

APPLICATION NOTE

Test for Saturation Magnetization

Introduction

The room temperature saturation magnetization ($4\pi Ms$) of a ferrimagnet is an intrinsic characteristic that is important to the microwave device engineer. The engineer uses 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 $4\pi Ms$ between 300 Gauss (G) and 5000 G.

Static or low frequency methods are generally used to measure $4\pi Ms$.

Magnetometer Method

The test specimen is a sphere with a diameter of approximately 0.100 inches. When placed in a uniform strong Direct Current (DC) 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 (i.e., to M_sV , where V is the volume of the sphere).

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

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

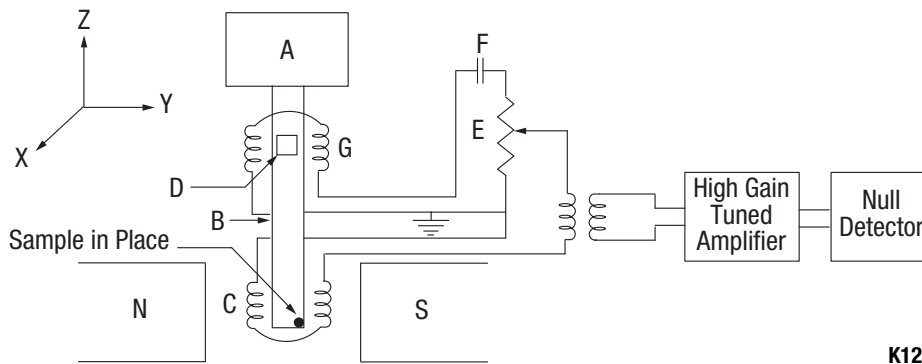
Where:

- R = Reading for the dipole field's strength.
- M = Magnetization.
- V = Volume.
- d = Diameters of the two spheres.

If M_2 is known, then Equation 1 permits experimental determination of M_1 .

Figure 1 shows a device for measuring the saturation magnetization of ferrimagnet spheres, which 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 DC 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 in Figure 1 is one of several satisfactory arrangements. In this case, the two coils are connected in series opposition with respect to stray fields, and 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.



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Figure 1. Typical Vibrating Sample Magnetometer Setup Diagram

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In Figure 1, a small DC permanent magnet (D) is mounted in the tube outside the DC 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.

Figure 1 shows a suitable means for selecting an adjustable fraction of the reference signal from these coils so that the specimen signal is balanced by a measured fraction of the reference signal.

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 at 180 °C 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

- Attach the specimen at the end of the rod, and then cause it to vibrate perpendicular to the DC 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.
- 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 DC magnetic field by 25% shall result in no more than a 1% decrease in the R indication.
- 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 G. This value applies to a nonporous specimen of density 8.90 G/cm³.

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