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External polarization source for dielectric elastomer generators : triboelectric generator

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Abstract— For the past decade, triboelectricity has been widely studied to design triboelectric based energy harvesters. In this work, we have deepened the studies on triboelectric generator used in a sliding mode, designing a fully equipped test bench to deal with high impedance load and strong capacitive couplings. An electrical coupling with a more conventional dielectric elastomer generator will be implemented in order to polarize the latest and thus make it electrically autonomous.

I. INTRODUCTION

In the coming years, wireless sensor used in IoT will be widely deployed in a huge range of applications, such as structural monitoring or remote healthcare. Harvesting energy directly from the ambient environment represents an effective way to power those sensors instead of conventional chemical batteries. Electrostatic harvesters are one way to convert mechanical energy into electrical one. In previous works, we developed soft Dielectric Elastomer Generators [1][2]: the principle of these DEGs is to exploit in an external circuit the electricity produced by a variation of capacitance induced by a mechanical deformation of the polymer. Developed DEGs are low cost, lightweight, can adapt complex shapes and can develop an energy density one hundred times higher than piezoelectric materials (1.7 J/g). Deformation of a sample of 5 cm length has been performed under 50% strain at 1Hz, leading to an experimental average output power of 33 μ W on a 300 k Ω output charge.

Two ways of polarizing a DEG have already been explored: the use of an electret [1] and the use of a piezoelectric cell [2]. The disadvantage of the first solution is a high sensitivity to external environmental conditions, while the second one presents a high encumbrance. That is the reason why a new way of polarizing a DEG has been suggested: the use of a triboelectric generator.

Introduced by Wang and co-workers [1], triboelectric generators develop a high power density (5.3W/m²), are light (density of few g/cm³), inexpensive and compliant so they can be installed in a huge variety of places, or easily integrated into technical textile. Triboelectric generators also operate at very low frequencies (around Hz), as well as DEG, hence the idea of coupling those two technologies to create an electrically autonomous electrostatic generator

II. EXPERIMENTS

A. Realization of a test bench

Although triboelectricity has been observed for a long time, the physical principle behind this is still poorly understood because many parameters are involved such as surface state, humidity, mechanical strains... The first step to study triboelectricity is the choice of material, based on triboelectric series, which are tables that quantify the amount and the polarity of the charge obtained by applying a tested material to a reference one. Then a test bench had to be designed in order to deal with the difficulties related to the measurement of electrostatic phenomena, such as high voltage (above 1kV), high internal impedance and high sensitivity to parasitic capacitance. Therefore, a test bench equipped with Trek electrostatic probes, a Keithley electrometer and a decade box from 1M Ω to nearly 2G Ω has been designed. Thanks to this over-equipped bench, we have monitored the transfer of electrical charges between couples of materials forming the TENG (copper, PET, PTFE.) over thousands of cycles in sliding mode.

B. Method and results

Some tests consisted of rubbing a sheet of PTFE (0.05*50*50 mm³) against a sheet of copper of the same surface. Until now, most of the experiments were performed without load to have a better insight of the physical phenomenon. One of the main observations obtained so far is that the surface charge density might be not as homogeneous as it is mostly presented in the literature. Indeed, this consideration is very advantageous during the realization of simulation, but the aim of those simulation is the dimensioning of prototype.

The set-up is the following: a sheet of PTFE was rubbed against a piece of copper of the dimensions described above, but here the usual electrode placed on the PTFE, which is usually polarized through electrostatic induction by the triboelectric charges, is replaced by three copper bands perpendicular to the translation direction. The potential of those three electrodes is then measured with electrostatic Trek voltmeters. These three electrodes provide a more accurate view of the triboelectric charge distribution than a single global electrode (FIGURE 1).

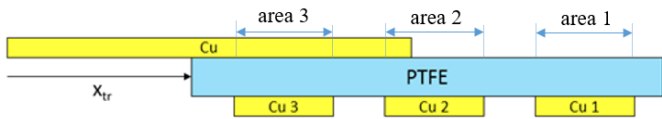


FIGURE 1. TENG with three electrodes

The simulation with Comsol uses the same geometric dimensions as the experiments, and a value of $1 \mu\text{C}/\text{m}^2$ is used on the surface of the PTFE rubbed. As observed in FIGURE 2, the potential of the electrodes rise when the copper film passes them, but where the two differ is on the final value of the voltages: in the simulation, the three voltages tends to reach -600V , whereas during the experiment the voltages reached are -120V , -150V and -220V . The experiment result suggests that the more a part of the PTFE is rubbed, the higher its surface charge density is. Therefore, area 1 would be charged with $0.33 \mu\text{C}/\text{m}^2$, while area 3 would only have $0.2 \mu\text{C}/\text{m}^2$. This result is interesting for the dimensioning of a prototype, as it shows that to reach higher voltage, increasing the surface of the prototype is not enough, it becomes more interesting to increase the translation stroke of the device rather than its width. Some aspect still need to be considered in this study, like the homogeneity of the pressure between the sheets of copper and of PTFE.

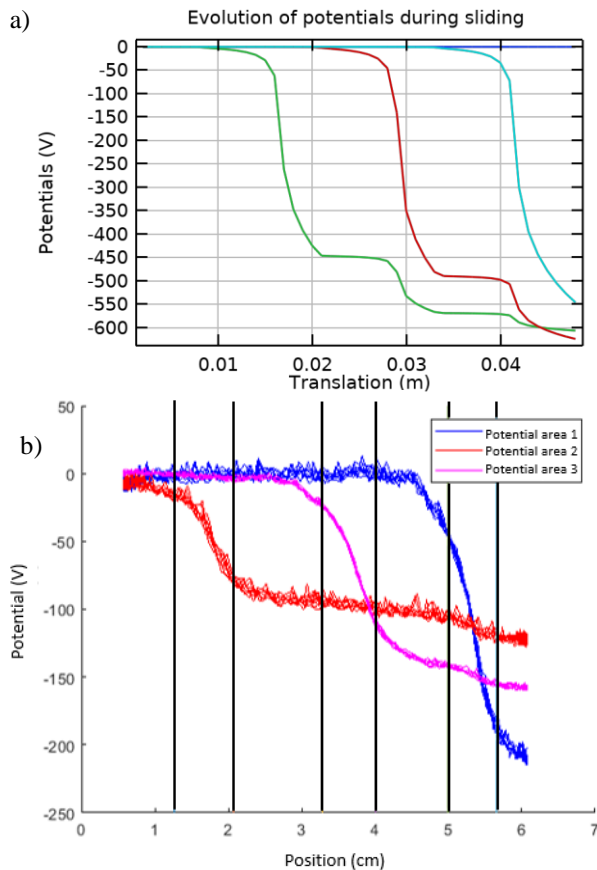


FIGURE 2 Comparison of surface potential between simulation under Comsol (a) and the experiment (b). Referring to FIGURE 1 for areas investigated.

III. PERSPECTIVES

The next step of these experiments is the addition of resistive and capacitive loads in order to compare the performance of a TENG alone and one coupled with a DEG. Some preliminary tests represented on **Erreur ! Source du renvoi introuvable.** have been performed with a wide range of resistor values. Those curves remind the fact that TENG present a large internal impedance, and that to optimize the power transfer, a load of few hundreds of ohms is required as the area described by the QV cycle is the widest.

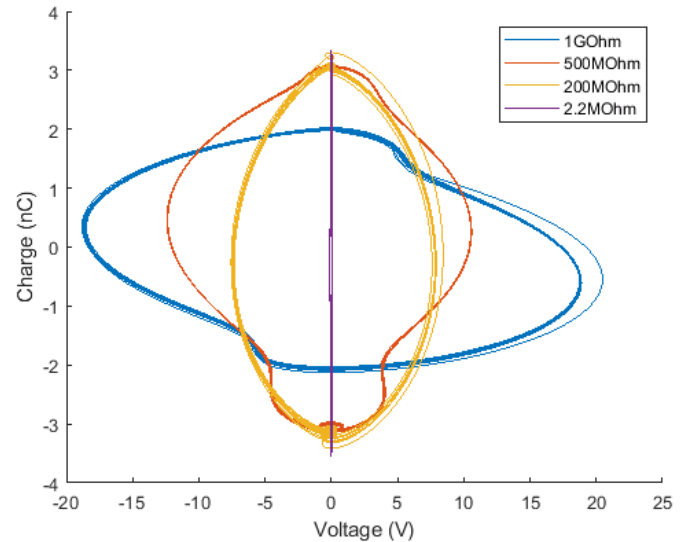


FIGURE 3. QV cycles for various loads

The other important aspect is the power conditioning, as the TENG is destined to charge a DEG, which is a variable capacitor. For that, different, different conditioner topologies already studied at Esycom laboratory [2] will be tested.

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