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Development of MEMS Generator with 3D Shape Multilayer Ceramic Circuit

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Abstract: We propose a new system and concept concerning to MEMS power generator. MEMS generators were reported to achieve a high power in small volume. However, these generators were usually electrostatic type generators that used electrets. One reason for avoiding the magnetic induction type is the fabrication difficulty of the magnetic materials and the winding structures. We fabricated the small magnetic circuit by the co-firing technology of magnetic ferrite material and silver conductor for the purpose of applying to MEMS micro generator. The dimensions of the generator were 3.6, 3.4, 3.5mm, length, width, height respectively. The output power was 1.92μVA. In addition, compared with winding wire generator system, our proposed MEMS generator was smaller size in the case of same energy density.

1. Introduction

Power MEMS (Micro Electro Mechanical Systems) has been paid attention as a new small power sources. For example, MEMS turbine type generators were reported to achieve a high power in small volume [1-2]. These generators were usually electrostatic type that used electrets. On the other hand, in a large scale electricity generator, high μ material such as the silicon steel and winding wire are used for a large-scale magnetic induction type dynamo, because the magnetic induction type shows high current property. However, the micro fabrication of the magnetic materials and the winding structures are difficult in the MEMS technology. The magnetic circuit composed of planer structure can be implemented using multilayer ceramic technology. For example, small inductor devices composed of ferrite magnetic material and printed silver conductor was developed [3]. Previously, we proposed the generator combined of MEMS and multilayer magnetic ceramic parts.

In this paper, we developed the MEMS generator with 3D shape multilayer ceramic circuit. And the design concept, the structure, and the fabrication process are described. Also, the flow rate, the rotational speed, the output power were measured. Particularly, the effectiveness of the combined generator is discussed comparing the winding wire type generator.

2. Design and Fabrication Process of the generator

The schematic illustration of the air turbine generator is shown in Figure 1 Power generation method was the electromagnetic induction revolving-field type generator. The air turbine rotated the magnets by injecting compressed gas. The components were fabricated by MEMS technology. At the bottom of the air turbine, the magnetic circuit of electricity generation was fabricated by the multilayer ceramic technology.

The schematic illustration of the air turbine part is shown in Figure 2 (a). The air turbine part was made of 7 silicon layers. The upper 4 layers were assigned for the air passage to the stator. The lower 3 layers were formed for the passage to the fluid dynamic bearing system. The disk shape magnet was attached to the rotor and placed inside the slot of the stator. The shape of the rotor blade was referred to quasi-ultrasonic wings. The rotor and each layer were fabricated by a photolithography process. Each part was assembled by making use of the aliment pin and holes, which reduced the dimensional error.

The schematic illustration of the magnetic circuit is shown in Figure 2 (b). The magnetic circuit was fabricated by the green sheet process. The magnetic material was low temperature sintering nickel cupper zinc ferrite with the permeability of 900. Silver internal conductor was patterned inside the ferrite body. The average particle diameter of silver paste was 1μm. The magnetic circuit was made of 24 layers. The wiring conductor pattern was formed around the outer periphery on the 10 ferrite layers. In addition, the upper 10 layers and the lower 4 layers were the ferrite without the conductor.

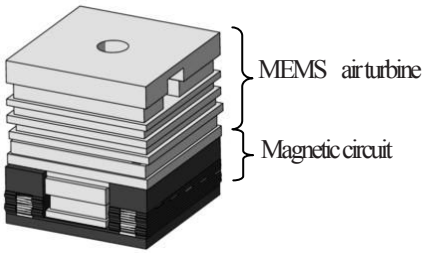

Figure 1. Schematic illustration of the generator.

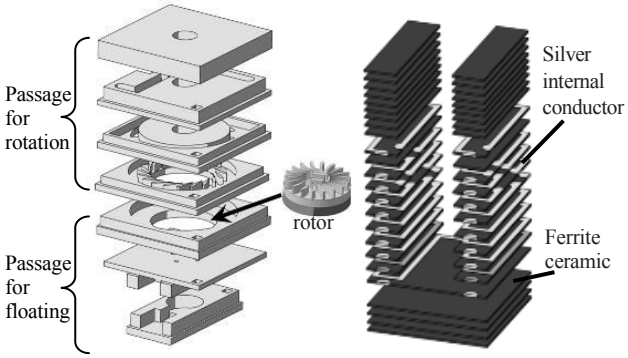

Figure 2. Schematic illustration of the air turbine and the magnetic circuit by ceramic and printed pattern.

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3. Measurement of fabricated generator

Figure 3 shows components fabricated by MEMS process. Also, Figure 4 (a) shows the etched rotor observed by scanning electron microscope. It is observed that the walls of the blade were formed perpendicular to the substrate. Figure 4 (b) shows fabricated inductor. Also, Figure 5 shows the generator combined of the micro air turbine and the magnetic circuit. The dimensions of the generator were 3.6, 3.5, 3.4 mm, length, width, height respectively.

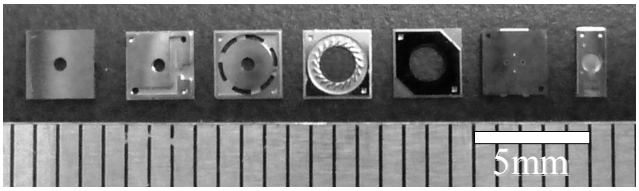

Figure 3. Fabricated turbine parts.

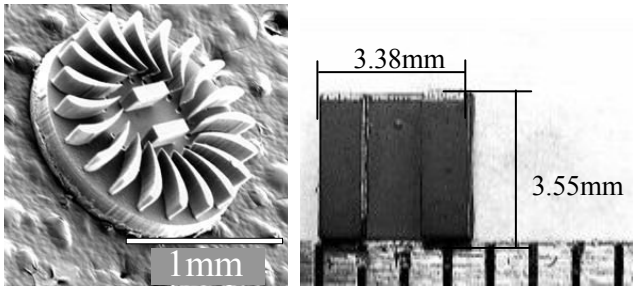

Figure 4. (a) The etched rotor observed by scanning electron microscope (b) Fabricated inductor.

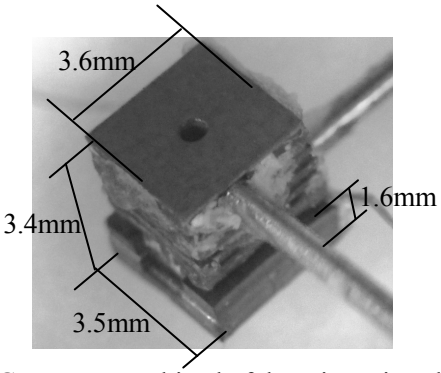

Figure 5. Generator combined of the micro air turbine and the magnetic circuit.

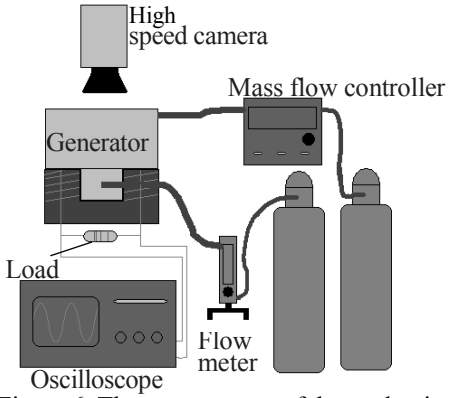

Figure 6. The arrangement of the evaluation.

Figure 6 shows the arrangement of the evaluation. Compressed gas was injected into the assembled micro air turbine. When the pressure was 0.28MPa, the maximum rotational speed achieved 58,000rpm. In this case, output power of generator was 1.92μW. Figure 7 shows wave form of the output voltage. As the rotating velocity rose, the amplitude of the output voltage increased. This result follows Faraday's Law.

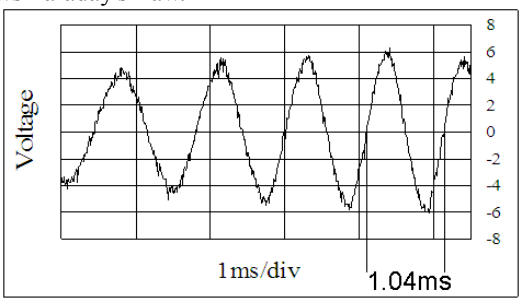

Figure 7. Wave form of the output voltage.

Figure 8 shows the winding wire type generator. 50 turns of winding wire were required to achieve same energy density as that of ceramic magnetic circuit, and the appearance size expanded to 4.4, 4.4, 4.1 mm, length, width, height respectively. Compared with winding wire generator system, our proposed multilayer magnetic circuit achieved same level energy density with smaller size and less turn number of the coil. The obtained structure was simple monolithic.

Figure 8. Winding wire type generator.

4. Conclusion

MEMS generator with 3D shape multilayer ceramic circuit was developed. The size of the generator was 3.6, 3.5, 3.4 mm. The maximum rotational speed of the rotor was 58,00rpm. And then the output power was 1.92μVA. Compared with winding wire generator system, our proposed multilayer magnetic circuit achieved same level energy density with smaller size and less turn number of the coil. The obtained structure was simple monolithic.

Acknowledgments

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