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SOLID STATE TRANSFORMATIONS IN Fe-Ni ALLOYS FROM METEORITES IN POWDER FORM[§]

by

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ABSTRACT

We report here Mössbauer studies by transmission and back-scattering technics, with Cape York and Santa Catharina meteorites in powder form. Martensitic transformation γ-phase to α-phase is induced by mechanical treatment and long-range order is affected.

Key-words: Solid state transformations in Fe-Ni alloys; Fe-Ni alloys in powder form.

INTRODUCTION

Mössbauer studies have been performed with thin slices of the Santa Catharina, lamellae of the Cape York and powder samples of both meteorites. With thin slices and lamellae, Mössbauer spectroscopy and X-ray diffraction methods have demonstrated that an ordered alloy Fe-Ni (tetrataenite) is present in these meteorites. However with power samples we have seen drastic modifications in the Fe-Ni phases of these meteorites. Some of these transformations induced by mechanical treatment have been observed in Fe-Ni alloys artificially produced [1].

The degree of order of tetrataenite from different meteorites have revealed large variation probably due to their different cooling rates, and can be measured through the Mössbauer hyperfine parameters [2]. From the Mössbauer spectra it was infered that the degree of order of the Cape York meteorite is higher than that of the Santa Catharina meteorite.

Absorbers for Mössbauer measurements of thin slices of the bulk of the Santa Catharina meteorite were prepared by polishing the slices to a thickness around 70 μm. Absorbers of the Cape York meteorite were 40-50 μm thick plates of taenite, which have been separated from bulk material by selective dissolution of the kamacite in dilute acid. The powder absorbers have been made by filling the slices and the lamellae up to a 400 mesh powder.

RESULTS AND DISCUSSION

The Mössbauer spectra of fine particles of the Santa Catharina and Cape York meteorites were found to be markedly different from that observed with the thin slices or lamellae. Martensitic transformation of γ-phase to α-phase is induced on filling the samples and also long-range order is decreased by the mechanical treatment. Figure 1 compares a spectrum of the Santa Catharina thin slice with one obtained in the same conditions with a 400 mesh powder. Table 1 list the hyperfine parameters.

The Mössbauer spectrum of the thin slices shows two distinct phases: a paramagnetic phase corresponding to a γ-phase with less than 30% Ni concentration and a magnetic hyperfine spectrum with $H_i \cong 290$ kOe and a quadrupole interaction which is typical of the ordered phase Fe-Ni 50-50 with superstructure L1o [3].

The percentage of the paramagnetic γ-phase decreases and becomes practically absent in a 400 mesh powder (Table 1). The powder spectrum can be fitted with two magnetic spectra. One corresponds in intensity and hyperfine field to the ordered phase, but the value of ΔE_Q is practically zero. The other presents a larger internal field $H_i \cong 330$ kOe, broadned lines and also no quadrupole interaction. This new spectrum corresponds to mechanically induced martensite. These changes manifest also in the X-ray diffraction spectra of the meteorite. The bcc-phase is absent in the slices but appears in the Debye-Scherrer of the powder with strong intensity.

Figure 2 reproduces the Mössbauer spectra of a thin lamellae and powder samples of the Cape York meteorite.

The spectrum of the lamellae exhibit a superposition of three well defined Mössbauer spectra: a) a six line spectrum with quadrupole splitting due to the ordered phase with superstructure Llo; b) a symmetric six line spectrum (without quadrupole splitting). This spectrum comes from a martensitic phase (α_2) an perhaps some α-phase from plessitic areas in the middle of the lamellae [4]; c) a single central line with a large absorption area due to a paramagnetic Fe-Ni γ-phase with less than 33% Ni.

From Figures 1,2 and Tables 1,2 it is seen that Santa Catharina and Cape York powder suffer similar changes, but in the Cape York case, the filling does not change so drastically the ΔE_Q value. This is a consequence of the fact that the degree of long range order is higher in the Cape York meteorite as compared to the Santa Catharina meteorite [5].

These results are also important to understand the differences between the Mössbauer spectra of a sample obtained by scattering (CEMS) and by transmission technics.

In the scattering spectrum a new magnetic component appears, corresponding to the martensitic phase. This phase is absent in the bulk of the meteorite and results from the martensitic transformation of the paramagnetic γ-phase in α-phase. This occurs as a consequence of two processes: the effect of mechanical polishing at the surface of the meteorite which is similar to the effects of filling; because the internal stresses normally present in the sample are relaxed in the surface which induces the martensitic transformation. This effect reaches a superficial layer of 2.000-3.000 Å depth, these are the representative layers for the conversion electron spectra. In the deeper layers already, as the ones reached by the X-ray emission spectrum, the martensitic phase is absent as is shown in Figure 3.

Our results indicate clearly that we must have a great precaution in conclude about the relative proportions of the Fe-Ni alloys in the bulk of the metallic phases by using conversion electron experiments.

FIGURE AND TABLE CAPTIONS

Fig. 1 - Mössbauer transmission spectra of thin slice and powder from the Santa Catharina meteorite at room temperature; source ^{57}Co in Rh.

Fig. 2 - Mössbauer transmission spectra of lamellae and powder from the Cape York meteorite at room temperature. Source ^{57}Co in Rh.

Fig. 3 - Mössbauer spectra of the Santa Catharina meteorite. (a) CEMS; (b) X-ray CEMS.

Table 1 - Hyperfine parameters of thin slice and powder of the Santa Catharina meteorite at room temperature.

Table 2 - Hyperfine parameters of lamellae and powder of the Cape York meteorite.

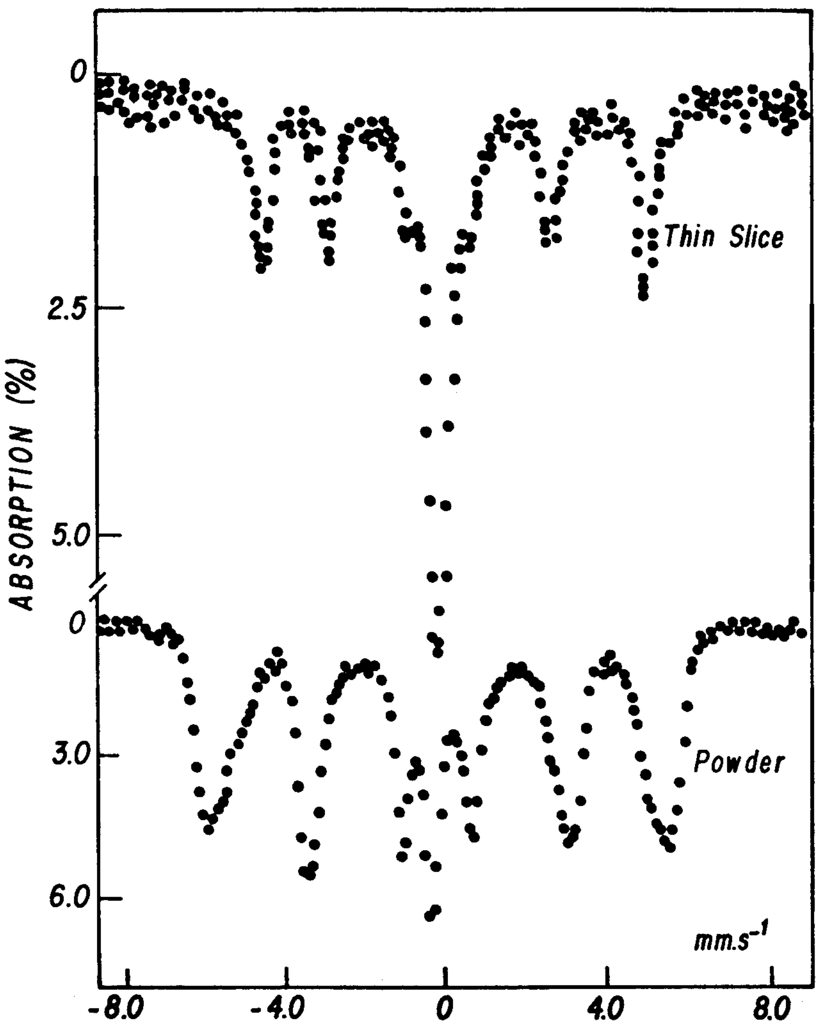

Fig. 1

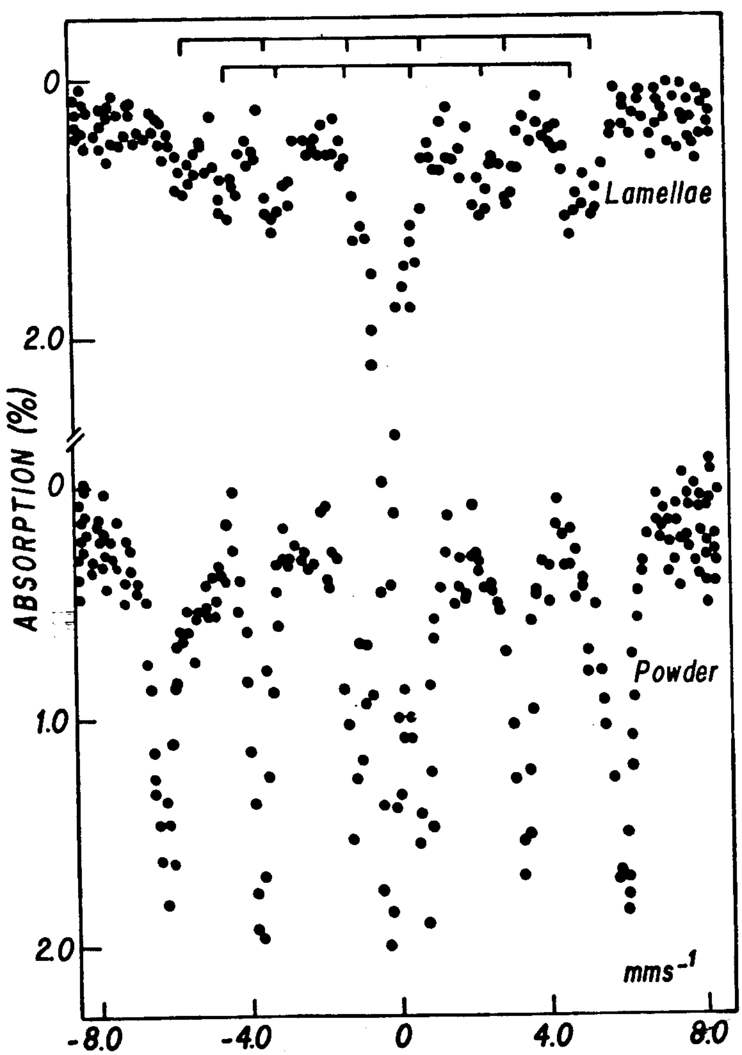

Fig. 2

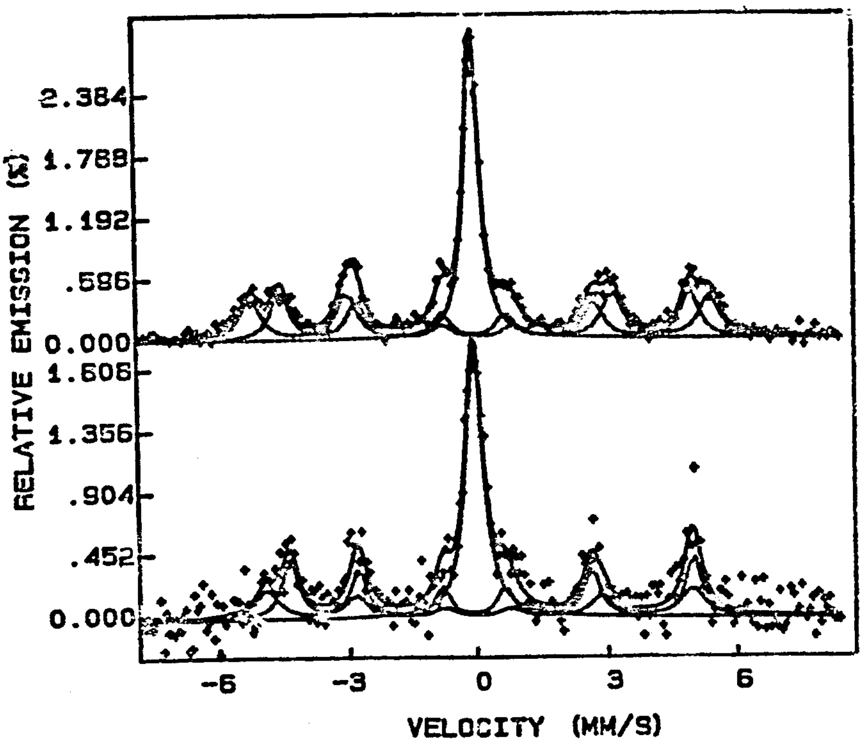
2.384
1.788
1.192
.586
0.000
1.606
1.356
.904
.452
0.000
RELATIVE EMISSION (%)
-6
-3
0
3
6
VELOCITY (MM/S)

Fig. 3

		IS mms^{-1}	ΔE_Q mms^{-1}	Γ mms^{-1}	H kOe	A %
THIN SLICE	Ordered Phase	-0.07	0.17	0.52	291	55.0
	Paramagnetic-γ Phase	-0.02	-	0.53	-	45.0
POWDER	Ordered Phase	-0.07	0.04	0.53	282	38.96
	α-Phase	-0.06	-	0.53	313	52.12
	Paramagnetic-γ Phase	-0.18	-	0.36	-	8.96

IS = Isomer Shift relative to iron foil; ΔE_Q = Quadrupolar interaction;
Γ = Line width; H = Magnetic hyperfine field; A = Relative area.

Table 1

		IS mms^{-1}	ΔE_Q mms^{-1}	Γ mms^{-1}	H kOe	A %
LAMELLAE	Ordered Phase	-0.10	0.20	0.41	289	24.95
	α-Phase	-0.04	-	0.42	341	28.00
	Paramagnetic-γ Phase	-0.17	-	0.57	-	47.05
POWDER	Ordered Phase	-0.03	0.19	0.54	289	17.42
	α-Phase	-0.03	-	0.54	337	71.61
	Paramagnetic-γ Phase	-0.26	-	0.45	-	10.97

Table 2

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