Rare Metal Materials and Engineering
Volume 45, Issue 2, February 2016
Online English edition of the Chinese language journal

Available online at www.sciencedirect.com
ScienceDirect

Cite this article as: Rare Metal Materials and Engineering, 2016, 45(2): 0272-0276.

ARTICLE

Direct Electrochemical Formation of Different Phases Al-Y Alloys by Codeposition in LiCl-KCl Melts

Yan Yongde[1,2], Yang Xiaonan[2], Huang Ying[2], Xue Yun[1], Zhang Milin[2], Han Wei[2], Zhang Zhijian[1]

[1] Fundamental Science on Nuclear Safety and Simulation Technology Laboratory，Harbin Engineering University 150001, China; [2] Key Laboratory of Superlight Materials and Surface Technology, Ministry of Education, Harbin Engineering University, Harbin 150001, China

Abstract: Electrochemical preparation of different phases Al-Y alloys were investigated in LiCl-KCl-$AlCl_3$-Y_2O_3 melts at 773 K by cyclic voltammetry, square wave voltammetry, open circuit chronopotentiometry and polarization curve. The electrochemical measurements show that the underpotential deposition (UPD) of Y on pre-deposited Al forms two Al-Y intermetallic compounds. The results of X-ray diffraction (XRD) indicate that the two different Al-Y intermetallic compounds are Al_2Y and α-Al_3Y. The microstructure and the micro-zone chemical composition of Al-Y alloys were characterized by scanning electron microscopy (SEM) and energy dispersive spectrometry (EDS), respectively. The results illustrate that element Y is mainly distributed on nubby precipitates. Different phases Al-Y alloys can be obtained by adjusting the concentration of $AlCl_3$.

Key words: molten salt; eletrodeposition; Al-Y alloys; Y_2O_3

Aluminium alloys are widely used as light alloys for structural components. With the rapid development of aerospace and military industries, mechanical properties of Al alloys are required to be further improved to satisfy the wide applications. Aluminium alloys possess hugely industrial significance because of their outstanding combination of mechanical, physical and tribological properties over the base alloys. These properties include high specific strength, high wear resistance, high stiffness, better high temperature strength, controlled thermal expansion coefficient and improved damping capacity[1,2]. These properties can be obtained through addition of alloy elements, cold working and heat treatment. Alloying elements are selected based on their effects and suitability.

It is well accepted that the additions of rare earth elements are of great importance to improve the microstructure and the mechanical properties of aluminum alloys[3-5]. The addition of Y is of great significance to further improve the mechanical properties. Agnew et al.[6] suggested that addition of Y could accommodate the *c*-axis deformation through accelerating the *c*+*a*-axis glide, which weakened the deformation anisotropy to improve plasticity. Sun and co-workers[7] found that the addition of Y in Mg-3Al-1Zn alloy formed uniformly distributed finer and harder Al_2Y precipitates which increased the hardness and wear resistance of the Mg-Al alloy. The Y addition to Mg-3Al-1Zn alloy also improved the corrosion resistance. Wu et al.[8] investigated the effects of Y addition on the microstructure and the mechanical properties of Mg-8Li-(1,3)Al alloys. Results showed that, the Y in LA81 and LA83 alloys could refine and spheroidize the microstructure of alloys. The mechanical properties of LA81 and LA83 alloys were improved because of the Y addition. The improvement of elongation percentage was

Received date: February 25, 2015
Foundation item: High Technology Research and Development Program of China (2011AA03A409); National Natural Science Foundation of China (51574097, 91226201, 91326113); Fundamental Research Funds for the Central Universities (HEUCF141502); Foundation for University Key Teacher of Heilongjiang Province of China (1253G016); Scientific Rescarch and Heilongjiang Postdoctoral Science Foundation (LBH-Q15019, LBH-Q15020, LBH-TZ0411)
Corresponding author: Yan Yongde, Ph. D., Associate Professor, College of Materials Science and Chemical Engineering, Harbin Engineering University, Harbin 150001, P. R. China, Tel: 0086-451-82569890, E-mail: y5d2006@hrbeu.edu.cn

much more obvious than that of strength. Li and co-workers[9] found that Y had a distinct grain refining effect on the Al-5 wt% Cu based alloy. Introduction of Y decreased the liquidus and shortened the crystallization range of Al-5 wt% Cu based alloy. Y additions decreased the hot-tearing susceptibility of the Al-5 wt% Cu based alloy significantly.

The conventional method for the preparation Al-RE or Al-Li-RE alloys is directly mixing the metallic elements. This method has some drawbacks, such as a complicated production process, serious oxidation problem and high energy cost. Molten salts especially molten chlorides have been extensively used as reaction media for performing selective solubilization or precipitation in chemical reactions [10].

Electrochemical preparation of Al-Li-Y alloys from molten salt has been reported by Li et al.[11]. However, they detected only one intermetallic compound signal, and ignored another intermetallic signal. In the present paper, different phases Al-Y alloys were investigated by cyclic voltammetry, square wave voltammetry, open circuit chronopotentiometry and polarization curve. Direct electrochemical preparation of different phases Al-Y alloys can be achieved by adjusting the concentration of $AlCl_3$.

1 Experiment

The LiCl-KCl mixture (LiCl:KCl=50:50, wt%, analytical grade) was dried under vacuum for more than 72 h at 473 K to remove excess water, and then melted in an alumina crucible which was placed in a quartz cell inside in an electric furnace. The temperature of the melts was measured with a nickel-chromium thermocouple protected by an alumina tube. The molten salts were purified by pre-electrolysis at −2.0 V (vs. Ag/AgCl) for 4 h. All experiments were performed under Ar atmosphere.

The electrochemical measurements were performed using an Im6eX electrochemical workstation (Zahner Co., Ltd.). The reference electrode (RE) was a silver wire (d =1 mm) which dipped into a pyrex tube containing a solution of AgCl (1 wt%) in LiCl-KCl (50:50, wt%) melts. All of the potentials were referred to this Ag/AgCl couple. A spectral pure graphite rod (d = 6 mm) served as the counter electrode (CE). The working electrode (WE) was molybdenum wire (d =1 mm, 99.99 %), which was polished thoroughly using SiC paper, and then cleaned ultrasonically with ethanol prior to use. The specimens for SEM/EDS were mounted in thermosetting resins using a metallographic mounting press and then mechanically polished, and finally etched with a solution of 2 vol% HNO_3 in alcohol. The active electrode surface area was calculated after each experiment by measuring the immersion depth of the electrode in the molten salts.

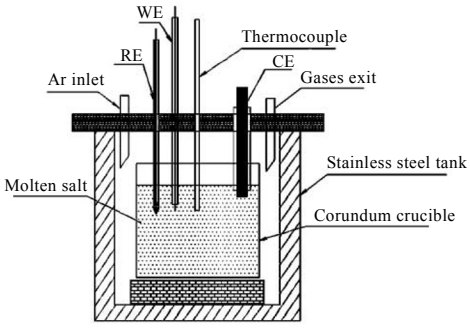

Fig.1 Apparatus of electrolysis cell

The Al-Y alloys were prepared by galvanostatic electrolysis with various $AlCl_3$ concentrations. These specimens were analyzed by XRD (X'Pert Pro; Philips Co., Ltd.) using Cu-Kα radiation at 40 kV and 40 mA. Scanning electron microscopies (SEM) (JSM-6480A; JEOL Co., Ltd.) was used to observe the morphologies of the alloys.

2 Results and Discussion

2.1 Cyclic voltammetry

Cyclic voltammetry was performed at 773 K on a molybdenum electrode in LiCl-KCl-$AlCl_3$ (2wt%)-Y_2O_3 (2wt%) melts (Fig.2). The cathodic/anodic peaks B/B' at about –1.03/–0.95 V correspond to the deposition and the subsequent reoxidation of aluminum. In the positive scanning, cathodic peak D occurs at approximately –2.14 V, which is associated with the formation of a Li-Al alloy by underpotential deposition of lithium on the solid aluminium already coated on the molybdenum electrode[12,13]. Anodic signal D' is caused by the oxidation of Li-Al alloy. In terms of the Al-Y phase diagram, Al and Y can form several inter-

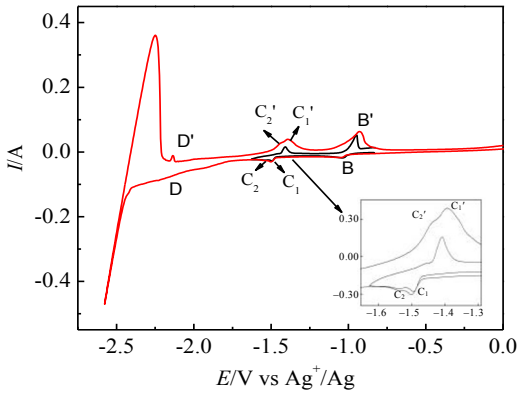

Fig.2 Typical cyclic voltammograms obtained at a molybdenum electrode (S= 0.322 cm^2) in LiCl-KCl-Y_2O_3 (2wt%)-$AlCl_3$ (2wt%) melts with different potential windows at 773 K (scan rate: 0.1 V s^{-1})