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MAGNETIC PROPERTIES OF THE MIXTURES OF Fe-Ni ALLOYS SIMULATED TO Y-74354, Y-74362 AND Y-74190 CHONDRITES

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Abstract: The magnetic properties of the mixtures of Fe-Ni alloys simulated to Y-74354, Y-74362 and Y-74190 chondrites have been investigated by magnetic measurements and the Mössbauer effect. It was explained from the martensitic transformation that the intensity of RM decreased after cooling at 77 K in zero magnetic field and was enhanced by cooling in geomagnetic field. The phase changes were observed by the Mössbauer effect. The thermo-magnetic properties were also discussed.

1. Introduction

The Fe-Ni alloys are the typical materials which characterize the magnetic properties of the meteorites.

The resemblance of the thermo-magnetic curve of Y-74646 chondrite to that of 29 at% Ni-Fe alloy was stimulated to investigate the magnetic properties of artificial Fe-Ni alloys in comparison with the magnetic properties of meteorites (MOMOSE and NAGAI, 1983).

The thermo-magnetic curve of 29 at% Ni-Fe alloy is explained by the martensitic transformation. The thermo-remanent magnetization (TRM) of this alloy is broken by the martensitic transformation after cooling in zero magnetic field. On the other hand, a suitable remanent magnetization is acquired by cooling the alloy at 77 K under the geomagnetic field because the magnetization is enhanced by the martensitic transformation in the magnetic field (MOMOSE *et al.*, 1984; MOMOSE and NAGAI, 1985). The TRM of Fe-Ni alloys with various Ni contents is much affected by their martensitic transformation (MOMOSE and NAGAI, 1986). These facts are very important for the paleomagnetic interpretation of the natural remanent magnetization of some chondrites.

The present work aims to investigate the magnetic properties of the mixtures of Fe-Ni alloys simulated to Y-74354(L6), Y-74362(L6) and Y-74190(L6) chondrites, because their compositions of metallic components are analyzed by NAGAHARA (1979) and their thermo-magnetic properties are studied in detail by NAGATA and FUNAKI (1981).

2. Experiments

The alloys were prepared by melting constituent elements of 99.99% purity in an induction furnace under argon atmosphere. The mixtures of Fe-Ni alloys were prepared in accordance with the EPMA analysis data of NAGAHARA (1979). Frequency distributions of bulk chemical composition of metal grains in Y-74354(L6), Y-74362(L6) and Y-74190(L6) chondrites are given in Table 1.

The mixture samples were made from several series of Fe-Ni alloys so that their compositions are nearly equivalent to the metallic components of chondrites.

The original TRM was acquired by heating these mixtures at 850°C for two hours and cooling them to room temperature in geomagnetic field in vacuum of 10^{-3} Pa.

Table 1. Frequency distributions of bulk chemical composition of metal grains in Y-74354(L6), Y-74362(L6) and Y-74190(L6) chondrites.

Y-74354(L6)		Y-74362(L6)		Y-74190(L6)	
Ni-content (%)	Abundance	Ni-content (%)	Abundance	Ni-content (%)	Abundance
2- 3	2	3- 4	1	32-33	1
5- 6	1	4- 5	2	33-34	1
7- 8	1	*5- 6	5	*35-36	3
9-10	2	6- 7	3	*36-37	3
10-11	1	7- 8	2	37-38	1
11-12	2	9-10	1	38-39	2
12-13	7	10-11	2	*40-41	3
*13-14	11	11-12	3	41-42	2
*14-15	31	*12-13	8	42-43	1
*15-16	16	*13-14	8	43-44	1
16-17	6	14-15	2	*44-45	3
*17-18	10	15-16	1	46-47	1
18-19	7	16-17	1		
*19-20	8	*17-18	4		
20-21	6	18-19	3		
21-22	4	22-23	3		
22-23	2	26-27	1		
23-24	1	*32-33	3		
24-25	2	34-35	1		
27-28	1	*35-36	3		
28-29	1	37-38	2		
32-33	1	46-47	1		
34-35	2	53-54	1		
35-36	1				
*36-37	6				
37-38	2				
38-39	2				
39-40	1				
41-42	1				
43-44	1				
44-45	1				

The abundance is in arbitrary unit. The alloys marked by (*) were mixed for the simulation to chondrites.

Table 2. Remanent magnetizations of alloy mixtures simulated to Y-74354(L6), Y-74362 (L6) and Y-74190(L6) chondrites.

[Y-74354(L6)]

	Original TRM (0)	Cooling at 77 K in geomag. field (1)	2nd TRM (2)	Cooling at 77 K in zero field (3)
D	350.85°	354.5°	352.62°	345°
I	46.93°	53°	57°	50.8°
$J\times10^{-3}$	8.547	8.667	8.18	6.169
J/J_0	$(=J_0)$	1.013	$(=J_0)$	0.754

[Y-74362(L6)]

	Original TRM (0)	Cooling at 77 K in geomag. field (1)	2nd TRM (2)	Cooling at 77 K in zero field (3)
D	335.54°	338.64°	332.2°	324.14°
I	49.53°	53.32°	50.71°	51.44°
$J\times10^{-3}$	8.162	11.794	8.130	6.802
J/J_0	$(=J_0)$	1.44	$(=J_0)$	0.837

[Y-74190(L6)]

	Original TRM (0)	Cooling at 77 K in zero field (1)	2nd TRM (2)	Cooling at 77 K in geomag. field (3)
D	23.16°	24.69°	17.23°	21.40°
I	56.63°	56.21°	54.93°	56.78°
$J\times10^{-3}$	20.04	16.209	18.768	18.471
J_0	$(=J_0)$	0.809	$(=J_0)$	0.984

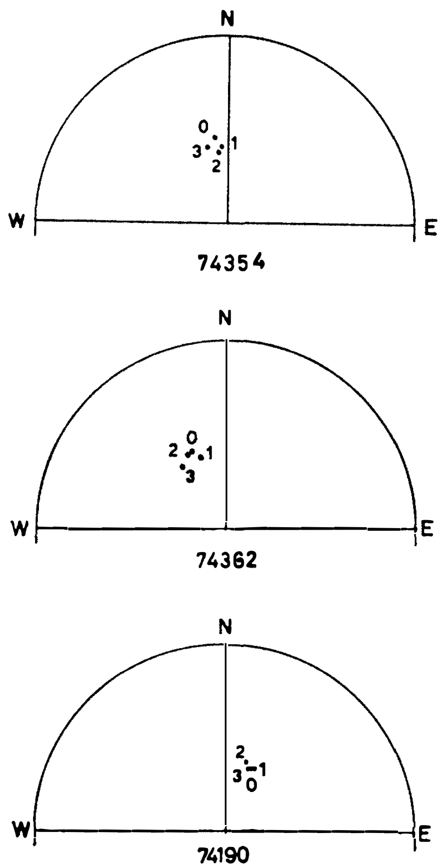

Fig. 1. The stereographic projections of RM of the mixture samples simulated to Y-74354 (L6), Y-74362 (L6) and Y-74190 (L6) chondrites.

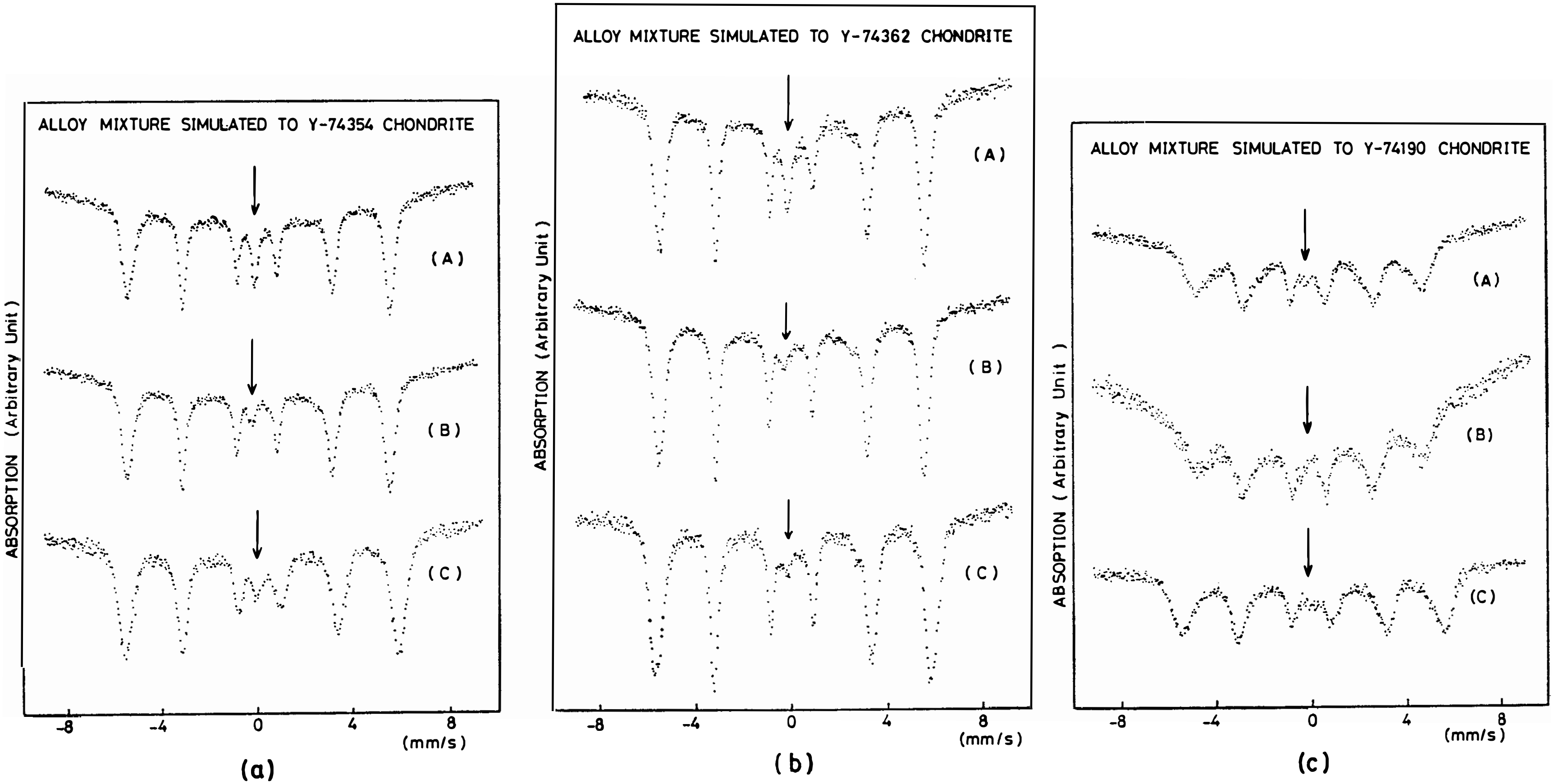

Fig. 2. The Mössbauer spectra of the mixture samples simulated to Y-74354(L6), Y-74362(L6) and Y-74190(L6) chondrites. Spectrum (A); at room temperature after heating at 850°C. Spectrum (B); at room temperature after cooling at 77 K. Spectrum (C); at 77 K.

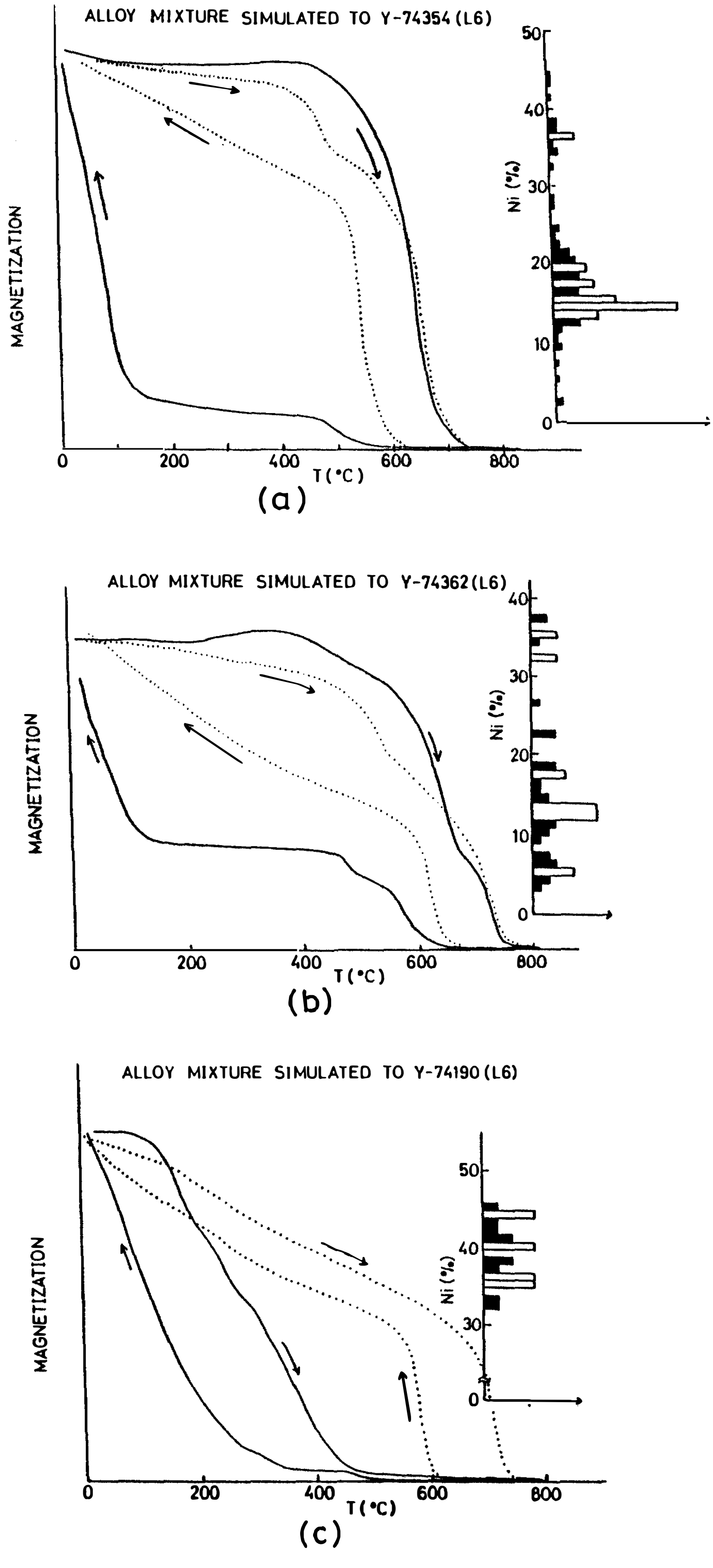

Fig. 3. The thermo-magnetic curves of the mixture samples simulated to Y-74354(L6), Y-74362(L6) and Y-74190 (L6) chondrites. The distribution of Ni-content in Y-chondrite by EPMA analysis by NAGAHARA *(1979) is in parentheses. The dotted lines are thermo-magnetic curves of the chondrites measured by* NAGATA *and* FUNAKI *(1981).*

Changes of TRM by cooling at 77 K in zero magnetic field and in geomagnetic field parallel to the original TRM were measured.

The experimental results of RM are listed in Table 2. The intensities of RM obtained by cooling at 77 K in zero magnetic field decreased by about 20%. No significant differences in the directions of RM were found by cooling at 77 K in both the geomagnetic and zero magnetic fields. The stereographic projections of RM of the mixture samples simulated to Y-74354(L6), Y-74362(L6) and Y-74190(L6) chondrites are shown in Fig. 1 where there are no significant changes in the directions of RM.

The partial phase changes after cooling at 77 K are observed by the Mössbauer effect as shown in Fig. 2 which shows the decrease of the non-magnetic fcc phase (marked by arrow) after cooling at 77 K in the mixture sample. The spectra (B) and (C) contain the martensitic transformation from fcc to bcc. It is originated from the decrease of the non-magnetic phase after cooling that the intensity of RM increased after cooling in comparison with the original TRM.

The thermo-magnetic curves of the mixture samples simulated to Y-74354(L6), Y-74362(L6) and Y-74190(L6) chondrites are shown in Fig. 3. In Fig. 3, the heating curves of the simulated mixture samples are in agreement with those of chondrites (NAGATA and FUNAKI, 1981), except for Y-74190(L6), while the cooling curves of the former are in disagreement with those of the latter. In the case of Y-74190(L6) the heating and cooling curves are in disagreement with those of the simulated mixture sample (see Fig. 3(c)). The swells near 400°C of the thermo-magnetic curves of the simulated samples in Figs. 3(a) and (b) are caused by the weak applied field (about 1 kOe) for magnetic measurements. In order to check the dependences of the thermo-magnetic curves on the kinds of alloys in mixing, the thermo-magnetic measurements were carried out on the simulated samples made of six kinds of alloys and all kinds of alloys according to EPMA analysis of Y-74362(L6) (NAGAHARA, 1979).

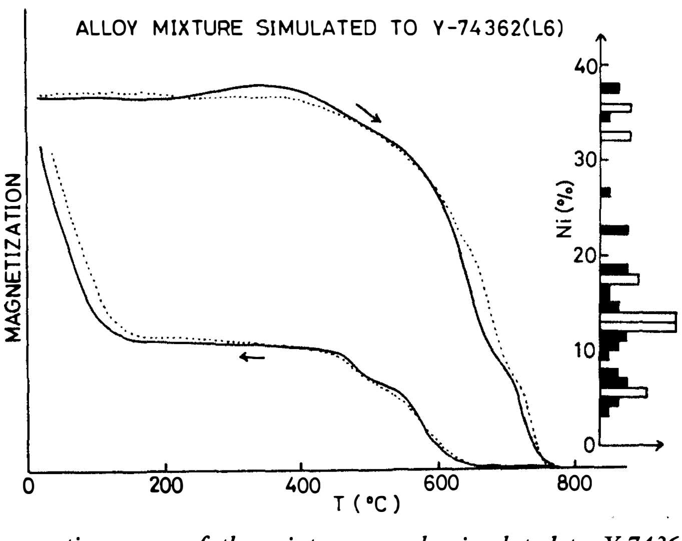

Fig. 4. Thermo-magnetic curves of the mixture sample simulated to Y-74362 (L6) chondrite. The solid lines are those of the sample made of six kinds of Fe-Ni alloys and the dotted lines are those of the sample including all kinds of Fe-Ni alloys in accordance with EPMA analysis by NAGAHARA (1979).

The thermo-magnetic curves of two kinds of simulated samples are in good agreement with each other as shown in Fig. 4. Then the simulated samples were prepared by mixing a few kinds of alloys in high abundance as marked by (*) in Table 1.

3. Discussion

The decrease of RM intensity by cooling in zero magnetic field is caused by the martensitic transformation from fcc to bcc (Momose *et al.*, 1984). Since the martensitic transformation breaks RM in zero field, the decrease of about 20% in intensity is due to the partial martensitic transformation in the sample which is observed by the Mössbauer effect as shown in Fig. 2. On the other hand, the martensitic transformation in geomagnetic field enhances the RM intensity, because the magnetization due to bcc phase increases in parallel with the field direction. No significant differences in the directions of RM by the partial martensitic transformation were observed between the geomagnetic and the magnetic fields as shown in Fig. 1.

The thermo-magnetic curves of the samples simulated to Y-74354(L6) and Y-74362(L6) chondrites are in good agreement with those of chondrites in the heating process. These magnetic behaviours are mainly due to bcc phase of Fe-rich alloys which have higher Curie temperature (T_c) than room temperature (T_0). In the cooling process, the thermo-magnetic curves of the simulated samples are due to bcc phase ($T_c<600°C$) and fcc phase ($T_c<100°C$), while those of chondrites are mainly due to bcc phase similar to those of the heating process.

The thermo-magnetic curves of the mixture sample simulated to Y-74190(L6) chondrite are due to fcc phase of Ni-rich alloys which have higher T_c than T_0 and are quite different from those of the chondrite.

These thermo-magnetic measurements of the simulated samples are not able to explain the thermo-magnetic properties of chondrites as yet.

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