# THE EXTRAORDINARY HALL EFFECT IN THE PARA-PROCESS REGION IN SOME SPINEL TYPE FERRITES

O. Žižić[1,3] and M.Lj.Napijalo,[2,3]

1. Facutty of Mechanical Engineering, Belgrade,
2. Department of Physics and Meteorology, Faculty of Science,Belgrade and
3. Institute of Physics, Belgrade.

The paper presents the results of investigation of the influence of magnetization on the Hall effect in Ni-Zn and Mn-Zn ferrites in the region from 10°C to 150°C. It is shown that the contribution of the magnetic Hall effect in Ni-Zn ferrite is dominant in the range of higher temperatures, while it has considerable influence in the entire temperature interval for both samples. The magnetic Hall coefficient $R_p$ is for both samples a decreasing temperature function. Its sign in Mn-Zn ferrite is opposite to the sign of the current carriers in the entire interval, while in Ni-Zn ferrite it changes within the same temperature interval $(32 < T < 42)$°C as the sign of the current carriers.

## INTRODUCTION

The study of the Hall effect in metals [ 1,2,3 ] and ferrites [ 4,5,6 ] has shown that the value of the extraordinary Hall coefficients, determined in strong and weak fields, in a general case are not equal, i.e. that it depends on the para process.

Volkov [ 7 ] was the first to point that it is necessary to introduce two different coefficients for the extraordinary Hall effect; the first, corresponding to the region of the technical magnetization, is caused by spontaneous magnetization and the second, corresponding to the para-process region, is caused by the real magnetization.

Following [ 6 ] the Hall EMF ($E_F$) in the region of para-process is given by the relation.

$$E_H = R_oH + R_sP_s + R_pP_p \qquad (1)$$

where $R_o$, $R_s$ and $R_p$ are the coefficients for the ordinary, spontaneous and magnetic Hall effect respectively, H is the applied field strength, $M_s$ and $M_r$ are magnetizations in the regions of technical and para-process magnetization respectively.

The field dependence of $E_H$ in ferrites in para-process region is complex; this may be taken to be the consequence of different contributions of magnetic sublattices to the resulting Hall-effect. According to [ 8 ] a different Hall coefficient ($R_p$) may be attributed to each sublattice and various sublattices give separate contributions of different sign to the resulting Hall EMF. The third term in relation (1) can be presented in the form

$$R_p M_p = R_{p1} M_{p1} - R_{p2} M_{p2} \qquad (2)$$

where $R_{p1}$ and $R_{p2}$ are the Hall coefficients and $M_{p1}$ and $M_{p2}$ magnetizations of two sublattices.

EXPERIMENTAL RESULTS

The paper presents the results of the study of the Hall effect in the para-process region in spinel·type ferrites of the following composition: 14,1 mol% ZnO, 33,6 mol% MnO, 52,3 mol% $Fe_2O_3$ and 25 mol% ZnO, 25 mol%NiO, 50 mol% $Fe_2O_3$. The measurements were carried aut in the interval from 10°to 150°C, in the field up to 2 kOe.

The method for. measuring the Hall EMF, magnetization and electric resistivity of material and all technical data and calculation methods have already been described in [ 9,10].

Fig. 1. shows the isotherms $E_H(M)$, obtained from directly registred dependences $E_H(H)$ and M(H) by the procedure schematically presented in Fig. 2. The broken line OABC represents the isotherm $E_H(M)$.

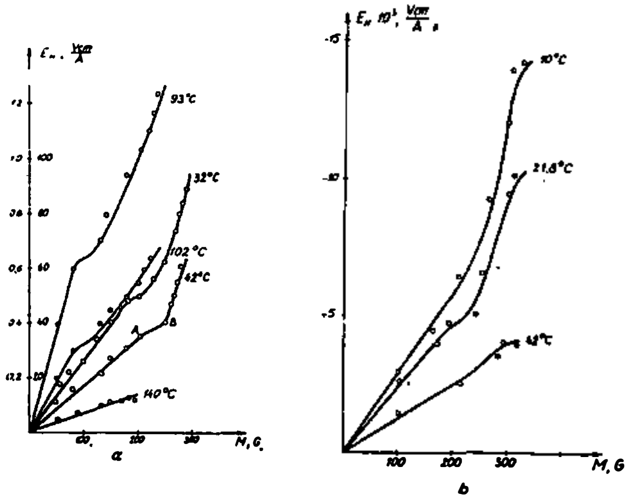


Fig. 1.
The dependence
$E_H(M)$
for a) Ni-Zn,
b) Mn-Zn ferrite.

The parts OA, AB and BC correspond to the displacement process, to the rotation process and to the para-process of magnetization respectively. The experimental isotherms (Fig. 1) are presented by the broken lines and exibit pronounced deviations from the linearity in the para-process region.

The change of the shape of the curve $E_H(M)$ with the increase of temperature may be caused by the fact that the saturation magnetization in the region of technical magnetization is achieved in weaker fields with the rise of temperature. Further, on the experimental isotherms $E_H(M)$ (Fig. 1) the different regions which should correspond to different

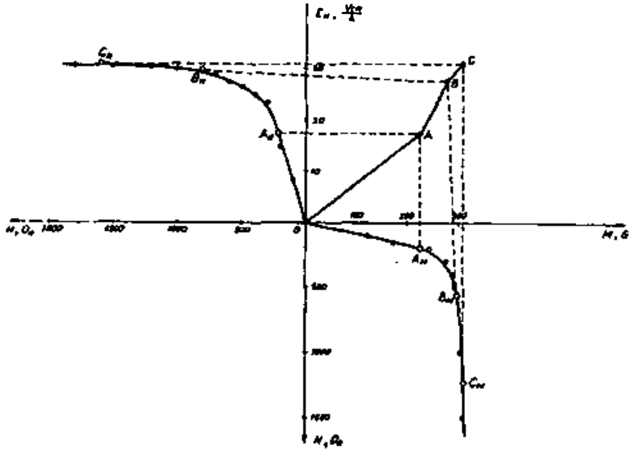

Fig. 2.
The procedure for the determining $E_H(M)$

mechanisms of magnetization (Fig. 2) are not clearly separated. This is caused by the fact that in real magnets the mentioned magnetizing processes are frequently overlapped.

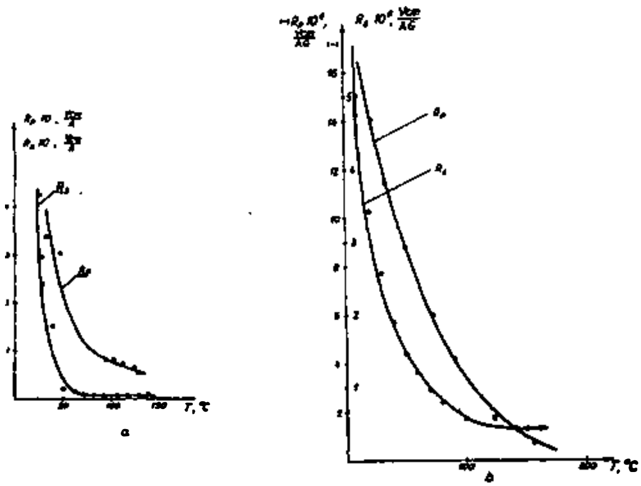

Fig. 3.
The dependences $R_s(T)$ and $R_p(T)$
a) Ni-Zn,
b) Mn-Zn ferrite.

The dependences $R_s(T)$ and $R_p(T)$ are shown in Fig. 3. According to the dependence $R_p(T)$, which is very intense in the entire temperature interval, one would say that the temperature dependent forms of scattering of the current carriers are dominant for the magnetic Hall effect. Since $R_p$ is a yardstick of real magnetization it is natural to assume that this coefficient, as well as $R_s$, is determined by the scattering of conduction electrons on magnetic inhomogeneities, i.e. that it is directly dependent on the magnetic part of electric resistivity $\rho_m$ [11].

The different behoviour of $R_s$ and $R_p$ with the temperature change requires also theoretical explanation.

Table 1. shows that the Ni-Zn ferrite is a semiconductor of the n-type. Coefficients $R_s$ and $R_p$ have the same positive sign up to some temperature ($32^o < T < 42^oC$) where $R_p$ changes the sign. Coefficient $R_p > R_s$ in entire temperature interval. The difference increases with the increase of temperature. Mn-Zn ferrite is, sudging by the sign of $R_o$, a semiconductor of the p. type, $R_s$ and $R_p$ have the same, negative sign, oposite tc the sign of the current carriers in whole temperature interval.

Table 1.

| Sample | $T^oC$ | $R_s.10$ (Vcm/AG) | $R_p.10$ (Vcm/AG) | $R_o.10^3$ (Vcm/AG) | $\frac{R_p}{R_s}$ | $R_sM_s : R_pM_p : R_oH$ |
|---|---|---|---|---|---|---|
| Ni-Zn ferrite | 30 | 2,95 | 4,20 | - 4,50 | 1,42 | 17,8 : 2,1 : 1,0 |
| | 70 | 0,09 | - 1,23 | - 0,40 | -14,00 | 5,5 : 6,1 : 1,0 |
| | 140 | 0,02 | - 0,74 | - 0,08 | -49,00 | 4,8 : 20,4 : 1,0 |
| | | $R_s.10^5$ | $R_p.10^5$ | $R_o.10^6$ | | |
| Mn-Zn ferrite | 20 | - 3,40 | -13,90 | 1,70 | 4,1 | 6,0 : 0,8 : 1,0 |
| | 60 | - 1,20 | - 7,40 | 0,62 | 6,2 | 5,2 : 1,0 : 1,0 |
| | 150 | - 0,40 | - 0,90 | 0,14 | 2,2 | 4,8 : 1,1 : 1,0 |

DISCUSSION

Particulary interesting is the change of the sign of $R_p$ in Ni-Zn ferrite. According to our measurements it cannot be ascribed to the change of the sign of current carriers. The sign of current carriers does not determine the sign of $R_s$ either. Let us mention that there are contradictory data in the literature as concerns the sign of $R_s$, while the sign of $R_p$ is not the topics of any study. Perhaps, when speaking about ferrite materials, the explanation is to be sought in the fact that the different sublattices may provide contributions of different signs to the Hall EMF in the para-process region.

The contribution of particular effects to the entire Hall effect depends also on the temperature in the region of real magnetisation (Table 1.). So, while the spontaneous Hall EMF is pronouncedly dominant in Ni-Zn ferrite at low temperatures, the contribution of the magnetic part suddently increases with temperature, to be most significant upon reaching $T = 140^oC$. In Mn-Zn ferrite the contribution of the magnetic Hall effect slightly increases with temperature, but the spontaneous Hal EMF is dominant in the entire temperature interval.

On the basis of the evaluation of contributions of particular effects we conclude that three-term relation (1) is suitable and indispensable for the description of the Hall EMF in examined ferrites in the para-process region for entire interval under observation.

At the end it is necessary to remark that the Hall effect in the region of the para-process magnetization has been studied for a small number of magnetic materials and that there is no microscopic theory of this effect existing at present. For these reasons it is not possible to give any explanation of the processes responsibles for the observed properties of the examined ferrites.

REFERENCES


1. Kondorskii E.I., ZhETF, 48,2,506, (1965).
2. Svirina R.P., Novikova E.A., Pisma v ZhETF, 9,2,96, (1969).
3. Phyne J.J., Phys. Rev., 172,523, (1968).
4. Lavin J.M., Phys. Rev., 123,4,1273, (1961).
5. Volkov D.I., Vesnik MGU, 4,19, (1960).
6. Belov K.P., Svirina E.P., ZhETF, 37,1212, (1959).
7. Volkov D.I., Vesnik MGU, 3,507, (1954).
8. Turov E.A., Shavrov V.T., Irkhin Yu.P., ZhETF, 47,296, (1964).
9. Napijalo Lj.M., Žižić O., J. of Eng. Phys., 12,33, (1975).
10. Žižić O., Ph. D. Thesis, Faculty of Science, University of Belgrade (1976).
11. Abelskii Sh.Sh., Irkhin Yu. P., FMM, 19,2,282, (1965).