

can yield information as to the predominance of one or the other of the interactions.

In the case of nonconservation of parity, the photons are circularly polarized. The dependence of the circular polarization on the frequency of the photon for a given  $\pi$ -meson energy and emission angle for the  $\pi$  meson and photon is given by:

$$P_{\gamma}^i = \frac{\Delta\omega_R - \Delta\omega_L}{\Delta\omega_R + \Delta\omega_L} = \frac{2x(1-x)}{1+(1-x)^2} \frac{\alpha_i + \alpha_i^*}{1+|\alpha_i|^2}, \quad (8)$$

$$x = \omega/\omega_m, \quad \omega_m = p(z^2 - 1)/2(z + \cos\theta).$$

Here  $\Delta\omega_R$  and  $\Delta\omega_L$  are the differential probabilities for decay with the emission of right-polarized or left-polarized radiation respectively;  $\omega_m$  is the maximum photon frequency for a given  $\pi$ -meson energy and angle of emission. The maximum value of the polarization  $P_{\gamma m}^i = 0.41$ , for  $\alpha = 1$ , is achieved with  $x = 0.6$ .

There is no circular polarization for charge invariance ( $\alpha = -\alpha^*$ ) or if parity is conserved

( $\alpha = 0$ ). It is easy to show that in these cases the radiation will consist of a superposition of unpolarized light and linearly polarized light.

In conclusion we wish to express our gratitude to Professor I. Ia. Pomeranchuk for suggesting this problem and for guiding its execution and to A. F. Grashin for a discussion of the results.

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94

## ON THE HALL EFFECT AT THE CURIE POINT

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THE magnetization of ferromagnets in the low-temperature region<sup>1</sup> is determined, roughly speaking, by an inversion process (the spontaneous-magnetization vector switches from one direction of easy magnetization to another) and a rotation process (the spontaneous-magnetization vector of the domain shifts away from the direction of easy magnetization). Sufficiently far above the Curie point  $\Theta$  the magnetization is caused by the change in the number of parallel and antiparallel spins when short-range order is absent. We shall call such a process true magnetization, in contradistinction to paraprocesses when short-range order is present and microdomains are formed. A paraprocess causes magnetization by the rotation of microdomains.

Measurements performed by us show that for each of these four processes of magnetization there is a corresponding Hall parameter. As far as the inversion and rotation is concerned, we have obtained the following results. When investigating

the Hall effect in iron-aluminum alloys we have observed that the Hall voltage depends in a non-linear fashion on the magnetization  $I$  in the region of technical saturation. However, for an alloy with a zero value of the anisotropy constant (12% Al),<sup>2</sup> we obtained a strictly linear dependence, while the slopes of the straight lines are the same in the regions of inversion and rotation. For alloys with a non-vanishing anisotropy constant we have observed a bending of the curve in the transition region from inversion to rotation. Since this bending is not substantial or very pronounced, it is desirable to perform a direct measurement of the Hall effect on single crystals to bring out the role

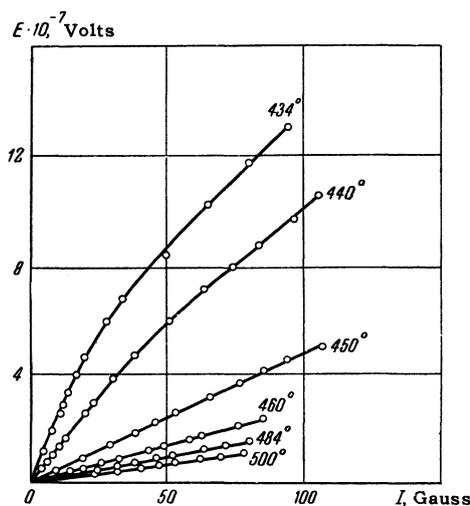


FIG. 1

played by anisotropy.

We further observed a sharp difference in the Hall parameters for the paraprocess and the true magnetization. It was established that the ferromagnetic Hall constant is practically equal to zero for true magnetization. This follows from the curves giving the dependence of the Hall emf  $E$  on the magnetization  $I$  above the Curie point (Fe-Ni, 46% Ni). As can be seen from Fig. 1, the tangent of the angle of inclination sharply decreases above the Curie point to zero (within the limits of experimental accuracy). This indicates that the spin distribution does not lead to a Hall effect, when there is no short-range order, even if  $I \neq 0$  (for  $H \neq 0$ ). When the Curie point is approached, short-range order sets in, as characterized by the formation of microdomains (complexes of electrons with a parallel spin alignment). The larger the number of such microdomains, the higher will be the value of the ferromagnetic Hall constant  $R$ . If we neglect the dependence of the Hall effect on the magnitude of the microdomains, we can thus consider such a curve  $R(T)$  above the Curie point (Fig. 2) as the characteristic probability for the formation of microdomains at different temperatures.

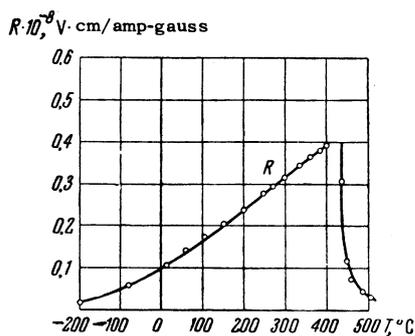


FIG. 2

Below the Curie point the microdomains agglomerate in the well-known way, forming larger complexes — the domains. The dependence of the Hall constant on the temperature becomes of the kind depicted in Fig. 2.

This dependence below the Curie point was shown by us<sup>3,4</sup> to be characterized by the relation

$$e = [a(\rho - \rho_0) + b(\rho - \rho_0)^2] I, \quad (1)$$

where  $e$  is the Hall emf per unit current density and unit distance between the Hall electrodes,  $\rho$  the specific electrical resistivity,  $\rho_0$  the residual resistivity, while  $a$  and  $b$  are temperature-independent constants. From (1) it follows that

there are two effects, one proportional to  $\rho$ , and the other to  $\rho^2$ .

A number of authors<sup>5</sup> have found a relation different from Goldhammer's (i.e., a linear dependence of  $e$  on  $I$ ), namely,

$$e = (c - fI_s^2) I, \quad (2)$$

where  $c$  and  $f$  are constants.

An analysis performed by us showed that (2) is a consequence of the general relation (1). To see this, one must take into account (for instance, using Gerlach's equation<sup>6</sup>) that the ohmic resistivity is itself a function of the spontaneous magnetization, i.e.,

$$\rho = \rho_0 - \alpha T + \beta(I_0^2 - I_s^2), \quad (3)$$

where  $I_s$  and  $I_0$  are the values of the spontaneous magnetization at the given temperature and at absolute zero, and  $\alpha$  and  $\beta$  are constants. After substituting (3) into (1) we get a relation of the kind (2), because the term  $\beta I_s^4$  is relatively small and the term  $\alpha T$  can for relatively small changes in  $T$  be considered to be a constant quantity. Combining (1) to (3) we have thus

$$dR/dI_s^2 = a d\rho/dI_s^2 \text{ or } f = a\beta. \quad (4)$$

This condition agrees well with experiments in the region of the Curie temperature. The relation (2), found by Komar and Volkenshtein, is thus a consequence of the general law (1) which is shown to be correct in a number of cases where (2) does not agree with experiments (e.g., for the alloy Fe<sub>3</sub>Al).

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