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Fabrication of the Electromagnetic Induction Type Micro Generator by MEMS Air Turbine and Magnetic Ceramic Material.

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Abstract: We present the electromagnetic induction type ultra micro air turbine generator. The micro air turbine consisted of an air turbine and a coil part. The micro air turbine part that consisted of silicon layers was fabricated by the MEMS technology. The magnetic circuit was constructed by the multilayer ceramic technology based on the green sheet process. The magnetic material used in the circuit was low temperature co-fireble ferrite, and the internal conductor was silver. The total dimensions of air turbine generator were 3.6×3.4×3.5mm. The output power of our constructed micro air turbine generator was 1.92μW in the condition of the injected air pressure 0.28MPa, the rotational speed of the rotor was about 58,000rpm

1. Introduction

Secondary Batteries have confronted a theoretical limit in energy density. UMGT (Ultra Micro Gas Turbine) was proposed by Epstein as a new small energy source to replace batteries [1]. The UMGT was fabricated by MEMS (Micro Electro Mechanical Systems) technology. However, miniaturization of the MEMS gas turbine has some difficulty. Silicon of the main material used in MEMS technology, but it cannot withstand operational temperature of a gas turbine, which exceed 1000 °C. The micro gas turbine has an additional problem. There is a loss of heat efficiency due to insufficient heat insulating properties the accompanied with the miniaturization. Instead of the gas turbine, air turbines operate using compressed air at room temperature. The air turbine that was the focus of our research is easier to miniaturize using MEMS technology than the gas turbine. Usually, the electromagnetic induction type dynamo is utilized in infrastructures. The high μ material such as the silicon steel sheet is used in a large-scale dynamo. However, the microfabrication of the magnetic metal and the achievement of a lot of winding structures are difficult in the MEMS technology. No winding inductors can be made by using make using multilayer ceramic technology. In this study, we fabricated the electromagnetic induction type micro air turbine generator using MEMS and multilayer ceramic technology. The design, fabrication, evaluation, and output are explained below.

2. Design of Micro Air Turbine

Fig.1 shows the schematic illustration of the air turbine. The total dimensions of air turbine were 3×3×3mm. The air turbine part was made of 7 silicon layers. The upper three layers were for the air passage. The center two layers were the stator, and the lower two layers formed the fluid dynamic bearing. The disk magnet was placed inside the stator. The shape of the rotor blades were fabricated referring to quasi-ultrasonic wings.

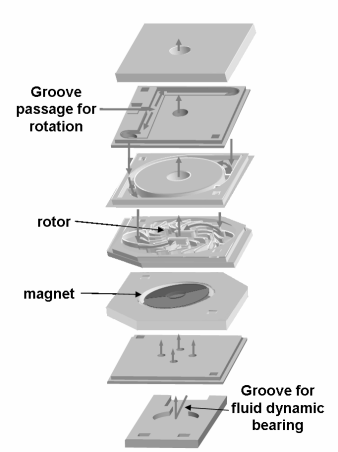

Fig.1 Schematic illustration of the air turbine.

3. Design of Magnetic Circuit

Fig.2 shows the schematic illustration of the magnetic circuit design. The magnetic circuit was composed of low temperature co-fireble ferrite, and the silicon internal conductor was silver. The shape of the multi layer magnetic circuit was concave. A pair of internal coils was placed inside the two square poles. These two coils were connected in the bottom ferrite layer.

Fig.2 Schematic illustration of the magnetic circuit by ceramic and printed pattern.

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4. Fabrication Method of Air Turbine

The rotor and each layers were fabricated by a photolithography process. After cleaning and drying the silicon chip, Al was deposited on the silicon chip by vacuum deposition. Rohm and Hass S1830 photoresist was coated on the chip with a spin coater, and it was pre-baked at 90 °C for 20 minutes. The mask pattern was transferred to the resist film by a contact aligner. Using Rohm and Hass MF-319 developer, the resist film was developed and then post-baked at 120 °C for 30 minutes. Al was etched by a wet etching using aluminum etchant, and then silicon was etched by ICP dry etching [2]. The micro air turbine was assembled by bonding each part. Each silicon piece was bonded by adhesive agent.

5. Fabrication of Magnetic Circuit

The magnetic circuit was constructed by the multilayer ceramic technology based on the green sheet process. The ferrite slurry of the magnetic material made the green sheet using the doctor blade. Then, the specimens were dried. The through-holes were made by the hole-forming using the punching machine. The circuit pattern formation of the green sheet was by the screen printing.

6. Expre Results and Discussion

Fig.3 shows the fabricated turbine. The parts were measured by a confocal microscope. Fig.4 shows the fabricated inductor. Fig.5 shows the assembled micro generator. The total dimensions of micro generator were 3.6×3.4×3.5mm.

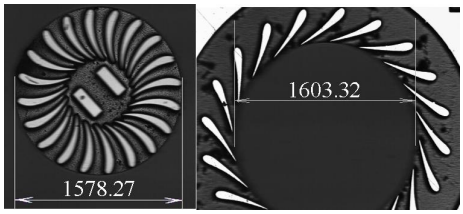

Fig.3 Fabricated turbine parts.

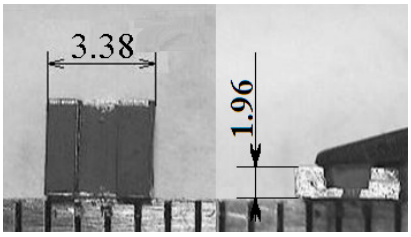

Fig.4 Fabricated inductor.

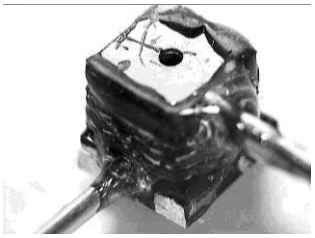

Fig.5 Micro Generator.

Compressed air was injected into the assembled micro air turbine. When the compressed air was 0.28MPa, the maximum rotational speed became 58,000rpm. In this case, output power of generator was 1.92μW. Fig6 shows the time dependence of the output voltage. As the rotating velocities rise, the amplitude of the output voltage increased. This result follows Faraday's Law.

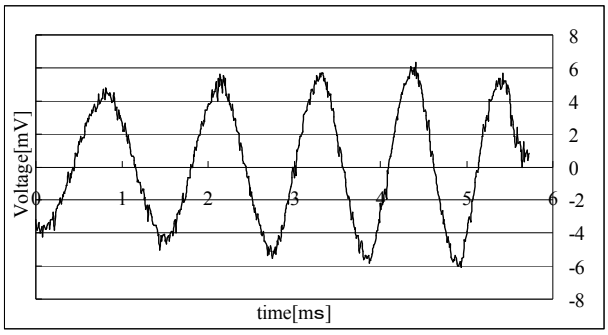

Fig.6 Time dependence of the output voltage.

The motion of the rotor was observed by a high-speed camera (Phantom, Vision Research). Fig7 shows an image taken by the high-speed camera. The shaky motion was observed and the rotor impacted the stator wall. The reason for this impact is thought to be that the pressure in the area around the rotor was insufficient. It is therefore necessary to design an appropriate clearance between the rotor and the stator in order to achieve higher rotational speeds.

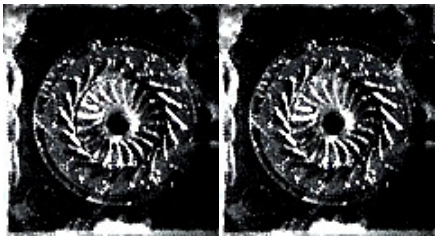

Fig.7 Image taken by high-speed camera.

7. Conclusion

The electromagnetic induction type micro generator was fabricated by MEMS and magnetic ceramic material. The size of the turbine was 3.6 × 3.4 × 3.5mm, and the rotor diameter was 1.6mm. The rotor of the turbine started to rotate when compressed air was injected. When the compressed air was 0.28MPa, the maximum rotational speed of the rotor was 58,00rpm. And then the output power was 1.92μW.

Acknowledgments

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Reference

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[2] Bhardwaj J. K., et al, “Advanced Silicon Etching Using High Density Plasmas”, Proceedings of SPIE 2639, p.224, 1995