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MÖSSBAUER SPECTROSCOPY STUDY OF THE METALLIC PARTICLES EXTRACTED FROM THE ANTARCTIC CHONDRITE ALLAN HILLS-769

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Abstract: Pieces of the Antarctic L6 chondrite Allan Hills-769 (ALH-769) have been submitted to magnetic and chemical separation in order to obtain small metallic grains of the special ordered crystal structure of AuCu-type tetrataenite. The samples have been analyzed in each step of preparation by Mössbauer spectroscopy and other techniques.

1. Introduction

The Fe-Ni ordered phase with $L1_0$ superstructure (AuCu) has been first produced only by neutrons or electrons irradiation of the disordered alloy (PAULEVÉ *et al.*, 1962; NÉEL *et al.*, 1964), because the diffusion process of the metallic atoms is very slow at the ordering temperature $T_c = 320°C$.

Since 1977 it has been known that an ordered alloy occurs in slow-cooled meteorites that contain taenite (f.c.c. iron-nickel alloy). Some years later this naturally occurring compound has been given the name Tetrataenite (CLARK and SCOTT, 1980). In many meteorites it is a common accessory mineral and in some it is more abundant than taenite.

The Fe-Ni ordered phase has been detected by Mössbauer spectroscopy (MS) and X-ray diffraction (XRD) in the taenite lamellae of octahedrites (PETERSEN *et al.*, 1977), Ni-rich ataxites (DANON *et al.*, 1979a), and metal particles of chondrites (DANON *et al.*, 1979b).

The identification of the $L1_0$ superstructure in Fe-Ni alloys by MS is based on the fact that the ordered phase exhibits an asymmetric six-line spectrum due to a quadrupole splitting arising from the non-cubic environment of the atoms in this structure. We report here MS, XRD and Scanning Electron Microscopy (SEM) measurements on the Allan Hills-769 (ALH-769) L6 chondrite. The ALH-769 was found in January 1977 in Allan Hills, South Victoria Land, Antarctica (YANAI, 1979).

2. Experimental

The transmission ^{57}Fe Mössbauer spectra were obtained at room temperature using a Co/Rh source in a conventional Mössbauer spectrometer. The MS has been performed with the metal particles of the chondrite obtained after magnetic and chemical separation. In magnetically enriched samples relatively large amounts of silicates and troilite still remain attached to the metallic phase. A complete separation is only achieved by HF treatment (DANON *et al.*, 1979b).

The lattice parameters were determined by refinement with the Rietveld method (YOUNG and WILES, 1981) applied to X-ray diffraction patterns obtained in a powder diffractometer with Bragg-Brentano focalization geometry operating in a step mode. The counting time per step was 10 s in the angular range $20° \leq 2\theta \leq 100°$ using Cu radiation ($\lambda = 1.5418$ Å) and a quartz monocromator plane (1011).

The metallic particles were studied using a scanning electron microscope (SEM) JEOL JSM-U3 working at 20 kV coupled to a Tracor Northern (model 5500) energy dispersive X-ray spectrometer (EDS). Sample composition was determined using a computer program in the EDS software package based on the ZAF technique.

3. Results and Discussion

We investigated the presence of tetrataenite in metal particles of ALH-769 using magnetically separated fractions that have been purified from troilite and iron silicates. The Mössbauer spectrum of the magnetically enriched sample before chemical treatment is rather complex (Fig. 1a) and exhibits a partial overlapping of lines which arises from the superposition of: iron silicates, α-phase (kamacite) or α_2-phase (martensite), γ-phase (taenite) and troilite. Due to the presence of silicates and troilite in the sample, it is very difficult to identify the presence of tetrataenite. Only after a complete separation of the metals it is possible to detect the Fe-Ni 50/50 ordered phase with $L1_0$ superstructure. The Mössbauer spectrum of the metal enriched sample after separation from silicates and troilite by HF treatment shows the coexistence of Fe-Ni γ-phases with different compositions (Fig. 1b); in this figure (1b) we can see an overlap of: a) a magnetic phase ($H_i = 288$ kOe) with a quadrupole splitting corresponding to the ordered Fe-Ni 50/50 (tetrataenite); b) a magnetic phase without quadrupole splitting ($H_i = 318$ kOe) corresponding to a ferromagnetic disordered Ni-rich taenite; c) a paramagnetic γ-phase due to the Ni-poor taenite ($<30\%$ Ni).

Table 1 lists the hyperfine parameters derived from the Mössbauer spectrum as well as the proportion of the Fe-Ni alloys in this meteorite. The hyperfine field (H_i) and the quadrupolar interaction (ΔEq) are similar to those observed for the ordered phases in irradiated iron-nickel alloys and in metal particles of LL and L non-Antarctic chondrites.

The lattice parameter $a_0 = 3.586 \pm 0.001$ Å obtained by XRD is in agreement

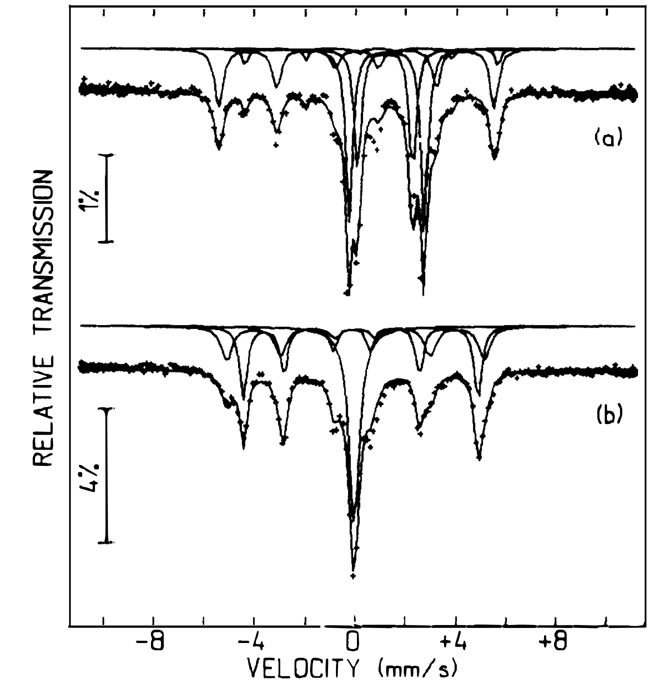

Fig. 1. Mössbauer spectra: a) magnetically enriched sample before chemical treatment, b) metal enriched sample after HF treatment.

Table 1. Mössbauer hyperfine parameters of metal enriched particles of ALH-769.

Fe-Ni phases	Γ (mm/s)	IS (mm/s)	ΔEq (mm/s)	H_i (kOe)	A (%)
Ordered Fe-Ni	0.37	−0.075	0.18	288	39
Disordered Fe-Ni	0.55	−0.10	0.0	318	25
Ni-poor γ-phase	0.52	−0.17	—	—	36

Γ=linewidth at half height (±0.03 mm/s), IS=isomer shift relative to $^{57}Co/Rh$ source (±0.01 mm/s), ΔEq=quadrupole splitting (±0.005 mm/s), H_i=internal hyperfine field (±5 kOe) and A= relative spectral area (±5%).

with that reported for the ordered phase (SCORZELLI and DANON, 1985; CHAMBEROD *et al.*, 1979) and is smaller than that of the disordered alloy $a_0=3.596\pm0.001$ Å. The (001), (110), (021), (112), and (221, 003) weak superstructure lines were detected and can be seen in an expanded scale in Fig. 2.

The results obtained by SEM show that the particles are irregular in shape and exhibit a sponge-like or foam-like aspect (Fig. 3). In EDS Ni mapping two regions are clearly seen: a Ni-rich one, with composition of ~50% Ni and another <30% Ni. These results are in good agreement with the Mössbauer fittings. However the analysis using SEM/EDS cannot distinguish the ordered and disordered 50/50 alloys.

The proportion of tetrataenite in this L-chondrite is smaller than the one already observed in some LL, since the relatively large Ni/Fe ratio found in the metallic phase of LL chondrites favors the formation of the $L1_0$ superstructure (tetrataenite), which is also common in the L chondrites. The ΔEq value of tetrataenite in this chondrite is smaller than that observed in other L and LL-chondrites (for example the LL6 chondrite St. Séverin). The presence of a consid-

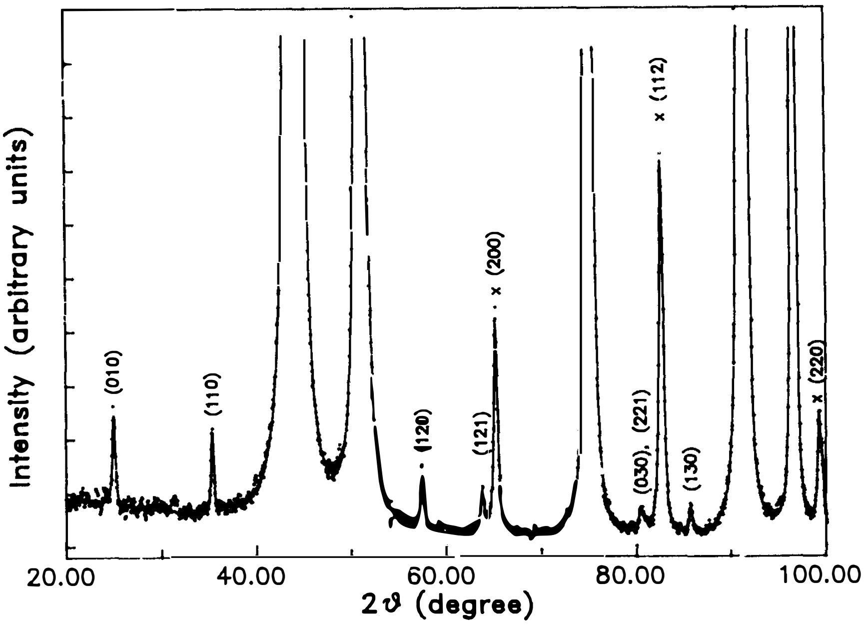

Fig. 2. XRD pattern of the metal enriched sample showing the superstructure lines (expanded scale).

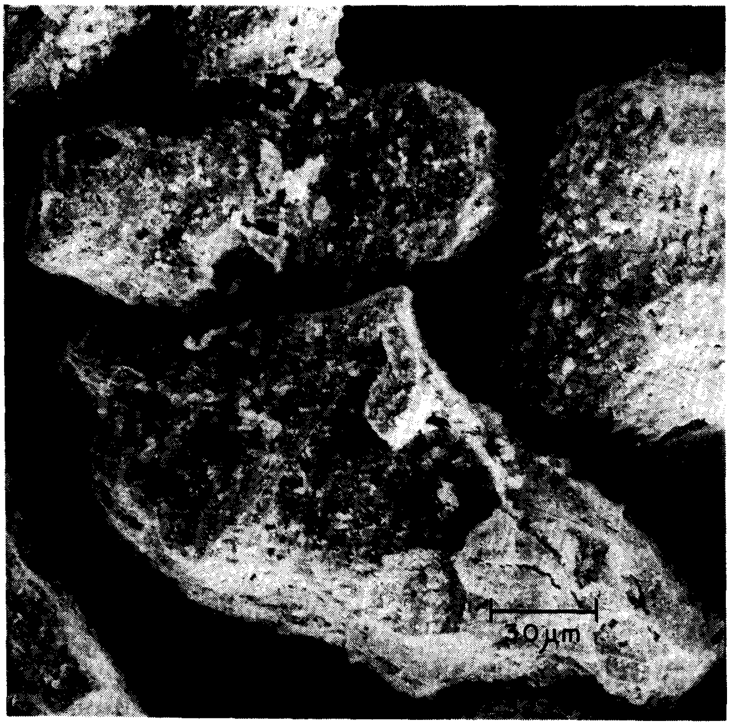

Fig. 3. SEM photomicrograph of metalic particles extracted from ALH-769.

erable proportion of the 50/50 disordered Ni-rich taenite coexisting with tetrataenite is remarkable and can be due to the occurrence of grains with different formation histories. A systematic Mössbauer study of several chondrites with different thermal and shock histories (DANON *et al.*, 1979b) showed that the disordering process leads to changes in the hyperfine parameters of the ordered phase.

Reflected light studies of etched material in thin section done by CHRISTOPHE-MICHEL-LÉVY (private commun., 1993) showed a L6 shocked chondrite exhibiting a particular thermal history evident through the metallic phases. Optical and electron probe data for silicates and metal phases are under investigation.

In summary, our results show that segregation of FCC phases with different compositions, as well as ordering, occurred in this L6 chondrite. This phase equilibrium problem can easily be observed by Mössbauer technique, which permits to distinguish phases in different magnetic states; however, other techniques, can give additional information to the Mössbauer results providing much information about the thermal and shock history of this chondrite.

For a better understanding of the order-disorder process in this meteorite, it is important to obtain more detailed information about the thermal and shock history during primary cooling or during secondary processes. Other experiments are currently under investigation in order to correlate the Mössbauer results with the history recorded by the metallic phases of chondrites.

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