Journal of Alloys and Compounds 679 (2016) 104–114

Contents lists available at ScienceDirect

Journal of Alloys and Compounds

journal homepage: http://www.elsevier.com/locate/jalcom

Effect of silicon carbide addition on the corrosion behavior of powder metallurgy Cu–30Zn brass in a 3.5 wt% NaCl solution

Mohammed Ali Almomani [a,*], Wa'il Radwan Tyfour [a], Mohammed Hani Nemrat [b]

[a] Department of Industrial Engineering, Jordan University of Science and Technology, P. O. Box 3030, Irbid 22110, Jordan
[b] Department of Mechanical Engineering, Institute of Applied Technology, Abu Dhabi, United Arab Emirates

ARTICLE INFO

Article history:
Received 27 November 2015
Received in revised form
24 March 2016
Accepted 1 April 2016
Available online 4 April 2016

Keywords:
Uniform corrosion
Localized corrosion
Metal matrix composite
Cartridge brass
Silicon carbide

ABSTRACT

A study was made to evaluate the corrosion behavior when Cu–30Zn alloy is reinforced with different weight fractions of silicon carbide (SiC) particles in a simulated sea solution (3.5 wt% NaCl aqueous solution). The composites were produced via powder metallurgy (PM) route. For the sake of comparison, the corrosion behaviors of unreinforced and reinforced alloy were examined. Electrochemical measurements (potentiodynamic testing) showed that the corrosion rate of the composites decreased with increase of SiC weight percentages, as a result of weak microgalvanic couple between reinforcement particles and Cu–30Zn matrix, and the low possibility of intermetallic phases formation. ANOVA test indicated that the variations of corrosion rate of the composites upon changing weight percentages of SiC particles are statistically significant. Polarization curves showed that the passive film tends to be less stable, and the potential difference between passivation and free corrosion points increased with increase of SiC weight percentages, as SiC cathodically protect the matrix material by sacrificial anodic dissolution of crevice regions about reinforcement particles. Scanning Electron Microscope (SEM) images of the sample's surfaces before and after testing are in agreement with the electrochemical results.

1. Introduction

The uses and applications of metal matrix composites (MMCs) are in continuous growth, as their properties can be tailored by controlling their constituents: matrix and reinforcement, and method of composite fabrication [1,2]. Copper based alloys have many outstanding properties; including: high strength, high thermal conductivity and good corrosion resistance. Therefore, they are commonly used in automotive industries, petrochemical heat exchangers, cooling water systems, external constructions [3,4]. Brass is copper zinc alloy, and its properties can be varied by controlling the percentage of both copper and zinc [5,6].

Casting has been used often to produce MMCs; due to its low cost. However, the nonuniform distribution of the reinforcement particles, their agglomeration during solidification of the molten metal, and the unwanted interfacial reactions are drawbacks that limit their use in some cases [7,8]. Therefore, powder metallurgy is being considered as an alternative to casting to produce them, as they are capable to overcome the previously mentioned drawbacks of casting. Also, its low cost, and ability to produce a near net shape products extend their use [9]. Although, PM products have great advantages, the presence of porosities limit the mechanical properties of PMs' product. Several studies have been conducted to decrease the pores, in order to increase the strength of the compact product. For example, shot peening was used and boron was added to Fe/Cu-graphite composites. The study found an improvement in the industrial properties by having a compressive stress on the surface layer [10].

The advantages of powder metallurgy (PM), and the promising applications of the copper based composites make them attractive materials for researchers. There have been studies on powder metallurgy copper reinforced with a single particle, i.e., SiC, G, Al_2O_3 [11].

Few papers have been published on brass alloy produced by powder metallurgy, and even most of that work focused on Cu–40Zn brass that is reinforced with different metallic alloying elements. For example, the effect of titanium addition on the properties of extruded Cu–40Zn brass alloy produced by powder metallurgy had been studied. The produced alloy revealed a considerable improvement in the strength over the conventional binary brass alloy due to precipitation hardening that caused by

* Corresponding author.
E-mail addresses: maalmomani7@just.edu.jo (M.A. Almomani), wrtyfou@just.edu.jo (W.R. Tyfour), mohammednemrat@yahoo.com (M.H. Nemrat).

http://dx.doi.org/10.1016/j.jallcom.2016.04.006
0925-8388/

adding titanium [12]. Other researchers incorporated tin into the brass Cu–40Zn–Ti in order to prevent titanium segregation to grain boundaries, which may limit the improvements achieved. It was found that tin results in a significant grain refinement, and thus improves strength [13]. Similar findings were obtained by adding magnesium particles to Cu–40Zn brass alloy, the strength of the extruded Cu–40Zn brass alloy produced by powder metallurgy have been significantly enhanced, as magnesium particles effectively hindered the grain growth and precipitated at the boundaries of the developed phases [14].

To the best of our knowledge, no work has been published on Cu–30Zn brass produced by powder metallurgy. Also, it seems that no work or little work have been done on this brass composites. The outstanding cold workability, and good hot formability, with good strength, high thermal and electrical conductivity, and high corrosion resistance of Cu–30Zn gave this alloy very attractive characteristics to be used for products in electrical, petrochemical, and marine industries, i.e., flashlight shells, bulbs sockets, fuses, terminal connectors, ammunition cases, plumbing accessories, heat exchangers, condensers tubes, radiators, tanks, etc [6,15–18]. The potential applications of this alloy can be further expanded by enhancing its strength. One way to achieve this is to disperse ceramic particles in the metal matrix. Silicon carbide is extensively used as reinforcement particles in MMCs due to its good mechanical and physical properties, it provides high strength, stiffness, good high temperature stability, and oxidation resistance to the matrix material [19]. As mentioned, the products of this alloy are widely used in many environments, where they are being in contact with chloride anions, which significantly affect their corrosion characteristics. Thus, this paper aims to investigate the corrosion characteristics of this alloy and composites of this alloy matrix that are reinforced with SiC particles in a sea water simulated environment (3.5 wt% NaCl), particularly that there is no or little work has been published in the literature on the corrosion of this composite.

2. Corrosion of metal matrix composites reinforced with SiC

The effect of addition of SiC on the corrosion resistance of MMCs is a controversy issue. The addition of SiC improves corrosion resistance in some cases, while it deteriorates the resistance in other cases. For example, adding SiC to magnesium based composites decreased their corrosion resistance as a result of the produced defective surface film [20]. Similar results were observed for AZ92 magnesium alloy reinforced with SiC particles produced by powder metallurgy, where the corrosion rate in 3.5 wt % NaCl solution increased as a result of rupturing the corrosion product layer into small fragment pieces [21]. In contrast, the corrosion resistance of both nickel, and nickel cobalt alloy were enhanced by incorporating inert SiC particles. This behavior was explained as a result of formation of a weak microglavanic couple between nonconductive SiC and conductive matrix, which hindered the current flow, and thus increased corrosion resistance [22,23]. The corrosion resistance of aluminum and aluminum alloys MMCs reinforced with SiC particles were also extensively investigated by many researchers at different media; including: NaCl solutions [24,25], sea water and acidic media [26], chloride solutions [27], NaOH solution [28], and Na_2SO_4 solution [29]. The effect of particle characteristics (i.e., particle size, and volume fraction), concentration of solutions, and temperature on corrosion resistance and susceptibility to pitting were also studied. It was found that the base alloy was more resistive to corrosion than composite material. Also, both SiC particle size, and its volume fraction in the composite greatly affected the corrosion resistance of the composite, where smaller SiC particles and/or large volume fraction reduced the corrosion rate of the examined composites at ambient temperature. These results were attributed to voids and cracks formation, and poor bonding at the reinforcement/matrix interface. The sequential steps of pits formation and enlargement were also described [30], as pits initiate at either secondary phase particles or intermetallic phases in Al6013–20SiC composites. However, opposite results were obtained for Al/SiC composites fabricated by powder metallurgy route, where they had a better corrosion resistance in a 3.5 wt% NaCl solution than the corresponding monolithic alloy. This behavior was a result of the strong bonding between SiC particles and aluminum matrix, and the low possibility of intermetallic phase (Al_4C_3) formation at matrix reinforcement interface for the examined composites, because of both high purity of the used Al and the used fabrication method (PM) [31]. The corrosion resistance of Al–Mg alloys reinforced with SiC was investigated in both acidic and alkaline solutions; the results showed that introducing SiC particles into composite reduces its corrosion resistance as compared with monolithic alloy [32].

3. Experimental procedure

Cu–30Zn alloy reinforced with silicon carbide particles were fabricated by powder metallurgy. Three different weight percentages (2 wt%, 10 wt%, and 15 wt%) of reinforcement particles were used. The producer or supplier and the characteristics of each one of the used powders are shown in Table 1. The powder was weighed to the required percentages using an electronic balance with an accuracy ±0.01 mg. The powder mixtures were vigorously shaken in a completely sealed container to obtain uniform dispersion of reinforcement particles within matrix material particles. Then, the powders mixture was pressed in a high carbon steel compaction die, shown in Fig. 1, and using universal testing machine at pressure of 500 MPa. The green compacts were placed in oxygen free closed die and sintered at 650 °C for an hour.

A customized flask was used as a corrosion cell container. The flask is tightly sealed with rubber stopper having three holes to hold the graphite counter electrode, the calomel reference electrode, and the working electrode, as shown in Fig. 2.

For the purpose of having only one exposed surface to electrolyte, the examined specimen was hot mounted using Metaserve mounting press, at 4 bars pressure, and for 30 min. Electrical connection was attained via electrical wire inserted into 4 mm diameter drilled hole on the side of the mounted sample.

Table 1
The examined powders producers/suppliers and characteristics.

Powder	Producer/Supplier	Powder characteristics
Alloyed Cu–30Zn	Zhejiang Jililai New Material Co., Ltd.	Mesh ≤ 100 Water atomized Irregular shape particles.
Silicon carbide	Sigma- Aldrich	Extra fine powder 300 grit size Density 3.22 g/ml at 25 °C.