Effect of structural changes during annealing on the electric and magnetic properties of $Fe_{81}B_{13}Si_4C_2$ amorphous alloy

A. MARIČIĆ, M. SPASOJEVIĆ, L. RIBIĆ-ZELENOVIĆ*, N. MITROVIĆ
Joint Laboratory for Advanced Materials of SASA, Section for Amorphous Alloys,
Svetog Save 65, 32000 Čačak, Serbia

Structural changes in the $Fe_{81}B_{13}Si_4C_2$ amorphous alloy during annealing were established using differential scanning calorimetry and X-ray analysis. The alloy is stable up to 200°C. Structural relaxation occurs in the temperature interval 200-400°C resulting in short term structural ordering. Nanocrystals of the α-Fe phase form from very unordered clusters in the alloy matrix. The effect of these structural changes on magnetic and electric properties of this alloy was established. After relaxation the magnetic permeability is higher for about 18% due to the increase of mobility of magnetic domain walls and better domain directionality. At temperatures above 310°C the magnetic permeability first gradually and then rapidly decreases with temperature growth to zero value at the Curie temperature. With the increase in participation of the crystal phase in the alloy the Curie temperature increases from 410 to 590°C. In the temperature interval from 500 to 560°C crystallization occurs leading to a rapid decrease of electrical resistance. Therefore, at room temperature the crystallized alloy has a magnetic permeability about 55% lower than the as quenched amorphous alloy.

(Received July 10, 2009; accepted August 04, 2009)

Keywords: Amorphous, Ribbon, Magnetic permeability, Electrical resistance

1. Introduction

Technical progress and the development of new technologies are significantly accelerated by the development of new materials. Due to their specific electrical, magnetic, corrosive and other properties amorphous and nanostructured materials have been widely applied [1-4]. Amorphous materials are characterized by a structure where distant order atom arrangement is absent. These materials are thermodynamically unstable. During heating their structure changes relatively easily. First, structural relaxation occurs at lower temperatures. At higher temperatures crystallization occurs. These structural changes significantly change electrical, magnetic, corrosive, catalytic and other properties of these materials [4-19]. Many amorphous alloys after structural relaxation have significantly improved magnetic and other properties. However, their extremely good magnetic properties disappear after crystallization, so these materials cannot be practically applied after crystallization.

Iron and boron alloys are significant among amorphous alloys due to their soft ferromagnetic properties with a high saturation magnetic flux density. These alloys are applicable in a variety of devices, including transformers, magnetic tapes and recorder heads [20-22]. The electronic structure of iron and boron amorphous alloys is still not clear. It is not known whether boron is an electron donor or acceptor [22-26]. Replacement of boron with silica in the iron and boron alloy gradually increases the Curie temperature. This results in a sharp increase of relatively constant room-temperature saturation magnetization in $Fe_{80}B_{20}$ to $Fe_{82}B_{12}Si_6$.

The alloy crystallization temperature grows with the increase in silica and decrease of the iron and boron contents. It has been established that $Fe_{81}B_{17}Si_2$ and $Fe_{82}B_{12}Si_6$ alloys have the highest saturation magnetization, high stability and ease of preparation [27]. It has been shown that the soft magnetic properties of the Fe-B alloy improve with reduction of crystal grain size of the α-Fe phase from 20 to 10 nm. Crystallization kinetics of the $Fe_{83}B_{17}$ amorphous alloys was determined by growth of two-dimensional nucleuses [27]. However, crystallization of the $Fe_{81}B_{13}Si_4C_2$ alloy occurred in the amorphous mass by forming three-dimensional nucleuses of the α-Fe phase [28]. Three-dimensional nucleuses of different phases also formed during crystallization of the $Fe_{81}B_{13.5}Si_{3.5}C_2$ amorphous alloy [29, 30]. At temperatures slightly higher than 507°C crystals of α-Fe and Fe_2B_3 phases formed. If the temperature is significantly increased a metastable γ-Fe phase also formed [27, 28]. Atomic rearrangement and amorphous-to crystalline transformations during isothermal annealing have been investigated by Mössbauer spectroscopy [29]. It was shown that rearrangement in the amorphous state consists of two processes depending on the annealing temperature. The first process is attributed to enhancement of the short-