Development of an Al2O3-Based Triboelectric–Piezoelectric Nanogenerator System for Self-Charging Wearable Devices

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Battery life remains a critical limitation in wearable electronics, as frequent charging shortens device lifespan and contributes to electronic waste. Hybrid TENG–PENG designs are promising; however, they rarely achieve fully integrated architectures that co-optimize triboelectric surfaces, in-plane PVDF IDTs, and shared low-loss rectification. These gaps highlight the need for device co-design approaches that account for both material optimization and user comfort. This project presents a hybrid energy harvesting system that integrates a sputtered Al_2O_3-based triboelectric nanogenerator (TENG) with a polyvinylidene fluoride (PVDF) piezoelectric nanogenerator (PENG). The goal is to enable continuous, motion-driven power generation for wearable applications. The system was developed using a combined materials–device co-design approach. The triboelectric layer was fabricated using Al_2O_3 thin films deposited via sputtering at 25, 150, and 200°C to investigate how oxygen content and surface states influence charge generation. The hybrid device combines contact electrification from the TENG with strain-induced polarization from the PVDF-based PENG, enabling broader bandwidth energy harvesting from low-frequency human motion. Electrical performance was assessed through battery charging profiles and open-circuit voltage measurements. Devices fabricated at higher deposition temperatures demonstrated a 525% increase in voltage output per 2 minutes, attributed to enhanced surface chemistry and stronger charge retention in the Al_2O_3 layer. The integrated hybrid system improved the voltage output by 44% per 2 minutes. The proposed solution has the potential to significantly reduce electronic waste, improve reliability, stability, and decrease the risk of battery depletion.

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