High-temperature wideband losses of sintered Mn-Zn ferrites.

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DC-100 MHz permeability and loss behavior of Mn-Zn ferrites subjected to different doping schemes are investigated up to T = 160 °C. It is shown that by acting on the type and concentration of soluble additives, like TiO_2, CoO, and NiO, one can achieve a monotonical decrease of the energy loss with T from DC up to a few hundred kHz. Such property can be interpreted in terms of doping-dependent strength and distribution of the anisotropy field and the ensuing balance between magnetization rotations and domain wall displacements as a function of frequency and temperature.

Keywords: Soft ferrites; Magnetic losses; Anisotropy field

1. Introduction

Magnetic cores employed in power electronics are subjected to complex exciting waveforms and increasingly high frequencies, making the rising temperature of the involved components a matter of concern [1]. This work shows that monotonically decreasing energy loss under increasing temperature can be achieved up to a few hundred kHz in suitably doped Mn-Zn ferrites.

2. Results and discussion

Mn-Zn ferrites containing 70.70 % Fe_2O_3, 23% MnO and 6.30% ZnO were prepared following the solid-state synthesis method. The mixed raw materials were pre-fired at 850 ^{0}C and milled for 9 hours. Doping levels of CoO and NiO, alone or in combination, varied between 0 and 4000 ppm, while standard doping (TiO_2, CaO, Nb_2O_5, and ZrO_2) was the same in all batches. The resulting powders were granulated and compacted as ring specimens of 20 mm outside diameter. Sintering was applied at 1300 ^{0}C for 3 hours following the Morineau-Paulus equilibrium equation.

The ring samples were characterized at defined peak polarization values J_p = 2 – 50 mT using a calibrated wattmeter-hysteresisgraph up to 1 - 3 MHz and a VNA setup up to 1 GHz. Both methods covered an intermediate frequency range, where overlapping results were obtained. The measuring temperature T, ranging between 23 °C and 160 °C, was associated with a decrease of the electrical resistivity, eventually approaching a lower plateau upon attaining the MHz range. Such a decrease generally affects, however, the energy loss $W(f, J_p)$ only beyond a few hundred kHz, depending on the sample thickness. Fig. 1 shows the monotonic decrease of the measured energy loss up to about 150 °C for J_p = 50 mT at 1 kHz and 200 kHz. This behavior contrasts with the usual T-dependence of $W(f, J_p)$ in the Mn-Zn ferrites, characterized by a minimum value around 80 – 100 °C, which is enforced by the decrease of the saturation magnetization with T. A shallow minimum in such a dependence is here observed around 140 °C – 150 °C for f > 200 kHz and the role of T becomes irrelevant beyond about f = 1 MHz (see Fig. 2).

The theoretical appraisal of the phenomenology of $W(f, J_p)$ and permeability $\mu = \mu' - j\mu''$ versus T and f is worked out in this work in the framework of the loss decomposition principle, generalized to the specific dissipation mechanisms taking place in the sintered ferrites. Such mechanisms, accompanying the motion of the domain walls and the rotation of the spins inside the domains, are affected by the distribution in strength and direction of the local anisotropy fields, which fluctuate from grain to grain. Given the low values of the magnetocrystalline anisotropy found in the Mn-Zn ferrites, the internal demagnetizing fields can largely contribute to the anisotropy fields. Consequently, they influence the distribution of the ferromagnetic resonance frequencies and the related absorption of electromagnetic energy.

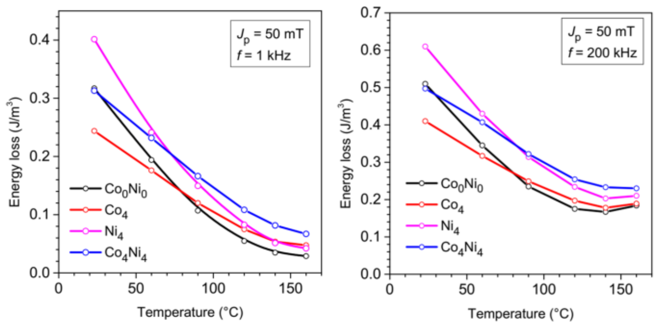

Figure 1: Examples of temperature dependence of the energy loss at J_p = 50 mT in the Mn-Zn ferrites doped with different contents of CoO and NiO. Co_4 and Ni_4 stand for 4000 ppm addition of the respective oxides. It is absent in the Co_0Ni_0 material. The loss decreases monotonically with T up to about 150 °C for f < 200 kHz.

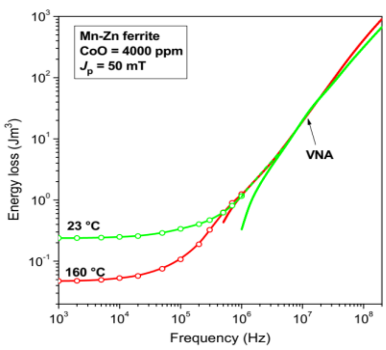

Figure 2: Broadband dependence of the energy loss at 23 °C and 160 °C for J_p = 50 mT in the 4000 ppm CoO-doped ferrite. Symbols: fluxmetric measurements. Continuous lines: VNA method. The trend towards loss independence on T upon approaching the MHz range is understood in terms of rotation-dominated magnetization process.

References

[1] J. Biela, U. Badstuebner, J.W. Kokar, IEEE Trans. Pow. Electr. 24 (2009) 288-300.

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