SPONTANEOUS HALL EFFECT AND TEXTURE OF MICROCRYSTALLINE Fe—Si—Sb ALLOYS[1])

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The spontaneous Hall effect and the grain texture of microcrystalline Fe - 6 wt. % Si — 0.08 wt. % Sb alloys were studied. The effect of the tensile stress was investigated too.

I. INTRODUCTION

The microcrystalline Fe—Si alloys of increased silicon content prepared by a rapid quenching roll method in ribbon form have excellent magnetic properties such as high permeability, low hysteresis losses, low magnetostriction and high electrical resistivity [1, 2, 3]. As the silicon content increases to 6 wt. %, the massive material becomes brittle, but a planar flow technique permits a ductile ribbons elaboration.

It is known that the addition of a small ammount of antimony is effective for developing the preferred (110) [001] texture and the (100) texture in grain oriented silicon steel [4, 5]. Therefore it is interesting to investigate microcrystalline Fe—Si alloys with a small ammount of Sb.

II. EXPERIMENTAL PROCEDURE AND RESULTS

The rapidly quenched Fe — 6.0 wt. % Si — 0.08 wt. % Sb alloys were prepared by a singleroll method on a steel wheel under an argon atmosphere. The starting alloy material was made from pure electrolytic iron (99.99 %), pure silicon (99.999 %) and $Fe_x Sb_y$ intermetallic compounds. The ribbon size abtained was ~35 μm in thickness and ~12 mm in width.

Grain diameter measurements were made by optical micrography on the ribbon surface after mechanical polishing and etching. The average grain size was 8 μm for as cast ribbon and about 100 μm for ribbon annealed at 1100 °C for 60 minutes in argon. After the annealing of ribbons a columnar structure of grains on the cross section was observed, while for as cast ribbons the dendritic structure was observed. A typical microstructure of ribbons in the as-quenched state is shown in Figs. 1 and 2. Fig. 3 shows that the grains grew across the whole width of ribbons annealed at 1100 °C for 60 minutes.

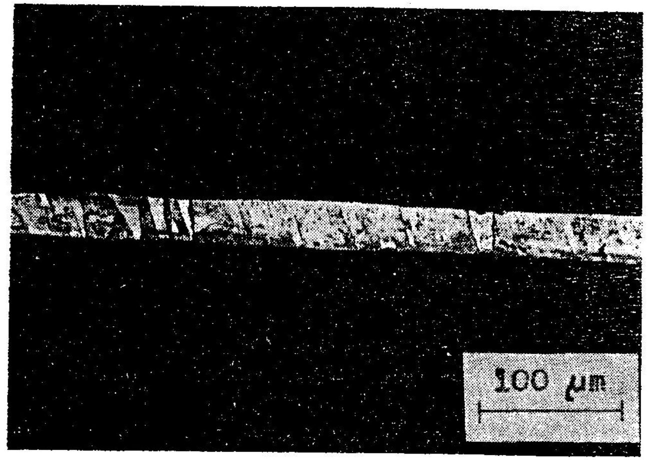

Fig. 1. Microstructure of Fe — 6 % Si ribbon (as quenched state, cross section, magnif. 200 ×)

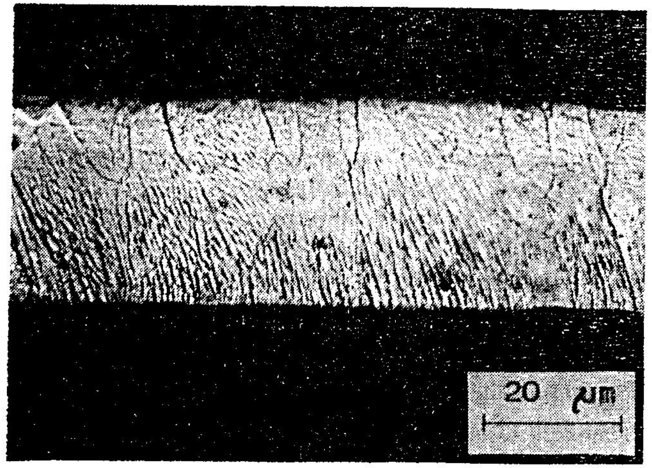

Fig. 2. Micrograph of Fe — 6 % Si ribbon (as quenched state, detail of the cross section, magnif. 1000 ×)

The grain texture was investigated by X-ray pole figure measurements. From a (200) and (110) pole figure analysis by computer some expressive maxima of an Orientation Distribution Function (ODF max) of grains were determined.

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These maxima for annealed Fe—Si and Fe—Si—Sb ribbons are shown in Table 1.

The Hall resistivity ϱ_H in ferromagnetic materials may be written as

$$\varrho_H = U.\frac{d}{I} = R_0 B + \mu_0 M(R_1 - R_0 N),$$

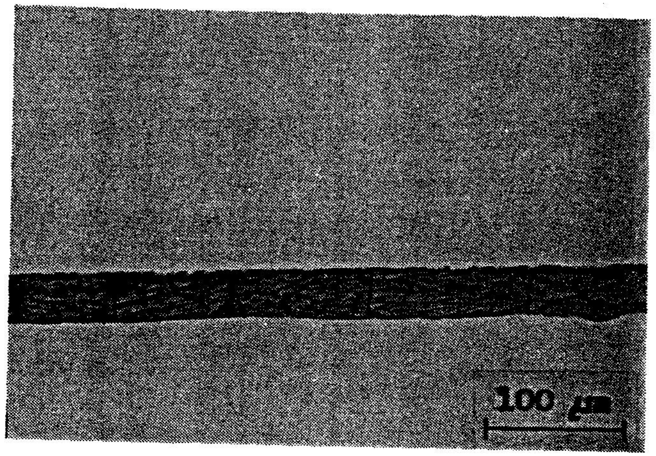

Fig. 3. Microstructure of Fe — 6 % Si ribbon after annealing at 1100 °C for 60 minutes in argon (magnif. 200 ×)

Table 1

The maxima of orientation distribution function of grains for annealed Fe—Si and Fe—Si—Sb ribbons.

(*hkl*)	[*uvw*]	Fe—Si ODF max.	Fe—Si—Sb ODF max.
001	100	6.2	9.7
001	011	18.6	29.7

where U is the Hall voltage, d the thickness of the specimen, I the electrical current, B the applied magnetic induction, M the magnetization, N the demagnetization factor (assumed equal to ≈ 1 for our geometry), R_0 and R_1 are the ordinary and extraordinary Hall coefficients, respectively; and $R_1 = R_0 + R_s$, where R_s is the spontaneous Hall coefficient. The ordinary effect (R_0) arises from the Lorentz force and thé spontaneous effect (R_s) is due to the scattering of spin-polarized carriers through spinorbit interactions from impurities and phonons.

Room-temperature measurements of the Hall effect were carried out with ordinary dc method (using a constant-current source, nanovoltmeter and minicomputer) with the possibility of tensile stress application. The Hall voltages were recorded as a function of the applied field at the constant tensile stress f. For $T < T_c$ (T_c is Curie temperature) there is $R_1 \gg R_0$ and $R_1 \approx R_s$ may be determined by the initial slope $\left(\frac{\partial \varrho_H}{\partial B}\right)_{B \to 0}$ [6, 7].

Table 2

Tensile stress dependence of the spontaneous Hall coefficient R_s for annealed Fe—Si—Sb alloys.

$f.3 \times 10^{-8}$ [Pa]	$R_s [10^{-10}\ m^3.A^{-1}.s^{-1}]$
0	1.89
1	1.86
2	1.84
3	1.82

The change of the spontaneous Hall coefficient R_s with tensile stress f for our annealed Fe—Si—Sb alloys are very small as can be seen in Table 2. The spontaneous Hall coefficient is closely connected with real electronic structure [6, 8]. When a tensile stress is applied parallel to the long axis of the Fe—Si—Sb ribbon, a deformation of the lattice may occur and this may lead to the change of the electronic structure. These effects can explain the observed small decrease of the coefficient R_s when the tensile stress increases.

III. CONCLUSIONS

The grain texture produced by a rapidly rolling ribbon is similar to the rolled texture of conventional silicon steel. The existence of the cubic (001) [100] texture in microcrystalline alloys probably leads to better magnetic properties at high inductions than in the conventional grain oriented steel [3]. We attribute the measured changes of spontaneous the Hall coefficient R_s with the tensile stress to the changes of the electronic structure due to the deformation of the lattice in our microcrystalline Fe—Si—Sb alloys.

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СПОНТАННЫЙ ЭФФЕКТ ХОЛЛА И СТРУКТУРА МИКРОКРИСТАЛЛИЧЕСКИХ Fe—Si—Sb СПЛАВОВ

В работе изучается спонтанный эффект Холла и зернистая структура микрокристаллических Fe—Si—Sb сплавов. Наряду с этим рассматривается влияние растягивающего напряжения.