Embedded Flexible Fe-Si-Al powder composite film inductor for a Low Power DC-DC Converter

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Introduction

- Of late, low power electronic systems are becoming increasingly compact; consequently, the sizes of the smaller passive components (magnetic components, capacitors) also are becoming critical. To enable compact magnetic design, the magnetic materials of magnetic components should have a higher magnetic saturation and permeability at high frequencies and flexible characteristics.
- Therefore, The Fe-Si-Al powder composite films can be a solution.
- The flexible characteristics of embedded inductors composed of Fe-Si-Al powder composite films are presented in this paper along with the experimental results of flexible-boarded low power DC-DC boost converter using this inductor.
- As an application, a thin and flexible DC-DC Boost Converter (2 W/5 V/400 mA) is designed, in which the flexible inductor is embedded.
- The experimental results on the flexible characteristics of the fabricated inductors are discussed.

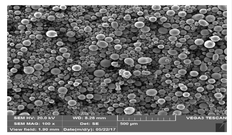
Flexible Fe-Si-Al powder composite film inductor

Magnetic powder composite films

- Magnetic powder composite films are typical soft passive components.
- The eddy current loss can be reduced.
- Magnetic powder composite films can maintain the inductance at high currents.
- A composition of 85% Fe-9% Si-6% Al alloy was utilized for the magnetic powder composite films In this paper.

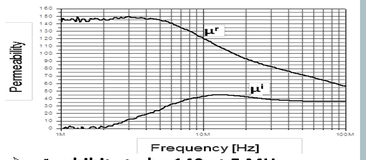
Fabrication

- The mean diameter of the particles is approximately 0.1 mm and the thickness, approximately 0.0015 mm.
- The composite films are fabricated by the coma blade coating method.
- The completed composite films have a thicknesses of 0.05mm and density of 3.25g/cc.



SEM image of the composite films

Permeability

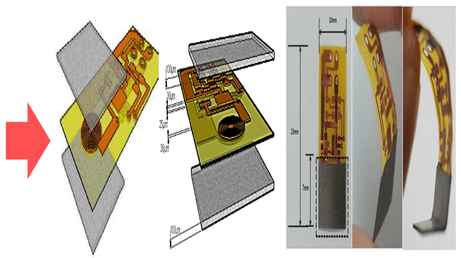


- μ^r exhibits to be 140 at 5 MHz.
- μ^i exhibits low values up to 3 MHz.

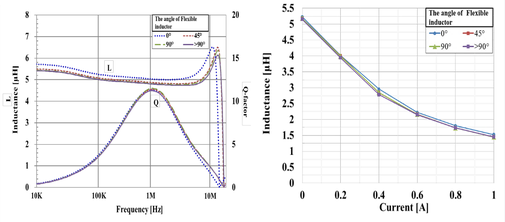
Flexible Fe-Si-Al powder composite film inductor and DC-DC Boost Converter

Dimensions of the copper coils and board

Parameters	Values	Units
Thickness	0.28	mm
height	0.07	mm
Gap for each trace	0.1	mm
Number of turns	18	-
Inductor thickness	0.3	mm
Board thickness	0.16	mm

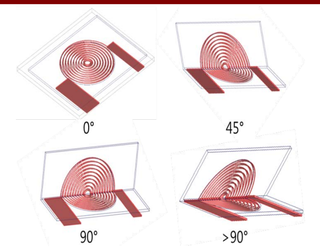


Schematic view and Photograph of A low power Dc-Dc Boost Converter with a proposed embedded flexible inductor

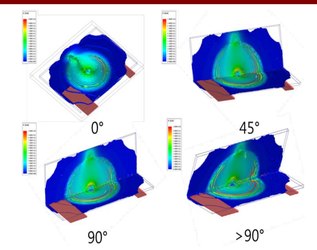


- Initial inductance and Maximum Q-factor is 5μH, 12.5
- The saturation Value and DC resistance is 450mA, 0.72Ω
- When the flexible inductor is folded (to 0°, 45°, 90°, and >90°), the initial inductance, Q-factor, and the saturation characteristics are almost similar.

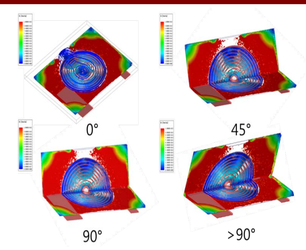
The result of maxwell 3D simulation



Simulation model of the flexible inductor



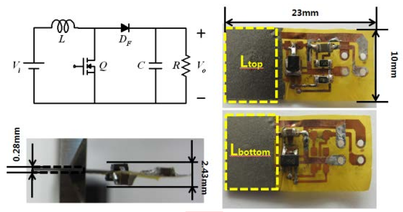
H-field Simulation model of the flexible inductor



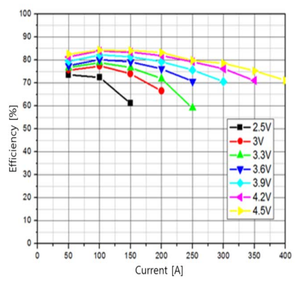
B-field Simulation model of the flexible inductor

- The characteristics of the inductor were simulated using the Maxwell 3D tool
- The magnetic flux distribution(H-field) is found to be almost constant, regardless of the folding angle.
- The magnetic intensity distributions(B-field) are also found to be almost similar, regardless of the folding angle.
- All the simulated inductances are approximately 5 μH and the resistances are approximately 0.77 Ω.

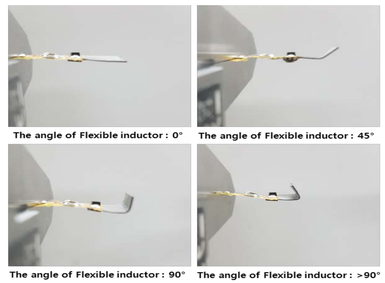
Converter Prototype and The result of experiment



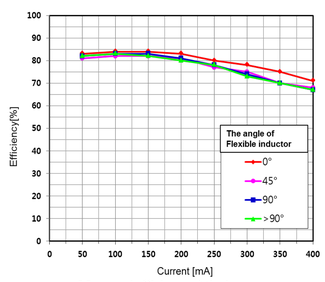
Parameters	Values	Units
Input voltage	2.5~4.5	V
Output voltage	5	V
Output Current	400	mA
Switching frequency	1.2	MHz
Maximum Output power	2	W



Measured efficiency of the DC-DC Converter



Photograph of the DC-DC Converter in Which the inductor is folded.



Measured efficiency of the low power DC-DC Converter belong to flexible inductor

- The maximum efficiency of the Fabricated flexible DC-DC Boost Converter is 84% at a 100mA load current.
- Folding the fabricated flexible inductor, the efficiency of the DC-DC Boost converter was tested on the same output specification (5 V/400 mA); Comparing the measured efficiencies by folding the fabricated flexible inductor, it can be confirmed that they are almost similar.

Conclusion

- the fabrication of an embedded flexible inductor using Fe-Si-Al metal alloy powder films and its application in a flexible DC-DC Boost converter circuit board is described.
- The fabricated inductor exhibited advantageous characteristics like thinness, flexibility, and high permeability.
- To verify the electrical characteristics of the fabricated inductor, simulation was carried using Maxwell 3D tool and measurements were carried out by folding the fabricated flexible inductor (to 0°, 45°, 90°, and above 90°).
- The measurement results were in agreement with the simulation results.
- The fabricated inductor was applied to a DC-DC Boost.
- the fabricated DC-DC Boost converter recorded a maximum efficiency of 84% for a 100mA load current and 0°of flexible inductor angle.
- The flexibility of the flexible inductor was verified by folding it; it was established that the flexible inductor performed its role suitably in the low power DC-DC converter.

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