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SPIN REORIENTATION IN ERBIUM IRON GARNET

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^{57}Fe Mössbauer measurements in the temperature range from 1.5 to 297 K on erbium iron garnet confirm the occurrence of a spin reorientation from the [100] to the [111] direction. They show that the reorientation takes place gradually between 74 and 95 K. The values and the signs of the quadrupole coupling constants at the octahedral and tetrahedral sites are determined.

There is some confusion in literature concerning the direction of the easy magnetic axis in erbium iron garnet (ErIG). Contradictory reports have been published on this subject. The confusion is mainly caused by the limited temperature range of most measurements.

Rodrigue et al.[1] performed ferrimagnetic resonance measurements at temperatures from 190 to 450 K and found that the easy axis is along the [111] direction. Pearson[2] confirmed this with torque measurements between 100 and 300 K. In studies of the magnetic structure of ErIG at liquid helium temperatures the [111] direction was assumed to be the easy axis[3-6]. Also Geller et al.[7] concluded from magnetometric measurements that the easy axis is in the [111] direction for temperatures below 83 K. The same conclusion was drawn by Atzmony et al.[8] from ^{153}Eu Mössbauer spectra at 4.2 K. Contrary to the results of the investigations[3-8], Pearson[2] showed that at 4.2 K the easy axis is along the [100] direction. Also Harrison et al.[9] found from magnetometric measurements that the [100] direction is the easy axis for temperatures below 40 K. This has been confirmed by Belyaeva et al.[10] and Orlich et al.[11,12] using optical measurements, by Streever et al.[13] using ^{57}Fe and ^{167}Er NMR and by Atzmony et al.[14] using ^{151}Eu Mössbauer spectroscopy.

Sivardiere et al.[15] first predicted theoretically a reorientation of iron magnetic moments in ErIG from the [111] direction at high temperatures to the [100] direction at low temperatures. From torque measurements in the temperature range between 77 and 293 K Perekalina et al.[16] showed that the temperature of this spin reorientation is equal to 135 K. Subsequent susceptibility studies by Kolachev et al.[17] and torque measurements by Kolacheva et al.[18] gave spin reorientation temperatures of 78.5 and 80 K, respectively.

We have studied the spin reorientation in polycrystalline ErIG using ^{57}Fe Mössbauer spectroscopy. It has been shown recently by Geller et al.[19-21] that this method is very useful in studying spin reorientation in garnets. Single crystals of ErIG were grown from the $PbO.PbF_2.0.15V_2O_5$ flux by the slow cooling method. The mixture containing 7 mole% of garnet forming oxides, 87 mole% of flux and 6 mole% of Fe_2O_3 was soaked at 1593 K during 6 h, then cooled to 1273 K at a rate of 1 K h^{-1}. Single crystals were separated by dissolving the flux in hot nitric acid.

The small crystals were ground to a fine powder from which an absorber containing 4.8 mg cm^{-2} of Fe was prepared. Mössbauer measurements were performed using a constant acceleration spectrometer. The velocity was measured simultaneously with a Michelson interferometer. Spectra have been recorded at 1.5, 4.2, 19.9, 60, 70.3, 77.4, 80.2, 80.9, 82.3, 83.1, 83.8, 85.4, 90.6, 99.5, 297 and 579 K. The stability of the temperature was 0.2 K. The ^{57}Co(Rh) source was kept at 4.2 K (for the spectra at 1.5 and 297, 579 K the source was kept at 1.5 and 297 K, respectively).

Fig. 1 shows Mössbauer spectra characteristic for the orientation of spins in the [100] direction, measured at 4.2 K, and the orientation in the [111] direction, measured at 297 K[22,23]. These spectra were fitted with three Zeeman sextets of Lorentzian lines. The angles θ between the direction of the magnetic hyperfine field and the principal axes of the electric field gradient tensor at the octahedral (a) and tetrahedral (d) sites, indicated in Fig. 1, were fixed in these fits.

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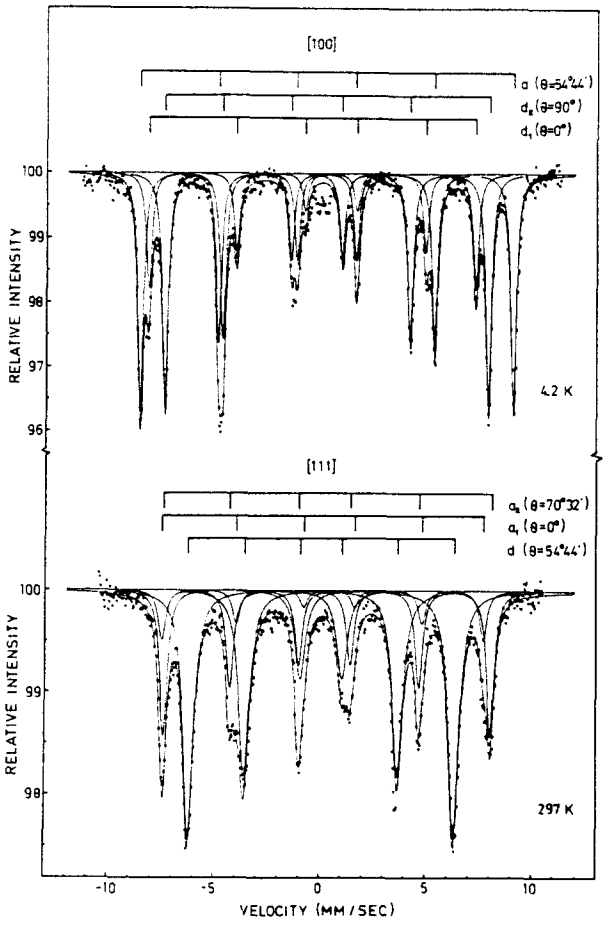

Fig. 1 Mössbauer spectra of ErIG at 4.2 and 297 K. The fitted spectra consist of three Zeeman sextets of Lorentzian lines marked by stick diagrams.

Their values are given in Table I of reference 22 (in the last column of this table the number 4 corresponding to the angle of 0^{o} should correspond to the angle of $54^{o}44'$). The values of the quadrupole coupling constant $\frac{1}{2}e^2qQ$ obtained from these fits are -0.384 (0.021) mm/s for the a site and -0.926 (0.011) mm/s for the d site. More accurate absolute values are obtained from the Mössbauer spectrum measured at 579 K, i.e. above Neel temperature of ErIG. They are 0.440 (0.005) mm/s and 0.996 (0.003) mm/s, respectively.

Sample spectra illustrating the spin reorientation process in ErIG are shown in Fig. 2. The spectra at 70.3 K and lower temperatures show that the easy magnetic axis is in the [100] direction, while those at 99.5 K and higher temperatures indicate that the [111] direction is the easy axis. The spectrum at 77.4 K marks the beginning of the spin reorientation process. The spectra at higher temperatures up to 90.6 K show the approach to the [111] easy magnetic axis. Fig. 2 shows that the spin reorientation process does not take place at a definite temperature[16-18]. This process does not have an abrupt character but occurs gradually in the temperature range from 74±3 K to 95±5 K. The accuracy of these figures is determined by the temperature intervals between successive spectra.

By means of Mössbauer spectroscopy the spin reorientations in suitable garnets can be investigated more quantitatively by examination of the temperature dependence of the effective quadrupole couplings. These values determined from fitted spectra in the appropriate temperature range depend on the angle θ, which changes with temperature in the spin reorientation region. Such a preliminary examination indicates that the easy axis in ErIG rotates in the temperature range from 74 to 95 K from the < 100 > to the < 111 > direction over an angle of $54^{o}44'$ in the {110} plane. Further detailed Mössbauer studies of spin reorientation in garnets are in progress.

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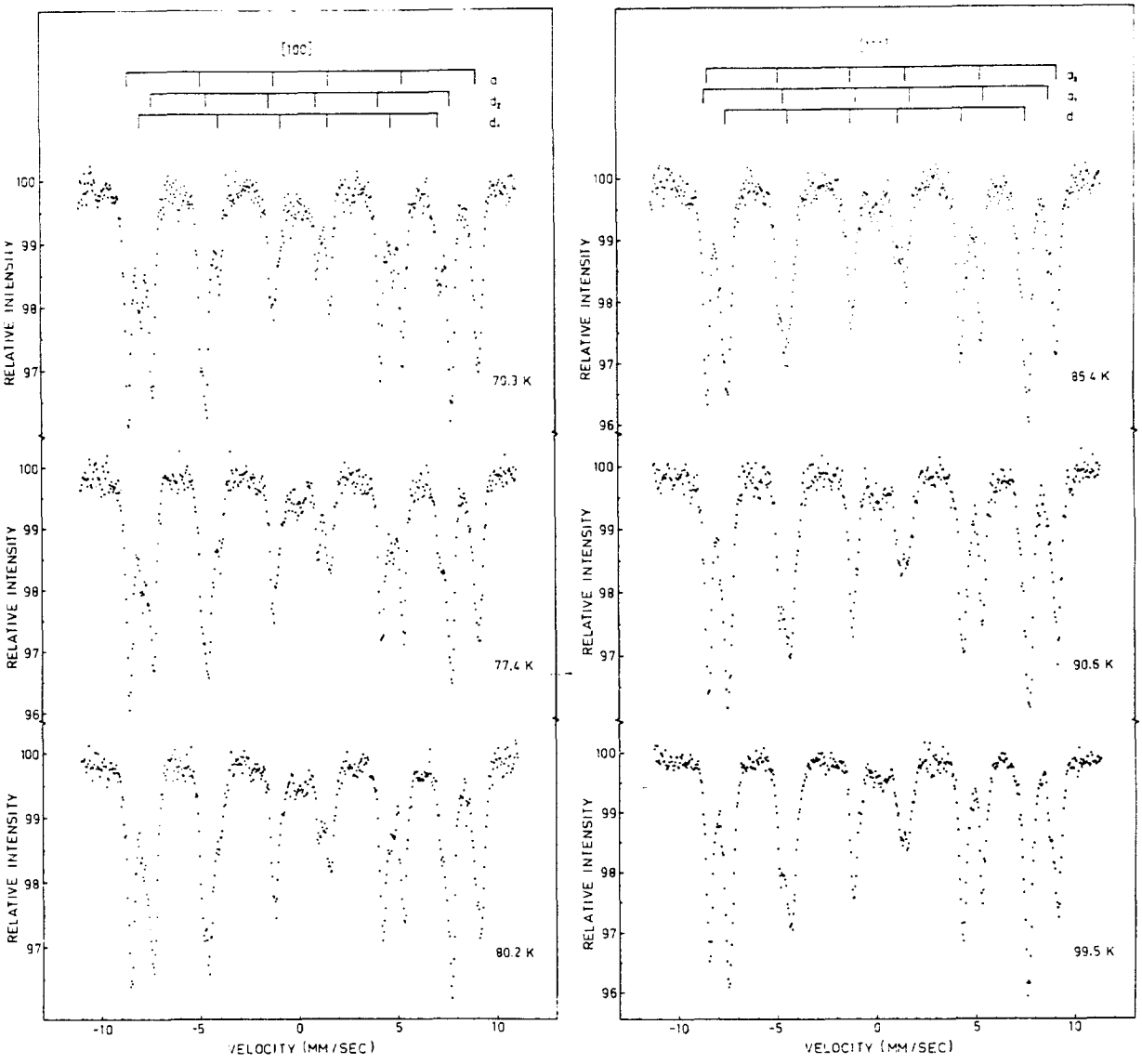

Fig. 2 Sample Mössbauer spectra of ErIG at different temperatures. A small absorption near zero velocity is caused by Fe impurity in Al foils between which the absorber holder was mounted in the cryostat. Stick diagrams show the theoretical line positions corresponding to the [100] and the [111] easy magnetic axis.

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