Stretchable Graphene-Based Electronic Skin by Femtosecond Laser Direct Writing

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Abstract

Artificial electronic devices with skin-like properties hold great promises in healthcare monitoring, soft robotics, and human-machine interfaces [1]. Conferring flexibility and stretchability to biomimetic sensing electronics thus allowing for their intimate contact with curved surfaces can drastically enhance their functions such as capturing high-quality signals [1]. However, it is still challenging to achieve stretchable devices that can maintain high performance under severe deformation. Here we report an all-laser-patterning strategy to design a stretchable electronic skin where the femtosecond laser direct writing (FsLDW) was employed to respectively fabricate a graphene-based temperature sensor on a low-melting polymer film and create regular patterns on an elastomer substrate. Ordered buckling structures were formed by transferring the graphene-based temperature sensor onto the pre-strained elastomer substrate, which enables the active sensor area to endure stretching and exhibit stable sensing properties until the buckling profile was converted to a flat configuration [2].

As shown in Figure 1a, a temperature sensor was fabricated by FsLDW on a graphene oxide (GO) film coated on a polyester (PE) film (thickness of 10 µm), where the pristine GO functions as active material and the interdigitated reduced graphene oxide (rGO) patterns serve as the electrodes. The temperature sensing properties was examined by monitoring the impedance change against temperature in the range of 20 to 70 °C in an open-air environment (relative humidity, RH = 57%). As shown in Figure 1b, the impedance increases monotonically with the temperature, which can be attributed to the desorption of water molecules at elevated temperature leading to a decreased ionic conductivity (Figure 1c) [3].



Figure 1. (a) Photograph of a patterned graphene-based temperature sensor, the morphology of the rGO is revealed in the SEM image. (b) The sensing property of the as-patterned temperature sensor. (c) The temperature sensing mechanism.

Regular ridges were created on the VHB substrate by high-power laser ablating the elastomer, with the ridge width of 100 µm and the spacing of 200 µm (Figure 2a). The depth of the ridges can be tuned by the laser ablation repetitive times. As compared in Figure 2b, the ridge depth was increased when the laser ablation repeated more times. Upon transferring the temperature sensor on a PE film onto the as-patterned VHB tape which was pre-strained to 100%, bucking structures were formed as shown in Figure 2c. The stretchability of the temperature sensor was subsequently examined by monitoring the impedance change when the device was stretched to different strains. Figure 2d plots the normalized impedance (Z/Z0) as a function of the tensile strain (ε) when placing the temperature sensor on a heater at 50 °C. The impedance change shows a negligible increase of 1.066 even when the sensor was stretched to 100% strain. This phenomenon suggests the device structure on top of the patterned area will accommodate strain, thus functioning properly when being stretched.



Figure 2. (a) and (b) SEM images of the ablated ridges on VHB substrate. (c) SEM image showing buckling structures were formed when the temperature sensor on a PE layer was transferred onto the VHB substrate. (d) Normalized impedance against the tensile strain for the sensor sensing the temperature of 50 °C.

References

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