

2D layered heterostructures for miniaturised textile energy harvesters

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Two-dimensional (2D) layered materials offer a unique platform for miniaturised energy harvesting systems, combining atomic-scale thickness with tuneable electronic, mechanical, and interfacial properties. When assembled into 2D heterostructures, these materials enable new mechanisms for charge generation, separation, and transport—key to advancing self-powered wearable technologies. However, translating these capabilities from rigid substrates to deformable textile platforms remains a fundamental challenge.

This talk presents a scalable strategy for integrating 2D layered heterostructures directly into textile architectures to realise miniaturised energy harvesters. Using a water-based, surfactant-free ultrasonic spray-coating approach, we deposit graphene [1–3] and semiconducting 2D materials such as transition metal dichalcogenides (TMDs) [5] conformally onto fabrics. This process treats 2D materials as electronic “dyes,” enabling uniform, large-area coating while preserving textile softness, breathability, and mechanical integrity, and providing a scalable route compatible with industrial textile processing.

By engineering heterostructured interfaces (e.g., graphene/TMD stacks) on textile fibres, we introduce functional energy conversion layers that act as active electrodes in textile-integrated triboelectric nanogenerators (TENGs) [2–4]. These miniaturised systems efficiently harvest low-frequency mechanical energy from human motion [2–4], vibration [4], and ambient stimuli such as acoustic waves [4], delivering stable electrical outputs suitable for powering distributed wearable electronics. Importantly, the heterostructure design enhances interfacial charge transfer and carrier modulation, improving energy conversion performance compared to single-material systems.

Beyond energy harvesting, these platforms enable self-powered, multiparameter sensing [6], where mechanical-to-electrical transduction is coupled with environmental and physiological monitoring. Through a tap-to-sense mechanism, we demonstrate detection of biomechanical motion, atmospheric humidity, body temperature, and volatile organic compounds (VOCs), including acetone and styrene [6]. Notably, the system achieves a 126% responsivity toward styrene vapours, representing the first wearable, self-powered styrene sensor [6]. Thermal modulation of charge transport within the MoS₂ component of the heterostructure enables accurate body-temperature monitoring with minimal cross-sensitivity under realistic environmental conditions. The devices exhibit excellent mechanical durability, maintaining performance under repeated deformation and long-term use.

References

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