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Abstract

Full Text

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PHYSICS

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ON THE RELATION BETWEEN THE BARKHAUSEN EFFECT AND THE MAGNITUDE OF THE RESIDUAL MAGNETIZATION OF NICKEL

(Presented by Academician A. V. Shubnikov, 5 March 1965)

A number of works have been devoted to the study of various aspects of the Barkhausen effect in ferromagnets. In most works, either the characteristics of the jumps themselves (size, duration) are investigated, or the influence of various factors (temperature, annealing, mechanical stresses, etc.) on their number, parameters, and distribution with respect to these parameters is studied ([1–6]).

At the same time, in our opinion, it is of great interest to establish the connection between the Barkhausen effect and the processes of magnetization and remagnetization, especially with hysteresis phenomena. Such a connection is natural to expect, since the Barkhausen effect is associated with irreversible phenomena in the process of remagnetization, while the most important characteristic of irreversibility is the hysteresis loop. In the present work we have succeeded in discovering a simple dependence between the magnitude of the residual magnetization and the number of remagnetization jumps in a specimen.

Fig. 1. Relation between the number of jumps and the magnitude of the residual magnetization of a nickel specimen under the influence of mechanical stresses

Measurements of the number of jumps N were carried out on an apparatus that in principle did not differ from that described earlier ([6]). The magnitude of the

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

residual magnetization was determined by ballistic and magnetometric methods. The specimens were nickel wires with diameters from 0.2 to 1.2 mm. Parallel measurements of the magnitude of the residual magnetization of the specimen I_R and the number of jumps N corresponding to remagnetization along one of the branches of the hysteresis loop were first made for an unloaded specimen, and then at various internal stresses produced by tensile loads. With increasing tensile load, both the number of jumps N and the magnitude I_R decreased.

Figure 1 shows the obtained dependence of I_R on N for a specimen of diameter $d = 0.4$ mm. For specimens of other diameters the graphs look similar.

Thus, between the magnitude of the residual magnetization and the number of jumps there exists a simple linear dependence

$$I = I_R^0 + kN. \tag{1}$$

According to the existing theory of hysteresis phenomena of E. I. Kondorskii ([7]), hysteresis is caused by three reasons: (a) delay in the displacement of boundaries between domains; (b) delay in the growth of remagnetization nuclei; (c) irreversible rotation processes.

Since the first two causes, as is known, also determine Barkhausen jumps, it seems natural to us to give the following interpretation of relation (1). The residual magnetization consists of two parts. First, of the residual magnetization due to the delay in the displacement of domain boundaries and to the delay in remagnetization nuclei. This part of the residual magnetization must be proportional to the number of defects causing the delays. But since these same defects ([8]) also cause Barkhausen jumps, the first part of I_R must be proportional to the number of jumps in the specimen. When the structure of the specimen changes, the number of defects causing jumps changes, and accordingly this part of the residual magnetization must change.

Fig. 2. Relation between the number of jumps and the magnitude of the residual magnetization for various minor hysteresis loops. The points on the graph correspond to field-strength amplitude values of 1, 2, ⋯, 8 oersted. Specimen diameter 0.5 mm

Fig. 3. Relation between the number of repolarization jumps and the shape of the hysteresis loop for a Rochelle-salt crystal under the influence of mechanical stresses

The other part of the residual magnetization is due to irreversible processes of rotation of the vector I_s. Defects that affect the motion of interdomain walls have little effect on rotation processes; therefore, a decrease in the number of jumps does not affect this part of the residual magnetization. Extrapolation of the graph to values $N = 0$ gives the value I_R^0, which, apparently, is the part of the residual magnetization due to irreversible rotation processes.

If the considerations expressed are correct, then one may expect that in weak fields, when rotation processes do not play an essential role, the relation

$$I_R = kN. \tag{2}$$

should hold.

To verify relation (2), we carried out the following experiment.

The number of jumps N and the magnitude of the residual magnetization were measured for a series of minor hysteresis loops, for which the amplitude value of the field strength varied from $H_A = 1$ oersted to $H_A = 12$ oersted in steps of 1 oersted. In this case (see Fig. 2), up to 8 oersted the relation between I_R and N corresponds to relation (2). At higher fields the growth of I_R, as was to be expected, outstrips the growth of N.

In conclusion it should be noted that an analogous relation between the Barkhausen effect and residual polarization should also occur in seg-

ferroelectrics. A qualitative confirmation of this assumption is the relation we obtained [9] between the change in the number of repolarization jumps and the shape of the hysteresis loop for a Rochelle-salt crystal (cut $X - 45°$) under the influence of mechanical stresses, shown in Fig. 3.

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Note: Figure translations are in progress. See original paper for figures.