# Maxwell's displacement current governed triboelectric nanogenerator for self-powered systems and blue energy

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## Abstract

Contact electrification (triboelectrification) effect, the most fundamental effect for electricity, has been known for over 2600 years since ancient Greek time, but its scientific mechanism remains unclear. The study of triboelectrification is recently revived due to the invention of the triboelectric nanogenerators (TENGs) by using the coupling of triboelectrification and electrostatic induction effects, which is the most effective approach for converting tiny mechanical energy into electricity for powering small sensors. TENG is playing a vitally important role in the distributed energy and self-powered systems, with applications in internet of things, environmental/infrastructural monitoring, medical science, environmental science and security. In this talk, we first present the physical mechanism of triboelectrification for general materials. The charge transfers between a case such as a metal-dielectric was attributed to the electron transfer between the filled states up to the Fermi level as governed by the Fermi-Dirac function. For the case of dielectric-dielectric, the charge transfer was attributed to between the surface states of the two materials. For a general case that the system cannot be described by a state surface model, an electron cloud-potential well model is proposed based on the overlap of electron wave functions across two atoms, which can be generally applied to explain all types of CE in conventional materials. Secondly, the fundamental theory of the TENGs is explored based on the Maxwell equations. In the Maxwell's displacement current proposed in 1861, the term $\varepsilon\partial\boldsymbol{E}/\partial t$ gives the birth of electromagnetic wave, which is the foundation of wireless communication, radar and later the information technology. Our study indicates that, owing to the presence of surface polarization charges present on the surfaces of the dielectric media in TENG, an additional term $\partial\boldsymbol{P}_s/\partial t$ should be added in the Maxwell's displacement current, which is the output electric current of the TENG. Therefore, our TENGs are the applications of Maxwell's displacement current in energy and sensors. TENGs have three major application fields: micro/nano-power source, self-powered sensors and blue energy. We will present the applications of the TENGs for harvesting all kind mechanical energy that is available but wasted in our daily life, such as human motion, walking, vibration, mechanical triggering, rotating tire, wind, flowing water and more. Then, we will illustrate the networks based on triboelectric TENGs for harvesting ocean water wave energy, for exploring its possibility as a sustainable large-scale blue energy. Lastly, we will show that TENGs as self-powered sensors for actively detecting the static and dynamic processes arising from mechanical agitation using the voltage and current output signals.

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