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Ferroelectric Energy Harvesters For Powering Smart Clothes

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Abstract

The concept of using ferroelectric-based energy harvesters to power smart clothing is presented. These materials can simultaneously convert deformation, motion, heat, and light into electric current and have a virtually unlimited lifetime.

Keywords: Smart clothes; Electrical charges; Batteries; Ferroelectric; Light

Introduction

In recent times, the Internet of Things is becoming more and more widespread, which makes it possible to endow familiar things with new possibilities. This trend has not bypassed the light industry and beauty industry. Elements of clothing and accessories get active stuffing that allows us to monitor our health, add the ability to communicate or track location, and add light or sound effects that improve our safety or make our wearer stand out from the crowd. To power these things, small, lightweight and long-lasting power sources are needed. For this purpose, lithium-ion batteries are mostly used, which are lightweight, have high specific capacity, and can be made in almost any shape. However, like all batteries, they need to be charged, they have a limited life cycle (storage time, a certain number of charge/discharge cycles), there is a problem with their utilization and they are subject to the possibility of spontaneous combustion in case of mechanical damage. Therefore, the world is searching for alternative power sources to improve the performance of smart things, including smart clothes or accessories. We are talking about energy harvesters that can convert heat, motion, deformation, or light into electricity. Smart clothes are very suitable because our clothes are usually seasonal (summer clothes are not worn in winter, and vice versa), hang in the closet for months, and are worn randomly. So, it is not very convenient to prepare them for use in advance (charge the batteries), we would like to just take them out of the closet and put them on. In the case of energy converters, this works. We put on a garment or accessory and the heat from our body or surroundings, incident light, or our movement provides energy to the embedded electronics.

Ferroelectric Energy Harvesters

Most energy harvesters convert only one, sometimes two, physical effects into electricity [1]. For example, photovoltaic cells respond only to light, piezoelectric cells respond to pressure or strain, and thermoelectric cells respond to heat. Therefore, energy harvesters based on ferroelectrics are more suitable. These are unique materials that possess spontaneous polarization in a certain temperature range. Applying external influences to the material results in a change in polarization (Figure 1).

Piezoelectric effect: When mechanical stress is applied to a piezoelectric sample, the crystal structure of the material is deformed, and this causes the movement of electrical charges (Figure 1a) [2].

Photovoltaic effect: When light is incident upon a photovoltaic cell, electricity is generated through the light absorption by the ferroelectric, excitation, hole/electron separation, and the transport of charges to the electrodes (Figure 1b) [3].

Pyroelectric effect: Pyroelectric energy harvesting technology is based on the change in spontaneous polarization of ferroelectrics due to temperature fluctuation (Figure 1c) [4].

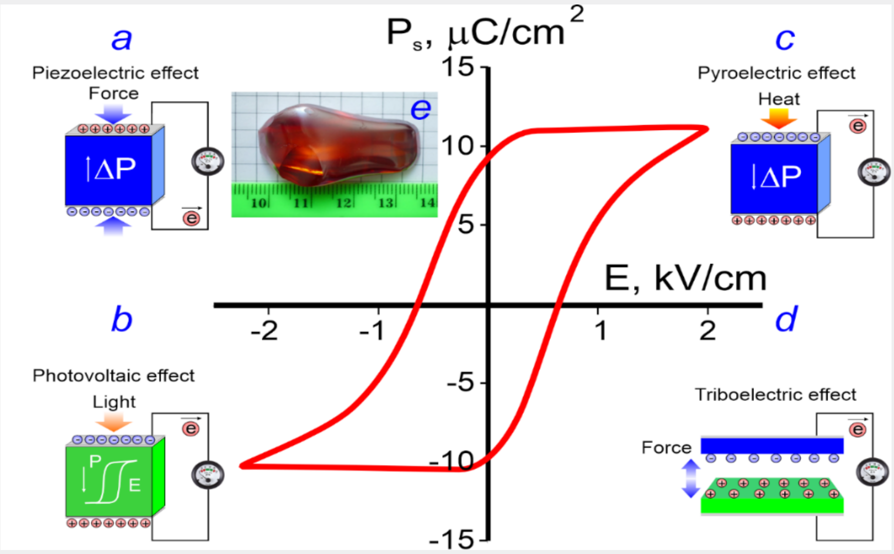

Figure 1: Dielectric hysteresis loop of $Sn_2P_2S_6$ crystal (center). Physical effects that can be used to generate electric current. a - piezoelectric effect, b - photovoltaic effect, c - pyroelectric effect, d - triboelectric effect, e – photo of the $Sn_2P_2S_6$ crystal.

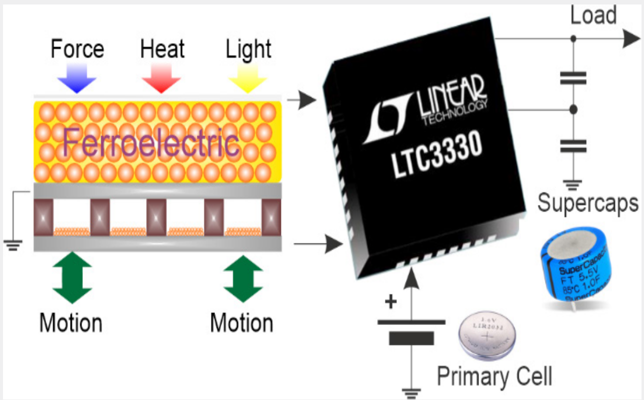

Figure 2: Ferroelectric based energy harvester and example of its connection using a specialized chip [6].

Triboelectric effect: In the contact electrification effect, a material surface becomes electrically charged after it comes into contact with a different material through friction, owing to charge transfer between the two materials (Figure 1d) [5].

Ferroelectric crystals simultaneously possess piezoelectric, pyroelectric, photovoltaic, and triboelectric properties, which makes it possible to convert deformation, heat, illumination, and motion into electricity [6]. The design of such converters, see Figure 2, is very simple: electrodes are applied to the plate of a ferroelectric on both sides (we get a kind of capacitor), one of which is translucent (a thin layer of gold or SnO). The converter is ready. If it is marked on a part of the clothing that is deformable (knee, elbows, soles), the piezoelectric properties of the material will be used. If it is placed on the surface of the garment, the incident light will be converted into electricity, due to the photovoltaic effect. Our body heat or ambient heat can be converted into current by the pyroelectric effect. And any movement or vibration can be utilized by the triboelectric effect. And the uniqueness of ferroelectrics is that all these can work simultaneously.

Example of Use

On the basis of such ferroelectrics as three-dimensional $Sn_2P_2S_6$ (both as a single crystal and as a composite) and layered $CuInP_2S_6$, universal energy harvesters have been created, which have been applied to power smart clothes for firefighters or emergency workers (Figure 3) [7]. The fact is that these professions are very traumatizing, so it was proposed to create smart clothes for them, which track the parameters of their wearers' vital activity (body temperature, blood oxygen level, EKG, body position in space

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and others) and the parameters of the environment (presence of radiation, poisonous and explosive gases, temperature, etc.). All received data are transmitted to the personnel control center and also displayed on the augmented reality glasses of the employee himself, warning him of danger. Since an alarm can be triggered at any moment, and the operation of eliminating the danger can last for days, it was logical to use ferroelectric energy harvesters to power this smart suit. Its sensors will work as long as there is motion, heat, or light.

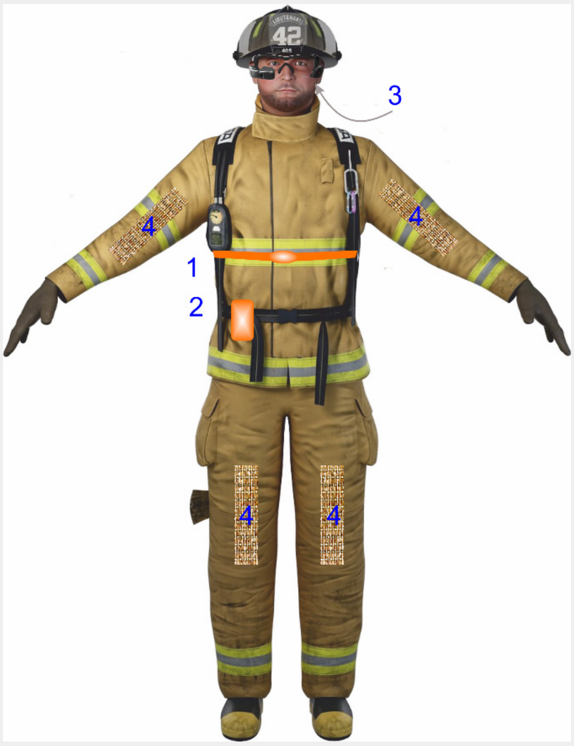

Figure 4: Firefighter Smart Clothing with life sensors (under clothing) - 1, center module - 2, augmented reality glasses - 3 and ferroelectric based energy harvester panels - 4.

Figure 4: Smart ring with OLED display and ferroelectric energy harvester power source.

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However, energy harvesters based on ferroelectrics will be useful not only in such critical applications but also in everyday life. For example, we can build them into necklaces, hoops, rings, or pendants. Imagine modern jewelry, which after wearing shimmer with rainbow colors, or photos of your loved ones appear on them. By the way, the fashion industry is not yet very much using the possibilities of modern electronics in the creation of jewelry, although the cost, weight and size of modern OLED displays have long made it possible to integrate them into rings (Figure 4), pendants or bracelets. And alternative power sources make it possible to provide them with an almost eternal life.

Of course, like all technologies, ferroelectric energy harvesters also have their limitations. For example, they do not operate above the phase transition temperature (although it can be above 100°C), and some of them are afraid of water or very strong mechanical effects. When using them, it should be taken into account that the piezoelectric response of these materials is hundreds of volts, and the photovoltaic or pyroelectric response is only hundreds of millivolts, respectively, to match them with the load must use special circuits that are produced by almost all manufacturers of electronic components (LTC3330, ADP5091, SPV1050 and others). In addition, the dynamic nature of the released electricity requires its accumulation, but this task is also easily realized through the use of modern supercapacitors, which do not have the disadvantages of lithium-ion batteries. However, all these disadvantages can be compensated for by competent design and integration into final products.

Conclusion

We have shown that ferroelectrics can be used to create universal alternative energy harvesters that can simultaneously convert motion, deformation, pressure, vibration, light, and heat into electric current. These could be used to power smart clothes elements or decorative wearable accessories.

References

1. Y Bai, T Siponkoski, J Perantie, H Jantunen, J Juuti (2017) Ferroelectric, pyroelectric, and piezoelectric properties of a photovoltaic perovskite oxide. Appl Phys Lett 110: 063903.
2. A Gritsenko, V Nikiforov, T Shchegolev (2012) Status and prospects of development of piezoelectric generators. Components and technologies, Fine Street, Russia: St. Petersburg 9: 63-68.
3. AV Solnyshkin, IL Kislova, AN Belov, VI Shevyakov, DA Kiselev, et al. (2019) Photovoltaic and photoelectric response of $Sn_2P_2S_6$ ferroelectric films. Journal of Advanced Dielectrics 9: 1950003.
4. MM Maior, MI Gurzan, Sh B Molnar, IP Prits, Yu M Vysochanskii (2000) Effect of Germanium Doping on Pyroelectric and Piezoelectric Properties of Sn2P2S6 Single Crystal. IEEE transactions on ultrasonics, ferroelectrics, and frequency control 47: 877-880.
5. O Molnar, V Gerasimov, IP Kurytnik (2018) Triboelectricity and construction of power generators based on it. Przeglad Elektrotechniczny 1: 167-171.
6. A Molnar, D Gal, H Ban, V Gerasimov (2021) Ferroelectric Based Multi-Type Energy-Harvesting Device to Power a Mobile Medical Telemetry System. Integrated Ferroelectrics 220: 110-119.
7. H Ban, D Gal, A Molnar, V Gerasimov (2017) Personal telemetry system for firefighters with Augmented Reality support. VII Inter University Conference of Students, PhD Students and Young Scientists. Engineer of XXI Century. University of Bielsko-Biala, Poland: 19-26.

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