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Al-Fe Composite Films from Dimethyl Sulfone Solution by Electrochemical Technique

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Abstract

Electrodeposition of Al-Fe composite films from the aluminum chloride ($AlCl_3$) - dimethyl sulfone ($DMSO_2$) plating solution with ferric chloride ($FeCl_3$) was investigated. The total metal chloride ratio (($AlCl_3$ + $FeCl_3$) / ($DMSO_2$ + $AlCl_3$ + $FeCl_3$)) is constant at 33.3 mol%. The ratio of $FeCl_3$ to $AlCl_3$ is controlled from 10 to 30 mol%. A current density is controlled from 300 to 1000 A/m^2. Fe content is controllable from 0 % to almost 100 %.

Keywords: Iron Aluminum Composite, Aluminum Plating, Electrodeposition, Non-aqueous Solution, Dimethyl Sulfone

1. Introduction

The physical property of Fe_xAl_{1-x} is not only scientific but also technological interest because of its wide variety of potential applications. The magnetic behavior of this system has been studied by several authors[1-7] because of its variety of magnetic phases such as paramagnetic, ferromagnetic and spin-glass phases. Magnetic film can be a promising candidate for practical applications[8-17]. Electrodeposition is one of the most effective methods for the synthesis of film composites. An aqueous solution has been widely prevalent in the plating solution for the electrodeposition. However, the limited electrochemical window and hydrogen evolution problems have considerably restricted the kinds of metals for the electrodeposition. Aluminum, that is less noble than hydrogen, can not be electrodeposited from aqueous solution. Therefore, the possibility of forming an aluminum film using an organic solvent[18-24], molten salts[25-28], hydride[29] or ionic liquid[30-39] has been studied. A dimethyl sulfone ($DMSO_2$) is one of the most promising candidates for non-aqueous solvent[20-24]. $DMSO_2$ has some distinctive properties for an organic compound, such as a high polarity, high boiling, aprotic solvent and relatively wide electrochemical window. Molten $DMSO_2$ is excellent solvent for a wide variety of compounds including inorganic salts, organics and polymers. The high solubility of many compounds in $DMSO_2$ as well as its high temperature stability makes it an ideal reaction solvent for plating. The plating solution was mainly composed of aluminum chloride ($AlCl_3$) and $DMSO_2$ for aluminum electrodeposition[20-24]. In spite of the large number of the electrodeposition studies for Al alloys from $DMSO_2$ solution, there have no reports on the Al-Fe alloy.

In this paper, we present the results of the electrodeposition of Al-Fe composite films from the $AlCl_3$-$DMSO_2$ plating solution with $FeCl_3$.

2. Experimental method

The plating solution was composed of $AlCl_3$, $FeCl_3$ and $DMSO_2$. The total metal chloride ratio, ($AlCl_3$ + $FeCl_3$) / ($DMSO_2$ + $AlCl_3$ + $FeCl_3$), was constant at 33.3 mol%. The ratio of $FeCl_3$ to $AlCl_3$ was controlled from 10 to 30 mol%. A current density was controlled from 300 to 1000 A/m^2. Since a melting point of dimethyl sulfone was from 107 to 109 ^oC, a plating temperature is necessary to be higher than this value. However, the aluminum plating was not sometimes performed at the temperature lower than 130 ^oC. Results of thermal desorption spectrometry (TDS) showed that the desorption peaks of H_2O appeared at 110 and 150 ^oC. This result suggests that the water in

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