

Effect of changing the silica coating pH on the corrosion characteristics of A6092/SiC/17.5p aluminum metal matrix composite in chloride media



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ABSTRACT

This paper is a continuation to our previous study aiming at optimizing the silica conversion coating treatment for improving the corrosion resistance of A6092/SiC/17.5p aluminum metal matrix composite (AMMC) in Cl^- media. Previous results showed that the corrosion rate and the susceptibility to localized corrosion decreased four times due to barrier properties of the silica layer. The optimum concentration was determined to be 50 g/l. The aim of the current paper is to find the optimum silica coating pH that can provide the highest localized corrosion resistance for AMMC. Corrosion performance, morphology, and electrochemical characteristics of silica conversion coatings on AMMC were examined as a function of silica solution pHs. Electrochemical impedance spectroscopy and polarization testing correlated to macro- and microscopic surface examination and visual inspection. The optimum pH was determined to be ~ 12.9 which is the neutral silica solution pH. It was found that this pH value is critical where increasing or decreasing it has a detrimental effect on the corrosion resistance due to formation of less protective or soluble silica compounds. At pH 9, the silica solution turns to “gel”. Accordingly, processes active during silica conversion coating treatment are kinetically dependent and strongly influenced by silica solution pH.

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1. Introduction

Aluminum alloys have been extensively used in automotive and aerospace industry due to their high mechanical strength to weight ratio. Increasing the industrial demand toward a material of superior mechanical properties was the main driving force for the recent innovation in aluminum matrix composites. Alloying of aluminum alloy matrix with non-metallic phase such as alumina, silicon carbide, graphite has proved to provide superior mechanical strength. However, the presence of non-metallic phase distributed in the alloy matrix has a detrimental effect on the corrosion resistance. Our previous study [1] confirmed the occurrence of several types of corrosion as a function of immersion time in Cl^- solution. Crevice corrosion was the early type of corrosion detected even before immersion in Cl^- media. The sharp potential

difference between the aluminum matrix and non-metallic phase enhanced the galvanic corrosion. With increasing the immersion time in corrosive Cl^- solution, intergranular and pitting corrosion have been identified.

Chromate conversion coatings (CCCs) have been extensively used for over 80 years for corrosion protection of metals and alloys including aluminum alloys and their composites [2,3]. CCCs contain hexavalent chromium Cr(VI) , a known carcinogen and toxic compound. Because of its known toxicity, Cr(VI) is highly regulated by several international communities such as the United States Environmental Protection Agency (EPA), United States Occupational Safety and Health Agency (USOSHA), the European Union Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) regulations, etc. Due to human health and environmental issues, Cr(VI) is now ranked as one of the 186 top toxic compounds.

Silica treatment was investigated for its toxicological and environmental properties as an alternative to chromate conversion coatings. Recently, silica has been proposed for improving the corrosion resistance of A6092/SiC/17.5p aluminum metal matrix composite in Cl^- media [4] due to the outstanding performance that

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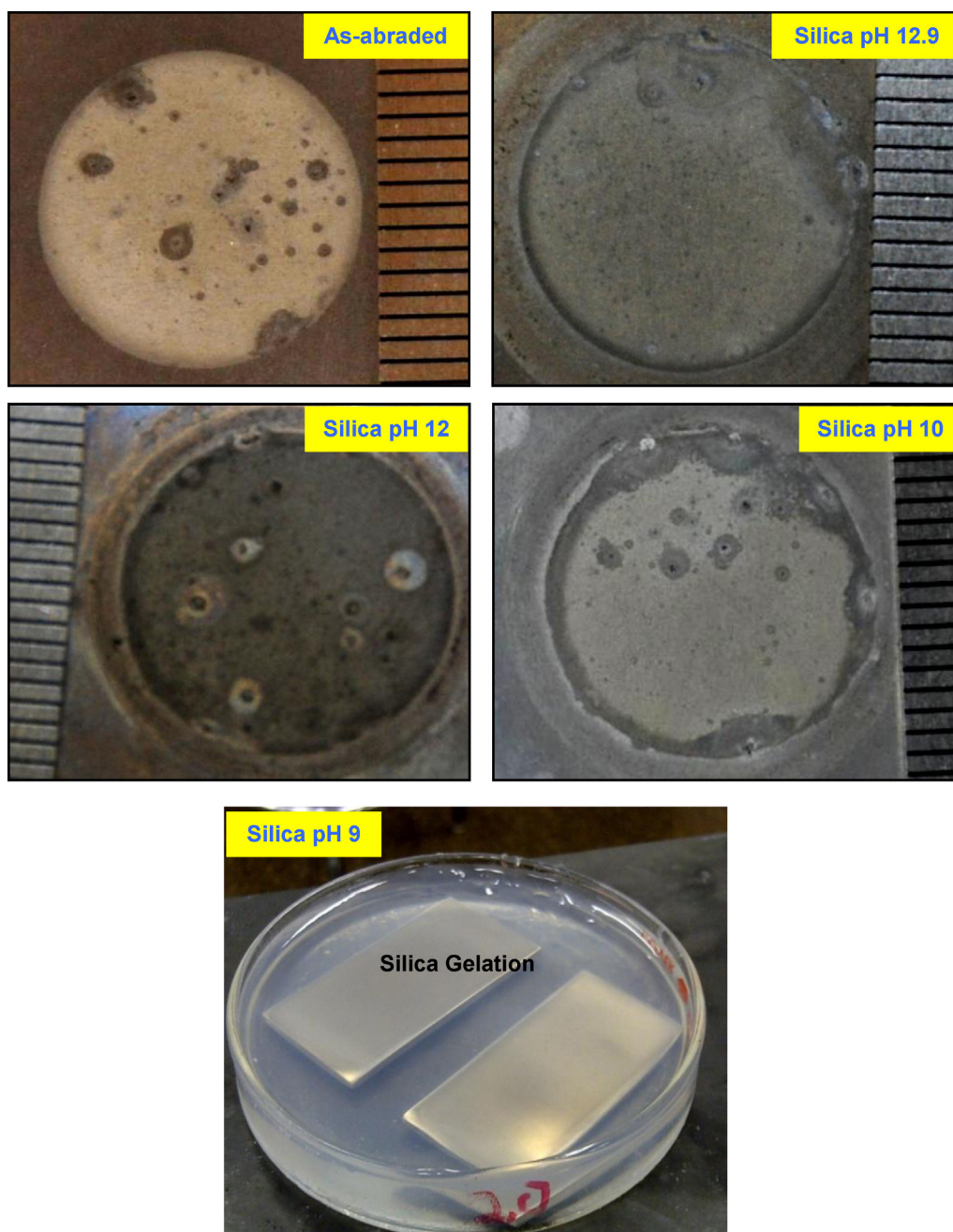


Fig. 1. Macro-images show the localized corrosion resistance as a function of silica coating pH of A6092/SiC/17.5p aluminum metal matrix composite after one week in 3.5% NaCl solution. The last figure shows the conversion of silica to gel at pH 9.

silica conversion coating offered when used for the corrosion protection of some aluminum alloys and composites materials [5–24].

Previous results showed that the optimum silica coating concentration of 50 g/l can improve the corrosion resistance of AMMC four times. Silica coating actively protects the substrate by slowing the kinetics of the oxygen reduction reaction that occurs at local cathodes (i.e., non-metallics) and anodic reactions across the alloy matrix.

This paper aims at determining the optimum silica coating pH that can provide the highest localized corrosion resistance for AMMC in 3.5 NaCl solution. This study focuses on acquiring scientific understanding of the inhibiting mechanism due to silica coating utilizing various techniques including standard electrochemical experiments and SEM/EDS analysis to study the corrosion morphology and kinetics.

2. Experimental

2.1. Materials

Aluminum alloy 6092 reinforced with 17.5% (vol) SiC in a particulate form T6 metal matrix composite was supplied as sheets from Aluminum Company of America (ALCOA). The samples were ground up to 600#, degreased, washed and dried at $\sim 55^\circ\text{C}$. The chemical composition was provided elsewhere [1,4].

2.2. Silica coatings with different pHs

There are two ways for changing the silica solution pH. The first one is to change the silica concentration as explained in details in our last paper [4]. The other way is to control the silica solution pH

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