Middle-entropy Alloy Design and Electrochemical performance characterization of the novel Al-based sacrificial anodes

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Abstract Al-based sacrificial anodes (SAs) with large theoretical discharge capacitance, high current efficiency, and lightweight, can effectively protect steels from corrosion through their own active dissolution and discharging. However, its discharge capacitance declines 5 ~ 30 % and current efficiency even decreases up to 18 % in deep-sea environments, due to the conditions of low temperature, low oxygen, and high pressure, inhibiting the reactions of active dissolution.

To obtain the novel Al-based SAs with high discharge activity and current efficiency especially used in deep-sea environments, 4 alloys were designed learning from the concept of high entropy alloys (HEAs). The high entropy effect and sluggish diffusion effect facilitate the formation of the uniform solid solution of active alloying elements, which improves the discharging capitance and current efficiency. Therefore, by Hume-Rothery criterion and first principle calculation, the novel Al-based high entropy sacrificial anode alloys were designed.

The microstructure and electrochemical performance of novel HEAs of Al-In-Ga-Sn-Zn-Mg were then assessed, compared with that of a commercial Al-Zn-In SAs. The designed alloys have smaller grain size, more regular grain shape, and uniform distribution of various phases and alloying elements, contributing to the improvement of current efficiency. The wider distribution of abundant activating elements and preferential dissolution of Mg_2Sn and $MgZn_2$ phases cause the increased discharge activity. However, the distribution of Mg_2Sn with the largest potential difference to other phases tends to be nonuniform. Thus, $Al_{46.08}In_{0.2}Ga_{0.6}Zn_{43.67}Mg_{8.45}$ presents the best electrochemical performance with the highest current efficiency of 82.20% and 87.08% in simulated shallow-sea and deep-sea environments, respectively.

Keywords Al-based sacrificial anodes; High-entropy alloy design; Electrochemical performance; Deep-sea environments.