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Usage of nanogenerators as active sensors in IoT

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Abstract:
In this paper we propose the review of currently used nanogenerators that can be used as active sensors. Because the Wireless sensor network (WSN) plays an important role in the part of Internet of Things (IoT) in sensing, tracking and monitoring, it is an important task to design the WSN nodes as energy efficient, smart and autonomous units. Most of WSN nodes need an external power source supply such as Li-Ion battery which is limiting aspect in practical applications and environmental waste. Nanogenerators can lead to self-powered WSN nodes.

INTRODUCTION

The Internet of Things (IoT) is a novel paradigm that is rapidly gaining ground in the scenario of modern wireless technology. The main strength of the IoT idea is the high impact it will have on several aspects of everyday-life and behavior of potential users. The things composing the IoT will be characterized by low resources in terms of both computation and energy capacity [1].
Wireless sensor network (WSN) plays an important role in the part of IoT in sensing, tracking and monitoring. It is an important task to design the WSN nodes as energy efficient, smart and autonomous units in many applications. Because of the WSN is usually large scale sensor network and nodes are not often easily accessible. A sensor node consumes energy while collecting, processing, and transmitting receiving data [2], so it's autonomous and energy efficient behavior is big advantage.

NANOGENERATOR

Nanogenerator is a device that converts mechanical or thermal energy into electricity, it can be used as energy harvesting device as well as self-powered active sensor. Triboelectric and piezoelectric nanogenerator can be used to sense/harvest the ambient energy such as vibration, motion, strain, tensile, pressure or another mechanical force, because it generates output voltage and current while mechanically stressed. Triboelectric nanogenerator can be also used as self-powered active chemical sensor. Pyroelectric nanogenerator can be used as active sensor for measuring temperature variation.
Nanogenerator can be made from low-cost organic materials.

Triboelectric

Triboelectric nanogenerators (TENGs), featuring high energy harvesting efficiency, an unambiguous process route, low manufacturing cost, high system reliability and stability, and environmentally friendly materials, have been invented for mechanical energy harvesting from the ambient environment [3]. TENG utilizes the triboelectric effect to convert the mechanical energy into electricity due to charge transfer between two thin organic/inorganic films that exhibit opposite tribo-polarity.
There is wide range of usage the TENG as active sensor or energy harvesting device in a lot of applications such as human-machine interfaces (HMIs), tactile sensors, micro liquid/gas flow sensor, pressure detection, wind energy harvesting device, biomechanical energy harvesting/sensing devices etc.

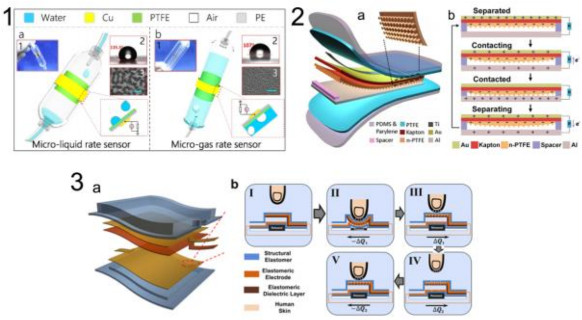

Fig. 1: Examples of using the TENG as: **1a**-Micro-liquid rate sensor [5], **1b**-Micro-gas rate sensor [5], **2**-Biomedical monitoring device (**2a**-Exploded view of structure, **2b**-Working mechanism in a vertical contact-separation mode) [3], **3**-Elastomeric TENG for harvesting/sensing the keyboard buttons (**3a**-Schematic design of structure, **3b**-Schematic illustrations showing the proposed working principle of the elastomeric TENG) [4].

Piezoelectric

The piezoelectric nanogenerator (PENG) working principle is based on piezoelectric effect. Under mechanical deformation, materials lacking inversion symmetry or with polarization domains produce polarization charges at surfaces/interfaces, known as the piezoelectric effect. This has been widely used for electromechanical sensing, actuation, and energy harvesting [6]. Since the concept of ZnO nano-wires PENG (2006), the understanding of the fundamental working principles improves, nowadays the PENG technology presenting its potential as miniaturized power sources.

Piezoelectric nanogenerators have wide variety of usage such as implantable biomedical device, smart wearable sensor or the self-powered wearable gesture sensor. The group led by prof. Zhong Lin Wang developed the ultrathin, wearable piezoelectric device for detecting human finger gestures.

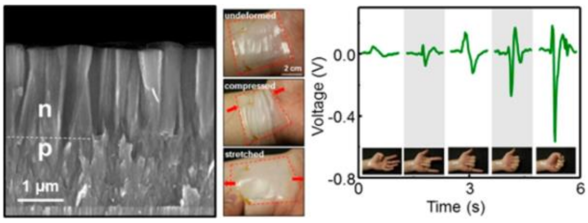

Fig. 2: Example of using the PENG as self-powered ultrathin wearable gesture sensor [6].

Pyroelectric

Pyroelectric nanogenerator is suitable for self-powered sensor for detecting change in temperature. It is based on single lead zirconate titanate (PZT) micro/nanowire that is placed on a thin glass substrate and bonded at its two ends, and it is packaged by polydimethylsiloxane (PDMS) [7]. The working principle is based on converting the external thermal energy into an electrical energy by using nano-structured pyroelectric materials that utilizes the pyroelectric effect. When the pyroelectric nanogenerator becomes to contact with heat source, the output voltage linearly increases with an increasing rate of change in temperature that can be recorded, processed and sent wirelessly.

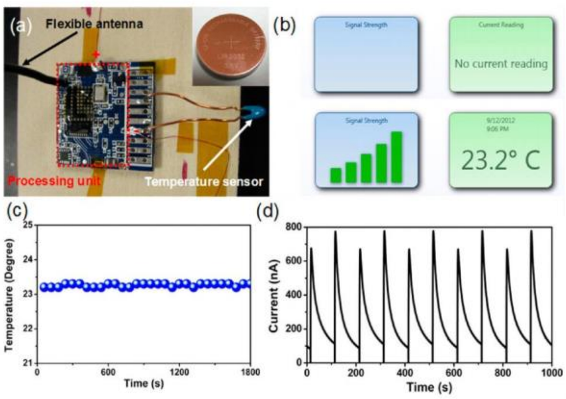

Fig. 3: Wireless temperature sensor. (b) The obtained temperature signals when the wireless temperature sensor was turned off and on. (c) The obtained temperature data in half an hour, where the temperature value was recorded in every 1 min. (d) Output current of the PENG. (Image source: [7]).

CONCLUSIONS

WSN are rapidly growing every day as well as intelligent systems connected to IoT scenario. However, most of the sensor nodes are still depending on external power source such as Li-Ion battery. The battery can be restrictive in some applications such as large scale sensor networks where the maintenance of battery can result in data loss, big expense and environmental waste. The usage of nanogenerators as active sensors and power harvesting device can led to fully autonomous and maintenance-free behavior of the WSN nodes.

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