THE MARTENSITIC TRANSFORMATION AND THE CHANGE OF THERMO-REMANENT MAGNETIZATION (TRM)

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Abstract: The changes of the direction and intensity of the TRM of 25at% and 29at% Ni-Fe alloys have been measured after cooling at 77 K in zero magnetic field and in geomagnetic field. TRM of fcc phase is not preserved in bcc phase after the martensitic transformation. The remanent magnetization of bcc phase is in the direction of the external magnetic field in the process of the martensitic transformation.

1. Introduction

The remanent magnetization (RM) of meteorite is mainly due to the included magnetic grains of the Fe-Ni alloys in stable fcc phase or in bcc phase martensitically transformed from fcc phase. The martensitic transformation of Fe-Ni alloys is caused by cooling, rolling or grinding, which depends on the sample shape besides the chemical composition. The experimental results are listed in Tables 1a and 1b.

In order to study the cosmic paleomagetism by RM of meteorite, it is very important to investigate whether RM of the Fe-Ni alloys change through the martensitic transformation, or not.

2. Experimental Results and Discussion

The thermomagnetic curves of Y-74646 chondrite were similar to those of 25at%-

Table 1a. The experimental results of Fe-Ni alloys.

Sample	Original	Annealing	Cooling at 77 K	Rolling (R) or grinding (G)
29at% Ni-Fe(b)	fcc(from melting P)	fcc(800–750°C)	bcc+fcc	bcc+fcc (R)
29at% Ni-Fe(p)	fcc(from melting P)	fcc(800°C, 1–2 h)	fcc	bcc+fcc (G)
28at% Ni-Fe(b)	fcc(from melting P)	fcc(800–750°C)	bcc+fcc	bcc+fcc (R)
28at% Ni-Fe(p)		fcc(800°C, 1–2 h)		bcc+fcc (G)
27at% Ni-Fe(b)	bcc≫fcc(quenched from 1150°C)	bcc≫fcc		bcc>fcc (R)
27at% Ni-Fe(p)		fcc(600°C, 1 h)	fcc≫bcc	
26at% Ni-Fe(b)	bcc≫fcc(quenched from 1150°C)	bcc≫fcc (750°C, 24 h)		bcc (R)
26at% Ni-Fe(p)		fcc(600°C)	fcc>bcc	bcc>fcc (G)

(b): block sample, (p): powder sample.

Table 1b. The thermal hysteresis of magnetization of powdered Fe-Ni alloy.

Sample	Temperature and magnetization
25at% Ni-Fe	(600°C ann.)→10.8 emu/g(T_r)→(liq.N_2)→170 emu/g(T_r)→(liq.He)→172e mu/g(T_r)
26at% Ni-Fe	(600°C ann.)→16 emu/g(T_r)→(70°C)→16 emu/g(T_r)→(liq.N_2)→37 emu/g(T_r) →(800°C 24 h)→21.5 emu/g(T_r)→(0°C)→21.5 emu/g(T_r)→(liq.N_2)→30 emu/g(T_r)
27at% Ni-Fe	(600°C ann.)→26 emu/g(T_r)→(−130°C)→26 emu/g(T_r)→(liq. N_2)→27.2 emu/g(T_r) →(liq.He)→40 emu/g(T_r)→(600°C)→26 emu/g(T_r)

ann.: annealing, T_r: room temperature, liq.N_2: liquid N_2, liq.He: liquid He.

29at% Ni-Fe alloys (MOMOSE and NAGAI, 1983). The experimental resultes show that the magnetic grains of Fe-Ni alloys in this chondrite are in bcc phase. In order to investigate whether or not RM of fcc phase is preserved in bcc phase after martensitic transformation, we measured at first TRM of 29at% Ni-Fe alloy which was in fcc phase at room temperature (T_r) after heat treatment (650°C). According to the measurements of the thermomagnetic curves of the Fe-Ni alloys, the 29at% Ni-Fe alloy satisfied the following conditions required for the investigations.

(i) The Curie temperature (T_c) of fcc phase is higher than T_r.

(ii) The starting temperature of the martensitic transformation (T_{Ms}) is lower than T_r.

(iii) Fcc phase changes to bcc phase at 77 K.

We measured TRM of three samples (A, B and C) of 29at% Ni-Fe alloy. The heatproof brick in which small thin plates of 29at% Ni-Fe alloy were stuffed was magnetized in the geomagnetic field by cooling from 650°C to T_r in vacuum of 10^{-3} Pa. The experimental method of the magnetic measurement is described in the previous paper (MOMOSE and NAGAI, 1983).

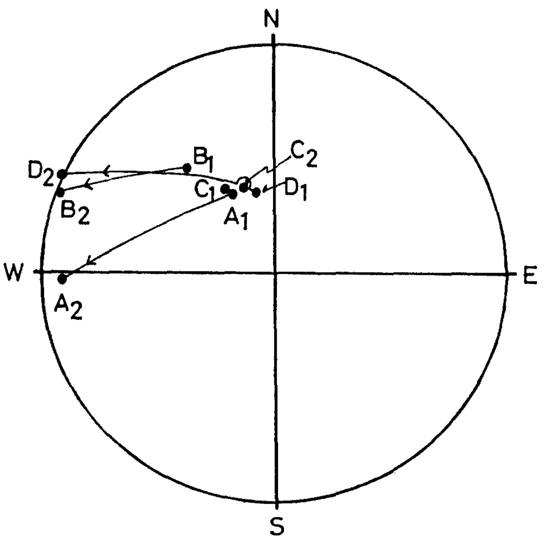

Fig. 1. The directions of TRM of the Fe-Ni alloys. Original (A_1, B_1, C_1, D_1): magnetized in geomagnetic field by cooling from 650°C to T_r. (A_2,B_2, D_2): cooling at 77 K in zero magnetic field. (C_2): cooling at 77 K in geomagnetic field. 29at% Ni-Fe (A, B, C), 25at% Ni-Fe (D).

By cooling from T_r to 77 K in zero magnetic field (less than 40γ) the direction and the intensity of the magnetization changed markedly ($J/J_0=0.161\sim0.286$). These results are shown by A and B in Fig. 1 and Table 2. This fact indicates that TRM of fcc phase is not preserved in bcc phase after martensitic transformation. By cooling from T_r to 77 K in geomagnetic field the direction of TRM was unchanged and the intensity became about twice larger than that of the original (before cooling). The results are shown by C in Fig. 1 and Table 2, and indicate that the magnetic field in the process of martensitic transformation affects TRM of the original sample.

Table 2. Various TRM of the Fe-Ni alloys (29at% and 25at% Ni) showing the directions, the intensities and the values of J/J_0.

	29at% Ni-Fe						25at% Ni-Fe	
	(A_1)	(A_2)	(B_1)	(B_2)	(C_1)	(C_2)	(D_1)	(D_2)
D	24.73°w	91.24°w	40.54°w	68.52°w	33.54°w	14.55°w	10.94°w	64.98°w
I	58.92°	8.30°	40.41°	1.90°	54.1°	59.11°	59.65°	2.88°
J	11.494 $\times10^{-3}$ ($=J_0$)	1.846 $\times10^{-3}$	5.905 $\times10^{-3}$ ($=J_0$)	1.688 $\times10^{-3}$	5.107 $\times10^{-3}$ ($=J_0$)	12.502 $\times10^{-3}$	7.208 $\times10^{-3}$ ($=J_0$)	3.036 $\times10^{-3}$
J/J_0		0.161		0.286		2.45		0.421

A_1, B_1, C_1 and D_1: Original (TRM 650°C).
A_2, B_2 and D_2: Cooling at 77 K in zero magnatic field.
C_2: Cooling at 77 K in geomagnetic field.
J: In unit of emu/g.

Furthermore, we measured TRM of 25at% Ni-Fe alloy whose T_{Ms} is higher than T_r and T_c of fcc phase is lower than T_r, namely, the martensitic transformation occurs partially above T_r in paramagnetic fcc phase. The direction and the intensity of the magnetization changed remarkably ($J/J_0=0.421$) by cooling from T_r to 77 K in zero magetic field. The results are shown by D in Fig. 1 and Table 2. TRM of the original sample (D_1) is due to partially transformed bcc phase.

RM of bcc phase of 29at% Ni-Fe alloy which was acquired in the process of martensitic transformation by cooling from T_r to 77 K in geomagnetic field (cycle (1)) is very stable. The direction and the intensity of RM do not change by cooling again

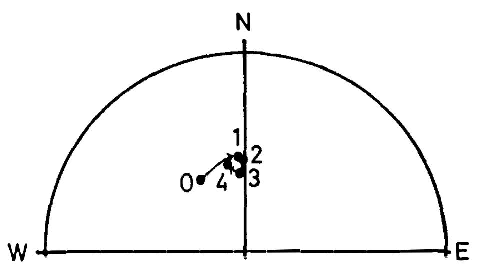

Fig. 2. The directions of TRM of the 29at% Ni-Fe alloy by cooling at 77 K in zero magnetic field and in geomagnetic field.

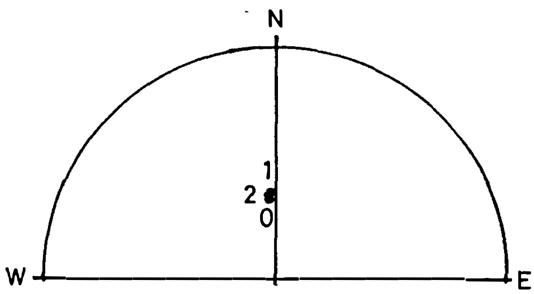

Fig. 3. The directions of TRM of the 50at% Ni-Fe alloy by cooling at 77 K in zero magnetic field and in geomagnetic field.

Table 3. TRM of the 29at% Ni-Fe alloy cooling at 77 K in zero magnetic field and in geomagnetic field.

	(0) Original (TRM 650°C)	(1) Cooling at 77 K in geomagnetic field	(2) Cooling at 77 K in zero magnetic field	(3) Cooling at 77 K in geomagnetic field perpendicular to (1)	(4) Cooling at 77 K in zero magnetic field
D	33.54°w	3.08°w	0°	1.14°w	11°w
I	54.01°	49.02°	52.49°	58.27°	52.74°
J	5.107×10^{-3} $(=J_0)$	10.256×10^{-3}	9.551×10^{-3}	10.392×10^{-3}	9.013×10^{-3}
J/J_0		2.01	1.87	2.03	1.76

J: In unit of emu/g.

Table 4. TRM of the 50at% Ni-Fe alloy cooling at 77 K in zero magnetic field and in geomagnetic field.

	(0) Original (TRM 650°C)	(1) Cooling at 77 K in zero magnetic field	(2) Cooling at 77 K in geomagnetic field
D	4.4°w	1.2°w	1.13°w
I	61.02°	58.8°	60.35°
J	11.7×10^{-3} $(=J_0)$	11.0×10^{-3}	11.11×10^{-3}
J/J_0		0.94	0.95

J: In unit of emu/g.

from T_r to 77 K in zero magetic field (cycle (2)) and in geomagnetic field perpendicular to RM (cycle (3)). These results are shown in Fig. 2 and Table 3.

TRM of 50at% Ni-Fe alloy whose thermomagnetic curve was reversible was very stable because the alloy is free from martensitic transformation. The results are shown in Fig. 3 and Table 4.

3. Conclusion

In order to study the cosmic paleomagnetism the meteorite is suitable where the included Fe-Ni grains have the reversible thermomagnetic curves. On the other hand, in the case of the irreversible thermomagnetic curve of the magnetic grains in meteorite we should take into consideration to study the cosmic paleomagnetism that NRM is a memory of the magnetic field in the process of martensitic transformation.

Reference

MOMOSE, K. and NAGAI, H. (1983): The application of thermomagnetic properties of Fe-Ni alloys to the thermal history of the Y-74646 chondrite. Mem. Natl Inst. Polar Res., Spec. Issue, **30**, 447–451.

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