Maxwell's Equations for a Mechano-driven Media System Theory Fundamental Theory and Experimental Verifications

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Abstract— The advent of the Internet of Things (IoT), robotics, and artificial intelligence presents new challenges, one of which is the sustainable powering of numerous electronic devices that are widely distributed, highly mobile, energy-efficient, yet vast in number. This energy issue is precisely the energy challenge we face in this new era. In 2006, we invented the piezoelectric nanogenerator, and in 2012, we first invented the triboelectric nanogenerator, proposing the original concepts of self-powered systems and blue energy. This new energy technology, applicable to the IoT, sensor networks, and the big data era, opens a new chapter in human energy utilization, offering a novel approach for achieving energy self-sufficiency and self-powering in micro/nano electronic systems, the IoT, and sensor networks. Currently, $> 22,000$ scientists across 100 countries and regions worldwide are following our research on nanogenerators.

To quantify the output power of nanogenerators, we began investigating electrodynamic problems in moving media. In classical electrodynamics, by motion, it always means a relative movement of two observers in inertia reference frames, so that the covariance of the Maxwell's equations is preserved respectively in two spaces under Lorentz transformation. The energy is thus conservative for the electromagnetic system. The theory for describing the electromagnetic behavior of the charged particles in vacuum space can be well described using the special relativity because of the invariance of the speed of light in vacuum. However, for engineering applications, the media have shapes and sizes and may move with acceleration, and a system may have multiple moving objects that may be correlated or independently under external mechanical triggering. This talk presents the theory for describing the electromagnetic phenomena in this electro-magnetic-mechano system. We mainly introduce the Maxwell's equations for a mechano-driven media system (MEs-f-MDMS) under low-speed approximation ($v \ll c$). We concluded that, the MEs-f-MDMS are required for describing the electrodynamics inside a moving object that moves not only with accelerated translation motion but also has rotation motion. The classical Maxwell's equations are to describe the electrodynamics in the region where there is no local medium movement. The full solutions of the two regions satisfy the boundary conditions, so that the rotation of the object affects the electromagnetic field at vicinity. The theoretical approaches for solving the MEs-f-MDMS are also presented.

Dr. Zhong Lin Wang is a preeminent physicist and materials scientist whose groundbreaking work has revolutionized the fields of nanotechnology, energy harvesting, and self-powered systems. He currently serves as the Director of the Beijing Institute of Nanoenergy and Nanosystems and holds the distinguished titles of Regents' Professor and Hightower Chair (Emeritus) at the Georgia Institute of Technology. Dr. Wang is widely recognized as the pioneer of the nanogenerators field, which has enabled advancements in distributed energy, self-powered sensors, and large-scale blue energy. Additionally, he coined and developed the fields of piezotronics and piezo-phototronics, which have significant implications for third-generation semiconductors.

Dr. Wang's scientific impact is unparalleled. Among 230,000 scientists across all fields worldwide (Top 2%) as ranked by Elsevier and Stanford, he is ranked **#1** simultaneously for career-long scientific impact and single-year scientific impact consecutively from 2019–2024. He is also ranked **#1** respectively in Materials Science and nanotechnology. His research has garnered over 510,000 citations on Google Scholar, with an extraordinary h-index of 340, underscoring his immense influence and contributions to science.

Throughout his illustrious career, Dr. Wang has received numerous prestigious awards, including the Global Energy Prize (2023), the Albert Einstein World Award of Science (2019), the ENI Award in Energy Frontiers (2018), the James C. McGroddy Prize in New Materials from the American Physical Society (2014), and the MRS Medal from the Materials Research Society (2011). His groundbreaking work has earned him memberships and fellowships in some of the world's most esteemed scientific academies, including the UK Royal Academy of Engineering, the Chinese Academy of Sciences, US National Academy of Inventors, the European Academy of Sciences, the European Academy of Engineering, the Korea Academy of Science and Technology (as a foreign member), the Academia Sinica, and the Canadian Academy of Engineering (as an International Fellow).

Wang's pioneering contributions to nanogenerators, piezotronics, and self-powered systems have not only advanced fundamental science but also paved the way for transformative technologies in energy harvesting, sensing, and semiconductor development. His exceptional scientific impact, numerous accolades, and leadership in the global scientific community underscore his status as one of the most influential materials scientists of our time.

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