From Graphene-Based Smart Textiles to AI-Assisted Transduction for In-Bed Posture Recognition

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Abstract

Nanotechnology-enabled functional materials offer the possibility of integrating sensing and transduction directly into large and mechanically compliant surfaces. In this work, graphene nanoplatelets are exploited to develop a piezoresistive smart textile in which mechanical loading produces measurable changes in the electrical response of the material. The approach is demonstrated through a full-size sensorized fitted sheet designed for unobtrusive in-bed posture monitoring.

The sensing layer is obtained by screen-printing a graphene nanoplatelet-based piezoresistive ink onto a textile substrate and is divided into three electrically isolated macrozones corresponding approximately to the head, pelvis, and feet regions. Mechanical interaction between the body and the coated textile modifies its impedance, thus providing the physical transduction mechanism from distributed pressure and load variations to electrical signals. A set of 64 boundary electrodes is used for multi-frequency AC measurements following an Electrical Impedance Tomography-inspired acquisition strategy. Rather than reconstructing conductivity images, the resulting complex voltage measurements are condensed into physically interpretable descriptors representing the electrical response and relative loading of the different sensing regions.

These descriptors are subsequently combined with machine-learning classification to recognize eleven in-bed configurations. Experiments conducted with three adult volunteers demonstrate that the combination of nanostructured piezoresistive materials, distributed electrical interrogation, and data-driven signal interpretation can transform a large textile surface into an intelligent transducer for human-state monitoring. In the calibrated multi-subject evaluation, the proposed approach achieved an overall accuracy and macro-F1 score of 0.97.