X-ray and Mössbauer study of rapidly solidified Ce$_{20}$Fe$_{80}$ ribbons; effect of the quenching rate

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Ce$_{20}$Fe$_{80}$ ribbons have been produced by planar flow casting under an He atmosphere at linear wheel velocities between 19 and 29 m s$^{-1}$. Analysis of ribbons by X-ray diffraction and $^{57}$Fe Mössbauer spectrometry in the temperature range 77–300 K shows that the ribbons are crystallized. For higher velocities, the ribbon is constituted of the two equilibrium phases CeFe$_2$ and Ce$_2$Fe$_{17}$, but, for lower velocities, there appears a third iron metallic phase, which can be explained by the quenching rate of the melt. A coherent hyperfine parameter set was deduced from fitting Mössbauer spectra in the whole temperature range.

1. Introduction

The iron–cerium equilibrium phase diagram seems to be now well known [1,2]. It gives evidence for two compounds, CeFe$_2$ and Ce$_2$Fe$_{17}$, although compounds such as CeF$_5$ or CeFe$_7$ were also reported [3–5].

The aim of this paper is to characterize the phases observed in Ce$_{20}$Fe$_{80}$ fast quenched ribbons in order to compare them to the equilibrium phases and to study the influence on the quenching rate. For the CeFe$_2$ and Ce$_2$Fe$_{17}$ equilibrium phases, previous Mössbauer results are in disagreement [6–10] and, here, a temperature dependent Mössbauer study is performed to deduce a hyperfine parameter set consistent for all the temperatures.

2. Experimental

The ingots were first prepared from high purity metals (better than 99.9%) by
induction melting in a helium atmosphere using a water-cooled copper crucible. The quenched materials were then obtained by planar flow casting in an He filled chamber (to avoid Ce oxidation), with linear velocities in the range 19–29 m s⁻¹.

Mössbauer samples made of parallel ribbons (1 mm wide, 0.1 mm thick) were placed perpendicular to the γ-beam. Mössbauer spectra were obtained with a triangular waveform spectrometer using a source of ⁵⁷Co in a rhodium matrix and fitted with a least-squares technique [11]. Reported isomer shifts are relative to metallic iron at room temperature.

3. Study of the Ce₂₀Fe₈₀ ribbon produced at \( v = 29 \text{ m s}^{-1} \)

**X-ray diffraction study.** The X-ray diffraction pattern is typical of a crystallized compound (fig. 1a). It can be indexed using only the two equilibrium phases CeFe₂ and \( \beta \)-Ce₂Fe₁₇ predicted by the equilibrium phase diagram.

**Mössbauer study.** Some spectra in the temperature range 77–300 K are shown in fig. 2. They exhibit narrow lines typical of a crystallized compound in agreement with the X-ray diffraction study. At 77 K, the spectrum consists of two magnetic subspectra characteristic of CeFe₂ and Ce₂Fe₁₇. CeF₂ becomes paramagnetic at a temperature close to 235 K, slightly higher than the published values (\( T_c = 230 \text{ K} \)) [6,8]. The magnetic transition of Ce₂Fe₁₇ seems to be rather broad because Ce₂Fe₁₇ is still partly magnetic at 300 K (to compare to the published \( T_c \) values close to 270 K [6]). The spectra were fitted according to the structure of CeFe₂ and Ce₂Fe₁₇. CeFe₂ has a cubic structure (space group Fd3m) [6], with only one iron site (symmetry group 3m). The 3 axis, lying along the \( \langle 111 \rangle \) direction, is a main axis of the electric field gradient tensor, which is axial (asymmetry parameter \( \eta = 0 \)). But this site will be split in inequivalent magnetic sites if the magnetization does not lie along the \( \langle 100 \rangle \) direction, for which the angle between the magnetization and the four diagonals is the same (54.7°). \( \beta \)-Ce₂Fe₁₇ is rhombohedral (space group R̃3m) [6], with four iron sites with multiplicity and symmetry group 6c-3m, 9d-2/m, 18h-m, 18f-2.

As the anisotropy in Ce₂Fe₁₇ lies in the plane perpendicular to c, there are six magnetic sites due to the splitting of the h (18→6 + 12) and f (18→6 + 12) sites [10,12]. So, the magnetic spectrum of Ce₂Fe₁₇ was adjusted with six sextuplets constraining the relative intensities to the theoretical values. A good fit needs to use two sites for CeFe₂ indicating that the magnetization deviates from the c axis. All spectra were consistently fitted (fig. 2). For the 77 K temperature, the results are reported in table 1. The values for CeFe₂ are in rough agreement with some of the previous publications [8,13]. The relative values of the fitted hyperfine fields at the different iron sites of Ce₂Fe₁₇ are in agreement with neighbouring iron and cerium. The mean hyperfine field dependence with temperature is given in fig. 3 for the two compounds. The fitted relative intensities for the two magnetic sites of CeFe₂...