Development of a flexible lithium-ion battery and integration of a triboelectric nanogenerator for self-charging energy systems

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The growing demand for wearable electronics has highlighted the need for lightweight, flexible, and autonomous energy systems. Conventional lithium-ion batteries, though effective in energy density and stability, lack the mechanical adaptability and self-sufficiency required for next-generation wearable devices. To address these challenges, this study proposes the development of a self-charging energy platform that integrates a flexible lithium-ion battery with a triboelectric nanogenerator (TENG) into a unified, stretchable architecture. While TENGs and flexible batteries have been studied individually, their combination remains largely unexplored. The proposed system aims to achieve continuous energy harvesting, high cycling stability, and practical usability in wearable electronics.

The flexible battery is fabricated on elastomeric substrates, ensuring conformability and durability under motion. Nanostructured conductive coatings are used to enhance electrical conductivity while preserving stretchability. A custom-developed gel polymer electrolyte is used to replace conventional liquid electrolytes, offering improved safety, leakage resistance, and mechanical compatibility with flexible form factors. The electrolyte exhibits high ionic conductivity and strong interfacial adhesion to electrode layers, ensuring stable electrochemical performance under deformation. The battery design is optimized for stable operation under bending, stretching, and repetitive mechanical stress conditions typical of wearable applications.

Simultaneously, the TENG is fabricated using electrospun nanofiber layers with high triboelectric polarity. These high-surface-area membranes harvest biomechanical energy from movements like walking or fabric deformation. The system includes custom energy conditioning circuits to convert the pulsed AC output of the TENG into a regulated form suitable for real-time battery charging.

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Kaan Yapıcı is a master's student in Materials Science with a background in Physics Engineering. His academic focus includes nanomaterials, conductive inks, and additive manufacturing techniques. He has experience in national and international research projects, particularly in the field of printed and flexible electronics. Kaan is interested in developing sustainable, high-performance materials for next-generation electronic applications.

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