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Development of Small Height Inductors for DC-DC Converter

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1. Introduction

The miniaturization of portable electronic devices is remarkable supported by the miniaturization and thinning of electronic parts. The conventional inductors used in a DC-DC converter circuit consist of a ferrite drum core and a leading wire wounded around it. This configuration disturbs the farther miniaturization of inductors. In this study, two types of inductors whose height was 1-1.6mm and inductance was 2-23 μH were proposed and fabricated.

2. Inductors with thin-film coils

Figure 1 illustrates the basic structure of small height inductor. Coil winding unit of this inductor consists of a lower electrode, an insulation layer, and an upper thin-film coil. A Ni-Zn ferrite core with a diameter of 2mm is inserted at the center of the thin-film coil. The thin-film coil unit was sandwiched by upper and lower Ni-Zn ferrite plates

(a) 4 μ H inductor

In a 4 μ H inductor, the thin-film coil unit was fabricated using photolithography. The manufacturing process of the coil unit was as follows: At first, 0.5 μ m thick Cu underlayer was sputter-deposited on a polyimide film substrate. A 75 μ m thick photo-resist sheet was pasted on the substrate, and was exposed using a mask-aligner and developed. Pattern-electroplating was introduced to make lower electrode thick. The Lower electrode was formed by etching the surplus parts of the underlayer using a ferric chloride solution. After that, an insulation sheet (epoxy resin, thickness: 50 μ m) was laminated on this. The upper thin-film coil was formed on the insulation sheet using the same fabrication process as lower electrode. Two 75 μ m thick photo-resist sheet was used to make the upper coil thicker.

Winding number of the lower coil was 1.5 turns, and its width, height and spacing were 1000 μ m, 40 μ m and 100 μ m, respectively. Winding number of the upper coil was 7 turns, and its coil width, height and spacing were 200 μ m, 150 μ m and 90 μ m, respectively. The coil unit was sandwiched by the 500 μ m thick ferrite plates.

The size of the manufactured inductor was 7mm in width, 8mm in length, 1.26mm in thickness. Inductance and impedance at 1kHz was 4.25 μ H and 77m Ω, respectively, as shown in Fig.2. This inductor was installed in a DC-DC converter circuit, and normal operation was confirmed.

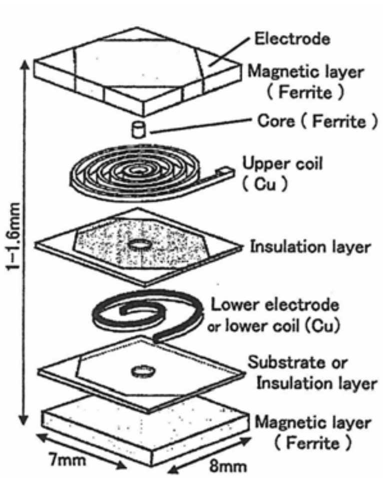

Fig.1 Inductor with thin-film coils.

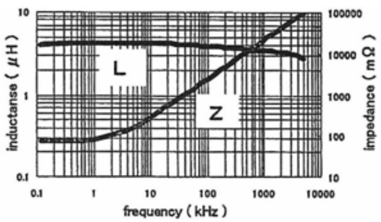

Fig.2 Frequency dependence of inductance and impedance for 4 μ H inductor.

(b) 23 μ H inductor

In a 25 μ H inductor, a 75 μ m thick Ni-Zn ferrite plate was used as a substrate, and thin-film coils were formed onto this ferrite substrate sequentially. The Ni-Zn ferrite substrate was processed by normal sintering method. To achieve sufficient smoothness for photolithography, an insulation sheet with a thickness of 50 μ m was pasted on this Ni-Zn ferrite substrate. The 9 turns lower coil were formed by the almost same method as 4 μ H inductor. The line width, height and spacing of the lower coil were 125 μ m, 110 μ m and 75 μ m, respectively. Prior to the fabrication of upper coil, planarization of the surface was carried out by spin-coating a liquid insulation material. After that, the 9 turns upper coil was successfully formed by the same process as the lower coil. The line width, height, spacing of the upper coil were 125 μ m, 150 μ m and 75 μ m, respectively. Figure 3 shows the photograph of the manufactured thin-film coil unit.

The size of this inductor was 7.5mm wide, 7.5mm long, 1.6mm in thickness. Inductance and impedance at 1kHz was 23 μ H and 367m Ω, respectively. For this inductor, DC loading current value at which the inductance decreased to 90% of that at zero DC load current was 400mA.

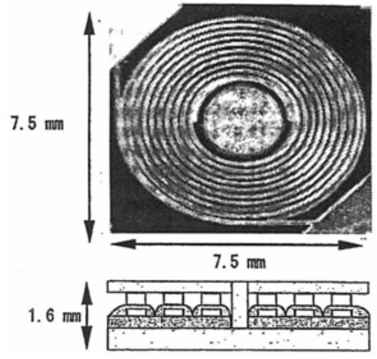

Fig.3 Top: Photograph of thin- film coil unit for 23 μ H inductor. Bottom: Cross-sectional illustration of inductor.

3. Coil-embedded-type inductor

The configuration of an inductor in which a coil was embedded into a ferrite core was shown in Fig. 4. The inductor was fabricated using Spark Plasma Sintering (SPS) method. In SPS method, ferrite powder materials suffer pressure in uniaxial direction and are heated up by Jule heat and the effect of spark plasma. The SPS has specific features of lower sintering temperature and shorter processing time than conventional sintering method. In fabrication of this inductor, eight turns Pt coil was put in ferrite powder, and then, SPS was carried out at a sintering temperature of 900℃, welding pressure of 29.4MPa and holding time of 5 minutes.

The size of the fabricated inductor was 15mm$^{\phi}$ × 1.1mm^{t}, and inductance was 1.9 μ H. This inductor has advantages of very simple fabrication process, rapid fabrication and low cost production.

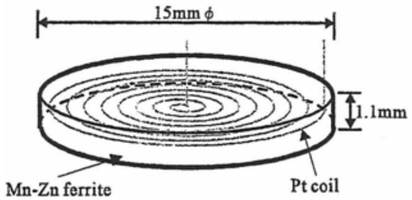

Fig.4 Coil-embedded type inductor.

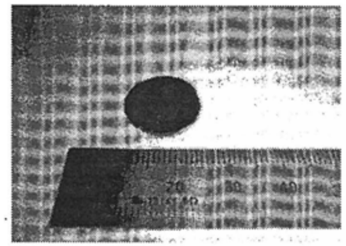

Fig.5 Photograph of coil-embedded-type inductor.

4. Summary

Two types of small height inductors were proposed and fabricated: One is composed of thin-film coils formed photolithography and ferrite core, and the other is coil-embedded-type inductor fabricated by Spark Plasma Sintering method. The former has an advantage of high inductance and possibility for further miniaturization. The advantage of the latter is low cost and short time processing.