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A NOTE ON THE ROLLING TEXTURE OF NICKEL-IRON-NIOBIUM ALLOY

L. C. TAI and ZEN-JUE TAN

Central Iron and Steel Research Institute, Beijing, China

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Abstract. The nickel-iron-niobium alloy containing about 79% Ni, 8% Nb and 13% Fe in sheet form has been prepared and fabricated. The rolling texture of the alloy after cold reduction of 50 and 94% has been determined by using X-ray counter diffractometer and the results are presented in pole figures. In comparison with Ni-Fe-Mo, the results are discussed from a view of the difference of mechanical hardness between these two categories of alloys.

INTRODUCTION

The reversible Ni-Fe alloys possessing high values of magnetic permeability at low magnetizing fields are generally known as permalloys. The highest value of initial permability occurs at about 78% Ni, the stoichiometric composition being related to the superstructure Ni_3Fe. With treatment at a critical range of temperatures below 600°C the change of magnetic properties is associated with the formation of superstructures.

The permalloys used in communication engineering are ternary Ni-Fe alloys containing Mo or quaternary alloys containing Cu and Mo or Cu and Cr. In the recent design of head materials used in magnetic tape recording not solely the magnetic properties are required, but also the resistance to wear and insensitivity to stress are important factors to be considered.

The properties of the system of Ni-Fe-Nb have been investigated in detail by Masumoto and his co-workers.[1] In our laboratory we have studied the physical properties of the Ni-Fe-Nb alloys.[2,3] It is found that adequate composition, fabrication and heat treatment of the material will yield optimum properties to meet the requirements in application as magnetic transducer materials.

As cold rolling plays a significant role in the fabrication of the material, in connection with other work we have studied the rolling textures of some of the specimens upon which the present note is chiefly concerned.

EXPERIMENTAL PROCEDURE

The alloy ingots weighing about 25 kg were prepared in the usual way by melting in a vacuum induction furnace. The ingots were hot forged and rolled into slabs of 3 mm thickness. Samples for chemical analysis were taken from the forged bars, examples being given in Table I.

TABLE I

Chemical Compositions of Ni-Fe-Nb Alloy in Wt.%

Ni	Nb	C	Mn	Fe
79.85	7.39	0.012	0.064	balance
79.54	8.00	0.015	0.037	balance

The slabs were cold rolled to a thickness of 1 mm after pickling. As the recrystallization temperature of the alloy is higher than that of the conventional permalloys, the intermediate anneal has to be carried out at a higher temperature. The material was then cold rolled to sheets of various thicknesses.

The textures of the cold rolled sheets after a reduction of 50% and a reduction of 94% were studied by using an X-ray counter diffractometer and the {111} pole figures were plotted accordingly.

EXPERIMENTAL RESULTS AND DISCUSSION

We measured some of the physical properties of the specimens, the results being summarized in Table II. In this table, the physical parameters of Mo-permalloy are mainly chosen from the work of Borzorth[4] except that the lattice constant was measured in our experiment with the specimens prepared in our laboratory. The specimens were annealed for 2 hours at 1000°C in dry hydrogen. With regard to the parameters of Ni-Fe-Nb, the results were obtained in our experiments. It will be noted from the data that the value of mechanical hardness of Ni-Fe-Nb is higher than that of the Mo-permalloy.

The pole figures of the alloy after cold deformation are represented in Figures 1 and 2. From the pole figures it is interesting to note that (110)[$1\bar{1}2$] is the major component of the texture. This implies a [111] direction parallel to the transverse direction. The component (110)[112], however, shows a considerable spreading about its positions

TABLE II

Physical Properties of Ni-Fe-Nb and Mo-Permalloy

Alloy	Composition Wt%	Composition at%	Curie Temp. Tc °C	Sat. Mag. 4π Ms(G)	Elec. Resis. (micro-ohm-cm) ρ
4 Mo-Permalloy	Ni 79 Fe 17 Mo 4	Ni 79.5 Fe 18 Mo 2.5	460	8700	55
Ni-Fe-Nb	Ni 79 Fe 13 Nb 8	Ni 80.4 Fe 14.4 Nb 5.2	297	6250	75

Alloy	Mod. of Elasticity, E	Vickers Hardness, Hv	Lattice Parameters (a), Å	Density, d (g/cm^3)
4 Mo-Permalloy	$\sim 2 \times 10^{12}$	120-140	(220) 3.563	8.72
Ni-Fe-Nb	2.156×10^{12}	200	(220) 3.571	8.8

as indicated by Burgers and Verbraak[5] for the f.c.c. metals in general.

In Figure 1, the component $(1\bar{1}0)[001]$ and other weak component of high indices may be assigned to the orientations. After heavy rolling, with reference to Figure 2, the major component $(110)[1\bar{1}2]$ of the texture in the specimen seems more concentrated. The spreading about the position is not so great in the specimen which has undergone a reduction of 50%.

Recently some authors classified the rolling textures of the f.c.c. metals and alloys into the "copper type" and the "brass type." The texture of the Mo-permalloy after a cold reduction of 99% has been investigated by Koh.[6] As we have pointed out that the Ni-Fe-Nb possesses higher mechanical hardness, so it seems reasonable to suppose that the rolling texture of Ni-Fe-Nb with the chemical compositions as above cited will near to the "brass type." From Figure 2, it will be seen that $(1\bar{1}0)[112]$ component of the texture in heavily rolled alloy is a dominant texture. We consider that for f.c.c. alloys, like Ni-Fe-Nb which possesses a higher value of mechanical hardness, the spreading from the major component will not be so great as that of the soft material, Mo-permalloy.

The phase diagram of the binary alloy of Ni-Nb has been studied by Duerden and Hume-Rothery.[7] When the concentration of Nb reached 4.2 at%, a precipitating phase will be formed in the alloy Ni-Nb at room temperature. In our present investigation the concentration of Nb in the ternary alloy of Ni-Fe-Nb is 5.2 at% and we have found no precipitating phase in the specimens. It shows that the solubility of Nb in Ni

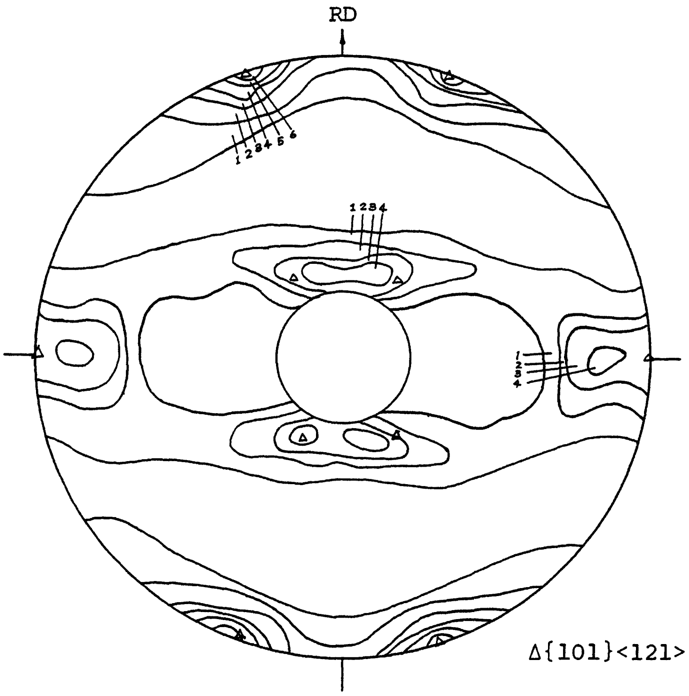

Figure 1. {111} Pole figure showing the rolling texture of Ni-Fe-Nb after a cold reduction of 50%.

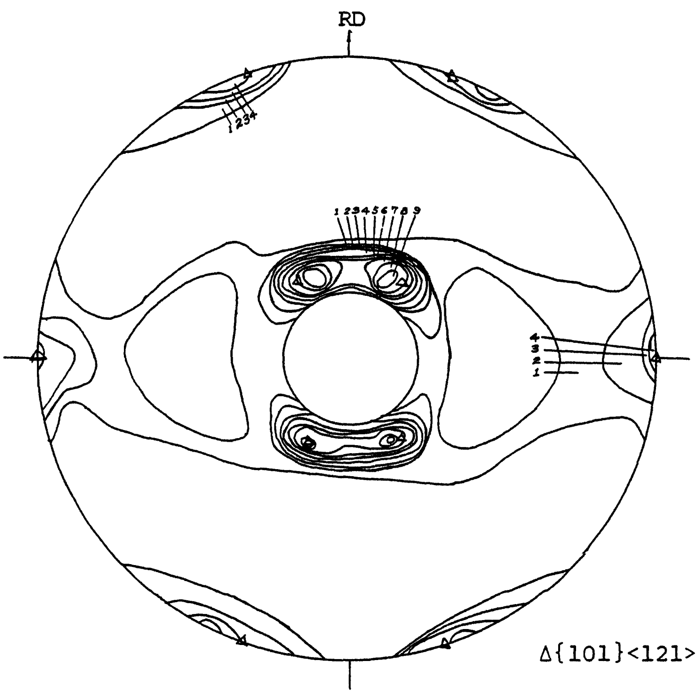

Figure 2. {111} Pole figure showing the rolling texture of Ni-Fe-Nb after a cold reduction of 94%.

may have been enlarged when Fe is added to the solution. By using the thin film technique in electron microscopy and the method of selected area in electron diffraction, it shows that both in Mo-permalloy and also in Ni-Fe-Nb after final anneal modulated structure is present in the specimens. The areas of the modulated structure are larger in Ni-Fe-Nb than in Mo-permalloy and the contrast is more in a state of pre-precipitation to which the hardness of the metal may be attributed.

SUMMARY

1. The ternary alloy Ni-Fe-Nb possesses higher recrystallization temperature and higher mechanical hardness in comparison with the conventional technical Mo-permalloy.
2. The rolling texture of the alloy after a cold reduction of 50% and of 94% has been studied and it shows that the major component (110)[$1\bar{1}2$] is more concentrated in the heavily rolled specimens.
3. It is considered that the higher mechanical hardness of the alloy may yield a component of the texture not so spreading from its positions in the process of deformation.

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