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Efficient self-powered wearable electronic systems enabled by microwave processed thermoelectric materials

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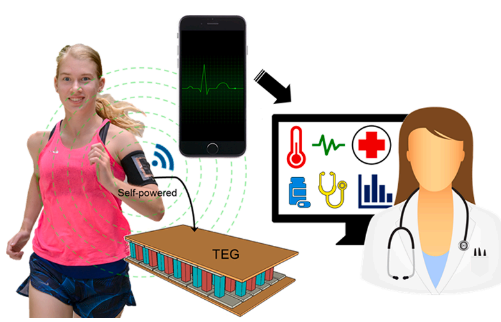
HIGHLIGHTS

- High-performance thermoelectric nanocomposites are developed for wearable systems.
- Material synthesis, device fabrication, and system-level optimization are presented.
- Microwave-induced decrystallization enables amorphous-crystalline nanocomposites.
- Comprehensive modeling for a self-powered wearable system is presented.
- Over 600% higher power than the commercial thermoelectric generators is achieved.

GRAPHICAL ABSTRACT



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ABSTRACT

The integrated body sensor networks are expected to dominate the future of healthcare, making a critical paradigm shift that will support people in the comfort and security of their own homes. Thermoelectric generators, in this regard, can play a crucial role as they can steadily generate electricity from body heat and enable self-powered wearable or implantable medical, health, and sports devices. This work provides a comprehensive analysis of the operation and the optimization of wearable thermoelectric generators under different human body conditions. Thermoelectric design principles, wearable system considerations, and a novel method to synthesize the materials specially designed for body heat harvesting are presented. The limitations of the materials and systems for wearable applications are deliberated in detail, and the feasibility of eliminating the heatsink for enhancing body comfort is examined. N-type $Bi_2Te_{3-x}Se_x$ was synthesized using a novel approach based on field-induced decrystallization by microwave radiation to achieve the optimum properties. This method resulted in amorphous-crystalline nanocomposites with simultaneously large thermopower and small thermal conductivity around the body temperature. Thermoelectric generators were fabricated from the optimized materials and packaged in flexible elastomers. The devices generated up to 150% higher voltage and 600% more power on the body compared to the commercial ones and, so far, are the best in class for body heat harvesting in wearable applications.

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