The GB showed a stronger tendency for oxidation than neighboring grains in terms of its structural and electronic properties, and Mg doping enhanced the tendency of O adsorption and electron localization on the GB, promoting the oxidation of Mg-segregated GBs. Our findings advance the mechanistic understanding of corrosion oxide film formation on GBs from near atomic-scale, and should help lower the susceptibility of Al alloys to IGC originating from the GB corrosion.

Keywords Al-Mg alloy, corrosion oxide film, grain boundary, quasi in-situ TEM

Reference

[1] V. Maurice, P. Marcus, Progress in corrosion science at atomic and nanometric scales, Progress in Materials Science, 95 (2018) 132-171.

[2] W. Xu, Y.C. Xin, B. Zhang, X.Y. Li, Stress corrosion cracking resistant nanostructured Al-Mg alloy with low angle grain boundaries, Acta Materialia, 225 (2022) 117607.

[3] J. Yan, N.M. Heckman, L. Velasco, A.M. Hodge, Improve sensitization and corrosion resistance of an Al-Mg alloy by optimization of grain boundaries, Scientific Reports, 6 (2016).

[4] H. Zhao, Y. Yin, Y. Wu, S. Zhang, A.M. Mingers, D. Ponge, B. Gault, M. Rohwerder, D. Raabe, How solute atoms control aqueous corrosion of Al-alloys, Nature Communications, 15 (2024).

[5] R. Zhang, Y. Qiu, Y. Qi, N. Birbilis, A closer inspection of a grain boundary immune to intergranular corrosion in a sensitised Al-Mg alloy, Corrosion Science, 133 (2018) 1-5.