# RELATIONSHIP BETWEEN MAGNETIC AND STRUCTURAL PROPERTIES OF AMORPHOUS $Fe_{47}Ni_{25}B_{18}Si_{10}$ RIBBONS*

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In the presented paper the relationship between the magnetic properties and the structural changes in the process of annealing of the amorphous alloy $Fe_{47}Ni_{25}B_{18}Si_{10}$ is studied. The results indicate the heterogeneous magnetic state of the alloy in the region of its subcritical heating. The alloy consists of two amorphous phases, the Curie temperature of one is $\approx$ 425 K, while that of the second is $\approx$ 628 K. The influence of the magnetic phase transition on the temperature dependence of the coercive force as well as the influence of the subcritical heating on the saturation magnetization are discussed.

## СВЯЗЬ МЕЖДУ СТРУКТУРОЙ АМОРФНЫХ ЛЕНТ $Fe_{47}Ni_{25}B_{18}Si_{10}$ И ИХ МАГНИТНЫМИ СВОЙСТВАМИ

В работе изучается связь между магнитными свойствами и структурными изменениями в процессе отжига аморфного сплава $Fe_{47}Ni_{25}B_{18}Si_{10}$. Результаты исследований свидетельствуют о наличии в сплаве гетерогенного магнитного состояния в области ниже точки его критического нагрева. Сплав имеет две аморфных фазы: точка Кюри первой равна 425 К, в то время как точка Кюри второй равна 628 К. Обсуждается влияние магнитного фазового перехода на температурную зависимость коэрцитивной силы, а также влияние подкритического нагрева на намагниченность насыщения.

## I. INTRODUCTION

In [1] the influence of heat treatment on the coercive force of the magnetic soft [2] amorphous $Fe_{47}Ni_{25}B_{18}Si_{10}$ alloy was studied. It could be concluded from the thermomagnetic curves and also from the temperature dependence of the magnetic susceptibility that the given alloy in the amorphous state is magnetically

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heterogeneous. This is evident from Fig. 1, (taken from [1]) which shows the temperature dependence of the remanence and that of the magnetization in the constant external magnetic field 80 A/m ($J_{80}$), resp. 2400 A/m ($J_{2400}$) on the decreasing branch of the hysteresis loop. The magnetic order of one of the amorphous phases disappears at $T_t^a \approx 425$ K, of the second at $T_c^a \approx 628$ K. In this connection it seems reasonable to study in more detail the influence of the structural alternations in the amorphous state on the coercive force and on the saturation magnetization. The aim of this paper is to study such a relationship.

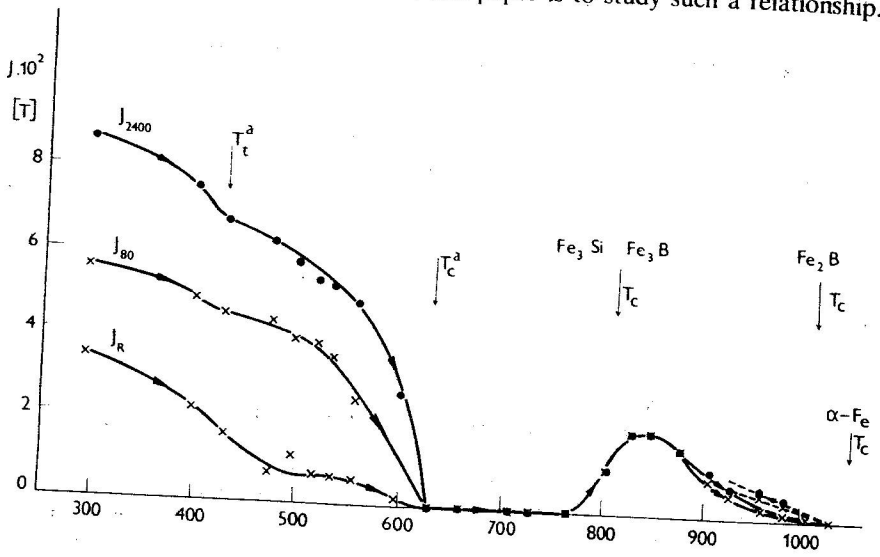


Fig. 1. Temperature dependence of the remanence and of the magnetization in the constant magnetic field 80 A/m ($J_{80}$), resp. 2400 A/m ($J_{2400}$), on the decreasing branch of the hysteresis loop. Rate of the sample heating ≈ 1.7 K/min (according to [1]).

## II. EXPERIMENTAL

Measurements were made on amorphous $Fe_{47}Ni_{25}B_{18}Si_{10}$ alloys prepared by the melt spinning technique [3]. The samples had the form of long ribbons 14 μm thick and 0.33 mm wide. Their amorphousness was verified by electron diffraction. Magnetic measurements were performed using an astatic magnetometer (up to 40 kA/m) and an induction magnetometer (up to 1.6 MA/m).

## III. RESULTS AND DISCUSSION

Fig. 2 shows the dependence of the coercive force $H_c$ upon the temperature $T$ when the rate of the temperature increase was ≈ 1.7 K/min. Curve A corresponds



to the case when the sample was heated to a temperature of 495 K and then cooled down to room temperature; similarly, curve B corresponds to the sample heating to a temperature of 660 K and curve C to the heating of up to 720 K — the cooling in both cases was as in the case A. (It is seen from Fig. 1 that sample heating to a temperature of 720 K does not lead to its crystallization; evidently the crystallization took place in the process of cooling as it is seen from the cooling curve). From the obtained dependence the influence of the subcritical heating on the coercive force is evident. After an initial decrease, which is connected with the influence of the annealing on the decrease in the strain — magnetostriction anisotropy [4], the characteristic increase of the coercive force in the temperature region 380—429 K may be observed. For this range of temperatures a loss of the

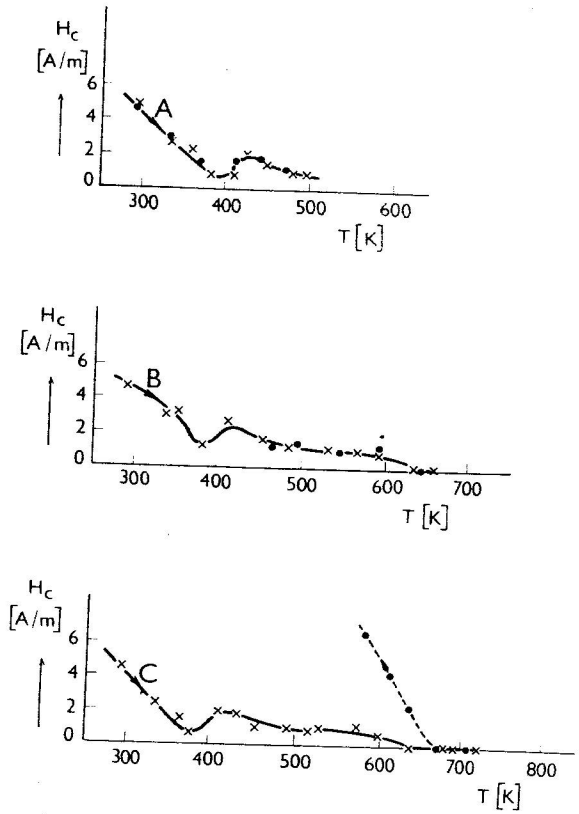


Fig. 2. Temperature dependence of the coercive force at the subcritical heating (crosses) to the temperature of 495 K (curve A), to 660 K (curve B) ant to 720 K (curve C). The full points correspond to the cooling of samples.

Table 1

| $T_{max}$ [K] | Magnetization [$10^{-4}$ Wb m kg$^{-1}$] |
|---|---|
| 293 | |
| 495 | 0.631 |
| 660 | 0.686 |
| 710 | 1.226 |
| | 1.438 |

magnetic order of one of the amorphous phases [1] in the given alloy is characteristic. When we suppose that in the amorphous rapidly quenched materials the mechanism of the coercive force due to domain wall displacements is applicable [5], then the formation of the paramagnetic regions in the process of heating may be put in connection with the observed increase of the coercive force, because these regions form new obstacles to the domain wall movement. An important role will pay here, of course, also the size of the formed non-ferromagnetic regions, with which the possible rearrangement of the domain structure is connected — this may be treated analogously as the influence of inclusions on the coercive force. However, this problem should be studied separately.

The following Table presents the measured values of the saturation magnetization at room temperature on individual samples after the subcritical annealing to different temperatures $T_{max}$. The increase of the saturation magnetization with the increase of the annealing temperature is evident. This fact indicates that in the amorphous state the crystallization temperature of the given alloy $T_{cr} \approx 766$ K the structural changes during annealing takes place, which may be considered as a preliminary stage for the later formation of the crystalline $Fe_3Si$, $Fe_3B$ and may be still others in the basal alloy. Such a mechanism of the formation of the crystalline phase from the regions enriched with the glass-former element is known from a number of works (for example [5, 6]).

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