Friction

Editorial

Editorial for Special Issue on Contact Electrification

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Contact electrification is a pervasive and complex phenomenon that has been known for more than 2,600 years, and its mechanisms have been debated for decades but remain inconclusive. Moreover, contact electrification has long been considered an unpredictable effect, which has hindered its application. In recent years, the study of contact electrification is in full swing, its mechanism has been analyzed in great depth, and its role in tribology, chemistry, biology, etc., has been increasingly emphasized. Based on the phenomenon of contact electrification, various sensing and energy harvesting devices have been designed. In the past decade, research on the mechanism and application of contact electrification has made great progress, and this phenomenon has become a hot spot in the tribological research community.

In order to further promote the development of contact electrification research, we have organized a special issue on contact electrification in *Friction*, aiming to bring together high-quality papers, both experimental and theoretical, on the basic science of contact electrification and its related phenomena. We invited a number of distinguished and specialized scientists and experts in contact electrification to contribute their work to the Special Issue on Contact Electrification. As a result, 11 papers have been compiled to provide an update on contact electrification and to reveal information on the most important developments in the field. These papers include:

- Two review articles on the application of triboelectric and electrostatic effect, and the techniques for exploring contact electrification.
- Eight research papers on the liquid flow sensing strategies based on contact electrification at liquid–solid interface, the sedimentation-driven method for fabricating the bifunctional single-layer triboelectric nanogenerator, the DNA-based recyclable moist-electric generator, the dynamics of electron transfer in triboelectrification, a quantitative theoretical model of triboelectric charge transfer considering flexoelectricity, an approach for monitoring lubrication and wear by triboelectrification under grease lubrication, the surface chemistry isotope effect on performance and durability of silicon-based tribovoltaic generator, and the interfacial charging performances of electrode in aqueous solution.
- One short communication on the tribo-informatics empowered research on triboelectrification.

Professor Xiangyu Chen's group provides a comprehensive understanding of the application progress of the triboelectric effect. They provide an overview of the basic theoretical mechanisms of triboelectric effect and a detailed review of the various applications of triboelectric effects and electrostatic induction in different fields, including electrostatic adsorption, electret formation, electrostatic self-assembly, triboelectric generators, self-powered sensor, and mechanical force catalysis. The authors explore different triboelectric materials and their preparation and modification methods for different application scenarios, discuss the prospects and challenges of triboelectric effects, and emphasize the necessity of further research and development of triboelectric effects in specific fields, such as energy, environmental sciences, and medicine, which provide valuable insights for future scientific research and practical implementation. (https://doi.org/10.26599/FRICT.2025.9440893)

Professor Tianmin Shao and his cooperators explore the field of contact electrification with a focus on methods for measuring transferred charge density on solid surface. Six experimental and first-principles computational methods are presented, including the parallel plate system, Faraday cup method, force equilibrium methods, trajectory tracking method, electrostatic charge probe, and atomic force microscopy (AFM) based methods, aiming to promote their proper use and to inspire the design of new methods. The authors analyze the shortcomings of the current research methods for contact electrification and present an outlook on the future development of the methods, pointing out the future trend of ultrafast and atomic-level precision measurements of surface charge. (https://doi.org/10.26599/FRICT.2025.9440968)

Professor Augusto Lima Burgo's group studies the tribo-charging between polytetrafluoroethylene (PTFE) and aqueous solutions, alcohols, and finds that the liquid flow in PTFE tubes will obtain excessive positive charge, and the pH of aqueous solutions is no effect on tribo-charging between liquid and PTFE in a wide range, and the charge accumulation of alcohols has an inverse relationship with the length of the carbon chain. Further, the authors designed a sensor based on the tribo-charge transfer law between the liquid and the PTFE tube by using graphite-based nanocomposite material as a non-contact induction electrode near the tube for flow sensing. (https://doi.org/10.26599/FRICT.2025.9440892)

Professor Dongwhi Choi's group proposes a one-step fabrication method for a single-layered bifunctional composite film-based triboelectric nanogenerator (BF-TENG) driven by the sedimentation of a sol-state precursor, for the extremely facile

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conversion of various ordinary items into energy harvesters. The maximum peak power of the BF-TENG is approximately 1.18 mW/m^2 when the contact frequency is 8 Hz, and the connected load resistance is 9 MΩ. The authors further study the electrical performance of BF-TENGs in response to various physical stimuli considering the mechanical energy sources available in daily life. And they convert ordinary surfaces such as desks and human skin into BF-TENGs through a single coating procedure and harvesting energy to power an electric device. (https://doi.org/10.26599/FRICT.2025.9440918)

Professor Liangti Qu and his cooperators report a DNA porous membrane-based moist-electric generator (DNA-MEG) capable of achieving an output performance of 1.2 $\mu A/cm^2$, 0.3 V, and 0.36 $\mu W/cm^2$ in air at 90% relative humidity. Importantly, due to the excellent water solubility of the DNA-based material, the DNA membrane in the DNA-MEG can be easily recycled after the device is damaged, and the regenerated device still maintains a very good power generation output performance. This stable and recyclable DNA-MEG will provide new ideas for the design of wet power generation devices, greatly expanding the application areas and paving the way for the development and application of environmentally friendly energy harvesting devices. (https://doi.org/10.26599/FRICT.2025.9440927)

Professor Xuefeng Xu et al. observe the charging-induced electric potential on the friction surface and the discharging-induced light emission from the contact region between insulators simultaneously. They find that the potential variation is very different between the charging and discharging conditions, which is attributed to the huge difference in mass between electrons and positive ions produced in the discharging process. Further, the authors propose a theoretical expression for the temporal evolution of the surface potential during triboelectrification process. Their work offers a new perspective for understanding the electron transfer dynamics in triboelectrification and provides potential applications in numerous fields involving triboelectrification. (https://doi.org/10.26599/FRICT.2025.9440931)

Professor Laurence D. Marks' group analyzes the contact between a metal asperity and a semiconductor, including contributions from the depletion zone of the semiconductor and from flexoelectric polarization that arises due to the strain gradients at asperity contacts. They discuss and calculate the free charges involved in charge transfer. As a result, authors develop a quantitative model for triboelectric charge transfer, which details how charge transfer scaling with contact parameters, and the relative influence of flexoelectricity. It is shown that the model agrees with various trends in multiple classes of triboelectric experiments. This work has important theoretical implications for understanding charge transfer at frictional interfaces. (https://doi.org/10.26599/FRICT.2025.9440937)

Professor Daoai Wang and his cooperators design a new lubrication *in-situ* monitoring system, which can monitor the lubrication and wear state of friction pairs through triboelectrification. Their lubrication *in-situ* monitoring system can measure the tribo-current and friction coefficient between two frictional surfaces simultaneously in high vacuum, and can be used to explore the intrinsic relationship between triboelectricity and friction coefficient curves. According to the corresponding relationship between the triboelectric current and the friction and wear status of the friction pair, the system can be used to monitor the operating status of the friction pair in real time through triboelectric signals. When the mechanical friction pair is worn, the early warning system will send out sound and light alarm signals and send real-time warnings to the mobile terminal through the Internet of Things, providing a new and reliable method for real-time monitoring of friction and wear of grease-lubricated machinery. (https://doi.org/10.26599/FRICT.2025.9440938)

Professor Simone Ciampi's group refines the wet chemical etching protocols to achieve deuterium-terminated and oxide-free Si (111) crystals. The authors conduct a systematic comparison between Si–D– and Si–H based Schottky tribovoltaic nanogenerators (TVNG). Owing to the superior ability of Si–D to mitigate anodic decomposition of the underlying substrate, substituting hydrogen with its heavier isotope can enhance the device longevity. Moreover, the authors unveil the presence of a flexoelectric component contributing to the TVNG output, suggesting the potential significance of strain gradients in the mechanical-to-electrical energy conversion mechanism within a Schottky TVNG. Their findings underscore the necessity of minimizing or addressing strain, and potentially shear, when conducting routine nanoscopic electrical measurements on metal–semiconductor junctions. (https://doi.org/10.26599/FRICT.2025.9440939)

Professor Ying Liu's group prepares silicon nitride (Si_3N_4) composites coated electrode by laser machining and magnetron sputtering, and proposes an interfacial charging mechanism, which is interpreted by the ion absorption of ceramic substrate and the conduction behaviors of electrode layers. The authors investigate the relationship between the convergent profile and zeta potential, propose a design criterion for self-sensing friction pairs for enhancement of interfacial charging performances. Their work builds a bridge between the interface charging mechanism and the self-sensing application of liquid–solid triboelectric behaviors based on streaming current input. (https://doi.org/10.26599/FRICT.2025.9441057)

Professor Zhinan Zhang's group proposes a new concept combining tribology and informatics, which is named as tribo-informatics. The authors discuss the development trends in triboelectrification and tribo-informatics, propose a method for information representation in triboelectric systems from a tribo-informatics perspective, and suggest a research approach based on tribo-informatics to achieve research goals, aiming to enable researchers to collect, process, and analyze tribological information more effectively to achieve specific research objectives. Their work not only provides a foundation for future research into tribological systems but also paves the way for practical implementations to meet the growing demand for renewable energy solutions. (https://doi.org/10.26599/FRICT.2025.9441045)