Effect of an electric field on the Mössbauer spectra of the ferrites $BaFe_{12}O_{19}$

E. G. Rozin, M. N. Shipko, and I. S. Zheludev
Institute of Crystallography, Academy of Sciences of the USSR, Moscow and V. I. Lenin Energy Institute, Ivanov

(Submitted 14 May 1982; resubmitted 24 September 1982)
Pis'ma Zh. Eksp. Teor. Fiz. **36**, No. 9, 316–318 (5 November 1982)

Mössbauer studies of single crystals of hexagonal ferrite $BaFe_{12}O_{19}$ in an external electric field are performed. An appreciable decrease of the local magnetic field at Fe^{57} nuclei situated in two crystallographic positions: trigonal bipyramid and octahedron, was observed in electric field for the first time.

PACS numbers: 76.80. + y, 75.50.Gg

Previous studies of the influence of an external electric field on the hyperfine structure of Mössbauer spectra were primarily performed on ferroelectrics. Thus the change in the parameters and shape of Mössbauer spectra with a phase transition in ferroelectrics or reorientation of domains in an electric field were studied in Refs. 1–4. There is yet no information on the influence of an electric field on the effective field (H_l) at Fe^{57} nuclei.

Ferrites are a convenient object for studying this problem. In ferrites the resonant nuclei are located at positions with considerable local distortions of the crystal lattice and have a relatively large free displacement in the coordination polyhedron.

We studied single crystals of hexagonal ferrites with the general chemical formula $BaFe_{12}O_{19}$. Hexagonal ferrites of the type BaM have high specific electrical resistance, which permits using relatively strong electric fields in experiments. The measurements were performed on specimens with a thickness of 80 ± 1 μm, cut perpendicular to the hexagonal crystal axis (C).

The elctrodes were deposited by vacuum evaporation of silver provided a resistive contact with the specimen. At maximum intensity of the electric field applied along the C axis of the crystal, the change in the temperature of the specimen did not exceed 1°, allowing the effect of temperature on the magnitude of H_l to be ignored.

Co^{57} in the chromium matirx with an activity of 25 μCi served as a source of γ-quanta.

Figure 1 shows the Mössbauer spectra of hexagonal barium ferrite in an electric field $E = 4$ kV/cm and without a field ($E = 0$). It is evident that both spectra have an identical structure. However, when the field is applied, the components from the ions Fe^{3+} situated at positions $12k$ and $2b$ [$a(E)$ and $e(E)$, respectively] are shifted toward lower velocities relative to $a(O)$ and $e(O)$. Computer analysis of the Mössbauer spectra showed that when the specimen is placed in an electric field the effective fields around Fe^{57} nuclei (H_l), the isomeric shifts (δ), and the quadrupole splitting (Δ) for a and e sublattices change (Table I).

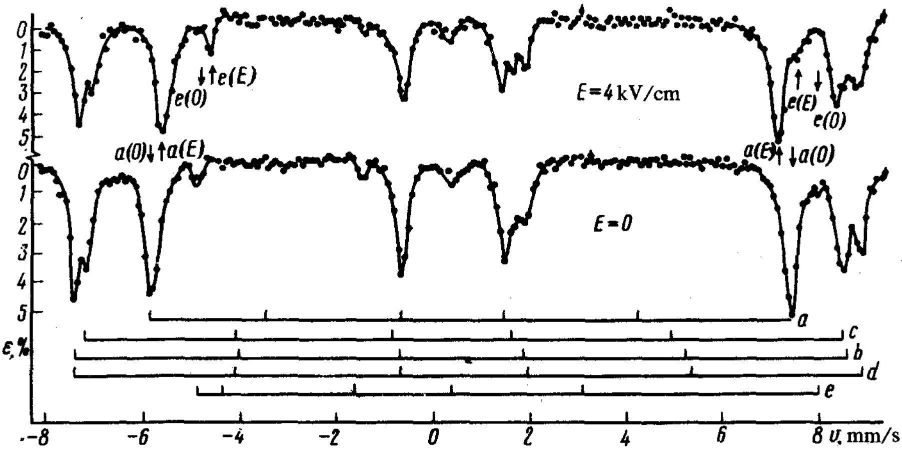

FIG. 1. Mössbauer spectra of single-crystalline specimen of the ferrite $BaFe_{12}O_{19}$, placed in an electric field ($E = 4$ kV/cm) and without a field ($E = 0$). The arrows show the position of components for the *a* and *e* sublattices in a field [$a(E)$ and $e(E)$] and without a field [$a(0)$ and $e(0)$].

The data obtained show that as the intensity of the external electric field increases, the energy state of the nuclei of iron ions situated in the *a* and *e* sublattices changes. It may be assumed that the reason for the change in the effective field at the nuclei of iron ions, localized in the trigonal bipyramid (sublattice *e*) and in the octahedron (sublattice *a*) is the displacement of Fe^{3+} ions under the influence of the electric field to one of the anions. As a result, the degree of overlapping of the electronic orbits of Fe^{3+} and O^{2-} ions changes and the fraction of covalent bonds between cations with anions also changes.

This assumption is based on the fact that the most appreciable changes in the parameters of the Mössbauer spectra are observed for iron ions which are situated in strongly distorted coordination polyhedra and which are less rigidly bound to the crystal lattice compared with ions localized in other positions.[5,6]

TABLE I. Parameters of Mössbauer spectra for Fe^{57} nuclei situated in *a, d,* and *e* sublattices with different intensities of the external electric field.

electric-field intensity E, kV/cm	*a* sublattice			*d* sublattice			*e* sublattice		
	H_L kOe	δ mm/s	Δ mm/s	H_L kOe	δ mm/s	Δ mm/s	H_L kOe	δ mm/s	Δ mm/s
0	418	0, 42	0, 44	512	0, 35	0, 13	406	0, 27	218
3, 3	407	0, 41	0, 38	508	0, 34	0, 16	392	0,32	2.09
4	400	0,39	0,37	507	0,32	0.1	380	0.32	1.93
error	± 3 kOe	± 0.04mm/s	± 0.04mm/s	—	—	—	—	—	—

It should be noted that the mechanism presented for the influence of the electric field on the parameters of the Mössbauer spectra of the ferrite $BaFe_{12}O_{19}$ is only an assumption, since the quantity H_L could change for a number of other reasons as well, including a change in the electron-vibrational interactions.[7]

[1]Sh. Sh. Bashkirov and V. N. Lebedev, Fiz. Tverd. Tela **21**, 262 (1979) [Sov. Phys. Solid State **21**, 156 (1979)].
[2]Sh. Sh. Bashkirov and V. N. Levedev in: Paramagnitnyĭ rezonans (Paramagnetic Resonance), Kazan, 1979, No. 15, p. 100.
[3]A. S. Ivanov, A. V. Kolpakov, and R. N. Kuz'min, Zh. Eksp. Teor. Fiz. **66**, 697 (1974) [Sov. Phys. JETP **39**, 336 (1974)].
[4]N. Bloembergen, Phys. Rev. Lett. **7**, 90 (1961).
[5]W. D. Townes, Z. Krist. **125**, 437 (1967).
[6]G. N. Belozerskiĭ and Yu. P. Khimich, Fiz. Tverd. Tela **17**, 1352 (1975) [Sov. Phys. Solid State **17**, 871 (1975)].
[7]I. B. Bersuker, Élektronnoe stroenie i svoĭstva koordinatsionnykh soedineniĭ (Electronic Structure and Properties of Coordination Compounds), 1976, p. 352.

Translated by M. E. Alferieff
Edited by S. J. Amoretty