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ELECTROCHEMICAL BEHAVIOUR OF RARE EARTH BASED ALUMINIUM ALLOYS

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Abstract

Amorphous alloys, on the merit of excellent mechanical and electrochemical properties compared to their crystalline counterparts, have aroused great interest for constructional and environmental applications. In this study, amorphous rare earth based aluminium alloys were synthesised by fast speed quenching. Electrochemical behaviour of the alloys was investigated using polarisation and impedance techniques and correlated with micro phases, chemical compositions and crystalline structures as examined by SEM-EDS and XRD. The result identifies amorphous Al alloys possess unparallel corrosion resistance compared to the multi-phased Al alloys, and consequently confer unique protection for constructional materials exposure to extreme environments, such as space, marine and soil.

Introduction

Traditional Al alloys such as AA 2024, AA 6061 and AA 7075, due to their high ratio in strength to weight, have been extensively applied in aeronautical, astronautical and national defense industries. The shortage in corrosion resistance, however, usually poses negative concern about their reliablity and lifetime when they service in variant harsh environments. Amorphous Al alloys have been reported to possess better resistance to both generalised and localised corrosion.[1-3] Therefore, the electrochemical behaviour of amorphous Al alloys was studied and compared with their traditional counterparts. The investigation highlights valuable exploration for the cutting-edge materials and protection technology for the critical environmental applications in space, marine and soil.

Methods and Materials

Ingots of rare earth based Al alloys, $Al_{85}Y_5Ni_7Ti_3$ and $Al_{88}Ce_8Co_4$, were synthesised by induction melting a mixture consisting of high purity (99.9%) Al, Y, Ni and Ti metals, and of Al, Ce and Co metals, respectively. The alloys ribbon was fabricated using a single roller melt spinning technique in inert atmosphere. Traditional Al alloys AA 2024, AA 6061 and AA 7075, commercially obtained were used for comparison with the rare earth based Al alloys. The microstructure of the Al alloys was examined using SEM-EDS and XRD, and electrochemical behaviour was investigated by polarisation and impedance techniques, refered to ASTM G-61-1986. The corrosion mechanism of the alloys was studied.

Results and Discussion

Figure 1 (a)-(e) show the plan-view micrographs of aluminium alloys AA 2024, AA 6061, AA 7075, $Al_{85}Y_5Ni_7Ti_3$ and $Al_{88}Ce_8Co_4$ as examined by SEM. Evidently, the former four alloys present multiple phases in their microstructure. However, the alloy $Al_{88}Ce_8Co_4$ exhibits only one uniform phase. Chemical analysis from EDS indicates the phases as marked A, B and C of AA 2024 are chemically composed of $Al_{97.3}Mg_{2.7}$, $Al_{73.1}Si_{10.7}Cr_{0.2}Mn_{0.7}Fe_{14.7}Cu_{0.6}$, and $Al_{77.2}Si_{9.9}Mn_{0.6}Fe_{11.9}Cu_{0.4}$. The phases marked as A, B and C in AA 6061 are of $Al_{86.6}Mg_{1.6}Si_{8.3}Fe_{3.2}$, $Al_{65.9}Mg_{10}Si_{20.5}Fe_{3.7}$, and $Al_{89.8}Mn_{0.2}Si_{5.9}Fe_{4.1}$, respectively. The phases signed by A and B as shown on AA 7075 have the chemical compositions of $Al_{92.6}Mg_{3.9}Zn_{2.2}Cu_{1.2}Mn_{0.1}$ and $Al_{52.2}Mg_{4.6}Zn_{0.8}Cu_{42.4}$ while the phases as marked A and B on $Al_{85}Y_5Ni_7Ti_3$ are $Al_{86.2}Y_{4.6}Ni_{5.8}Ti_{3.4}$ and $Al_{53.7}Y_{2.3}Ni_{3.5}Ti_{2.4}Cu_{38.4}$

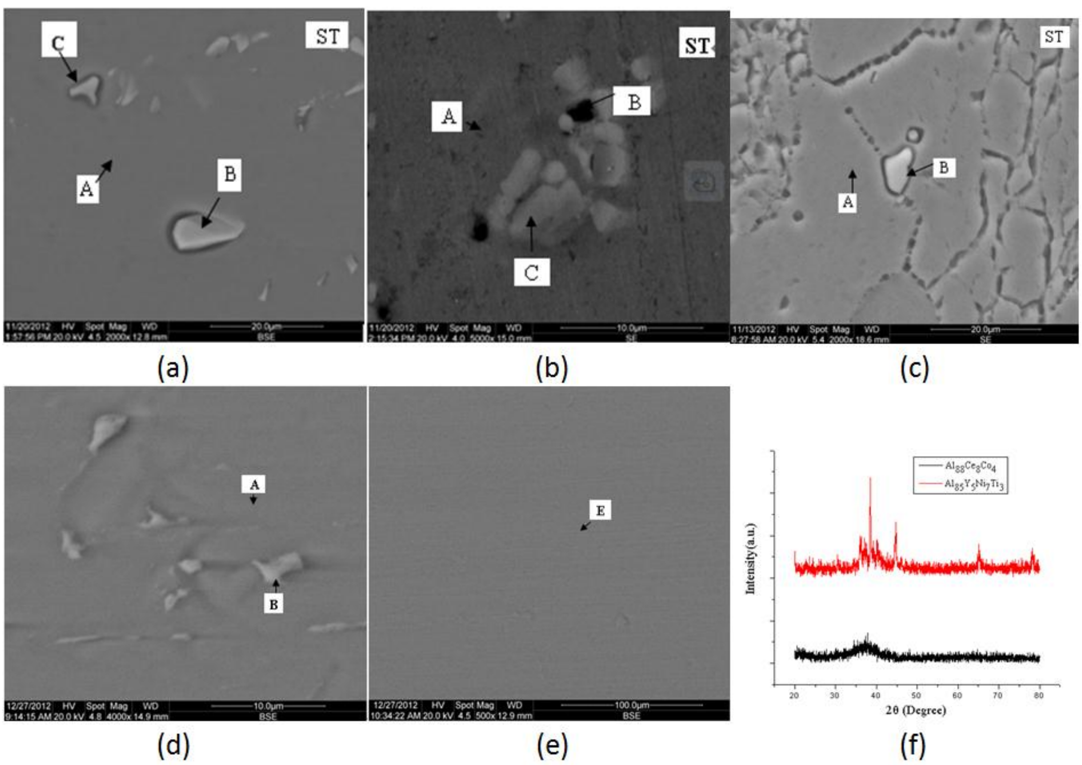

Figure 1: Micrographs of alumimum alloys (a) AA 2024, (b) AA 6061, (c) AA 7075, (d) $Al_{85}Y_5Ni_7Ti_3$ and (e) $Al_{88}Ce_8Co_4$ and (f) XRD patterns of $Al_{85}Y_5Ni_7Ti_3$ and $Al_{88}Ce_8Co_4$

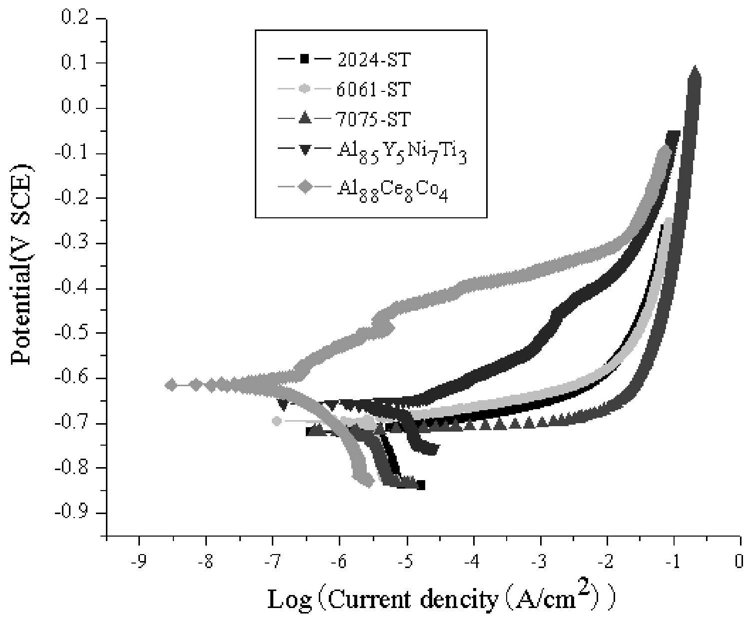

Figure 2: Potentiodynamic polarisation curves of the alloys AA 2024, AA 6061, AA 7075, $Al_{85}Y_5Ni_7Ti_3$ and $Al_{88}Ce_8Co_4$

Figure 1 (f) depicts the XRD diffraction patterns of the alloys $Al_{85}Y_5Ni_7Ti_3$ and $Al_{88}Ce_8Co_4$ (note: the XRD diffraction patterns of AA 2024, AA 6061, AA 7075 are not shown due to limited space), and the results indicate that alloys $Al_{85}Y_5Ni_7Ti_3$ (as well as AA 2024, AA 6061 and AA 7075) consist of multi-phases where particularly crystalline phases are formed in the alloys. However, alloy $Al_{88}Ce_8Co_4$ exhibits to be only one phase which is fully amorphous.

Figures 2 and 3 present the potentiodynamic polarisation curves and electrochemical impedance spectra of the alloys AA 2024, AA 6061, AA 7075, $Al_{85}Y_5Ni_7Ti_3$ and $Al_{88}Ce_8Co_4$. As seen from the figures, the alloy $Al_{88}Ce_8Co_4$ shows much higher corrosion resistance than the other four kinds of aluminium alloys. The measured electrochemical parametric data are given in Table 1.

Table 1: Measured electrochemical parametric data of the aluminium alloys

Alloys	E_{corr}(V/SCE)	I_{corr}(μA/cm^2)	Rp (kΩ)	Ba (V)	Bc (V)	B (V)
AA2024	-0.7206	1.3	10	0.063	0.439	0.024
AA6061	-0.7206	2.2	14	0.060	0.516	0.023
AA7075	-0.7173	3.5	11	0.187	0.403	0.055
$Al_{85}Y_5Ni_7Ti_3$	-0.6568	25	28	0.066	0.104	0.018
$Al_{88}Ce_8Co_4$	-0.6178	0.4	56	0.064	0.146	0.019

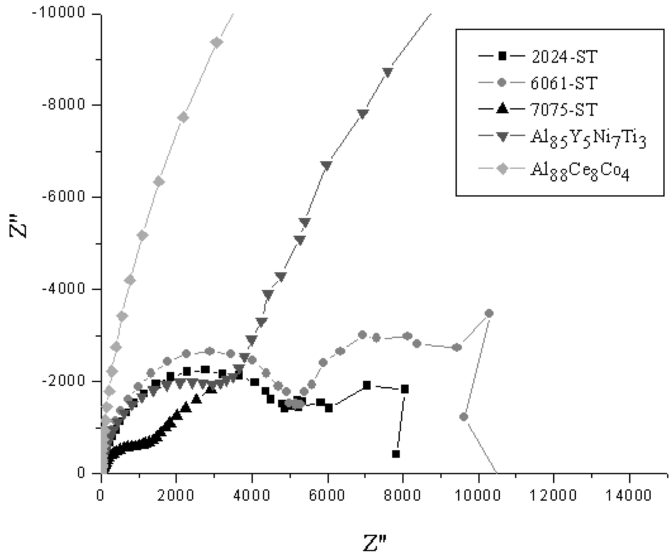

Figure 3: Electrochemical impedance spectra of the alloys AA 2024, AA 6061, AA 7075, $Al_{85}Y_5Ni_7Ti_3$ and $Al_{88}Ce_8Co_4$

Conclusions

From this study, it demonstrates that amorphous AlCeCo4 alloy has higher corrosion resistance than that of the alloys AA 2024, AA6061, AA 7075 and AlYNiTi which consist of multi-phases. The chemical composition and microstructural phase substancially determines the alloy's corrosion resistance. The fully amorphous alloy such as $Al_{88}Ce_8Co_4$ keeps electrochemical homogenenity, thus presents better corrosion resistance while the alloy with multiple phases shows less resistant to corrosion due to its electrochemical inhomogenity concurred by different phases. The result greatly encourages further penetrating exploration on the rare earth based amorphous Al alloys.

Acknowledgements

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