Magnetic loss decomposition in Co-doped Mn-Zn ferrites.

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Magnetic energy losses have been investigated versus frequency (DC $\leq f \leq$ 1 GHz) and peak polarization (2 mT $\leq J_p \leq$ 200 mT) in Mn-Zn ferrites, prepared with additions of CoO ranging between 0 and 6000 ppm. By doping, one chiefly aims at improving the soft magnetic response and the temperature stability of the material exploiting sign and strength of the additional anisotropy brought about by the Co ions. The loss versus frequency behaviors of the doped and undoped ferrites have been comprehensively analysed by the Statistical Loss Model, generalized to the case of semi-insulating materials and predominant spin damping dissipation mechanism. The energy loss $W(f)$ is therefore decomposed into a rotational (classical) component $W_{rot}(f)$, calculated by modeling the complex permeability via the Landau-Lifshitz equation and distribution of local anisotropy fields (Fig. 1a), and a domain wall contribution $W_{dw}(f)$, dominating at high and low frequencies, respectively. The latter separates in turn into hysteresis (quasi-static) $W_h(f)$ and excess $W_{exc}(f)$, components. It is verified that doping mostly affects $W_{dw}(f)$, with minimum value attained, at low and intermediate frequencies, for CoO = 3000 – 4000 ppm. No significant effects can in fact be put in evidence beyond about 10 MHz, where $W_{dw}(f)$ tends to disappear (Fig 1b), concurrent with the full relaxation of the domain wall processes. This is the frequency range where the eddy current losses can possibly play a role, depending on sample thickness (Fig. 1a). Improvement of the soft magnetic response of the Mn-Zn ferrite with CoO doping is found to be consistent with the mechanism of anisotropy compensation by the Co^{+2} ions, which appears, however, to be smoothed out at the typical device working temperatures of 80 °C – 100 °C.

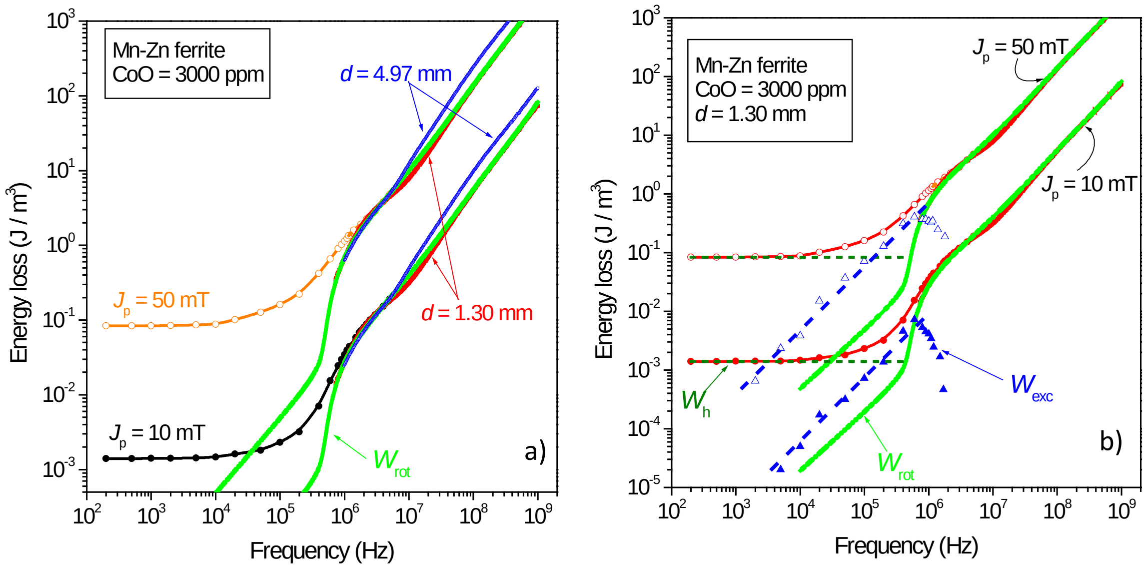

Figure 1. Energy loss $W(f)$ measured in Co-doped Mn-Zn ferrite ring samples up to 1 GHz at two different peak polarization values. a) On passing from the sample thickness d = 4.97 mm to d = 1.30 mm, the eddy current losses are made negligible and the theoretically predicted spin damping based rotational (classical) loss W_{rot} accounts for the high-frequency $W(f)$ behavior. b) Loss decomposition applies, according to $W(f) = W_h + W_{exc}(f) + W_{rot}(f)$, with W_h and $W_{exc}(f)$ the hysteresis and the excess loss components, respectively.