The World Easiest and Efficient Power Generator with Ultrahigh Voltage for Lighting, Charging and Self-powered Systems

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Abstract

Can you imagine that when you slide on the polymer plate with your hands, the generated electromagnetic field can drive 28-watt fluorescent tube lamps and can even charge the mobile phone? The progress of science and technology subverts traditional cognition. In this work, the easiest and efficient power generator (EEPG) in the world, with ultrahigh voltage is invented, which can light up several 1-watt bulbs and 28-watt fluorescent tube lamps by simply rubbing a polymethyl methacrylate (PMMA) plate with hands or other objects. The average output voltage and current of planar EEPG can reach up to nearly 5000 V and 116 μA respectively. Not only can it be used for lighting, but also for charging, and even for mobile phones. The rotary EEPG can be used to harvest the wind energy and tidal energy, which overcomes the shortcomings of traditional electromagnetic wind power generation working only when the wind speed is greater than 5 m/s. In addition, as a self-powered system, the EEPG power generator can be utilized as foot switch and trajectory tracking tool. Further analyses on its working principle of EEPG power generator were proposed. This is likely to become the easiest and the most effective method of power generation in the world up to now, which will have great significance in the field of new energy and self-powered systems. We can expect that, in the near future, we can charge our mobile phones by just rubbing their backs. Collecting the green wind energy more easily and efficiently will be truly realized.

Key words

the easiest power generator; new energy; self-powered system; high voltage

1. Introduction

Currently there is an ever-growing interest in upgrading and reorganizing traditional rigid electronic apparatus to wearable electronics that are being envisioned for applications such as motion sensing and health monitoring[1, 2]. Along with this trend comes the increasing demand for finding eco-friendly and everlasting power units currently presented by lithium ion batteries (LIBs)[3, 4]. While significant progresses have been made in reducing the power consumption and increasing the energy density, LIBs also need to be charged, frequently or not, and further disposed, which make such a power solution not that perfect and calls for complementary energy technologies for sustainable operations.

Renewable and clean energy is gaining more and more attention due to the depleting of fossil fuels and the worsening of environmental pollution[5, 6].Studies have shown that the collection of mechanical energy such as human activities, wave energy and wind energy is a sustainable and feasible way of energy harvesting[7-9]. Currently, devices for mechanical energy harvesting mainly include electromagnetic generator (EMG), piezoelectric nanogenerator (PENG) and triboelectric nanogenerator (TENG) [10-12]. EMG is a traditional generator, which is based on the Faraday's law[10, 13, 14]. EMG is by far the most mature and the most widely used power generation method. However, EMG often requires a high-frequency and big scale energy input to ensure its high output[15]. PENG was designed to convert mechanical energy into electrical energy by using the mechanism of the piezoelectric effect of piezoelectric materials and piezoelectric ceramics when it was subjected to external tension or compression [16-18]. But ceramic materials are brittle, inflexible and have low inherent breakdown strength [19, 20]. TENG is a new energy harvesting technology invented by Zhong Lin Wang in 2012 that uses the coupling effect of triboelectricity and electrostatic induction to collect low-frequency mechanical energy

in the environment[21-23]. Triboelectricity has been applied for the first time in energy harvesting since it was discovered for thousands of years[12]. It has considerable prospects in self-powered sensing, micro/nano power sources, blue energy, high voltage power sources and other fields, because of its small size and high efficiency [24, 25]. However, TENG has low current output, large internal resistance, various interference factors and unstable output, which is failed to come up with sufficient electric output for lighting or charging [26].

When talking about the use of triboelectrification, it is difficult for people to link triboelectrification with lighting. If we rub object by hand, according to energy conservation law, how much mechanical energy can be converted into electrical energy? In people's traditional notions, it's even harder to imagine that the electromagnetic energy generated by rubbing objects with hands can be used for lighting, or even charging mobile phones. The progress of science and technology will constantly subvert people's traditional cognition. In this paper, the easiest and efficient power generator (EEPG) in the world up to now, with ultrahigh voltage was invented only by rubbing a polymer plate with hands or other objects. The average output voltage and current of the EEPG can reach up to nearly 5000 V and 116 μA respectively. The working principle and the working mode of the EEPG based on the electromagnetic energy are analyzed in detail. The EEPG can light up several 1-watt bulbs and several fluorescent tube lamps and can be used for charging mobile electronic devices, even charging for mobile phone. EEPG can collect different forms of mechanical energy like wind energy and ocean energy, when it works in rotary mode. The rotary EEPG can collect the wind energy at any wind speed, which overcomes the disadvantage of traditional electromagnetic wind power generator that can only generate electricity when the wind speed is greater than 5 m/s. This work provides a new method for the more effective use of triboelectricity and has great significance in the field of new energy and self-powered systems. Just like Tesla's genius prediction on the wireless in 1926[27], it may appear in the near future that our mobile phone can be charged only by rubbing its back and wind power generator can

work effectively in much low wind speed.

2. Results and discussions

Recently we have found that all matters under forces can generate electromagnetic energy, even under a tiny force like wind blow [28, 29]. Wherever an object is touched by friction, where electric field and triboelectric charges are immediately generated. Figure 1a shows the experimental setup of a simple power generator (SPG) for investigating the releasing of electromagnetic energy by friction. A polymethyl methacrylate (PMMA) plate was prepared with two conductive tapes fixed to the back of it. Slide on the PMMA plate with our hands or an object and see if there is an electromagnetic field generated. Figure 1b-c show that the as generated voltage can reach up to 750 V, and the as generated current can be up to 7 μA. Figure 1d shows a 1-watt bulb can be driven by the SPG power generator, although the light is weak. In order to collect the electromagnetic energy by friction more effectively, the improved SPG-- the easiest and efficient power generator (EEPG) was designed with conductive tapes grid and diodes on the back of PMMA plate as energy collector. Figure 1e and Figure 1f show the experimental setup of EEPG. Slide on the PMMA plate and detected the electrical signals of the EEPG. Figure 1g-h show the as generated voltage can reach up to nearly 5000 V, and the as generated current can be up to 116 μA. The as generated voltage should be higher, which is highly beyond the scope of the oscilloscope. Compared with the SPG power generator, the output has been greatly improved. Figure 1i shows five 1-watt bulbs can be driven by the EEPG, and the light was strong enough for everyday lighting. The book can be illuminated by the bulbs, which demonstrates highly efficient capability of power generation. More shining results can be seen in the video (Supplementary Video 1). The EEPG is a very efficient way for harvesting the electromagnetic energy released from the friction.

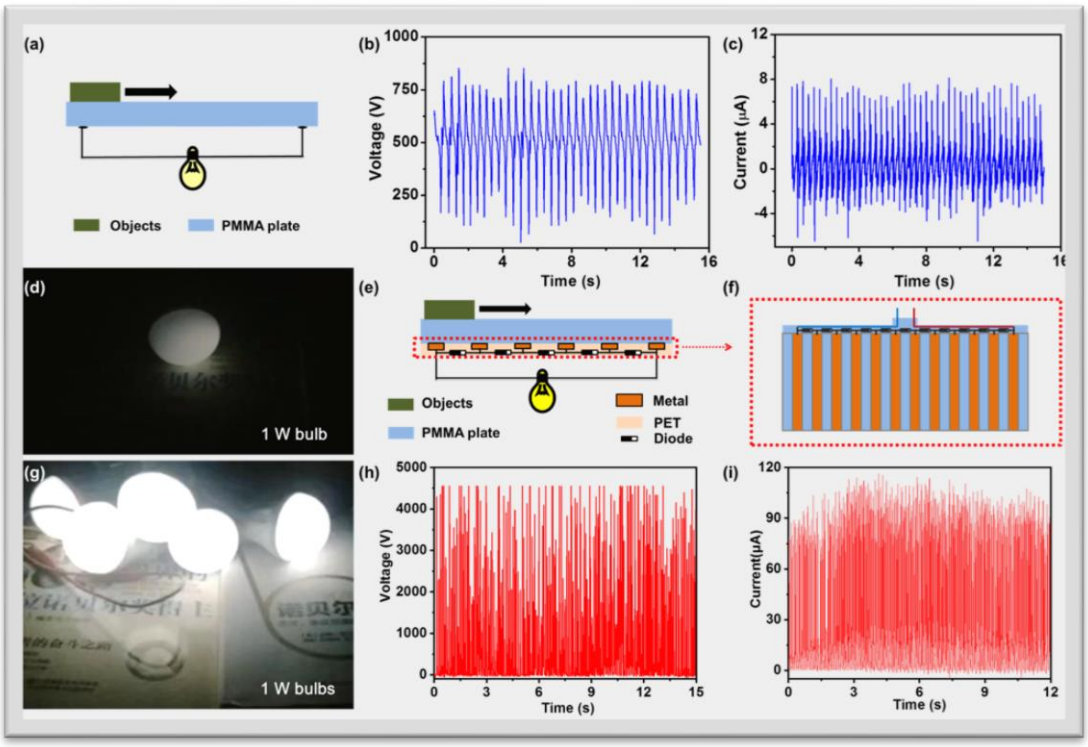

Figure 1. The easiest and efficient power generator. (a) Experimental setup of the SPG power generator for investigating the releasing of electromagnetic energy; (b) The voltage of the SPG power generator; (c) The current of the SPG power generator; (d) The photo of a lighted 1-watt bulb driven by the SPG; (e, f) Experimental setup of the EEPG power generator; (g) The photo of five lighted 1-watt bulbs driven by the EEPG; (h) The voltage of the EEPG power generator; (i) The current of the EEPG power generator.

We found that where there is a touch, there is electromagnetic field[28, 29]. The principle of EEPG has been analyzed based on the triboelectrification and electromagnetic energy. The friction under force can generate the electromagnetic energy, which can be collected by the conductive tapes grid and diodes. The electro potential difference and electro charges raised from the rubbed PMMA plate surface can be captured and accumulated. According to the different charge distribution, two working principles were proposed. As shown in Figure 2a, the triboelectric charges on

the surface of the PMMA plate will quickly dissipate over time after the PMMA is rubbed by the object. The closer the PMMA plate is to the rear end of the object, the higher the surface charge density of the PMMA plate is. Conversely, the farther away from the object, the lower the charge density. There will be electro potential difference around the PMMA plate. The charge generated by the friction on the PMMA plate will change with the position of the object, and the electromagnetic energy will be generated. As shown in Figure 1a ii-iv, the positive charges in the external circuit will flow through the diode, when the object slides to the right. If the diode is replaced with the LEDs, it will light up one by one. The unidirectional conductivity of the diode can only conduct electricity in one direction. As shown in Figure 2b, there will be no current in the external circuit and no charge exchange between the diodes, when the object slides in the opposite direction. There is no reverse current during the reverse sliding process, which is consistent with the current in Figure 1i.

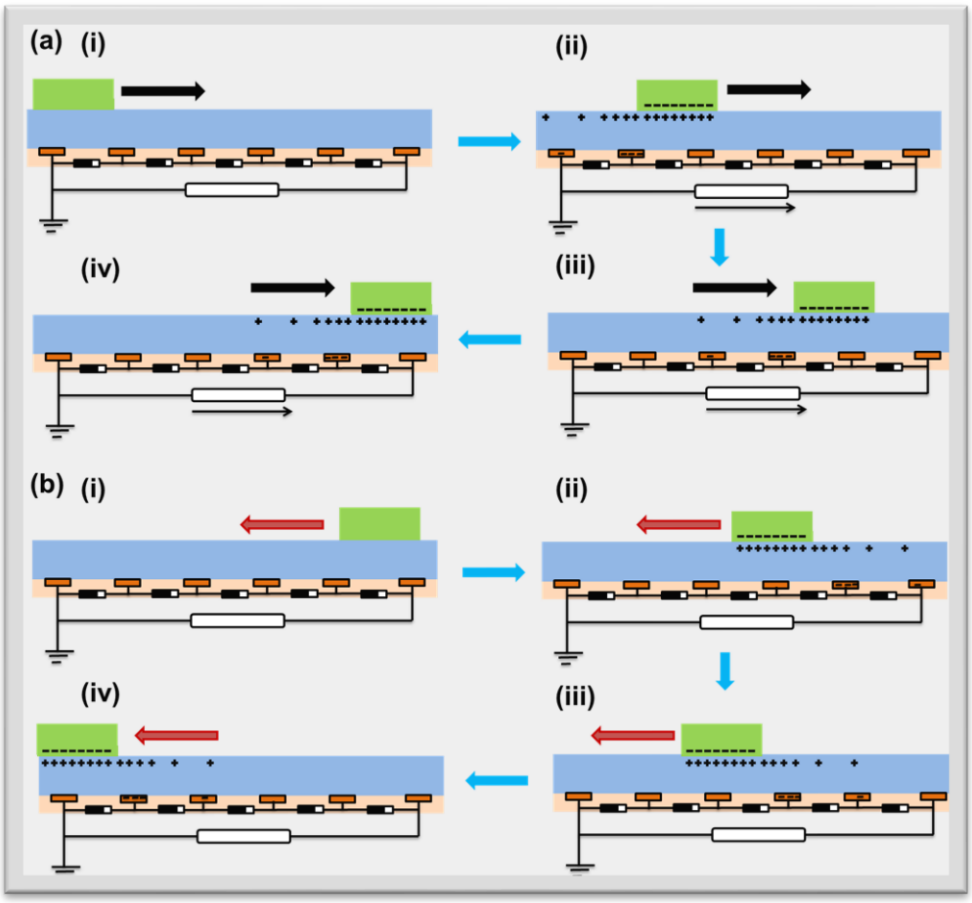

Figure 2. Working principles of EEPG power generator. (a) Working principle of EEPG power generator when the object moves from left to right; (b) Working principle of EEPG power generator when the object moves from right to left in the reverse direction.

Meanwhile, there is another explanation for this principle of EEPG power generator when the PMMA plate can hold the surface charges. As shown in Figure 3, the charges are evenly distributed on the PMMA plate after repetitive frictions. When the object slides on the PMMA plate, there is electro potential difference, and the opposite charges will be induced on the bottom electrodes. As the object slides, the electromagnetic energy will be released from the friction. It will exchange the charges between the diodes, and generate current in the external circuit, as shown in Figure 3a i-iv. In addition, the diode has unidirectional conductivity that it can only conduct electricity in one direction. If the object slides in the opposite direction, there will be no charge exchange between the diodes and no current in the external circuit. Figure 3b i-iv shows there is no current when the object moves from right to left in the reverse direction, which is also consistent with the current in Figure 1i.

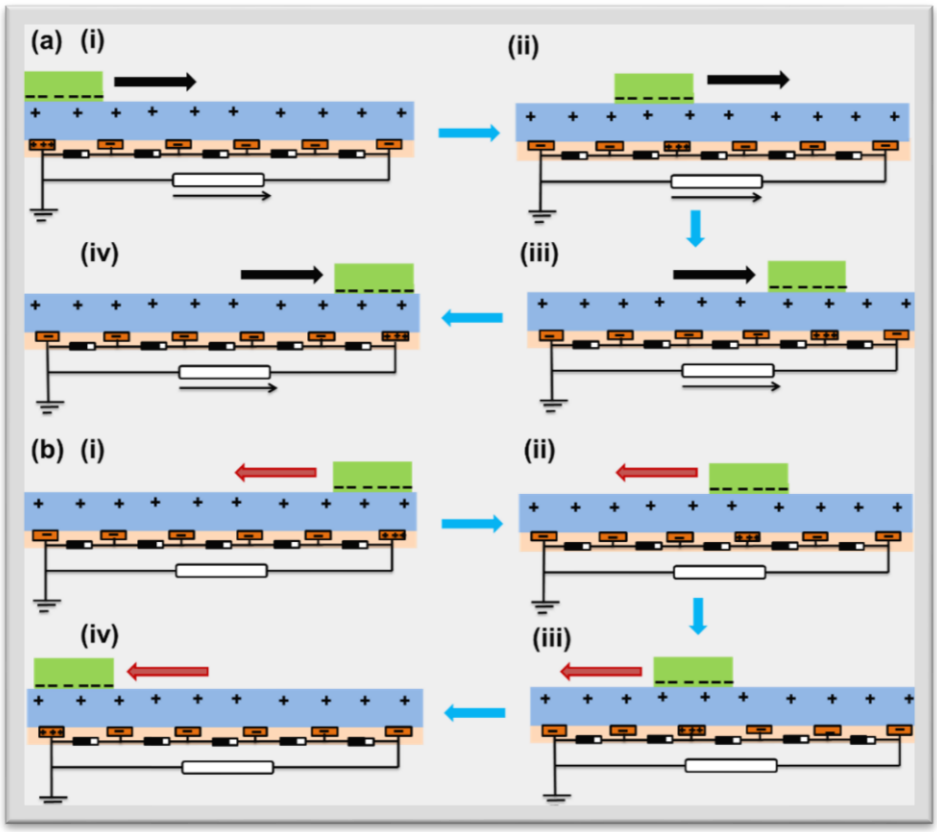

Figure 3. Another explanation for working principles of EEPG power generator. (a) Working principle of EEPG power generator when the object moves from left to right; (b) Working principle of EEPG power generator when the object moves from right to left in the reverse direction.

The EEPG power generator also can work to collect the mechanical energy because the electromagnetic energy will be released from the process of contact and separation. As shown in Figure 4, it is also a DC output process and no charge will pass through the external circuit during the separation process. Figure 4a shows the object and the PMMA plate can generate electrostatic charges and induced charges on the electrode after contact and separation. The closer the part of PMMA plate gets to the bottom of the object, the higher the surface charge density of the part of PMMA plate. The farther away the part of PMMA plate is, the lower the charge density is. The charges generated by the contact electrification on the PMMA plate will change

with the distance between the object and the PMMA plate, thereby generating current flow in the external circuit. So the electro potential difference and electro charges raised from the PMMA plate can be captured and accumulated. Besides, EEPG also can work if the PMMA plate can hold the surface charges. As shown in Figure 4b, the charges are evenly distributed on the PMMA plate. The electromagnetic energy can be collected by the electrodes and diodes. Charge exchange occurs between the diodes and generating current in the circuit while the object and the PMMA plate are contacted and separated. Therefore, this new EEPG has multiple working modes that can collect all kinds of mechanical energy in the environment like wind energy and ocean energy.

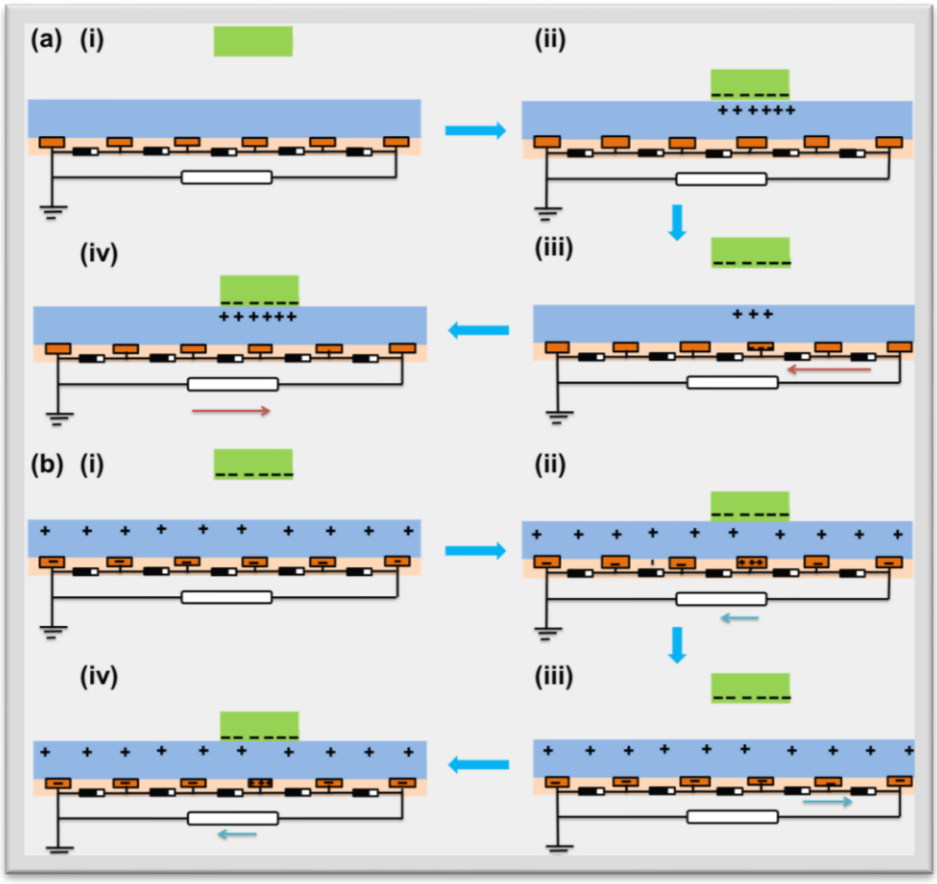

Figure 4. Working principles of EEPG power generator in the process of contact and separation. (a) Working principle of EEPG power generator when the object moves from left to right; (b) Working principle of EEPG power generator when the object moves from right to left in the reverse direction.

The EEPG power generator is very different from the previous power generation devices such as normal TENG and EMG. Especially, the EEPG has good performance that can produce high voltage and high current output. As shown in Figure 5a, it can provide energy for daily fluorescent tube lamps for lighting and powering small electrical appliances. Figure 5b-e show that the fluorescent tube lamps can be directly lighted for reading book by rubbing EEPG with our hands. (Supplementary Video 2) This is something that currently cannot be achieved by normal TENG, which is a major breakthrough in the collection of mechanical energy. It is no longer limited to small-scale nanotechnology but uses macroscopic objects to form the simplest and most convenient device, which can collect the energy of low frequency and low amplitude around us for producing real green energy. As shown in Figure 5f and Figure 5g, the mobile phone connected with EEPG will be charged if we rub quickly. (Supplementary Video 3) It displays directly the high efficiency of EEPG as a power source for collecting the mechanical energy. Figure 5h and Figure 5i respectively show that the EEPG can be used to continually charge the multi-functional indicator and calculator. (Supplementary Video 4-5) It shows a good application prospect in power supply for mobile electronic devices. Besides, a rotary EEPG power generator based on the working mode was designed for lighting in Figure 5j, which can be also used to harvest the wind energy. Figure 5k-m show that five fluorescent tube lamps can be driven for lighting by the rotary EEPG, which intuitively highlights the advantages of high voltage and high efficiency of EEPG. (Supplementary Video 6) Traditional electromagnetic wind power generation can be effectively generated only when the wind speed is 5 m/s or above. But the rotary EEPG can collect the wind energy of low or high wind speed due to its advantages of high efficiency. As long as there is wind, it can generate electricity.

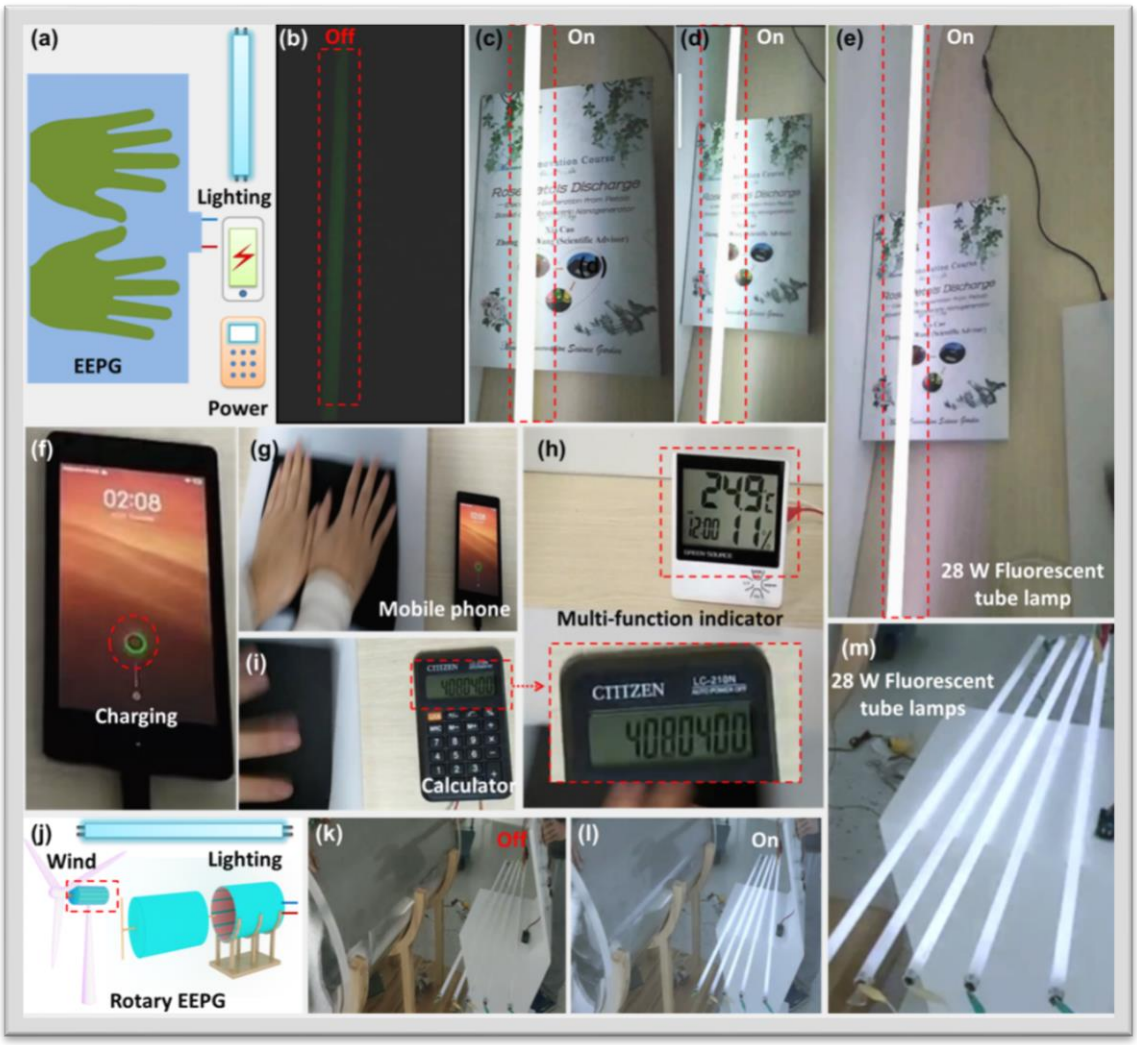

Figure 5. EEPG power generator for lighting and powering small electrical appliances. (a) Schematic diagram of EEPG power generator used for lighting and power; (b-e) EEPG for lighting up the 28 W fluorescent tube lamp; (f, g) EEPG for charging the mobile phone; (h) EEPG for charging the multi-function indicator; (i) EEPG for charging the calculator; (j) Rotary EEPG power generator that can harvest the wind energy for lighting; (k-m) Rotary EEPG power generator for lighting up five 28 W fluorescent tube lamps.

Furthermore, this simple and convenient power generating device (EEPG) can be also integrated into self-powered systems. EEPG power generator can be used not only for power generation, but also for sensing and trajectory tracking. Figure 6a and

Figure 6b vividly shows EEPG power generator as a foot switch by placing it under the bedside carpet to control the table lamp. When we step on the carpet connected with the EEPG, the table lamp will be lit up (Supplementary Video 7). As demonstrated in Figure 6c, EEPGs can be also placed on different positions under the carpet to achieve self-powered trajectory tracking. When someone walks by, the electrical signal generated by the EEPG power generator will be transmitted to the controller, so that the person's motion trail can be judged. Figure 6d-g show that the controller can record the position of the person when the person walks from "1" to "8". (Supplementary Video 8) It provides a new method for the more effective use of triboelectricity, which has great significance in the field of new energy and self-powered systems.

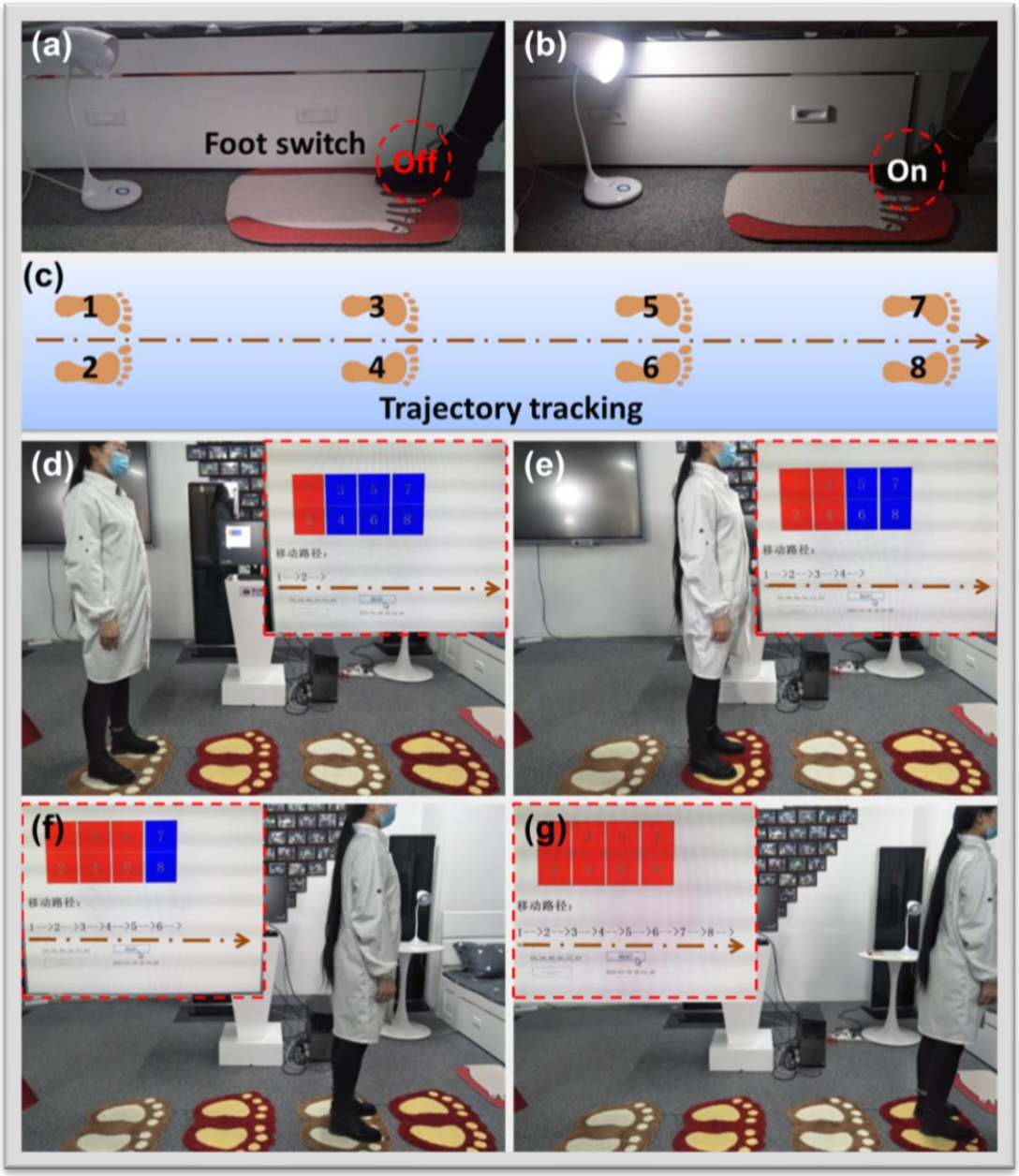

Figure 6. EEPG power generator for self-powered systems. (a, b) EEPG power generator for self-powered foot switch; (c) Schematic diagram of self-powered trajectory tracking integrated with multiple EEPGs; (d-g) The self-powered trajectory tracking integrated with EEPGs showing the records of the person's positions from "1" to "8".

3. Conclusions

In conclusions, the easiest and efficient power generator (EEPG) in the world up to now, with ultrahigh voltage was designed only by rubbing a polymer plate with hands or other objects in this work. The average output voltage and current of the driven by EEPG power generator can reach up to nearly 5000 V and 116 μA respectively only by rubbing by hands. The working principle of this special device has been firstly discussed and expounded. By utilizing evenly distributed conductive tapes and diode arrays as collectors, the electro potential difference and electro charges raised from the rubbed PMMA plate surface is being captured and accumulated. This device can not only be used for lighting but also be used for charging, even charging our mobile phone. In addition, it can be used as a self-powered system (foot switch, trajectory tracking). The EEPG power generator can collect different forms of mechanical energy like wind energy and ocean energy, when it works in a rotary mode. Traditional electromagnetic wind power generation can only be effectively generated by the wind of 5 m/s or above, but the rotary EEPG can collect the wind energy at any wind speed. This research would have great significance in the field of new energy and portable device. We expect that we can charge our mobile phones by just rubbing their backs one day. Meanwhile, we believe that the rotary EEPG can truly realize the efficient collection of green wind energy.

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Note: Patents have been filed to protect the reported inventions.