APPLICATION NOTE

No. 663: Test for Saturation Magnetization

Introduction

The room temperature saturation magnetization ($4\pi M_S$) of a ferrimagnet is an intrinsic characteristic that is important to the microwave device engineer. He utilizes the saturation magnetization as a design parameter that enters into the initial selection of a ferrimagnetic material for microwave device applications. Typical ferrimagnets exhibit values of $4\pi M_S$ between 300 and 5000 gauss.

Static or low frequency methods are generally employed to measure $4\pi M_S$. The technique described below for the measurement of $4\pi M_S$ has been gaining general acceptance.

Magnetometer Method

The test specimen is a sphere approximately 0.100 inch diameter. When placed in a uniform strong D.C. magnetic field, the sphere becomes uniformly magnetized in a direction parallel to the applied field. External to the sphere the field resulting from this magnetization is exactly that of a magnetic dipole located at the center of the sphere oriented parallel to the magnetization. The strength of this dipole field is proportional to the magnetic moment of the sphere, that is, to $M_S V$, where V is the volume of the sphere.

If R_1 is the reading for the strength of the dipole field of one sphere of magnetization M_1 and volume V_1, and R_2 is the reading for a second standard sphere (say nickel) of magnetization M_2 and volume V_2, then

$$\frac{R_1}{R_2} = \frac{M_1 V_1}{M_2 V_2} = \frac{M_1 d_1{}^3}{M_2 d_2{}^3} \qquad (1)$$

where d_1 and d_2 are the diameters of the two spheres. If M_2 is known, this equation permits experimental determination of M_1.

Figure 1 shows an arrangement for measuring the saturation magnetization of spheres of ferrimagnets. Such a device is called a vibrating sample magnetometer. By means of an electromechanical transducer (A) and tube (B), the sample is vibrated vertically between pickup coils (C) in a horizontal D.C. magnetic field. A suitable frequency of vibration may be 100 cps. As a result of the changing linkage of the dipole flux with the coils, a signal is induced in the coils at the vibration frequency. The coil arrangement shown is one of several satisfactory ones. In this case the two coils are connected in series opposition with respect to stray fields: the signal voltages in the two coils will then add. The size of this "specimen signal" is proportional to the magnetic moment of the ferrimagnet under test.

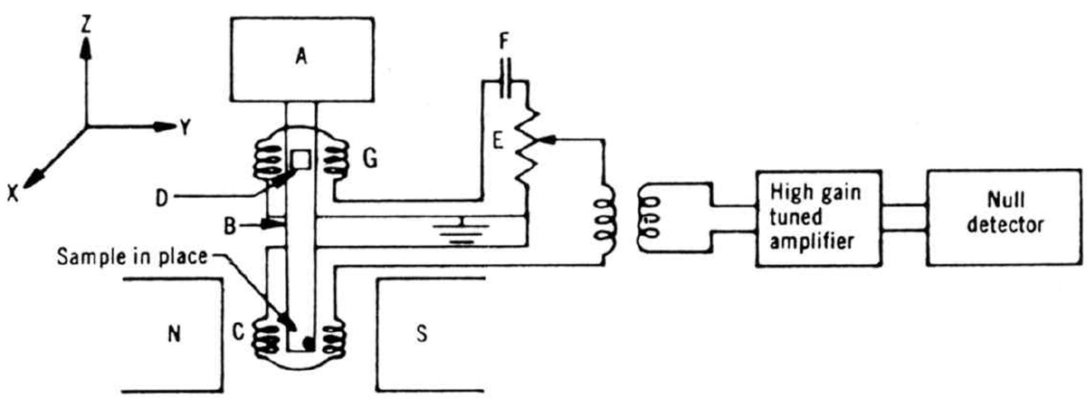

Figure 1. Diagram Of Typical Vibrating Sample Magnetometer Set Up

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A small D.C. permanent magnet (D) is mounted in the tube outside the D.C. magnetic field and situated between another set of pickup coils (G). This magnet is oriented so that its magnetic moment lies on the line connecting the centers of the two coils. A suitable means is provided for selecting an adjustable fraction of the "reference signal" from these coils such that the specimen signal is balanced by a measured fraction of the reference signal. One means of accomplishing this is shown in the figure. The fraction of the reference signal used is chosen by the precision potentiometer (E) and the reading of the potentiometer dial is proportional to the fraction. This signal is combined 180° out of phase with the specimen signal by means of the transformer. The capacitor (F) resonates the inductance of the reference coils, thereby avoiding an undesirable phase difference between the specimen and reference signals applied to the transformer. The strength of the dipole field is thus proportional to the reading R of the potentiometer dial when the fraction of the reference voltage is adjusted to obtain a null in the output of the amplifier. The amplifier is tuned to the vibration frequency.

Measurement

(a) Attach the specimen at the end of the rod and cause it to vibrate perpendicular to the D.C. magnetic field. To minimize dependence on the specimen position, center the specimen with respect to the coils by positioning for a minimum of specimen signal with respect to motion in the Y direction and for a maximum with respect to motion in the X and Z directions. Determine the reading R corresponding to the fraction of the reference signal required to balance out the specimen signal.

(b) The measurement of saturation magnetization requires that the specimen be saturated. For most microwave ferrites, a satisfactory criterion for saturation is that a decrease in the applied D.C. magnetic field by 25 percent shall result in no more than a 1 percent decrease in the indication, R.

(c) The $4\pi M_s$ of the unknown ferrite specimen may then be calculated from Equation 1. A suitable material for the standard specimen is pure nickel. The saturation induction of pure nickel at room temperature is 6070 gauss. This value applies to a nonporous specimen of density 8.90 g/cm^3.

References

American Society for Testing and Materials (ASTM) tentative standard C527-63T.

Foner, S., "Versatile and Sensitive Vibrating-Sample Magnetometer," Rev. Sci. Instr., Vol. 30, 1959, pp. 548-557.