Ultra-broadband and ultra-high sensitivity permeability measurements by transformer coupled permeameter (TC-permeameter)

S. Tamaru

(Spintronics Research Center, Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, 305-8568 Japan)

Magnetic materials are ubiquitously used in various high frequency electronics systems as inductors, transformers, noise filters and noise suppression sheets, which often determine the entire system performance. One such example is an inverter. Among many components used in the inverter circuit, inductors and transformers usually have the lowest high frequency performance, thus limit the entire system performance such as the switching frequency, conversion efficiency and unit size. For this reason, improvements of these magnetic components are crucial for the development of modern electronics systems. High frequency magnetic components are often made of magnetic particles by either sintering or dispersing into polymer resin. Currently the permeability of the magnetic particles can be measured only in the final component form because of the limited sensitivities of permeance measurement techniques currently available. This is a serious limitation in the development of the magnetic components, because it is impossible to study the effects of the processes done on the magnetic particles, such as crashing, micro forging, annealing and solidifying, on the permeability, and therefore one can only guess the effects by characterizing the magnetic component in the final form. In order to overcome this difficulty and accelerate the developments of high frequency magnetic components, a technique to measure the permeability with high sensitivity has been strongly sought.

For measuring the permeability of a single magnetic particle with sufficiently high sensitivity, we have developed a permeability measurement technique, which we named as "transformer coupled permeameter (TC-permeameter). Figure 1 shows the block diagram of this technique. A magnetic particle is sandwiched by two short terminated coplanar waveguides (CPWs). These two CPWs are electrically insulated by Kapton tape, thus this structure forms a loosely coupled single-turn transformer. Each CPW is connected to the port 1 (P1) and 2 (P2) of a vector network analyzer (VNA) that measures the transmission parameter (S₂₁) twice, first under the magnetic field of interest, and second under a sufficiently strong magnetic field to saturate the magnetic particle. The difference of S_{21} under these two magnetic fields reflects the permeability. Figure 2 shows the permeability of a Permalloy particle with a lateral size of approximately 100 µm and thickness of 0.5 µm, which is similar to the size of magnetic particles contained in commercial noise suppression sheets, measured by the TC-permeameter. The figure shows that the permeability can be measured over a very wide frequency range from 10 MHz up to 20 GHz with a high signal-to-noise ratio (SNR). In the presentation, the measurement principle of the TC-permeameter technique, including the jig structure, the reason why this technique can enhance the sensitivity, how to calibrate the system to give the absolute value of the permeability, and how the measurement limits are determined, will be explained.

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magnetic particle is sandwiched by two short Permalloy particle over 10 MHz - 20 GHz. terminated CPWs that form a loosely coupled transformer, and the VNA measures the S_{21} parameter.

Fig. 1, Block diagram of the TC-Permeameter. The Fig. 2, Complex relative permeability of a single