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SMALL HEIGHT INDUCTOR FOR DC-DC CONVERTER

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1. Introduction

Recently, miniaturization of portable electronic devices is continuing supported by the progress of integrated circuit technologies. Individual electronic parts such as resistors and capacitors used in the portable devises are becoming smaller and thinner. The miniaturization of power modules which is inevitable in the portable devices is also strongly required.

In the conventional inductors for DC-DC converter circuit, the leading wire is wounded around the ferrite drum core. This configuration disturbs drastic miniaturization of inductors. Therefore, we have started to develop small height inductors to promote the micro-miniaturization of DC-DC converter circuit. In this study, we manufactured thin-film inductor with the size of 7mm wide, 8mm long, 1mm in thickness, and inductance of 4.7 μH.

2. Structure and Fabrication Process

Fig.1 illustrates the basic structure of manufactured small height inductors. Coil winding part of this inductor consist of a lower electrode, an insulation layer, and a thin-film coil. The width of thin-film coil was 200 μm and the space between coils was 90 μm. Number of turn of coil was seven. The thickness of thin-film coil was 150 μm. To achieve the requested inductance of 4.7 μH, it is necessary to increase the total number of coil windings. The 1.5 turn thin-film coil was also formed in lower electrode part. Ni-Zn ferrite core with a diameter of 2mm and height of 1.5mm was inserted at the center of the thin-film coil. Thin-film coil unit was sandwiched with upper and lower Ni-Zn ferrite plates whose size is 7mm wide, 8mm long, 0.5mm in thickness.

As a substrate of under electrode and thin-film coil, *METAROYAL* in which an 8 μm thick Cu film was adhered on a 50 μm thick polyimide film. Photo-resist sheet whose thickness was 75 μm was laminated on the *METAROYAL* substrate by laminate machine, and was exposed using a mask-aligner with g-line irradiation, and then developed. The photo-resist sheet was processed, and then lower electrode was formed by etching this using a ferric chloride solution. After that, an insulation sheet (epoxy resin, thickness: 50 μm) was laminated on this, and formed on lower electrode using the same fabrication process as lower electrode's.

Finally, upper thin-film coil was formed on this. Fig.2 illustrates fabrication process of upper thin-film coil. A 0.5 μm Cu thin-film was sputter-deposited by DC magnetron sputtering apparatus as the underlayer of pattern plating. Then, two photo-resist sheets (thickness:150 μm) was laminated on the sample (Fig.2(a)) and processed by exposed and developed (Fig.2(b),(c)). Then, the parts of coil was made thick by pattern electroplating using a copper sulfate solution (Fig.2(d)). The current density of the cathode was 45mA/cm^2, the time of electroplating was 190 minutes. Photo-resist sheet was removed by acetone solution, and then coil was formed by etching the surplus parts of under layer in this sample (Fig.2(e)).

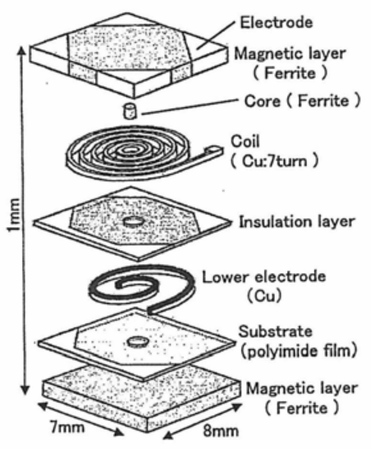

Fig.1 Schematic view of thin-film inductor

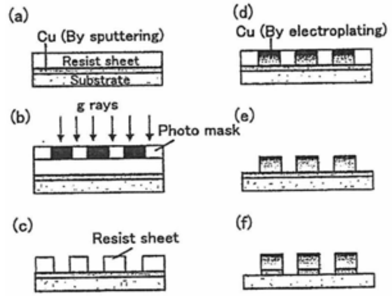

Fig.2 Fabrication process of thin-film coil.

3. Results and Discussions

Characteristic of manufactured proto-type inductor

Inductance and impedance at 1kHz of manufactured proto-type inductor by above mentioned method was 4.8 μH and 184mΩ, respectively. This inductor was installed in a DC-DC converter circuit, and tested. It didn't operate for a long time because the electric resistivity was so high that heat was generated. Reduction of electric resistivity became a critical issue in modification of this inductor.

Modified inductor

Resistance of manufactured thin-film inductor was calculated for reduction of impedance. According to the results of calculation, the resistance of connecting area between electrode and coil occupied more 50 percents in all (Fig.3(a)). It was expected that the resistance of this area could be reduced by making this area thicker. Modified thin-film inductor was manufactured by adding new process to make the connecting area thicker than the proto-type inductor.

Inductance and impedance at 1kHz of manufactured inductor by the above new process was 4.8 μH and 127mΩ, respectively. Gained inductance agreed with requested value, but more reduction of impedance was necessary. It was thought that making lower electrode thicker was effective method to decrease resistance (Fig.3(b)).

The thickness of lower electrode was 40 μm that was effective in reduction of impedance. Pattern electroplating was introduced to the fabrication process of lower electrode for forming coil and making lower electrode thicker. The time of electroplating was 60 minutes, and then coil was formed in lower electrode by etching. The treatment of an anticorrosive was added to the ever process after electroplating and etching process for protecting oxidation of metal surface. Also, reverse sputtering was made before sputtering Cu underlayer for electroplating after forming insulation layer to clean the surface of connecting between electrode and coil. Modified thin-film inductor was manufactured by both these process and above process. Fig.4 illustrates frequency dependence of inductance and impedance of manufactured inductor. Inductance and impedance at 1kHz was 4.25 μH and 77mΩ, respectively. This modified inductor could operate in a DC-DC converter.

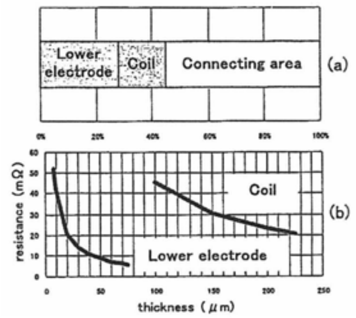

Fig.3 The results of calculation of resistance of manufactured inductor
(a) Percentage of resistance of proto-type inductor
(b) Thickness dependence of resistance of lower electrode and coil

4. Summary

The novel fabrication process of the small height inductor was established. Thick coil conductor was successfully achieved by sticking the photo-resist sheet instead of spin coating of photo-resist. Reduction of impedance was succeeded by making the lower electrode thicker and connecting area between electrode and coil wider. The size of manufactured thin-film inductor was 7mm wide, 8mm long, 1.255mm in thickness. Inductance and impedance at 1kHz was 4.25 μH and 77mΩ, respectively.

Also, it was confirmed that the inductor installed in a DC-DC converter circuit operated normally.

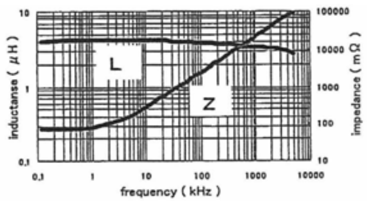

Fig.4 Frequency dependence of inductance and impedance.
(after making the connecting area and lower electrode thicker.)