Measurement of complex permeability of Co- and Ti-substituted Sr-M by short-circuited coaxial transmission line method

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The recent trend of mobile communication technology directs the usage of X-band (8-12 GHz) frequencies in near future. As a result, the study of various hexaferrite materials, owing to their moderate permeability and very low loss, has surged up over the last few years,[1] while the challenging task of accurate measurement of magnetic characteristics beyond 10 GHz has also attracted a lot of interest. Among various measurement techniques, non-resonant type measurement with the help of simple transmission line offers easy, accurate and broadband measurement. In this report, high frequency (up to 30 GHz) magnetic characterization of Co- and Ti- substituted Sr-based M-type hexaferrite particles ($SrCoTiFe_{10}O_{19}$, will be called SrCoTiM hereafter) is demonstrated by adopting coaxial transmission line based measurement technique. Instead of the usual lumped element approximation that induce large model errors in case of measurements beyond a few GHz, the new lumped element expression of short-circuited transmission line is used to restrict the model error within permissible limit.[2]

SrCoTiM powder was procured and mixed with epoxy resin (at 5:1 volume ratio in favor of ferrite) to make a semi solid paste, which was then used to form a thin layer of ~200 μm. A toroid-shaped sample with inner and outer diameter of 3 mm and 7 mm respectively was punched out from that thin sheet of ferrite. Frequency dispersion of complex relative permeability of the sample was estimated by analyzing reflection coefficients (s_{11}) obtained by placing the sample at the short-end of the transmission line fixture. It is to be noted that the distributed element expression for the input impedance of short-circuited transmission line was judiciously approximated by considering only the first two terms of its Taylor series expansion. This slight modification in the analysis increases the range of measurable frequencies and accuracy. Magnetic hysteresis of SrCoTiM, measured by room temperature VSM, shows saturation magnetization of ~200 emu/cc and coercivity of ~330 Oe (Fig. 1b). Moreover, it is found that the saturation is attained gradually over a wide span of fields. The saturation field, which can be viewed as the anisotropy field of well-formed ferrite particles, is believed to be around 7000 Oe. The measured FMR, found to be ~20.6 GHz as shown in Fig 1c. More than one FMR peaks can be attributed to the presence of particles with wide size distribution (Fig. 1a). The loss (μ”) profile is found to be negligible up to 15 GHz, while μ’ is independent of frequency up to 12 GHz, which in turn, indicates that the material could be well suited for various application such as inductors for X-band and electromagnetic noise suppressor for Ku-band. However, the measurement above 26 GHz requires further investigation.

In essence, high frequency magnetic characterization up to 26 GHz of an important class of hexaferrite is demonstrated by using a simple short-circuited coaxial transmission line equipped with a slightly modified analysis technique.

Reference

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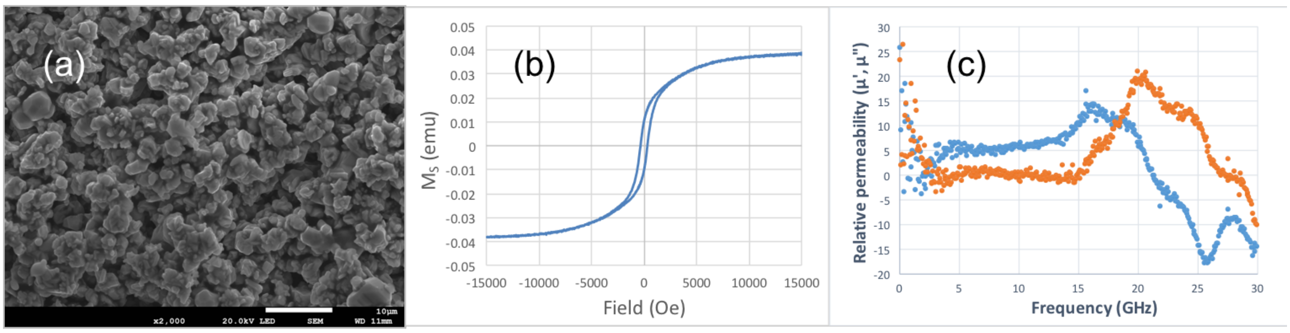

Fig.1: (a) SEM image, (b) Hysteresis plot and (c) complex permeability spectra of SrCoTi-M+epoxy mixture