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SHORT COMMUNICATION

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# Triboelectric nanogenerator (TENG)-driven water splitting for green hydrogen production

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## Background of the Promising Technology

Triboelectric nanogenerators (TENGs) are innovative energy harvesting devices that can convert mechanical energy into electrical energy through the triboelectric effect. The triboelectric effect refers to the generation of an electric charge when two different materials come into contact and then separate due to the redistribution of electrons between them. This effect has been extensively explored for various applications, including TENG-driven water splitting [1-3].

Water splitting is a chemical process that involves the decomposition of water into its constituent elements, hydrogen ($H_2$) and oxygen ($O_2$), through the application of an external energy source. The resulting hydrogen can serve as a clean and sustainable fuel for various applications, such as power generation and transportation, while oxygen can be utilized in various industrial processes. TENG-driven water splitting aims to utilize the mechanical energy generated by TENGs to power the water splitting process. By integrating TENGs with appropriate catalysts and electrodes, the mechanical energy produced by the TENG can be directly converted into the chemical energy required for water splitting.

## Typical Steps for the Process

The TENG-driven water splitting process involves four typical steps, namely mechanical energy harvesting, charge accumulation and separation, electrical energy generation, and finally water electrolysis. TENGs are designed to harvest mechanical energy from external sources such as human motion, vibrations, or flowing water [4,5]. When these energy sources are applied to the TENG, it undergoes contact and separation cycles, resulting in the generation of electrical charges. The TENG consists of two different materials with contrasting triboelectric properties. When these materials come into contact and separate, electrons are transferred between them, leading to the accumulation of charges on their respective surfaces. The charge separation is facilitated by the triboelectric effect. The accumulated charges on the TENG surfaces create an electric potential difference, which can be harnessed to generate electrical current or voltage. This electrical energy is used to power the subsequent water splitting process. The electrical energy generated by the TENG is supplied to the water splitting system, which typically includes an electrolyzer. The electrolyzer contains electrodes, usually made of materials such as platinum that act as catalysts to facilitate the water splitting reaction. The electrical energy drives the electrolysis process, causing water molecules to dissociate into hydrogen and oxygen gases.

## Advantages for the New Technology

TENG driven water splitting offers several distinct advantages. Firstly, it utilizes a renewable energy source by harnessing mechanical energy from ambient sources such as human motion or flowing water, ensuring a sustainable and continuous energy supply for the water splitting process. Secondly, TENGs are scalable and portable, allowing for their integration into various systems and applications, ranging from small-scale portable devices to large-scale industrial implementations. This flexibility enables TENG-driven water splitting to be adaptable to diverse settings and energy demands [6,7]. Additionally, TENGs can harvest energy from ambient mechanical sources, reducing dependence on external power sources and batteries, thereby promoting self-sufficiency and minimizing reliance on traditional energy infrastructure [8,9]. Moreover, TENG-driven water splitting is environmentally friendly, as it produces clean hydrogen fuel without emitting greenhouse gases or pollutants, contributing to the mitigation of climate change [10]. Cost-effectiveness is another advantage, as TENGs can be fabricated using low-cost materials and manufacturing techniques, and the elimination of external energy sources reduces operational costs over time [11]. Furthermore, TENG-driven water splitting offers independence from grid infrastructure, making it suitable for remote or off-grid locations, where access to electricity is limited. Finally, TENGs can be integrated into existing water systems, optimizing resource utilization and enhancing overall system efficiency. In summary, TENG-driven water splitting combines renewable energy utilization, scalability, portability, versatility, low environmental impact, cost-effectiveness, independence from grid infrastructure, and integration with existing systems, making it a promising and advantageous approach for sustainable hydrogen production and clean energy generation.

## Challenges and Prospects

TENG driven water splitting still faces several challenges that need to be addressed for its successful implementation. Firstly, improving the overall energy conversion efficiency of TENGs is a significant challenge. Losses can occur during mechanical energy harvesting, charge separation, and electrical energy conversion, leading to reduced system performance [12]. Enhancing these conversion processes and minimizing energy losses are crucial for maximizing the efficiency of TENG-driven water splitting systems. Secondly, finding

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suitable catalyst materials for efficient water splitting reactions is essential. Identifying cost-effective, abundant, and stable catalysts that can facilitate the water electrolysis process and reduce energy requirements is a key challenge in optimizing TENG-driven water splitting systems [13]. Additionally, scalability and durability are important considerations. Ensuring that TENGs can be produced in large quantities, with consistent performance and long-term reliability, is necessary for the widespread adoption of TENG-driven water splitting technology. Furthermore, system integration and engineering challenges need to be addressed to effectively connect TENGs with water splitting devices and optimize their overall performance. Moreover, the availability and quality of mechanical energy sources can vary, posing challenges in achieving reliable and consistent energy generation. Lastly, cost reduction remains an important challenge. Although TENGs have the potential for cost-effective energy harvesting, further advancements are required to reduce material costs, manufacturing expenses, and overall system costs to make TENG-driven water splitting economically viable on a larger scale. Addressing these challenges through continued research and development efforts will be crucial for realizing the full potential of TENG-driven water splitting technology.

TENG driven water splitting holds significant prospects for the future of sustainable energy production. One of the key prospects lies in its ability to harness renewable energy from mechanical sources. TENGs can capture and convert mechanical energy from ambient sources such as human motion, vibrations, or flowing water, providing a continuous and sustainable energy supply for water splitting. This makes TENG-driven water splitting an attractive option for decentralized and self-sufficient hydrogen production, reducing reliance on traditional energy infrastructure.

Another promising prospect is the scalability and portability of TENGs. These devices can be designed in various forms, including flexible and wearable formats, allowing for integration into diverse systems and applications. This flexibility enables TENG-driven water splitting to be adapted to different settings and energy demands, from small-scale portable devices for personal use to large-scale implementations in industrial and commercial settings.

Additionally, TENG-driven water splitting offers the potential for decentralized energy generation. By leveraging TENGs to produce hydrogen locally, communities and industries can achieve energy independence and reduce transportation costs associated with centralized hydrogen production. This opens up opportunities for localized hydrogen economies and greater energy security.

Furthermore, ongoing advancements in TENG technology and materials research hold the prospect of improving the overall energy conversion efficiency of TENGs, reducing system costs, and enhancing the durability and reliability of these devices. As these technological advancements progress, TENG-driven water splitting could become increasingly efficient, cost-effective, and commercially viable for widespread adoption.

## Summary

Researchers are exploring the utilization of TENGs to drive the water splitting process, aiming to establish an efficient and sustainable method for hydrogen production. TENGs offer numerous advantages, including the capability to harvest energy from diverse mechanical sources and the potential for scalable and portable energy generation. However, substantial research and development efforts are still underway to optimize TENG design, enhance energy conversion efficiency, and improve overall system performance in TENG-driven water splitting. The combination of TENG-driven water splitting's ability to harness renewable energy, its scalability, portability, potential for decentralized energy generation, and ongoing technological advancements make it an appealing choice for sustainable hydrogen production. With further research, development, and investment, TENG-driven water splitting has the potential to assume a significant role in shaping the future of clean and renewable energy systems.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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