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Letter

A Mössbauer study of microcrystalline $YFe_{10}V_2$

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1. Introduction

The use of rapid quenching techniques (*e.g.* melt-spinning, splat-cooling) is of great importance in the preparation of rare-earth intermetallic compounds. The reasons for this are twofold. Firstly, it is possible to prepare intermetallic phases with a microcrystalline structure which can lead to substantial magnetic coercivity and, ultimately, good permanent magnets [1]. Secondly, rapid quenching can produce compounds, both stable and metastable, which cannot be produced by conventional methods such as arc-melting and induction-melting [2].

The discovery of the $Nd_2Fe_{14}B$ family of compounds in 1984 [1, 3] provided the impetus for the widespread use of rapid quenching in the preparation of intermetallic compounds. It has been demonstrated that the coercivity of rare-earth intermetallics is strongly dependent on the quench rate [1]. A comprehensive study of the magnetic and crystallographic properties of $Nd_2Fe_{14}B$ prepared at different quench rates has been published by Cadogan *et al.* [4].

Recently, attention has turned to the tetragonal $ThMn_{12}$ type compounds [2, 5, 6] and the compound $SmFe_{11}Ti$ which has been identified by Coey *et al.* [7, 8] as a potential permanent magnet material. A number of rapid quenching studies of the $ThMn_{12}$ compounds have been carried out, with emphasis on the Sm–Fe–Ti and Sm–Fe–V systems [9–17]. The main aim of these studies has been the preparation of microcrystalline structures which exhibit coercivity. Schultz *et al.* [17] have obtained a coercivity of 1.17 T in Sm–Fe–V prepared by mechanical alloying. Yamagishi *et al.* [12] have obtained a coercivity of 0.98 T by annealing over-quenched $SmFe_{10}TiV$.

The aim of the present work was the preparation of $YFe_{10}V_2$ in both the microcrystalline and amorphous states, and the characterization of the iron magnetization in both states by Mössbauer spectroscopy.

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2. Experimental details

Ingots of $YFe_{10}V_2$ were prepared by arc-melting in an atmosphere of titanium-gettered argon. Rapidly quenched $YFe_{10}V_2$ was prepared by melt-spinning in a helium atmosphere on a steel substrate at a peripheral wheel speed of 40 m s^{-1}. The spun material was analyzed by X-ray diffraction using Cu Kα radiation. ^{57}Fe Mössbauer spectroscopy was carried out in conventional transmission mode at 295 K using a $^{57}CoRh$ source.

3. Results and Discussion

In Fig. 1 we show the X-ray diffraction pattern obtained with rapidly quenched $YFe_{10}V_2$. For comparison, the X-ray pattern of crystalline $YFe_{10}V_2$ [18] is also shown. Despite numerous attempts, we were unable to produce amorphous $YFe_{10}V_2$. We note that other authors [11, 14] report similar experiences with $SmFe_{10}V_2$.

The X-ray pattern in Fig. 1 indicates that the rapidly quenched $YFe_{10}V_2$ has a microcrystalline $ThMn_{12}$ structure. The broadening of the x-ray diffraction lines allows one to obtain an estimate of 450 Å for the mean crystallite size in the spun $YFe_{10}V_2$, using the Debye–Scherrer method. Saito *et al.* [10] studied $SmFe_{11}Ti$ and reported that this compound undergoes a phase transformation from the tetragonal $ThMn_{12}$ structure to the hexagonal $TbCu_7$ [19] structure as the quenching rate is increased. Simple X-ray diffraction is unlikely to provide clear evidence for such a transformation since the X-ray diffraction pattern attributed to the $TbCu_7$ structure by Saito *et al.* could quite easily be attributed to a broadened microcrystalline $ThMn_{12}$ pattern.

In Fig. 2 we show the 295 K ^{57}Fe Mössbauer spectrum of microcrystalline $YFe_{10}V_2$. The spectrum of crystalline $YFe_{10}V_2$ [18] is included for comparison. The microcrystalline spectrum was fitted with a distribution of ^{57}Fe hyperfine

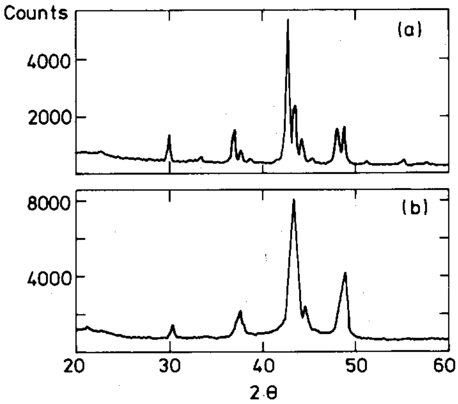

Fig. 1. Cu Kα X-ray diffraction patterns of (a) crystalline $YFe_{10}V_2$ [18] and (b) melt-spun $YFe_{10}V_2$.

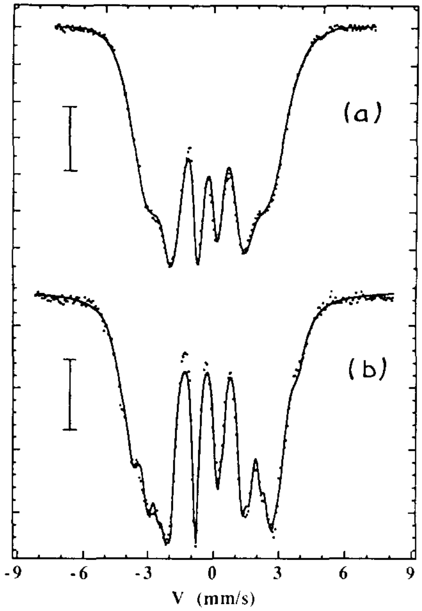

Fig. 2. ^{57}Fe Mössbauer spectra obtained at 295 K of (a) melt-spun $YFe_{10}V_2$ and (b) crystalline $YFe_{10}V_2$ [18]. The full lines are fits to the spectra and the vertical bars represent 2% absorption.

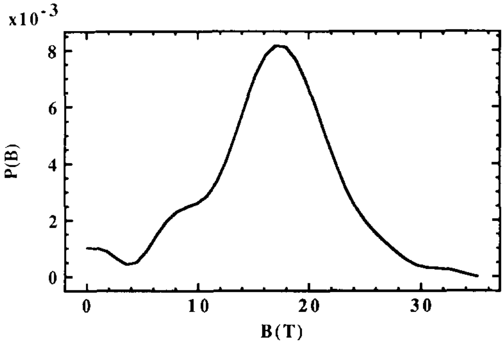

Fig. 3. ^{57}Fe hyperfine field distribution at 295 K of melt-spun $YFe_{10}V_2$, deduced from Mössbauer spectroscopy.

field, using the method of Le Caër and Dubois [20]. The fitted ^{57}Fe hyperfine field distribution is shown in Fig. 3. The average ^{57}Fe hyperfine field (at 295 K) in microcrystalline $YFe_{10}V_2$ is 16.5 T, with a standard deviation of 5.9 T. The corresponding average iron magnetic moment is 1.14 μ_B, assuming a field-moment conversion of 14.5 T/μ_B [21]. This average hyperfine field is significantly lower than the value of 20.1 T obtained with crystalline $YFe_{10}V_2$ [18]. A similar reduction in average ^{57}Fe hyperfine field has been observed in $GdFe_{10}Al_2$ by Wang *et al.* [2] and is most probably due to a reduction in Curie temperature in the microcrystalline material compared with the crystalline material [4, 10, 14, 16]. A correlation between isomer shift (δ) and hyperfine field (B) of the form

$$\delta(\text{mm s}^{-1}) = -0.26 + 0.005\ B(\text{T})$$

was deduced from the fit to the microcrystalline $YFe_{10}V_2$ spectrum. The mean isomer shift, relative to α-Fe, is -0.18 mm s^{-1} for microcrystalline $YFe_{10}V_2$. The corresponding value for crystalline $YFe_{10}V_2$ is -0.14 mm s^{-1} [18].

4. Conclusions

Microcrystalline $YFe_{10}V_2$ has been prepared by melt-spinning. The average crystallite size is 450 Å, as deduced from X-ray diffraction. Attempts to prepare amorphous $YFe_{10}V_2$ by melt-spinning were unsuccessful. The average ^{57}Fe hyperfine field at 295 K, deduced from Mössbauer spectroscopy, is 16.5 T, which corresponds to an average iron moment of 1.14 μ_B.

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