Composites Part B 156 (2019) 332–343

Contents lists available at ScienceDirect

Composites Part B

journal homepage: www.elsevier.com/locate/compositesb

A study on Mg and AlN composite in microstructural and electrochemical characterizations of extruded aluminum alloy

L.X. Bach[a], D.L. Son[b], M.T. Phong[c], L.V. Thang[c], M.Z. Bian[d], N.D. Nam[e,*]

[a] University of Science and Technology of Hanoi, 18 Hoang Quoc Viet Street, Hanoi, 100000, Viet Nam
[b] Dong Nai Technology University, Nguyen Khuyen Street, Trang Dai Ward, Bien Hoa City, Dong Nai Province, 810000, Viet Nam
[c] Ho Chi Minh City University of Technology, VNU-HCM, 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, 700000, Viet Nam
[d] School of Materials Science and Engineering, Anhui University of Technology, 59 Hudong N Rd, Huashan Qu, Ma'anshan, 243002, PR China
[e] Institute of Fundamental and Applied Sciences, Duy Tan University, 10C Tran Nhat Duat Street, District 1, Ho Chi Minh City, 700000, Viet Nam

ARTICLE INFO

Keywords:
Aluminum alloy
Alloying
Extrusion
Microstructure
Neutral corrosion
Passivation

ABSTRACT

A combination of composites and metallic materials has been shown to be an effective way to modify the microstructure and thus enhance the corrosion properties. This study focuses on the development of a new aluminum alloy using Mg and AlN composite and the hot extrusion processing. The microstructures and electrochemical properties have been characterized using the advanced surface analysis and electrochemical techniques in a naturally-aerated 0.1 M chloride solution. Open circuit potential and potentiodynamic polarization results indicate that Mg and AlN composite additions could improve corrosion and pitting potentials as well as passive film quality formed on the alloy surface. Electrochemical impedance spectroscopy has confirmed that the addition of Mg and AlN composite also increases the passive film and charge transfer resistances, resulting in an improvement of passive film stability and pitting resistance. X-ray photoelectron spectroscopy suggests that Mg and AlN composite addition promotes the stable passive film formed on the aluminum alloy surfaces due to the existence of Mg oxides/hydroxides and AlN incorporating with Al oxides/hydroxides. The improved pitting resistance could be attributed to the reduction in the grain sizes and defects in the alloy matrix that are observed by electron backscatter diffraction and could directly relate to the alloy dissolution and passive film formation.

1. Introduction

Aluminum and its alloys are one of the most important metallic materials in a wide range of fields such as the aerospace, marine, cycling, and automobile, as well as air and gas cylinders due to lightweight, much less flammability, high strength-to-weight ratio, formability, weldability and low cost [1,2]. As a result, aluminum alloys have been used in a wide range of applications, spiking its demand and usage in recent years [1]. Research activities on aluminum alloys have significantly raised in the technological development of casting alloys, wrought alloys and advanced manufacturing processes, and associated microstructural, mechanical, and corrosion properties [3–7]. Particularly, the aluminum oxide could form on the alloy surface as a protective layer to reduce corrosion of aluminum alloys in most environments and chemical agents [8–10]. These phenomena could be attributed to the increased hardness and dielectricity, as well as thermal stability. Unfortunately, aluminum alloys is susceptible to pitting corrosion due to the penetration of the aggressive ions such as chloride ion through the flaws or defects containing in the flimsy oxide layer on alloy surface [11,12]. Therefore, out of pitting corrosion resistance, aluminum and its alloys need a deep look for reaching its requirements in wide industrial applications. To satisfy this requirement, many efforts have been made to improve the pitting resistance of aluminum alloys via corrosion inhibitors [13,14], or surface treatments [15,16], or microstructure control [12,17], or alloying elements [18,19], or coatings [20,21].

Silicon is the most common of the alloying elements due to easy casting, reduction in melting temperature and cost of a raw material for producing the Al-Si series alloys with good mechanical, corrosion, and wear properties for the different fields of industrial applications [22,23]. However, the casting defects such as a pore or a shrinkage pore as the result of the shrinkage of liquid in the solidification process are still questionable [24]. In addition, Si-containing particles in the matrix could produce a microgalvanic phenomenon, suggesting an initial electrochemical corrosion at these sites. It could result in localized corrosion, producing pitting when these particles were left during

* Corresponding author.
E-mail addresses: nguyendangnam@dtu.edu.vn, namnd@pvu.edu.vn (N.D. Nam).

https://doi.org/10.1016/j.compositesb.2018.08.139
Received 4 August 2018; Received in revised form 30 August 2018; Accepted 31 August 2018
Available online 04 September 2018
1359-8368/

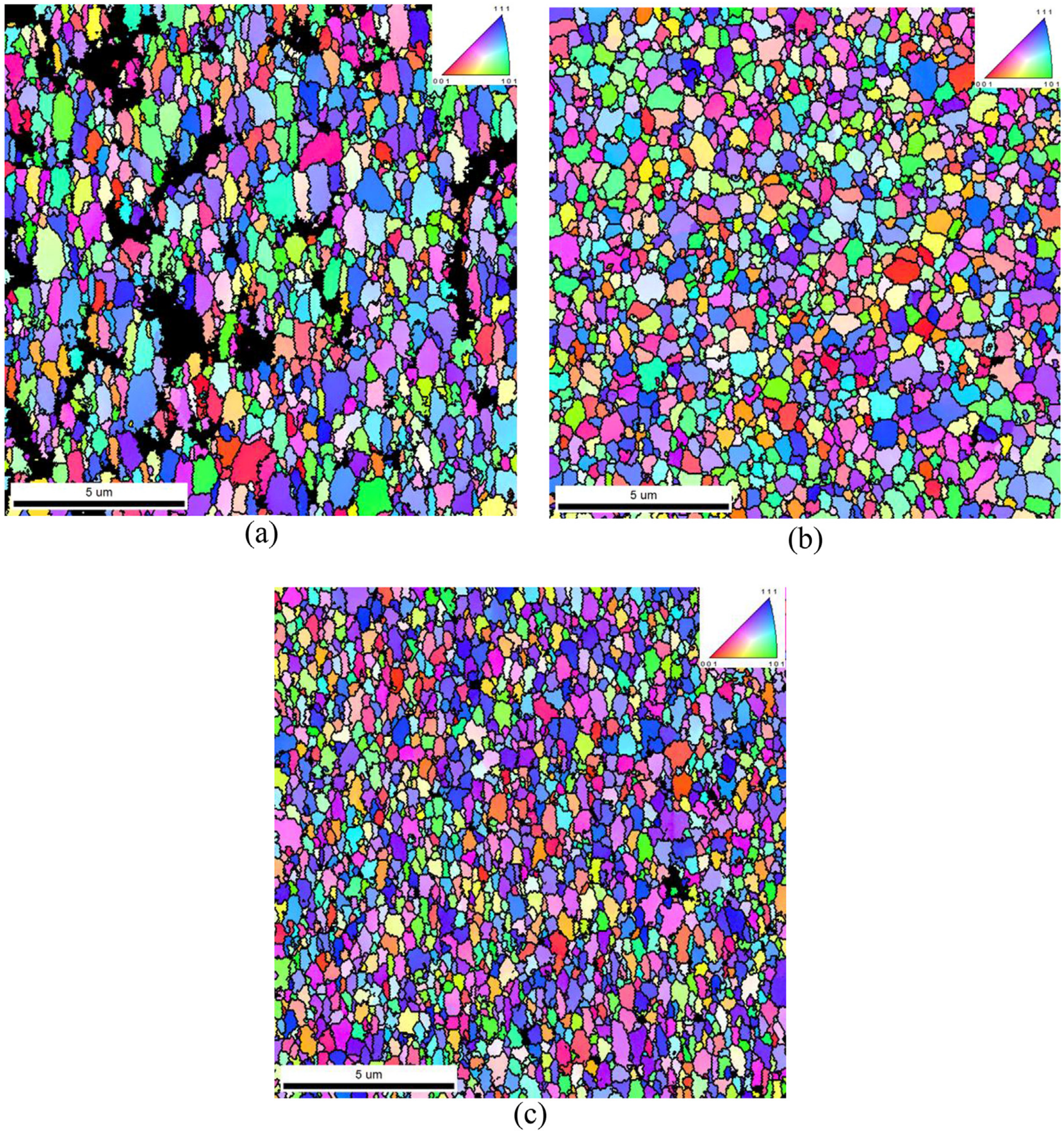

Fig. 1. Electron backscatter diffraction inverse pole figure (EBSD-IPF) map of: (a) Al-based, (b) Al-25AlN, and (c) Al-25AlN-4Mg alloy-structured specimens.

corrosion process [25]. To date, magnesium has been considered as an interest alloying element for producing Al-Mg series alloys due to its advantages such as lighter than other series, much less flammability, light weight, corrosion and wear resistances, as well as high strength [26–28]. Particularly, magnesium added to aluminum alloy could reduce the ductility proportional to increased magnesium content, resulting in possibly useful application for various industries [29]. Furthermore, this series could supply sheets and plates for automobile components, electronics, chemical tankers etc. Unfortunately, hydrogen embrittlement are still in question and this alloy series become more sensitive at elevated temperatures when they are exposed in this condition for a long time as shown by the high equilibrium volume fraction of second phase precipitation at the grain boundaries [30,31]. Therefore, other elements such as Zn, Fe, Mn, and Si, as well as Al_2O_3 composite have been alloyed for improving both mechanical and corrosion properties of Al-Mg series alloys [32–35]. Gopinath and coworkers reported that a decreased of Al_2O_3 particles' volume fraction in Al-4wt.% Mg alloy could result in an improved corrosion resistance [35]. In addition, they also suggested that microgalvanic phenomenon between the reinforcing particles and Al-matrix can be reduced by a suitable amount of Al_2O_3 addition.

Recently, aluminum nitride (AlN) and its composites have been found to have thin films of nitride and/or oxide formed at the surface of the metal in the initial stage of the reaction [36], suggesting an improvement in mechanical and electrochemical properties of materials. AlN is stable with hydrogen and carbon dioxide in the atmosphere at high temperatures and can resist most molten salts. Particularly, it can be slowly dissolved in acidic and strongly alkaline environments through the grain boundary [37]. Furthermore, AlN can be accounted for high thermal conductivity, electrical resistivity, high dielectric strength, as well as low dielectric constant. Based on accumulated experimental results, AlN could be a promising candidate for applying structural materials as an alloying element for Al-based alloy [38,39]. In this study, the Mg and AlN composite were added to aluminum alloys and the effects of these alloying elements were analyzed using electrochemical and surface analysis techniques.

2. Procedures

Pure Al (0.001% Mg, 0.11% Fe, 0.01% Cr, 0.02% Si, 0.005% Ni) and Mg (0.01% Al, 0.11% Fe, 0.01% Cr, 0.02% Si, 0.005% Ni) and particulate AlN nanopowders were used as raw materials. The calculated amounts of 0, 25 vol% AlN, 4 wt% Mg were used as alloying elements. The mixture was milled for 25 h to achieve the steady-state condition.