Enhancement of DC Bias Characteristics in NiCuZn Ferrite-Zn_2SiO_4 Composites with Core-Shell Structure

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A Novel NiCuZn Ferrite material including Zn_2SiO_4 and Bi_2O_3 was developed to enhance DC bias characteristics. The material exhibited a low change rate of inductance under DC bias compared to conventional NiCuZn ferrites. In addition, it was found to show a composite structure of NiCuZn ferrite and Zn_2SiO_4, and core-shell structure with NiCuZn ferrite cores surrounded by SiO_2-rich shells using STEM-EDS analysis. This composite-core-shell structure in the material is considered to contribute to improved DC bias characteristics.

Keywords: Ferrite materials; DC bias characteristics; additives; composites; core-shell structure

1. Introduction

Ferrite materials are crucial for inductors in electronic devices. The trend towards miniaturization and performance enhancement of ICT devices requires smaller, more efficient inductors. A key property is the DC bias characteristic, ideally with minimal inductance change under DC bias. To achieve this, the material must be less magnetically saturated by the magnetic field of the coil. An air gap in ferrite cores is a well-known method. Additionally, mechanical stress can also affect the material's permeability due to magnetostriction [1]. To make use of those effects, non-magnetic materials that act both as an air gap and as a source of mechanical stress due to thermal expansion differences were investigated. In this study, A New NiCuZn Ferrite material including Zn_2SiO_4 and Bi_2O_3, which exhibited improved DC bias characteristics, was developed.

2. Results and discussion

The Ferrite powder was prepared by a solid-state reaction. Fe_2O_3, NiO, CuO, and ZnO were mixed for 48 hours in a ball mill. The mixture was dried and calcined for 10 hours. The calcined powder was weighed with 15% Zn_2SiO_4 and 2% Bi_2O_3, based on the weight of the calcined powder. This mixture was mixed for 72 hours in a ball mill and dried. The powder was granulated with PVA and pressed into circular, square toroidal, and disk shapes. These were sintered at 900°C for 2 hours in air. The products were characterized by powder X-ray diffraction. Electromagnetic properties were measured using an impedance analyzer, a LCR meter, and a BH tracer. The microstructure was observed by energy dispersive X-ray spectroscopy in scanning transmission electron microscopy (STEM-EDS).

The phases of NiCuZn ferrite and Zn_2SiO_4 were confirmed by powder X-ray diffraction. Impedance analyzer measurements indicated a permeability of 4.2 at 10 MHz. As shown in Fig. 1, the change rate of inductance under DC bias for the ferrite material with Zn_2SiO_4 and Bi_2O_3 was smaller than that of the conventional NiCuZn ferrite with similar permeability, suggesting better DC bias characteristics. As shown in Fig. 2, the STEM-EDS analysis revealed a composite structure of NiCuZn ferrite, Zn_2SiO_4, and SiO_2 phases. Furthermore, NiCuZn ferrite grains showed a core-shell structure with a NiCuZn ferrite core and a SiO_2-rich shell, indicating a coexistence of a composite structure and a core-shell structure. This composite-core-shell structure in the material is considered to play a part to enhance DC bias characteristics.

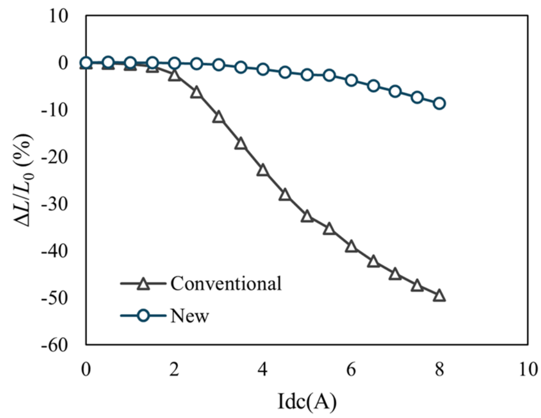

Fig. 1. Change rate of inductance under DC bias of a new ferrite material including Zn_2SiO_4 and Bi_2O_3 (open circle), and a conventional NiCuZn ferrite (triangle).

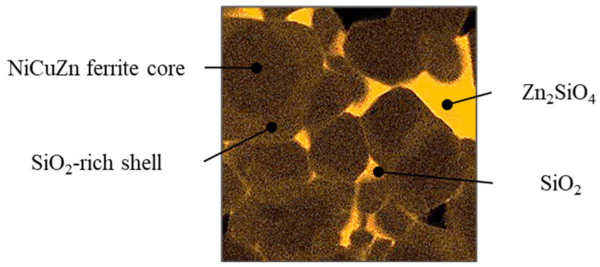

Fig. 2. Elemental mapping of Si by STEM-EDS analysis. Observations showed a NiCuZn ferrite-Zn_2SiO_4 composite structure with NiCuZn ferrite cores surrounded by SiO_2 shells.

References

[1] J. Smit and H. P. J. Wijn, *Ferrites* (Philips' Technical Library, 1959), p. 317-319.

Acknowledgements: We sincerely thank Mr. Hidekazu SATOH for his essential advice throughout this study and Mr. Yukio TAKAHASHI for his continuous support.