A SIMPLE MICRO ELECTRET POWER GENERATOR

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Abstract **– We developed a novel, yet simple, micro electret power generator prototype for low-frequency energy harvesting applications. In this prototype, two electrodes of the power generator are placed on the stator. The rotor is only a plate with metal strips of half of the spatial frequency of the stator plate. The packaging is to simply fix the stator to a container and put the rotor directly on top of the stator. CYTOP, a MEMS-compatible perfluoropolymer, served as the electret material and charged with corona charging. The power output was 2.267 μ W at 60Hz.**

I. INTRODUCTION

During last decade, much attention has been drawn towards devices that can harvest vibration energy from the environment and have the potential to replace batteries in handheld devices or wireless sensors. Most of the published works were focused on only two approaches: the electromagnetic paradigm [1-3], and the piezoelectric paradigm [4-6]. However, these approaches all have to count on the spring-proof-mass design so their performance is always limited to certain narrow bandwidth around the mechanical resonant frequency, while natural harvestable vibration power spectrum usually spans from low to ~100 Hz with higher energy in the low frequency end. To overcome these fundamental problems, the third approach of electret power generators without springs (hence no resonant frequency) emerged to have a major advantage of broadband operation. For examples, Boland et al demonstrated the first liquid-rotor Teflon AF electret power generator of 0.43 μ W production with a 28Hz shaker [7]. Tsutsumino et al showed a linear solid-rotor power generator of 37.7 μ W production with a 20Hz shaker [8].

As for the electret material, different materials have been examined as electrets [9]. Teflon AF charged with a back-lighted thyratron was used in Boland et al's work. Tsutsumino et al discovered that CYTOP, an amorphous perfluoropolymer from Asahi Glass Co., Ltd. can also work as an electret material [8]. CYTOP has also been demonstrated to be a better electret material than Teflon AF with higher charge density [8]. Taking this into consideration, we chose CYTOP as the electret material for our device.

II. DEVICE DESIGN

For electret power generators, the biggest issue is that they do require careful gap control between the rotor and stator; otherwise, these devices lose performance greatly [7] [8]. This stems from the fact that the two electrodes of the power generator are placed in such a way that one is on the rotor and the other is on the stator, as shown in Fig. 1, and the fact that power output depends on the capacitance between these two electrodes.

To overcome this issue, we developed a new electret generator design that requires no precise separation gap control and hence greatly simplify the packaging requirement. The schematic of this design is shown in Fig. 2. The device is made of two parts, the rotor and the stator. Both the two electrodes of the power generator are placed on the stator. The rotor has simply floating metal strips with ½ of the spatial frequency of the electrodes on the stator. The packaging is to simply fix the stator to a container and put the rotor directly on top of the stator. The rotor and the stator are in mechanical contact, where the electret material, CYTOP for our devices, serves as the low-friction bearing.

III. DEVICE FABRICATION

The device consists of two parts, the rotor and the stator. Fabrication of the rotor and the stator started with a soda lime wafer. 1500-Angstron gold along with 200-Angstron chromium was thermally evaporated onto the soda lime wafer and patterned by photolithography and wet etching according to the design.

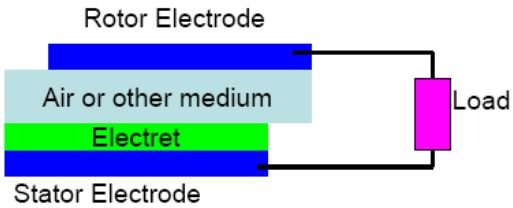

Figure 1. General design of an electret power generator

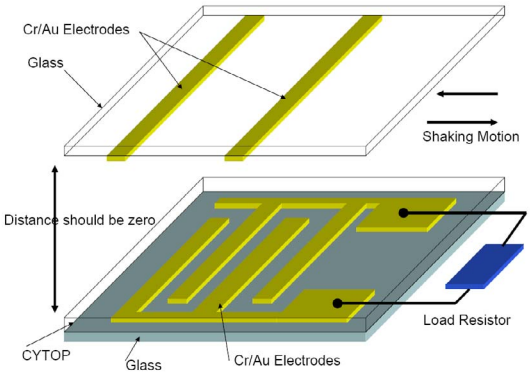

Figure 2. Schematics of the new electret power generator

The electrodes on the stator were 18mm long and 1mm wide with 50 μ m separation, and they are connected alternately.

The electrodes on the rotor were floating metal strips with 1/2 of the spatial frequency of the electrodes on the stator. CYTOP (CTL-809M), as purchased from Asahi Glass Co., Ltd., was spin-coated on the stator at a speed of 1000 rpm for 20 seconds and soft-baked at 100℃ for 30 minutes. This spin-coating process was repeated 7 times to obtain 20-μ m thick CYTOP film. Finally the CYTOP film was fully cured at 185℃ for 90 minutes. Fig. 3 shows the fabricated stator and rotor.

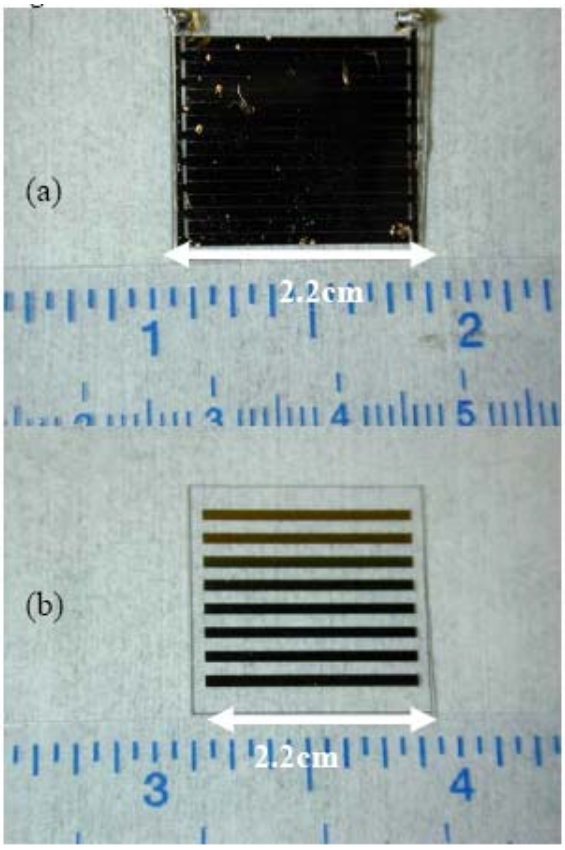

Figure 3. Fabricated devices: (a) the stator and (b) the rotor.

TABLE I. CONDITIONS OF CORONA CHARGING

Needle Voltage	-6kV
Grid Voltage	-600V
Temperature	100℃
Charging time	10 minutes

After fabrication, the CYTOP electret was charged by corona charging. The condition of the corona-charging is listed in Table 1. The surface potential distribution after charging is shown in Fig 4. The average surface potential is around -300V and the average charge density is 0.5578mC/m^2.

IV. EXPERIMENTAL DETAILS

The stator was glued onto a CNC-machined acrylic container. All necessary wires were soldered and the rotor was directly placed on top of the stator, as shown in Fig. 5. Power generation experiments were performed using a shielded box mounted to Labworks Inc. ET-132-2 electrodynamic shaker, which was driven sinusoidally by a HP33120A function generator through a power amplifier. The acceleration of the power generator was measured using an Endevco256HX-10 accelerometer. The shaking frequency was varied from 10Hz to 100Hz. The micro electret power generator was connected to a resistive load and the voltage across the load was measured from a National Semiconductor LF356N op-amp used as a 10^{12}Ohm input impedance voltage buffer.

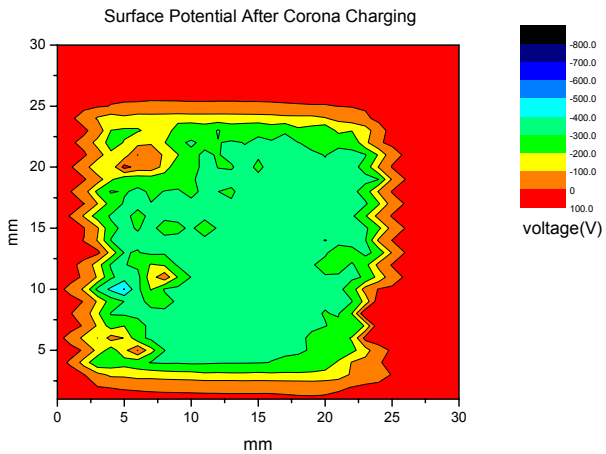

Figure 4. Distribution of surface potential after charging. (The red part is the area outside the device)

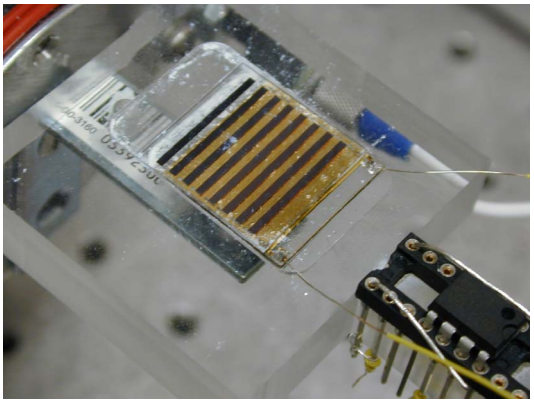

Figure 5. Testing setup

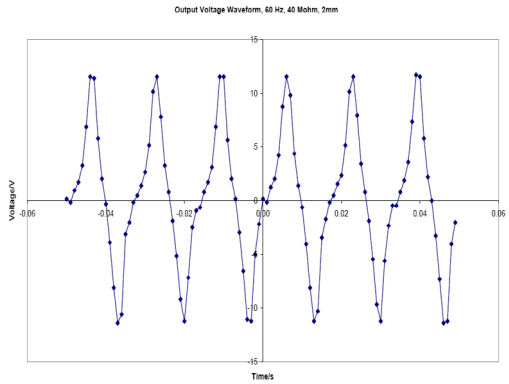

Figure 7. Time trace of power output at 60Hz with load resistance of 40M Ω .

V. RESULTS AND DISCUSSION

As expected, the power generated depends on the load resistance and the driving frequency. Due to the capacitive nature of this device, there is an optimal load for the optimal power generation. Fig. 6 shows the power output versus load resistance at different driving frequencies. From the graph, it follows that the optimal load resistance is 40-50M Ω . Using this optimal 40M Ω load resistance, the maximum power generated was 2.267 μ W at 60 Hz. The time trace is shown in Fig. 7.

The relative low power output, compared to that of Ref. [8], can be attributed to the relatively low efficiency of corona charging. Under the same condition, the surface potential after charging was merely around -300V, while that of Ref [8] was around -1000V. Another possible cause would be that the rotor and stator plates are not perfectly flat and contact each other perfectly, leaving some air gaps in certain area. Further work is underway to boost the power output.

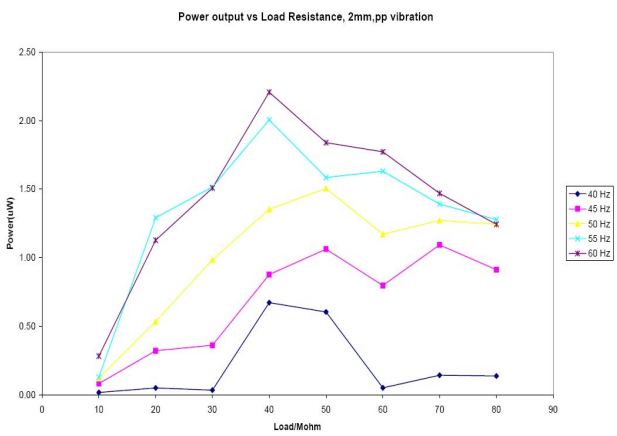

Figure 6. Power output versus load resistance at different frequencies

VI. CONCLUSIONS

We have developed a simple micro electret power generator using CYTOP as the electret material. The micro power generator requires neither precise gap control nor complex packaging. The maximum power output obtained is 2.267 μ W at 60 Hz with load resistance of 40M Ω .

Further work is underway to boost power output as well as to integrate the device into other portable systems.

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