K6-21

Electromagnetic Induction Type MEMS Air Turbine Generator With Single-Phase Multilayer Ceramic Magnetic Circuit

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Abstract: This paper provides an electromagnetic induction type MEMS air turbine generator with a single-phase multilayer ceramic magnetic circuit. A multilayer ceramic technology for the magnetic circuit and a micro electro mechanical systems (MEMS) technology for the air turbine parts were used in the developed generator. The multilayer magnetic circuit shows a low internal resistance because it can form a helical coil structure and used a magnetic material. The magnetic material was low temperature sintering nickel cupper zinc ferrite with the permeability of 900. The generator was combined of the air turbine and the magnetic circuit. The internal resistance was 1.05Ω and output power was 1.74μVA at 30,000 rpm

1. Introduction

Miniaturization of the energy sources has been strongly demanded accompanied with the miniaturization of portable equipments. MEMS generators have been studied in order to respond to this request extensively all over the world [1]. Conventionally, the electrostatic type generator that is usually used an electret has been researched. This generator have problems that show a high output impedance and small output current due to the saturation of charge. On the other hand, an electromagnetic induction type MEMS generator has been studied because this type shows a large output current. Magnetic circuit formed a spiral coil structure is usually used because the MEMS generator composed with planer structure [2]. However, the spiral coil has some problems as the high internal resistance. It is possible to reduce the divergence of the magnetic flux by introducing the magnetic material in the core of the coil.

Therefore, we developed an electromagnetic induction type power generator that combines MEMS air turbine and multilayer ceramic magnetic circuit. The developed circuit is possible to form a helical coil that is integrated with magnetic material by using a multilayer ceramic technology. Also, the developed multilayer circuit is used a magnetic material to catch divergence magnetic flux. Therefore, the downsizing of the coil is possible. As a result, the length of the conductor is shortened and a low internal resistance in obtained. In this paper, the two type magnetic circuit structures are fabricated. In addition, we report the generation experiment with a generator that combined of the MEMS air turbine and the multilayer ceramic magnetic circuit. Generators were compared power generation from the comparison of the structure of magnetic circuits.

2. Structure and Fabrication Process

The electromagnetic induction revolving-field type is used for the power generation method. Figure 1 shows a schematic illustration of MEMS air turbine and a multilayer ceramic magnetic circuit. In the generator, at the bottom of the silicon air turbine, the magnetic circuit is combined.

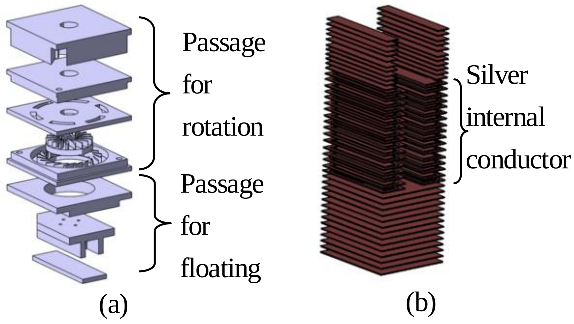

Figure 1. Schematic illustration of a MEMS air turbine and multilayer ceramic magnetic circuit.
(a) MEMS air turbine (b) Magnetic circuit

The MEMS air turbine is fabricated by a photolithography process. The air turbine part is made of 7 silicon layers. The upper layer is assigned for the air passage to the stator. The lower layer is formed for the passage to the fluid dynamic bearing system. The rotor is placed in the center of the MEMS air turbine. The samarium cobalt magnet that is magnetized to a semicircular is attached to the rotor. The magnetic circuit is constructed by the ceramic green sheet process. The magnetic material is low temperature sintering nickel cupper zinc ferrite with the permeability of 900. Silver internal conductor is patterned inside the ferrite body. Figure 2 shows a conceptual diagram of magnetic circuit. The horseshoe shape magnetic circuit is made of 30 layers. The stepwise shape magnetic circuit is made of 40 layers. In addition, the upper 14 layers and the lower 10 layers are the ferrite without the conductor. A couple of the 12 turn coil is

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placed in two portions, and the number of the total turns is 24. Stepwise shape was put on a magnetic material to catch for the magnetic flux. Two type magnetic circuits were compared in power generation experiment by using faburication air turbine.

(a) (b)

Figure2. Conceptual diagram of magnetic circuit. (a) Horseshoe shape (b) Stepwise shape

3. Result and Discuss

Two type of magnetic circuits were fabricated samples. Internal resistance of the fabricated multilayer ceramic magnetic circuit was 1Ω. The power generation was conducted experiments using a generator that combines a magnetic circuit and MEMS air turbine. Generator with horseshoe shape was maximum rotational speed of the rotor was 58,000rpm on the condition of the injected pressure of 0.28MPa, and the output power was 1.92μVA. Also, magnetic circuit using a stepwise shape. Figure 3 shows the generator combined of the MEMS air turbine and the magnetic circuit. The obtained size of the MEMS air turbine generator was 3.47 × 3.50 × 3.86mm. Figure 4 shows the output voltage. Compressed nitrogen gas was injected to the inlet of the generator through a needle of 0.6mm diameter. A load resistance of 1Ω was connected to the output of the magnetic circuit. The output waveform was measured by an oscilloscope. The maximum rotational speed of the rotor was 30,000rpm on the condition of the injected pressure of 0.28MPa, and the output power was 1.74μVA. The stepwise shape shows a large power generation than the horseshoe shape circuit. Figure 5 shows the magnetic circuit of magnetic field analysis. Stepwise shape is caught the magnetic flux in the magnetic circuit than horseshoe shape.

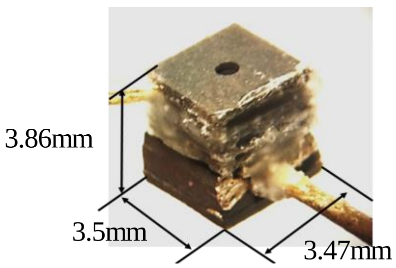


Figure 3. Generator combined with the MEMS micro air turbine and the magnetic circuit.

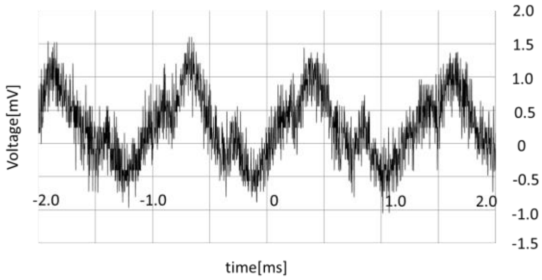
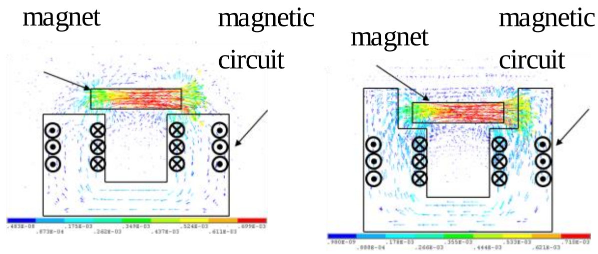


Figure 4. Waveform of the output voltage at load resistance of 1 Ω.



(a) (b)

Figure5. Magnetic field analysis of magnetic circuit. (a) Horseshoe shape (b) Stepwise shape

4. Conclusion

The electromagnetic induction type MEMS air turbine generator was fabricated by MEMS technology and multilayer ceramic technology. The maximum rotational speed of the rotor was 30,000rpm on the condition of the injected pressure of 0.28MPa, and the output power was 1.74μVA at load resistance of 1 Ω. Stepwise shape is caught the magnetic flux in the magnetic circuit than horseshoe shape.

5. Acknowledgments

The fabrication of the micro air turbine was supported by Research Center for Micro Devices, Nihon University.

6. References

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