Highly stable kirigami-structured stretchable strain sensor

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[Introduction] Human-friendly strain sensors have been widely developed in monitoring human motion. Although some significant progress has been achieved through the exploration and optimization process of ultra-sensitive strain sensors, a reliable strain sensor with simultaneously high stability and repeatable stretchability is still challenging for practical application. In this study, we investigate two kinds of kirigami-based ecoflex-coated strain sensors with distinct performance.

[Experiment & result] The strain sensors were fabricated by laser direct writing and different ecoflex protection methods. Via employing the laser direct writing method, uniform graphene films (Fig. 1a-b) as the strain sensor material and kirigami structure (each cutting unit: 8 mm×0.75 mm) are generated on polyimide films (thickness: 25 μm and 130 μm). Ag electrodes are screen printed and cured at 70°C during the process for interconnection. At last, the integrated devices (Fig. 1a) are protected by ecoflex in two different ways to realize grid-wrapped coating and film-encapsulated configuration. Fig. 1c and 1d show the resistance at different tensile strains for film-encapsulated thick device and grid-wrapped thin device, respectively. The sensitivity of the thicker device achieves ~80 % of resistance change at 60 % strain, while the thinner device can only obtain 5 % even it shows much higher stretchability. For stability test, high stability more than 60,000 stretching cycles are confirmed. Furthermore, both of these two strain sensors can successfully and precisely detect human motion and monitor human perspiration for long time. Fig. 1e presents the results of film-encapsulated devices for human perspiration monitoring. Each spike signal corresponds to the perspiration rate.

[Conclusion] This work demonstrates highly stable and stretchable strain sensors realized by kirigami structures and ecoflex passivation layers. Their performances are verified by different applications of human motions and perspiration monitoring. These scalable, highly stable and stretchable strain sensors pave a new way toward reliable skin-inspired wearable devices.

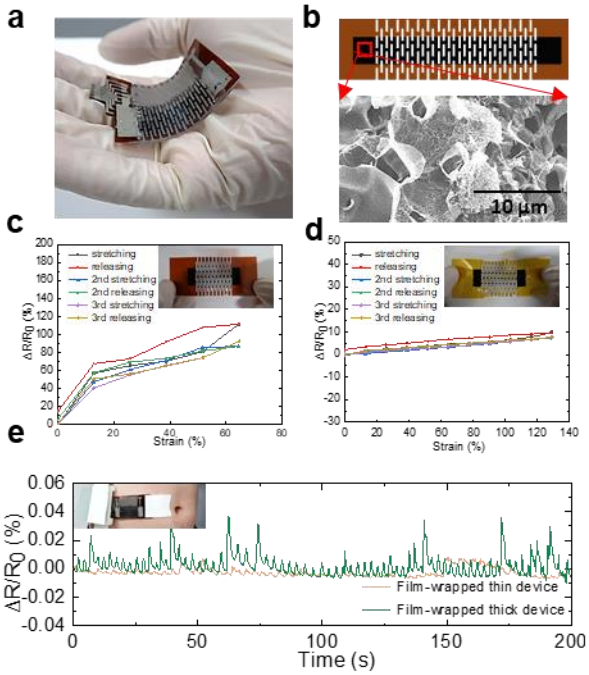

Fig1. (a) Picture of fabricated strain sensor (b) Schematic and Scanning Electron Microscope (SEM) images of graphene. Strain dependences of (c) the film-encapsulated thick device and (d) the grid-wrapped thin device. (e) Real-time human perspiration monitoring results.