Printed Magneto-Electric Energy Harvester

Product: Printed Magneto-Electric Energy Harvester
Development Stage: Proof of Concept and Early Prototype
Primary Inventors: Amer A. Chlaihawi, Massood Z. Atashbar, Bradley B. Bazuin, Sepehr Emamian, Binu Baby Narakathu, Department of Electrical and Computer Engineering
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Contact: Steven J. Weber Ph.D., steven.weber@wmich.edu 269-387-8282

Background: Advancements in manufacturing processes have enabled the development of miniaturized electronic devices for numerous applications. Due to the relatively low power requirements of such devices, energy harvesters - which capture ambient energy and convert it to electricity - have become increasingly viable. Energy harvesters can charge, supplement, or sometimes even replace the batteries that typically power these devices. Some examples of an ever growing list of devices that can utilize energy harvesters include: wearable medical monitors, implanted medical devices, portable and wearable consumer electronics, toys, recreational equipment, and navigation equipment.

Among the different types of energy harvesters, those based on the magneto-electric effect provide certain advantages in that they generate relatively larger output voltages under low magnetic fields, along with higher power densities. Examples of ambient magnetic “waste” energy sources readily available for harvesting include: electrical power transmission lines, home and office appliances including their power cables; automobiles, trains, subways, and other vehicles/transportation apparatus; and electronic communications infrastructure.

Presently, some types of magneto-electric energy harvesters are fabricated using silicon substrate technology, including MEMS technology. Other magneto-electric energy harvesters are manufactured by sandwiching various layers of materials to form piezoelectric-magnetostrictive laminate composites. Unfortunately, these devices are often fabricated on rigid substrates which can present reliability problems and use-constraints. Furthermore, the manufacturing processes for existing devices typically require clean room facilities, high temperatures, and/or complex bonding techniques, all of which add cost and complexity to the production process.

Accordingly, there is a need for new devices and new manufacturing processes which overcome the current drawbacks associated with the fabrication of magneto-electric energy harvesters. Such advancements will preferably utilize flexible and light weight, functional materials.

Technology Description: At WMU, a novel low frequency magneto-electric energy harvester was developed for powering microelectronic devices. When the energy harvester experiences a magnetic field, a magnetostrictive layer temporarily bends the device which induces
mechanical strain in a piezoelectric layer, thereby producing an amount of electricity that can be utilized. Physically bending the flexible energy harvester can also produce electricity.

The novel energy harvester can be fabricated using additive print manufacturing processes such as screen, inkjet, gravure, and flexographic printing. These methods provide various advantages such as low manufacturing temperatures, reduced materials usage, and simpler fabrication processes compared with silicon or laminate based fabrication methods. Structurally, the flexible device construction provides the added benefits of durability as well as consistent performance under various mechanical stresses.

An experimental magneto-electric energy harvester prototype was designed with an overall device dimension of 25×15×0.035 mm and consisted of three layers: flexible Metglas® substrate (amorphous metal alloy), polyvinylidene fluoride (PVDF) ink piezoelectric layer, and silver (Ag) ink top electrode (Fig. 1). The WMU prototype was fabricated by screen printing the PVDF ink on a flexible, magnetic Metglas® substrate. The silver ink top electrode layer was then deposited on the printed PVDF layer, also via screen printing.

The experimental performance of the printed device was investigated by measuring the DC output voltage and maximum power delivered at varying load resistances for a frequency range of 20 Hz to 100 Hz, in steps of 20 Hz. The wide range of tested frequencies illustrates impressive potential performance for various real-world scenarios, such as for those magnetic fields generated by electrical power transmission infrastructure, household appliances, etc.

The response of the printed magneto-electric energy harvester towards varying load resistances is shown in Figure 2. It was observed that the DC output voltages increased with increase in load resistances. In addition, the voltages also increased as the frequency was increased. Figure 3 shows the calculated power generated from the printed magneto-electric energy harvester as a function of varying load resistances. Here, a right-skewed bell-curve is revealed where the power increased and then decreased as the load resistance was increased from 4 kΩ to 2 MΩ.

As seen in these Figures, the maximum power generated was 8.41 µW at a load resistance of 100 kΩ and frequency of 100 Hz. This relates to a power density of 639.59 µW/cm³ for the fabricated magneto-electric energy harvester, demonstrating ample powering capability for current and future miniature electronic devices. Note also the substantial DC output voltage and power output in the frequency range of 60Hz, which is typical of common magnetic field sources in the USA. These results demonstrate the feasibility of the proposed design as well as the promise of employing additive print manufacturing processes for the fabrication of cost-efficient, light-weight and flexible magneto-electric energy harvesters.

Potential Benefits:

- Light weight, flexible structure enables next generation applications
- Over 600 uW/cm³ energy density demonstrates ample powering capability
- Performs well over a wide range of frequencies
- Additive manufacturing process enables low cost, reliable, large volume production
Figure 1. Schematic of magneto-electric energy harvester and Photo of screen printed magneto-electric energy harvester

Figure 2. DC output voltage as a function of varying load resistances at constant magnetic field
Figure 3. Power generated as a function of varying load resistances at constant magnetic field