First-Order Magnetic Anisotropy Constants of Ferrites

J. B. BIRKS

British Dielectric Research Ltd., London W. 12, England

(Received May 26, 1955)

Certain sources of error in attempting to derive the first order anisotropy constants of ferrites from magnetostatic data are pointed out. High-frequency observations, particularly of the natural spin resonance frequency, are preferable.

WEISZ[1] has recently reported quasi-theoretical values of the first-order anisotropy constant K_1 of several ferrites. These were derived by substitution of experimental values of the initial permeability μ_0 and the saturation magnetization M_s in the equation

$$\mu_0 - 1 = kM_s^2/K_1. \tag{1}$$

The constant k, for which theoretical values of π, $4\pi/3$ and $8\pi/3$ have been variously proposed, is obtained by substitution in (1) of experimental data for magnetite ($\mu_0 = 45$, $M_s = 480$, $K_1 = -1.1 \times 10^5$ ergs/cm^3). This gives $k = 21$, and the same value is assumed for the other ferrites. The purpose of the present note is to point out several potential sources of error in this procedure, and to mention some earlier published work which appears to have been overlooked.

1. The quantity μ_0 in (1) refers to the component of the initial permeability due to spin rotation only, and not to the total static initial permeability μ_s, the experimental values of which are used by Weisz.

2. Although Birks[2] and later Went and Wijn,[3] have shown spin rotation to be the principal magnetization process in several low-conductivity ferrites, the difference between μ_s and μ_0 is not always negligible; for example, for Ni—Zn ferrite, $\mu_s = 40$, $\mu_0 = 34$.[2] The error introduced by equating μ_0 and μ_s can be eliminated by permeability measurements at frequencies of ~ 200 Mc/sec, between the dispersion regions due to translational (domain wall displacement) and rotational processes.

3. The error is particularly significant in magnetite,[2] in which $\mu_s \sim 2\mu_0$. The magnetic dispersion[4] at 5–20 Mc/sec in this material is attributed to relaxation of the translational magnetization component, and it is only at higher frequencies that the initial permeability becomes equal to μ_0.

4. The translational component ($\mu_s - \mu_0$) is associated with the conductivity, which is relatively high in magnetite compared with the other ferrites. μ_s is therefore susceptible to impurities and strains. This probably accounts for the major difference between the values for magnetite powder of $\mu_s = 15$, $\mu_0 = 8$, observed by Birks,[2] and the value for sintered magnetite of $\mu_s = 45$, used by Weisz.[1] The former experimental data substituted in (1) give a value of $k = 3.8$, which lies within the range of theoretical values of this constant.

5. An alternative method of determining $|K_1|$ for powdered ferrites by observations of the natural spin resonance frequency in the internal anisotropy field has been described previously.[2] This method gives a value of $|K_1| = 1.3 \times 10^5$ ergs/cm^3 for magnetite, compared with that of $K_1 = -1.1 \times 10^5$ ergs/cm^3 derived[2] from the single-crystal data of Quittner,[5] and subsequently confirmed by Bickford[6] and Danan.[7]

There are insufficient data available to estimate the resultant errors in the absolute values of $|K_1|$ derived by Weisz,[1] but it is unlikely that they are of sufficient magnitude to modify the broad qualitative correspondence found between $|K_1|$ and J, the inner quantum of the M^{++} ions in the ferrite structure, $MO \cdot Fe_2O_3$.

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