Nanocomposite Fabric Sensors for Human Performance and Health Monitoring

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Flexible and wearable sensors for human performance sensing have received increased attention, particularly for fitness, healthcare, sports, and military applications. In particular, the measurement of human vital signals provides rich datasets for assessing the subject’s physiological or psychological condition, which are directly linked to performance. Instead of using conventional, bulky, wearable transducers, the objective of this study is to design and validate a conformable, non-invasive, and fabric-like sensing system for monitoring body motions, respiration, and temperature. The main sensing element is a piezoresistive multi-walled carbon nanotube (MWNT)-polymer thin film fabricated using spray coating. The films are integrated with stretchable and waterproof fabrics to form the wearable strain sensor.

In total, two types of experimental tests were conducted for characterizing sensor performance. First, the fabric sensors were subjected to uniaxial and cyclic tensile loads and temperature variations. The wearable sensors exhibited stable strain- and temperature-sensitive electrical properties, and high repeatability was demonstrated (Figure 1). Second, upon characterizing sensor properties (e.g., their sensitivities and calibration curves), the strain-sensitive fabric sensors were adhered onto human subjects for validating human performance monitoring. Here, three sets of tests were performed. The first test utilized a small fabric strip mounted on the individual’s index finger to validate sensing of finger movements and bending angles (Figure 2). The second test entailed the design of a chest band that incorporated the nanocomposite fabric sensor. The results showed that sensor electrical properties varied according to chest movements due to respiration activity. The final test investigated these sensors for monitoring distributed pressure. To do so, an electrical impedance tomography (EIT) algorithm was implemented. EIT utilized applied electrical excitations and voltage measurements obtained along fabric sensor boundaries for solving the inverse problem and reconstructing the corresponding 2D spatial distributions of electrical properties. Since the entire fabric was pre-calibrated to strain (and strain induced by out-of-plane applied pressure), EIT outputted the corresponding pressure map. Experiments performed in the laboratory confirmed the applicability of fabric sensors for monitoring pressure distributions (Figure 3). Overall, the proposed wearable fabric sensor design exhibited favorable features such as being flexible, easy to fabricate, light-weight, low-cost, non-invasive, and comfortable to wear.

Fig1. Resistance time history of fabric sensor subjected to tensile cyclic strains.
Fig2. Finger bending monitoring test.
Fig3. Distributed pressure map from fabric sensor measurements and EIT analysis.