



Research Highlight

The first technology can compete with piezoelectricity to harvest ultrasound energy for powering medical implants

Han Ouyang^{a,b}, Zhou Li^{a,c,d,*}^a CAS Center for Excellence in Nanoscience, Beijing Key Laboratory of Micro-Nano Energy and Sensor, Beijing Institute of Nanoenergy and Nanosystems, Chinese Academy of Sciences, Beijing 100083, China^b Beijing Advanced Innovation Centre for Biomedical Engineering, Key Laboratory for Biomechanics and Mechanobiology of Ministry of Education, School of Biological Science and Medical Engineering, Beihang University, Beijing 100083, China^c School of Nanoscience and Technology, University of Chinese Academy of Sciences, Beijing 100049, China^d Center on Nanoenergy Research School of Physical Science and Technology, Guangxi University, Nanning 530004, China

Sustainable operation of implanted medical devices is essential for clinic applications. However, limited battery capacity is a key challenge for most implantable medical electronics [1]. Higher-capacity battery is not an ideal choice, because battery capacity is usually linearly dependent on battery volume [2]. New energy harvesters have been developed as promising alternative solutions, which extracted energy from the ambient environment and biosystem for powering implantable devices [3]. However, the energy reclaimed from body and ambient environment also have power limitation, such as thermal gradient and bioelectric potential. Delivery ultrasound or RF energy into the body and generate electrical power by a converter is a reliable solution.

Nowadays, ultrasound is widely used to diagnose and monitor diseases. The piezoelectric ultrasonic transducer based on lead zirconate titanate (PZT), PMN-PT and BaTiO₃ (BT) [4] etc., can convert ultrasound energy to electricity. Some demonstrations reported piezoelectric ultrasonic energy harvester for enabling self-powered implantable biomedical devices [5].

Triboelectric nanogenerator (TEG) has been developed since 2012 by Prof. Zhong Lin Wang [6]. It is a new technology that can convert mechanical energy into electricity. Implantable TENG [7] and biodegradable TENG [8] were developed to power implanted devices or directly work as a stimulator. TENGs have also been implanted beside rat stomach as a self-powered vagus nerve stimulation device [9] and beside porcine heart as a power source of symbiotic cardiac pacemaker [10]. Fig. 1 shows the research roadmap of implantable triboelectric energy harvester and self-powered implantable medical system based on TENG.

Recently, a significant breakthrough from Prof. Sang-Woo Kim's group in Sungkyunkwan University was reported in *Science*, for overcoming the limitation of present ultrasound energy harvest technology (Fig. 2). They proposed a new device [11] based on TENG, which can effectively harvest the ultrasound mechanical energy *in vivo* and in liquids. The ultrasound can drive the vibrating and implantable triboelectric generator (VI-TEG) to generate electric power. In their work, they recharged a lithium-ion battery at a rate of 166 $\mu\text{C/s}$ in water. The voltage and current generated *ex vivo* by ultrasound energy transfer reached 2.4 V and 156 μA under porcine tissue.

This VI-TEG device achieved the sustainable power generating *in vivo* and in liquids. This work changed the status quo that triboelectric devices can only harvest the limited biomechanical energy *in vivo*. The electric current improves 1000 times by using the ultrasound waves. Lithium ion battery (0.7 mAh) recharged to 4.1 V in 4.5 h by the VI-TEG, with an average charging rate of 166 $\mu\text{C/s}$. Thus, the triboelectric device can meet the power requirements of most implanted devices. For example, the daily consumption of cardiac pacemakers is 0.2–0.3 mAh. These encouraging findings show that VI-TEG can compete with piezoelectricity, which is the first time, to harvest ultrasound energy for powering medical implants.

With the contribution from worldwide researchers, the triboelectric nanogenerator technology expects to provide more promising method to harvest ultrasound energy *in vivo*, with advantages of wide choice of materials, high outputs, light weight, excellent durability and low cost [12]. Implantable TENG also shown remarkable mechanical durability and cytocompatibility [10], which are determinant for long-term implantable devices.

* Corresponding author.

E-mail address: zli@binn.cas.cn (Z. Li).

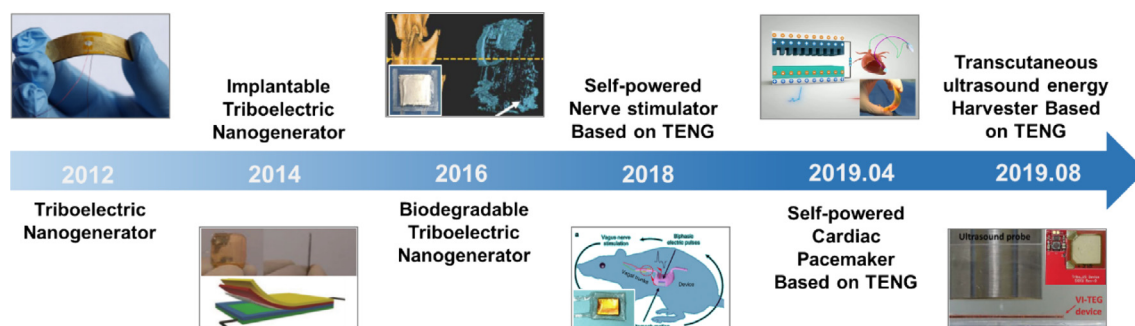


Fig. 1. Research roadmap of implantable triboelectric energy harvester and self-powered implantable medical system based on TENG [6–11]. Copyright © 2014 John Wiley and Sons. Copyright © 2012 Elsevier. Copyright © 2016, 2019 AAAS. Copyright © 2018, 2019 Springer Nature.

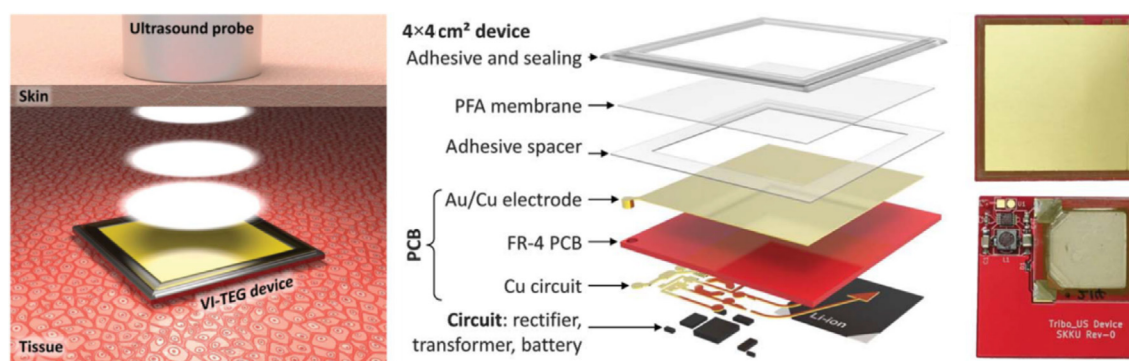


Fig. 2. Illustration and photo of US energy harvesting under skin using the VI-TEG [11]. Copyright © 2019 AAAS.

Conflict of interest

The authors declare that they have no conflict of interest.

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Han Ouyang received his Bachelor's Degree from Southwest University of Science and Technology in 2014, and Doctor's Degree in University of Chinese Academy of Sciences in 2019. He is currently a Postdoctor Researcher in Beijing Advanced Innovation Centre for Biomedical Engineering, Beihang University. His research interests mainly focus on self-powered wearable and implantable medical devices, nanogenerators, nanomaterials.



Zhou Li received his Bachelor's Degree from Wuhan University in 2004, and Doctor's Degree from Peking University in Department of Biomedical Engineering in 2010. He joined School of Biological Science and Medical Engineering of Beihang University in 2010 as an Associate Professor. Currently, he is a Professor in Beijing Institute of Nanoenergy and Nanosystems, Chinese Academy of Sciences. His research interests include nanogenerators, *in vivo* energy harvesters and self-powered medical devices, biosensors.