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EFFECT OF HEAT TREATMENT ON STRUCTURAL CHANGES IN METASTABLE AlSi10Mg ALLOY

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Abstract

This paper presents a study on structural changes occurring in a rapidly quenched metastable AlSi10Mg alloy during heating cycles within the temperature range from room temperature to 800 K. Measurement of electrical resistivity of a ribbon showed that structural stabilization takes place at temperatures ranging from 450 K to 650 K. The isotherms of the electrical resistivity measured at temperatures 473 K, 483 K and 498 K revealed two stages of structural stabilization i.e. a kinetic process and diffusion process. Measurement of the thermoelectromotive force of the thermocouple made from the investigated alloy and a copper conductor by a mechanical joining was used to determine relative changes in the electron density of states of the quenched sample after successive heat treatments. The same alloy sample was subjected to successive heat treatments at temperatures up to 503 K, 643 K, 683 K and 763 K. The change in the thermopower suggested that each heating was followed by an increase in free electron density in the alloy. Therefore, the abrupt decline in electrical resistivity was induced by an increase in both the mean free electron path and free electron density during the thermal stabilization of the structure.

Keywords: Metastable AlSiMg alloy, Melt spinning, Thermoelectric properties, Structure relaxation

1. Introduction

Amorphous and nanostructured metallic alloys are among advanced materials with functional properties suitable for use in all technical fields [1], particularly electrical engineering [2]. These materials are commonly obtained by rapidly quenching of molten alloys consisting of transition metals (Fe, Ni, Co, Ti, Mo, Nb, V, Cr, Zr, Pd) - which determine functional (magnetic, mechanical and electrical) properties and metalloids (B, Si, P, C, Ge) - which are responsible for inhibition of crystallization during the hardening process. High cooling rates of about 10^6-10^8 K/s attained during melt-spinning enable atomic arrangement of less than 1 nm [3].

However, amorphous structure of the materials is structurally and thermodynamically unstable and highly susceptible to partial or complete crystallization during thermal treatment. Therefore, it requires knowledge of alloy stability at different temperatures. Generally speaking, stability refers to the thermally active transition from a metastable, disordered amorphous structure to an orderly arranged crystal structure. During synthesis of amorphous alloys, obtained by casting, special care should be taken regarding the proportion of components in the alloy, in order to achieve property improvement, such as enhanced glass-forming ability, good alloy castability (resulting in a good surface finish and high homogeneity of alloy ribbons) and improved thermal stability of the amorphous structure [4-6].

Intensive research into the kinetic properties of amorphous and nanocrystalline alloys suggests a correlation between the physical nature of the anomalous behaviour of the electron state density at the Fermi level, thermal conductivity, heat capacitance and electrical resistivity, as well as structural inhomogeneities of these materials [7-9]. During annealing of amorphous alloys at temperatures about 100 K lower than crystallization temperature, two competitive processes take place: free volume decreases, leading to a reduced rate of diffusion mass transport, and arrangement processes, which bring the alloy closer to the crystallized state and, hence, increase its readiness to crystallize. The thermoelectromotive force (TEMF) measurements of amorphous/metastable alloys can be successfully used for investigation of structural transformation during crystallization process [10].

The objective of this study was to evaluate the effect of structural changes of the metastable AlSi10Mg alloy during annealing on its thermoelectrical properties. The AlSi10Mg alloy is known as very well casting alloy with low density, good thermal properties and suitable mechanical properties [11]. Brandt and Neuer [12] reported

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