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Effect of heat treatment on phase transformations and magnetization of amorphous $Co_{69}Fe_4Cr_4Si_{12}B_{11}$ microwires

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Abstract

The results of qualitative and quantitative changes in phase composition as well as microstructure changes of amorphous $Co_{69}Fe_4Cr_4Si_{12}B_{11}$ microwires at three stage crystallization process of are presented. After first and second stages the amount of crystalline Co-phase was 36 wt. %. To study magnetization of the alloy during heating, exposure and cooling a unique vibration magnetometer with a chemical microreactor was used. The unique vibration magnetometer was used for low inertia real-time measurements under controlled atmosphere. The Curie temperatures of phases formed in the crystallization process were determined. Based on the analysis of magnetization kinetic curves, nucleation and growth mechanisms were established on the stage of primary crystallization. It was found that a one-dimensional mechanism is responsible for the growth of Co-based crystals and leads to the formation of a specific needle-shaped structure. At the second crystallization stage of a metastable phase with a $Co_{23}B_6$ structure type was formed. The Curie temperature of this phase was 165 °C.

Keywords:
Amorphous ferromagnetic microwire, cobalt alloy, magnetic measurements, crystallization, Curie temperature, crystal growth

1. Introduction

Thin amorphous glass coated ferromagnetic microwires obtained by Taylor – Ulitovsky method possess a unique combination of magnetic and strength properties [1, 2]. As-prepared magnetic microwires based on Co-rich composition are typically characterized by a quasi-linear magnetization curve and exhibit a large giant magnetoimpedance effect in the presence of weak magnetic fields [3–6]. Various annealing treatments were proposed to improve giant magnetoimpedance effect or to complete change of the microwire magnetization curve from quasi-linear to a magnetic bistable type with low switching fields [7–10]. In these cases, the annealing temperature was well below the crystallization temperature and did s not produce structural transformations. Recently, the method of a giant increase in coercivity of a magnetization curve was reported for microwires of $Co_{67.7}Fe_{4.3}Cr_3Si_{11}B_{14}$ composition after a directional crystallization [11]. Hard magnetic microwires are of interest as micromagnets, but a lot of questions related to crystallization process are still open.

There are many questions related to qualitative and quantitative composition of the phases such as their stability, the kinetics of crystallization, the nature of the components redistribution and the effect of structure and phase transformations on the magnetic properties which have not been studied in detail. It should be noted that the systematic studies of structure and phase