



Nanogenerators and piezo/tribo-tronics



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1. Introduction

The fourth international conference on nanogenerators and piezo-tronics (NGPT 2018) was held at Sungkyunkwan University (SKKU) in Korea from May 8 to 11, 2018, which attracted over 400 participants from 17 countries and regions with more than 300 papers contributed to the conference. The aim of NGPT 2018 conference is the fundamental understandings and development of nanomaterials and systems capable of converting mechanical energy, and coupling effects between piezo-electric polarization and semiconductors. This special issue published in *Nano Energy* collects some selected papers presented in the conference to comprehensively review and communicate some of the most important progresses in the fields. These papers mainly belong to the following categories.

In recent days, the development of devices in various scales (nano-to micro-) and thereby systems is vital for sensing and monitoring various environmental activities such as medical, biological, chemical, acoustic and tactile information. Concerning necessity of multiple functions, it is highly desirable for devices to be powered by itself, so called self-powered system. Nanogenerators (NGs), referred as a mechanical energy harvester from the working environment through piezoelectric and triboelectric phenomena, have been proposed as self-powered energy sources for micro/nano-systems. Since mechanical energy is triggered in our living environment, NGs are appropriate energy source to power future devices and systems. In 2006, nanogenerators using piezoelectric nanowires were first proposed by Prof. Z. L. Wang. These piezoelectric NGs are very flexible and sensitive so that they can harvest energy from biomechanical movement or electromechanical coupling of daily life. NG-based self-powered sensor possesses great potential for human-machine interfacing, sound, security and healthcare monitoring. Triboelectric nanogenerators (TENGs) have been developed on the basis of triboelectrification and electrostatic induction in 2012 by Wang's group. TENGs have represented as promising mechanical energy harvesters due to their numerous advantages, including extremely high output voltage, low cost, stability, simple structure and manufacturing method, as well as environmentally friendly design. Structural designs of TENGs have been proposed that relies on various types of mechanical motions such as contact, sliding, rotation and vibration aiming at

efficient energy harvesting in various circumstance. In addition, TENGs can serve as self-powered sensors which detect touch, pressure, water droplets, wind and environmental stimulation without an external power source.

Other than serving as a powering source, those features including piezo/triboelectric effects have reported to be applicable for controlling electronics. As for the semiconductor devices, the formation of junctions at material interface is usually the essential part for realizing function of the device. The feature of piezotronics originates from a regulation of charge carrier transport through the modulation of the band structure at contact interfaces. The piezotronic effect first proposed in 2007 by Wang is about how strain tunes the carrier transport/separation/recombination characteristics in devices such as a piezotronic sensor, LEDs and solar cells based on piezoelectric semiconductors. The idea of piezotronics evolves from the vertically aligned nanowire arrays to, recently, 2D materials. In this regard, piezotronics has great potential regarding with diversity in application including human-machine interface, smart MEMS, nanorobotics and sensor applications. By further introducing photo excitation, piezo-phototronic effect is to use the piezopotential to tune/control the charge generation, separation, transport and/or recombination at junction for achieving superior optoelectronic property, which has also been proposed in 2010. By establishing the direct interaction mechanism between the external strain and electronic/photoelectronic devices, the piezo-phototronics have potentially contributed to improving efficiency in inorganic/organic hybrid light-emitting diodes, photovoltaic cells, and chemical sensing feature.

As inspired by the ideas of gating effect of the piezoelectric potential, the surface charges induced by contact-electrification (triboelectricity) can also serve as a gate voltage for controlling the carrier transport in a field-effect transistor device. Tribotronics introduced in 2015 is referring the devices using the electrostatic potential created by triboelectrification to tune/control electrical transport in semiconductors for characterizing any mutual interaction. This can be an effective means for converting a biomechanical action into an electronic control, which was the original idea for introducing the tribotronics. Tribotronics has made rapid research progress and numerous tribotronic functional devices, such as tribotronic tactile switching

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system, memory, hydrogen sensor and phototransistor, have been studied with a variety of materials spectrum.

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