Battery-Free Charging Methods for Driving E-paper Devices

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ABSTRACT

Owing to the inherent feature of ultra-low-power-consumption, E-Paper has been regarded as important display device for future IoT environments. Herein, we proposed two kinds of advanced driving methods for E-paper devices: in-situ triboelectric and wireless power supplies within 30cm. These methods are battery-less which will facilitate future IoT display applications.

1 Introduction

Electronic paper (E-paper) is a novel kind of reflective display, which realizes display function by reflecting external light with controllable reflectance. The bistability feature of the E-paper reduces most power consumption for only driving the unit while updating the image. These features make the E-paper display of low power consumption and high outdoor contrast and thus great potential in various applications.

Currently, low power consumption is widely pursued by portable and wearable electronics. In the future network of IoT, the huge power consumption of numerous display and sensor devices is unacceptable. Utilizing other advanced power supply methods, such as in-situ energy harvesting or wireless charging brings E-papers broader application scenarios, especially when replacing battery is not convenient.

Herein, we proposed two kinds of advanced power supply methods as triboelectric and wireless charging, and their applications on E-paper's driving. A Self-powered E-paper (SPEP) integrated with a transparent triboelectric nanogenerator (TENG) was demonstrated, which achieved the driving by in-situ sliding motion on the surface of SPEP directly [1]. Besides, an E-paper sample was driven by the wireless charging module successfully, and more effects should be devoted to optimiz the performance. Furthermore, the concept and applications of E-paper combining with several power supply methods in the future were briefly discussed.

2 SEPE integrated with TENG

The TENG is an emerging technology to convert mechanical energy into electricity, through the coupling of triboelectric effect and electrostatic induction [2, 3]. High converting efficiency is the advantage of TENG , which helps to generate energy even with information input from low-frequency mechanical motions, such as touching, sliding, stretching [4-6]. Besides, the TENG can be transparent, flexible, or stretchable due to its versatility in structure and material designs. These features make TENG ideal for integrating with E-papers for self-powered displays.

In our previous work [1], a SEPE device integrated with TENG was proposed, as its structure showed in Fig. 1. A TENG was attached to the surface of E-paper as the self-powered module. When friction between tribo-positive layer and tribo-negative layer accrued, alternative current (AC) was generated through the triboelectric effect and electrostatic induction. After rectification, the AC was applied to the driving electrodes of E-paper, which changes the distribution of pigment particles inside the E-paper, in other words, the grayscale of E-paper. When the friction stopped, the grayscale of E-paper could be maintained since the bistability of E-paper, which reduced the average power consumption.

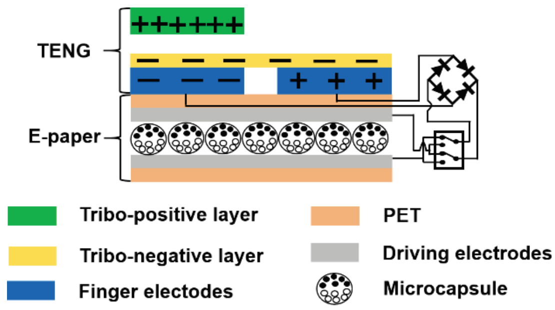

Figure. 1 The structure of SPEP device [1]

In order to optimize the performance of SPEP, the structure of TENG was adjusted for higher output current intensity, such as the number of finger electrodes, the width of each finger electrode, as showed in Fig. 2 (left). Besides, a TENG with high transmittance (85% at 550nm) was prepared for SPEP integrated with TENG to enable SPEP to display on both sides. Finally, a monochromic SPEP integrated with transparent TENG was demonstrated, as showed in Fig. 2 (right).

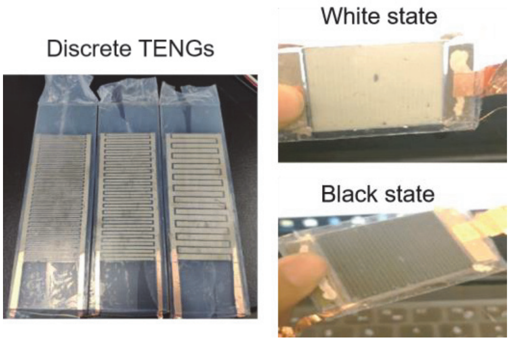

Figure. 2 Discrete TENGs (left) and the demo of SPEP integrated with transparent TENG (right, constrast radio around 8)

Further than the power supply module, TENG in SPEP device could also be the sensing module since the mechanical motion like touching and sliding could directly trigger the change of grayscale of E-paper. These features above provide a wide range of application scenarios in future IoT background.

3 E-paper driven by wireless charging module

Wireless power transmission (WPT) is a technology that allows energy transmission without any physical connection, which could greatly simplify the structure of devices because of the removal of batteries [7]. Electrical energy was first converted into the form of the electromagnetic wave by the emitting module in order to transfer in medium (usually air). Afterward, the electromagnetic wave was received and converted into electrical energy again by the receiving module. Regarding the transmission distance, WPT could be categorized into far-field [8] and near-field WPT [9]. Near-field WPT processes high transfer efficiency in a short distance of several centimeters. However, in order to pursue various applications in the future, especially in the background of IoT, far-field WPT was essential for wireless power supply in relatively long distances [10, 11].

Since the transfer loss in the air, the transfer efficiency of far-field WPT is unsatisfied currently, which leads to the limitation of far-field WPT in applications. However, some devices with low power consumption as E-paper could still be charged by far-field WPT within acceptable energy loss.

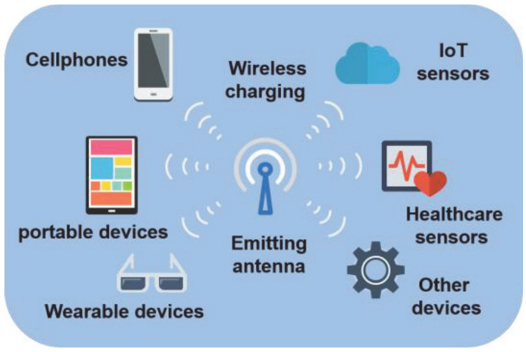

Figure. 3 Far-field WPT applications in future

Herein, an E-paper sample driven by microwave wireless charging module was proposed, as showed in Fig. 4. A microstrip antenna was utilized in this wireless charging module. It should be noted that E-paper was bistable, which meant that the display contends would be maintained without power supply. This feature means that the driving of E-paper with the wireless charging module is an instant process instead of a constant process compared with other display devices. Thus, the power consumption of E-paper was ultra-low, which made the poor transfer efficiency of far-field WPT acceptable in applications.

In future research, the wireless charging distance should be extended to be more practical, and the driving system should be optimized for better performance. Moreover, the transparent antenna may be a good candidate for the integrated wireless charging module of display in the future.

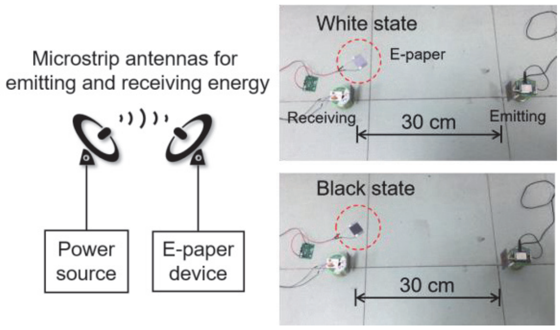

Figure. 4 E-paper driven by wireless charing module

4 E-paper with several power supply methods in future applications

In Section 2 and 3, two kinds of power supply methods for E-paper were discussed, both of which made the best use of the bistability feature of E-paper and provided it with various application scenarios. Furthermore, the concept of E-paper with several power supply methods was discussed in this Section.

From Section 2, TENG integrated on the surface of E-paper was not only the power supply module but also could be a self-powered sensing module, which enabled the human-machine interaction by touching. Besides, the wireless charging module enabled the control of E-paper devices without manual operating, greatly reducing the maintenance cost, especially for numerous devices. Thus, E-paper with these two power supply methods would have more universal applications in the future since the various power supply and operating methods. It could be predicted that E-paper with several power supply methods would be one of the significant components in future IoT networks.

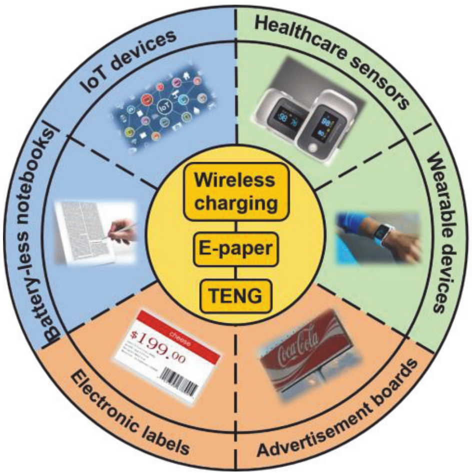

Figure. 5 Various applications of E-paper with several power supply methods

5 CONCLUSIONS

In conclusion, two kinds of power supply methods for E-paper, as in-situ triboelectric and wireless power supplies within 30cm, were proposed with recent works. These methods can be used to drive the E-paper without using battery or bulky power supply modules, which provides the E-paper device with a promising future for IoT applications.

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