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Evaluation of a Ni-Zn ferrite for use in temperature sensors

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Abstract – The aim of this work is to analyze the variation of the real part of the complex magnetic permeability of a Ni-Zn ferrite for application in temperature sensors. Ferrite samples were fabricated by means of the conventional ceramic method, using zinc, nickel and iron oxides as raw materials. The samples were sintered in temperatures between 1200 ^oC and 1400 ^oC. The magnetic permeability of the samples was measured in temperatures from -40 ^oC to +50 ^oC. It was verified that the temperature sensitivity of the magnetic permeability is affected by the sintering temperature.

Ferrites are materials of relatively low cost and are applicable in several kinds of sensors, such as the ones for sensing: current, magnetic field, mechanical stresses, gas, and temperature [1-2]. In the case of temperature sensors based on the dependence of magnetic properties with temperature, the Curie temperature (T_C) of the ferrite is an important parameter to be assessed. Ni-Zn ferrimagnetic ferrites have T_C ranging from -140^{o}C to +570 ^{o}C approximately, depending on the Ni:Zn proportion. Literature has shown that, near T_C, the magnetic permeability (μ) of a Ni-Zn ferrite increases, with an increasing rate, and decreases sharply when $T>T_C$. In these temperature ranges in which the variation rate of μ is increased, the ferrites may act as temperature transducers. The aim of this work is to analyze the variation of the real part of the complex magnetic permeability of a Ni-Zn ferrite, in temperatures (T) between -40^{o}C and +50^{o}C, when T_C is between +20^{o}C and +50^{o}C.

Ferrite samples were fabricated by means of the conventional ceramic method, using zinc, nickel and iron oxides as raw materials in the following proportion: 54.35%Fe_2O_3 – 38.04%ZnO – 7.61%Ni_2O_3. The samples were sintered in temperatures between 1200 ^{o}C and 1400 ^{o}C. The relative complex magnetic permeability of the samples was measured, in the 100 kHz – 100 MHz frequency range. The variation rate of the real part (μ_r') of the relative complex magnetic permeability was evaluated at the frequency of 100 kHz.

Figure 1 shows the variation of μ_r' (at 100 kHz) with temperature for each sintering temperature. One can observe that for $T<T_C$ the relationship between μ_r' and T is approximately linear and that $d\mu_r'/dT$ increases with sintering temperature. A steep drop of μ_r' is observed for $T>T_C$ and in some shorter temperature ranges above T_C, $d\mu_r'/dT$ present the highest values. These temperature ranges are 20-30^{o}C for a sintering temperature of 1200 ^{o}C, 30-40^{o}C for sintering at 1400 ^{o}C, and 40-50^{o}C for sintering at 1300 ^{o}C. The 35-42^{o}C temperature range is particularly interesting for sensors of human body temperature and one can observe that the ferrite studied may become a sensitive transducer in this temperature range. Fig. 2 shows $\mu_r' \times T$, between 30-40 ^{o}C, of the samples sintered at 1400 ^{o}C. In such temperature range above T_C, $\mu_r' \times T$ relationship isn't linear.

The ferrite studied may be used as a temperature transducer, based on the magnetic permeability variation of the ferrite, which may present a temperature sensitivity of near 100 $^oC^{-1}$. The temperature range of maximum sensitivity may be adjusted by means of the selection of the adequate sintering temperature.

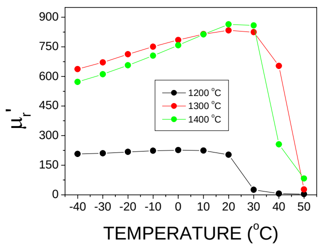

Figure 1: μ_r' at 100 kHz for the ferrite sintered at different temperatures.

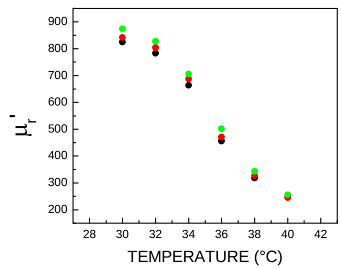

Figure 2: μ_r' at 100 kHz of three ferrite samples sintered at 1400^{o}C.

References
[1] V. L. O. Brito, A. C. C. Migliano, L. V. Lemos, F. C. L. Melo. PIER 91 (2009) 303.
[2] H-S Shin. Ferrite device for sensing temperature, US Patent 5,775,810 (1998).