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Highly Sensitive Temperature–Strain Hybridized Sensors for Human Health Status Monitoring

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ABSTRACT

The measurement of human-body-induced signals such as arterial pulses, blinking motions, and muscle twitching requires a flexible and stretchable multifunctional sensing platform that can measure multiple parameters in response to various body signals. As such, the integration of single-parameter sensors into a common substrate for each stimulus has limited the widespread application due to their expensive and sophisticated fabrication. In addition, the single functional device for multiple stimuli is also restricting the efficient and reliable measurement of individual parameters due to the proper choice of functional materials.

Herein, a dual-parameter temperature-strain sensor is proposed and successfully realized in a single design platform using a composite material of black phosphorous (BP), a recently augmented family of 2D materials, and laser-induced graphene (LIG) obtained by laser engraving of commercial Kapton polyimide (PI) films. To modulate the dual-modal temperature and strain sensing functionality, the sensor patterns obtained by drop-casting of passivated BP dispersion on LIG were transferred into an ultrathin and highly resilient polystyrene-*block*-poly(ethylene-*ran*-butylene)-*block*-polystyrene (SEBS) substrate. Compared to the conventional substrate materials for flexible and stretchable sensors (e.g. silicone), the SEBS polymer matrix ensures excellent mechanical strength, high cycling stability, and offers conformal contact to the human skin. Moreover, the strain-insensitive temperature sensors design strategy enables us an efficient and accurate determination of each parameter without interfering with each other. In the hybridized platform, the temperature sensor outperforms as a positive temperature coefficient (PTC) of resistance behavior with a thermal index of 8106 K (25-50 °C) and temperature coefficient of resistance (TCR) of 0.17% $°C^{-1}$ within the human physiological temperature range. Similarly, the strain sensor endows a high strain sensitivity (i.e., gauge factor, GF) of up to 2765 for strain >19.2% and ultralow strain resolution of 0.023%. An ultralow detection limit of the sensor indicates that the sensor can be used for the real-time monitoring of subtle deformation-induced from the human body, such as arterial pulses and jugular venous pulses (JVPs). Finally, the sensor was employed to measure JVPs, one of the health indicators, by mounting the sensor on top of the jugular venous area on the human neck.

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