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Non-nickel-based sealing of anodic porous aluminum oxide in $NaAlO_2$

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ABSTRACT

A fast and non-toxic sealing method based on the use of $NaAlO_2$ solution is investigated in detail. AlO_2 sealing is carried out using $NaAlO_2$ as the sealant, which is neutralized with H_2SO_4 and optimized to pH 7. Temperature, sealing time, pH is optimized in terms of chemical/mechanical properties, measured by Vickers hardness test, Tafel analysis, and sealing quality test based on ASTM-B680. The Vickers hardness, corrosion resistance, and sealing properties of the samples obtained by the proposed sealing method are found to be superior compared to those of the samples prepared by the conventional sealing methods. XPS data show a high intensity of boehmite (AlOOH) peaks in the sample obtained by the $NaAlO_2$-based sealing, similar to the case of the sample obtained by hydrothermal sealing. During the $NaAlO_2$ sealing process, a hard and dense layer of boehmite, which is formed from the dissipated AlO_2^- present in the sealant solution and the dissolved anodic oxide, is deposited within the pores of the anodic alumina in a short time; this leads to enhanced chemical/mechanical properties of the anodic porous alumina sample sealed using $NaAlO_2$.

1. Introduction

Anodization of aluminum has been studied for a long time with the aim of forming a thick oxide layer on the metal surface, to enhance not only the decorative properties but also the corrosion resistance [1–3]. In order to produce a thick oxide layer, a porous-type structure is typically prepared under acidic conditions. It is well known that the thickness of the porous aluminum oxide layer is primarily determined by the anodization time [4,5]. The growth rate of the porous oxide layer is dependent on the type of the electrolyte, applied voltage, and bath temperature. In addition, the pore diameter and interpore distance vary as a function of the type of the electrolyte and applied potential [4–10]. The porous oxide layer exhibits different colors in anodic aluminum oxide, depending on the type of pigment inside the pores [12]. Other coloring methods such as porous oxide itself depending on various incorporated anions or Bragg's mirror effects by alternative different pore size in the depth direction have been reported [13,14]. In addition, the porous oxide layer has been widely used in various applications such as nanotemplates because of its uniformity and regularity, which are obtained by a simple process [4–18].

Sealing of the porous oxide layer is essential not only to retain pigments inside the pores but also to enhance its chemical and mechanical properties [19–21]. Typically, sealing of the pores is carried out by immersing aluminum oxide in hot deionized water, the so-called hot water sealing, hydration sealing, or hydrothermal sealing [22]. However, the process shows slow kinetics, involving high energy consumption. Other methods such as the cold or hot nickel acetate (Ni-acetate) sealing [19,23], sodium silicate sealing, cold nickel fluoride impregnation [24], Cr_2O_3 sealing [25] and sol-gel sealing [26] have been reported by various groups [25,27–29]. Among them, hot nickel acetate sealing and hydrothermal sealing are widely employed in the industry due to their outstanding properties [19] since nickel itself is involved in the sealing process, resulting in high-quality sealing. Nevertheless, nickel acetate sealants contain toxic heavy metal compounds. Thus, sealing processes based on nickel acetate cannot be used in the food/pharmaceutical industry [19,26,28,30]

In this study, we demonstrate a new environment-friendly and low energy consumption process based on $NaAlO_2$, which is a well-known additive used in the microarc oxidation coating of Mg alloys to reduce the porosity and increase the corrosion resistance of the coating due to transforming to $MgAl_2O_4$ by $NaAlO_2$ during MAO coating procedure [31]. $NaAlO_2$ lead to formation of Al_2O_3 deposits and AlOOH in the hot solution. Therefore, we thought that it is similar to form the deposits in the pores by $NaAlO_2$ during the sealing procedure.

2. Experimental

2.1. Preparation of porous anodic alumina

Pure aluminum disc (99.999%) was degreased by ultrasonication using acetone, subsequently washed with deionized water, and air-dried. The degreased aluminum disc was electropolished in a mixture

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