Flexible and Wearable Optoelectronic Sensors for Biomedical Technologies: Crumpled Graphene Stretchable Photodetector

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Wearable optical sensors can monitor various physiological signals such as heart rate and oxygen levels, and optical chemical sensors can measure chemical composition of body fluids, for example pH level from human sweat. For such optical sensors, high performance flexible photodetector is desired. High performance photodetectors have been developed based on various materials and approaches, but they were limited mostly on rigid substrates. Recently, photodetectors on bendable plastic substrates have been also demonstrated, yet with limited performance with respect to stretching. Here we show a highly stretchable photodetector with enhanced and strain-tunable photoresponsivity based exclusively on crumpled/buckled three dimensional (3D) graphene structures. We achieve more than an order-of-magnitude enhancement of the optical extinction by increasing graphene's areal density via a buckled 3D structure, which simultaneously leads to a ~400% enhancement in photoresponsivity. Furthermore, we demonstrate a new concept of strain-tunable photoresponsivity by showing 100% modulation in photoresponsivity with a 200% applied strain. Finally, we demonstrate unique strain-tunable wavelength selectivity by integrating colloidal photonic crystal, a strain-tunable optomechanical filter, with the stretchable graphene photodetector. Our photodetector shows potential applications in implantable biomedical optoelectronics and epidermal electronics, where high-performance photodetection systems in a highly flexible and conformal configuration are needed.

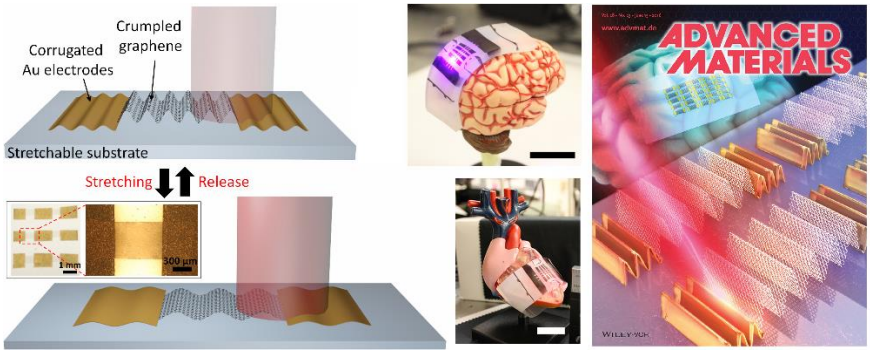

Figure. Schematic illustration of the crumpled graphene stretchable photodetector (upper/lower Left) and its biomedical applications (upper/lower middle). The image (right) of showing this research achievement, which was selected for the front cover of the journal of Advanced Materials (June 9, 2016).

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