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Selective Electret Charging Method for Energy Harvesters Using Biased Electrode

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Abstract

A lot of energy harvesting devices using electret material has been developed. Since the power from the electret energy harvester is proportional to the surface charge concentration, i.e. charged voltage on the electret, frequency and dynamic range of the capacitance change. To fabricate the electret, the corona discharge is a very popular charging method that consists of a high voltage needle for corona ions generation, and a grid electrode applying a bias voltage that implants the electrons from corona ions to the electret material. In this study, we introduce a novel charging method with fine patterns using the buried grid-electrodes applied with a bias voltage. We also describe FEM analysis and experimental results.

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Keywords: Energy harvester; Electret; Corona discharging; CYTOP

1. Introduction

The energy harvesting devices draw a lot of attention as next generation power sources [1]. The electret based energy harvesters need fine patterned and high-voltage charged electret materials in order to achieve a lot of harvesting power. Nowadays, the corona discharging is a very popular charging method, which consists of a high-voltage needle electrode for corona ions generation and a grid electrode applying a bias voltage that implants corona ions to the electret material. Typically, the electret material for the energy harvester has employed some insulators such as polymer CYTOP (CTL-809M; Asahi glass Co., Ltd. Japan) [2]. The CYTOP shows good insulation and is easy to use in a MEMS processing so that it is very popular material for the electret energy harvesters.

We introduced a novel charging method to obtain a charged electret, made of the CYTOP, with fine patterns using the buried grid-electrodes with a bias voltage [3]. It has a very simple process that does not require the

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complicate patterning and etching processes to the electret material. In this study, a mechanism, an FEM analysis and some experimental results for the novel electret charging method are described.

2. Electret charging methods with corona discharging

Figure 1 shows a simplified schematic diagram of electret harvester [4]. It consists of two elements, one is moving plate with counter electrodes (CE), and the other is a static plate with charged electret on the base electrodes (BEs). The BE underlying the electret film are set to the reference potential of the ground (0 V). The movement of the counter electrodes causes a charge transfer by the electrostatic induction between the BE (connected to the ground) and the CE through the load resistance. Then, the charge transfer as an AC current derived the harvested energy. In the fixed displacement condition, the power of the energy harvesting depends on the moving frequency, capacitance change ratio between the BE and the CE, and charged potential of the electret. Thus, the electret should be charged with fine pattern area.

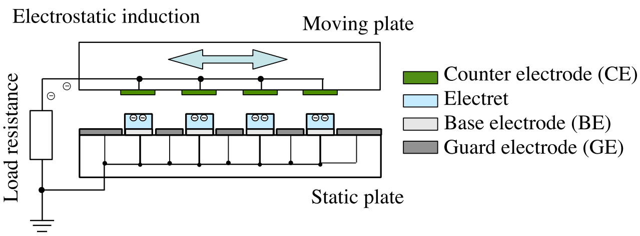


Fig. 1. Schematic structure of an electret energy harvester.

Figure 2(a) shows a typical electret charging setup by the corona discharging [5]. The electrodes on the substrate are used for the BE and guard electrode (GE) that connected to the ground. The CYTOP film was spin coated, finely patterned and etched out except on the BE. Finally, the electron emitted from the needle is implanted into the CYTOP film on the BE, which is caused by the electric field between the grid and the BE. The CYTOP etching requires a metal mask that makes the process slightly complicate.

In order to improve the feasibility of the process for obtaining the fine patterned electret, we use the GE as buried grid electrodes (BGEs) in Fig. 2(b). The BGE and the grid electrode have same potential so that the electric field between the grid and the BGE becomes negligible. Thus it is expected that the CYTOP film on the BGE do not be charged during a charging process.

3. Electrostatic simulation

Using an FEM analysis (ANSYS® /University intermediate, Ver. 12), the charging mechanism of novel method was evaluated. Figure 3(a) illustrates the top view of the contour map for the electrostatic potential distribution. The

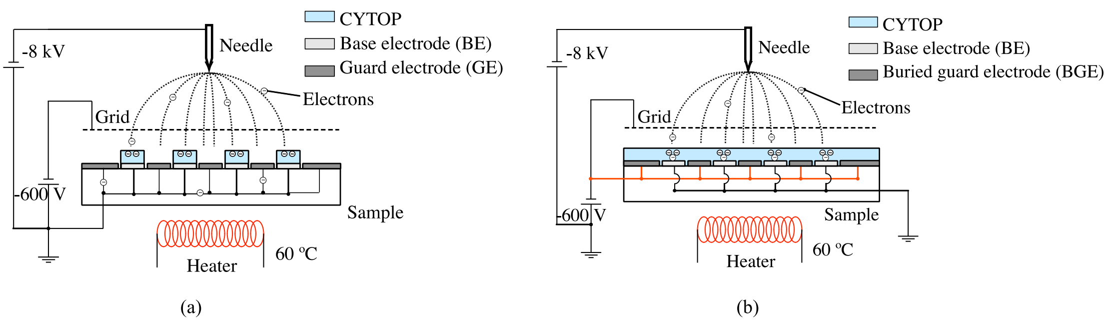
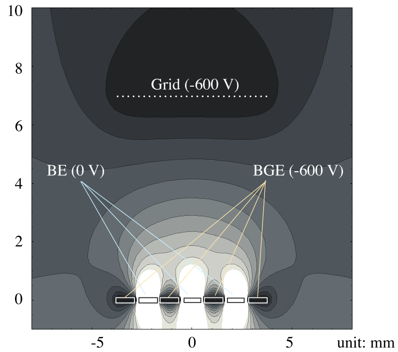
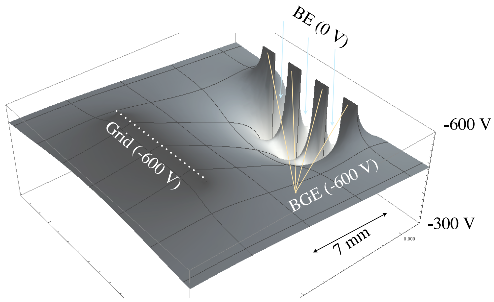


Fig. 2. (a) Typical electret charging apparatus by using corona discharging; (b) novel electret charging apparatus with BGE.

simulation performed with the -600 V for the grid electrode and the BGE, and 0 V for the BE. The distances from the grid electrode to the BE and the BGE are 7 mm, respectively. The BE and BGE aligned in 1 mm line and 100 µm space. The map shows that the electric potential is drastically changed near the BGE; there may be strong electric field. As is evident in the 3D plot of Fig. 3(b), it is projected that almost all electrons will be implanted to CYTOP on the BE not the BGE.



(a)



(b)

Fig. 3. (a) The top view of the contour map of the electrostatic potential; (b) the 3D oblique view of the electrostatic potential.

4. Electret charging experiment

The test sample for the corona charging is shown in Fig. 4. The BE and the BGE (the GE for the conventional method), they are made of 500 nm thickness aluminum, were deposited on the glass substrate of 30×30×0.5 mm^3 with 1 mm line and 100 µm space. The CYTOP with thickness of 3 µm was coated on the both BE and BGE for novel method, just on the BE for the conventional method. The voltages of the needle, the grid electrode and the BGE are -8 kV, -600 V and -600 V, respectively. They are completely same dimension as the FEM analysis one. The corona discharge was performed for both conventional and the novel BGE methods. The conventional method has not the CYTOP film on the GE, and novel method has CYTOP on the BGE. Finally, the corona discharging was performed within 3 minutes at the stage temperature of 60 deg. C.

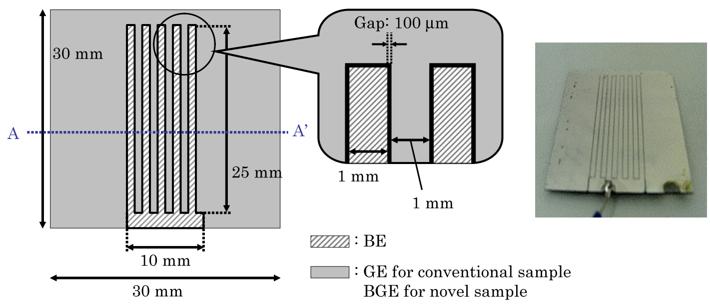


Fig. 4. The schematic structure of the charging test sample and the fabricated sample photo.

5. Results and discussions

Figure 5 shows profiles of the surface potential on the A-A' line in the Fig. 4 for the both conventional and novel charging methods, which were measured by the contactless surface-electrostatic voltmeter (Model 279; Monroe

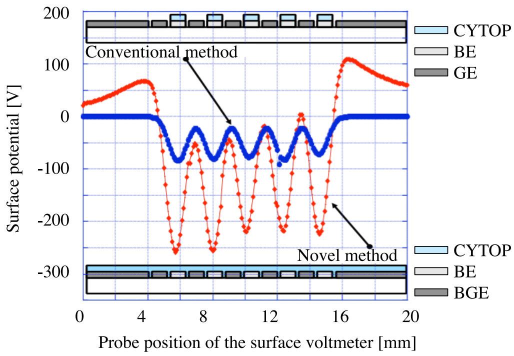


Fig. 5. Surface potential profile of the conventional charging method (blue dot) and the novel method (red dot).

Electronics Inc. USA). The potential profile should be looked rectangular shape, but it looks sinusoidal curve because of a lack of spatial resolution of the electrostatic surface voltmeter (2.5 mm at the 500 µm probe separation). The both methods have similar profiles instead of two things, the amplitude and the polarity. First, the novel method shows higher peak-to-peak surface potential (about 200 $V_{p\text{-}p}$) than the conventional method's one (about 60 $V_{p\text{-}p}$), which will be expected the improvement of the harvesting energy. This high potential may be obtained from that the electron have been implanted by the electric field between not only the grid and the BE but also the BGE and the BE. It is possible as shown in Fig. 3(b) that the BGE and the BE make significant high electric fields. Second, in the novel charging method, there are some positive potential areas on the BGE. Unlike the conventional method, the novel method has a non-charged CYTOP area that surrounded by the negatively charged CYTOP. As a result, we suppose that the intrinsic CYTOP would be polarized by the electrostatic induction from the negatively charged CYTOP on the BE. This positive potential will be also expected the improvement of the harvesting energy.

6. Conclusions

In summary, the novel patterning method for electret with corona discharging by using biased BGE was presented. The method presented here is very simple, and it showed good characteristics of patterned electret. This method makes the electret energy harvesters to improve the productivity.

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References

[1] Boland J, Chao C.-H, Suzuki Y and Tai Y.-C. Micro Electret Power Generator. *Proc. of the MEMS2003;* 2003, pp. 538–541.
[2] Tsutsumino T, Suzuki Y, Kasagi N and Tsurumi Y. High-Performance Polymer Electret for Micro Seismic Generator. *Proc. of the Power MEMS2005*; 2005, pp. 9–12.
[3] Toyonaga T, Nakade K, Fujita T and Maenaka K. Novel Corona Charging Method For Electret Power-Harvester Using Buried Grid-Electrodes. *Proc. of the APCOT2010*; SSASN5, 2010 (in press).
[4] Tsutsumino T, Suzuki Y, Kasagi N, Kashiwagi K and Morizawa Y. Micro Seismic Electret Generator for Energy Harvesting. *Proc. of the PowerMEMS2006*; 2006, pp.279-282.
[5] Sakane Y, Suzuki Y and Kasagi N. Development of High-performance Perfluorinated Polymer Electret and Its Application to Micro Power Generation. *J. Micromech. Microeng*; 2008, **18**, 10-104011, 6pp.