Self-Rechargeable Electret based on Vibration Energy Harvester

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Abstract. In this paper, we propose a new method to corona charge the electret after device packaging, based on the common electret based electrostatic vibration energy harvester (e-VEH) with the out-of-the-plane gap closing scheme. Combined with a new portable corona charging system, the electret in the device has been charged successfully. Here, new portable corona charging system is designed to be powered by another e-VEH directly. In our demo, one e-VEH powers the portable corona charging system first, and then the system releases the energy to corona charge the electret in the other device through some build-in corona tips. After charging, the electret possesses a uniform surface potential, and the device shows a better power output then before charging. In the future, if the surface potential of the electret decays after the e-VEH has been working for a long time, we can also use this new method to recharge the electret directly.

1. Introduction
In recent years, more and more people pay attention to the field of micro energy harvesting with the development of the low power consumption devices and systems. Because the micro energy harvester will probably be the next generation power supply which can provide a sustainable source to the micro systems, like wireless sensor networks, or other personal health monitoring systems [1]-[4]. The vibration energy harvester (VEH) is one kind of micro energy harvesters, which has attracted much attention from both academia and industry, because all kinds of objects in the environment are vibrating and the VEH can convert the kinetic energy into the electric energy. The VEHs are mostly designed based on a moveable structure that can sense the vibration. And combined with other different energy conversion principles, different kinds of VEHs could be fabricated. At present, there are many studies about VEHs with high power outputs are the triboelectric generator [5], [6], electromagnetic harvester [7], [8], and piezoelectric harvester [9], [10].

In addition, there is another VEH called electret based electrostatic vibration energy harvester (e-VEH) where the main structure is a variable capacitor [11]-[13]. The e-VEHs have some advantages which are the simple MEMS fabrication process and the good compatibility with the IC process. Recently, we have achieved a high output power density in a broad bandwidth [14]. Some other
structures have also been developed to optimize the power density and operating bandwidth of the device, such as the dual resonant structure [15], the perforated electrode [16], and the packaged sandwich structure with dual electret layers [17].

There is another issue of the output stability of the e-VEH. In e-VEH, the surface potential of the electret is a very important factor to affect the output power of the device. The electret is usually considered to be a material which can store charges permanently in some specific stable environments. But in fact, the e-VEH may be used in random or many harsh environments. The surface potential of the electret actually decays, and the output stability of the device could decrease. Some useful methods have been developed to improve the charge stability of the electret [18], [19]. In this paper, we propose a new method to improve the work stability of the e-VEH, which is to design a rechargeable electret based on the packaged e-VEH. In the next section, we will describe our design and discuss the test results in detail.

2. Characterization

Generally, in the fabrication process of the e-VEH, the electret is corona charged before device bonding and packaging by a large corona charging setup. If we can find a method to corona charge the electret after device packaging, the e-VEH will become a self-rechargeable device. In that case, when the surface potential of the electret decays after working for a long time, we can use the corona charge setup to recharge the electret, and the output performance must be increased again.

2.1. System design

In corona charge setup, the key component is the corona tip, which plays a role of enhancing the local electric field. When the local electric field intensity exceeds the ionizing field intensity of the gas, it will ionize the gas to positive and negative molecules. The electret can trap the charged molecules under the electric field. So, if the corona tip could be encapsulated inside the device, the electret may be corona recharged after packaging. Based on this idea, we have designed a new e-VEH with some corona tips inside as shown in Figure 1.

In our design, we choose the tungsten needle with a tip diameter of 5 μm as the corona tip, and the initial gap between the tip and the electret is 400 μm, which is also the initial gap of the variable capacitor. In the measurement, we found that if the traditional high-voltage supply was used to provide a high voltage for the tip, there will be a strong breakdown discharge in the device. This is because the 400 μm spacing is too small and the sustainable energy supply is too high. So, we further developed a portable corona charging system which can be powered by e-VEH directly as shown in Figure 2. Combined with this system, the electret in the rechargeable e-VEH was successfully corona charged.
2.2. Experimental results

In our demo, the electret in the e-VEH was corona charged by the traditional corona charging setup before packaging. Its surface potential was about -800V. The portable corona charging system was powered by this device at the resonant frequency of 119 Hz with vibration amplitude of 16.74 m/s². Here, the impedance of the corona charging system at 119 Hz is about 1.03 MΩ, so we have tested the output power of the device on 1 MΩ, as shown in Figure 3. We can find that 5.85 μW is good enough to power this new corona charging system. As shown in Figure 4, the 200 μF capacitor can be charged from 0 V to 4.1 V in 873 s, and after releasing the energy to the super capacitor of 10 F it will be recharged from 2.95 V to 4.1 V periodically. When the voltage of super capacitor reaches to 1.15 V, it will release energy to the stabilivolt module. Finally, the voltage of the stabilivolt module (3.3 V) is amplified by 2000 times though the voltage boost module to corona charge the electret in the rechargeable e-VEH by the build-in corona tips.

![Figure 3. Power outputs of the power supply e-VEH on 1MΩ at 16.74m/s².](image1)

![Figure 4. Voltages on the capacitors of 200 μF and 10 F during the charging and energy releasing.](image2)

As shown in Figure 1, for this new rechargeable device, we have designed three types of corona tip configurations. And after corona charged by the portable corona charging system, we can find the surface potential of the electret charged by nine corona tips is more uniform as shown in Figure 5. The average surface potential of the electret reaches to -388.2 V. So, finally, we test the output power of this device after corona charged by the nine tips as shown in Figure 6. It indicates that the maximum power output of the device on 1 MΩ after charging is 12.9 times higher than before charging at 5.02 m/s². When the acceleration of 12.55 m/s² is applied, the maximum power of 0.12 μW can be achieved. It’s an obvious improvement than before charging.

![Figure 5. Surface potential of the electret under different configurations of corona tips.](image3)

![Figure 6. Power outputs of the rechargeable e-VEH before and after charged by nine corona tips.](image4)
3. Conclusion
In this paper, we propose a new rechargeable e-VEH with the out-of-the-plane gap closing scheme. Nine corona tips are successfully designed and installed into the device. And also, we have developed a new corona charging system to match this new device. In the test, we successfully realize the corona charging of the electret after device packaging. We think this study is useful for the improvement of the work stability of e-VEH. If the output of the e-VEH decreases after working for a long time, we can recharge the electret, and the output performance must be increased again.

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