Combined Experimental Measurements to identify the effect of the additives in Soft Magnetic Ferrites for Industrial applications

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Using advanced laboratory techniques such as SEM/EDS/EDX/B-H Analyzer and temperature-dependent permeability measurements, it has been detected how the microstructure and magnetic/electrical behaviour of soft ferrites can be affected by the presence of additives such as bismuth or cobalt. Understanding this relationship has allowed for solutions to problems in industrial applications.

Keywords: Inductance; Temperature; Material Composition; Magnetic Anisotropy; Additives.

1. Introduction

Ferrites are ceramic materials made of iron oxide mixed with other metal oxides (NiO, MnO_2, MgO, ZnO, BaO, etc). The resulting microstructure and final electrical and magnetic properties of such materials highly depend on their chemical composition: Mixing ratio between magnetic (Fe, Ni, Mn, Co), non-magnetic elements (Zn, Mg) and additives (Cu, Bi).

The combined use of advanced characterization techniques (SEM; EDS; EDX; B-H Analyzer; μ_i vs T; L vs T; Z vs F vs DC_{bias}) has made it possible to identify the relationship between material composition, the inclusion of additives, with changes in the microstructure, magnetic anisotropy and overall electric/magnetic performance of these soft magnetic materials.

The combined efforts of theoretical knowledge [1] and advanced laboratory measurements have led to improve the performance of passive components that uses soft ferrites in real-world industrial applications.

2. Results and discussion

The inductance behaviour over the temperature in passive components are strongly related with the magnetic anisotropy of soft ferrite cores, figure 1. Also, the magnetic anisotropy can be tuned with the grain size and the density of the core [2]. Furthermore, these factors are related with the material composition and the number of additives that are mixed before the sintering process.

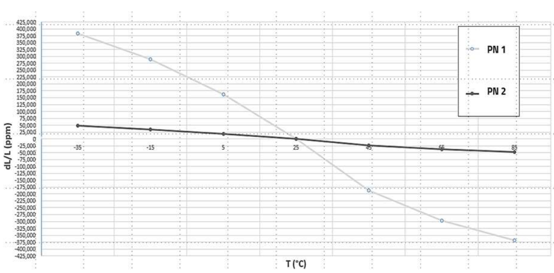

Figure 1: Inductance Behaviour of RFI soft ferrites

Figure 1 shows the variation in ppm of the dL/L over the temperature for two Ferrite SMT inductor. The reference PN 2 shows an steady behaviour less than 50k ppm, instead the PN1 displays a huge change, aprox. 375 ppm in the dL/L the temperature increase. This huge variation makes the PN1 not suitable for industrial applications that requires an stable temperature behaviour of the inductance and permeability.

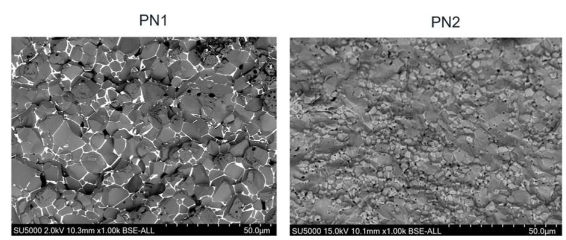

Figure 2, SEM results.

EDS and SEM analysis revealed the presence of bismuth as an additive (bright lines in the particles boundaries, figure 2-PN1), which can enhance inductance by promoting particle growth and altering magnetic anisotropy. This occurs through reduced density, smoother cross sections, and fewer grain boundaries or pores. However, while this improves structural uniformity, it worsens temperature stability, as fewer defects make domain wall movement easier under thermal agitation.

Afterwards, this complete analysis gave us the chance to fulfil the expected performance of the PN 1, by formulating a new material composition to replace the affected part, with no Bismuth and different core density.

Additional experiments were conducted to identify the influence of additives in the derating performance and curie temperature of MnZn and NiZn based passive components.

References

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