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Ultra-Sensitive Capacitance-Based Pressure Sensors Using Porous Conductive Composites for Health Monitoring

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Abstract

Recent advances in enhancing the sensitivity of capacitive pressure sensors have primarily focused on developing dielectric layers with intricate surface or porous structures or employing materials with high dielectric constants. However, these approaches have proven effective mainly within low pressure ranges (up to 3 kPa). To address this limitation, we introduce an elastomer-based pressure sensor leveraging a novel and cost-effective fabrication process, designed for health-monitoring applications. This sensor employs a water-soluble polyvinyl alcohol (PVA) mold, created via 3D printing, to cast a polydimethylsiloxane (PDMS) matrix infused with graphene nanoplatelets. Upon hardening, the PVA mold is dissolved in water, yielding a flexible, stretchable, and electrically conductive PDMS/graphene composite foam. The 3D printing technique allows precise control over the mold's pore size, facilitating the tuning of the sensor's stiffness and sensitivity. The foam is sandwiched between two conductive layers with an insulator, forming a capacitor whose capacitance changes due to variations in conductivity and distance between electrodes under pressure.Through material, electrical, and mechanical characterization, we demonstrate the sensor's superior response. This study presents a simplified analytical model to predict optimal graphene nanoplatelet doping levels, enhancing the sensor's hybrid piezoresistive and piezocapacitive responses. Our findings indicate that this approach significantly improves sensitivity across a wide pressure range, making it suitable for detecting subtle pressures such as temporal arterial pulses as well as larger forces like footsteps.

Keywords: Porous Composite Foam, Graphene Nanoplatelets, 3D printing, Piezoresistivity, Human health monitoring