Stretchable and transparent electrodes using hybrid structures of graphene-metal nanotrough networks with high performances and ultimate uniformity

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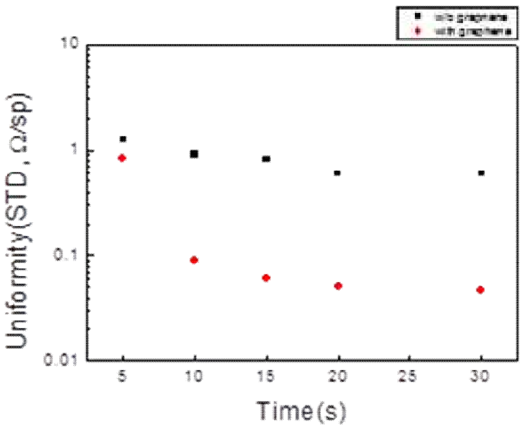
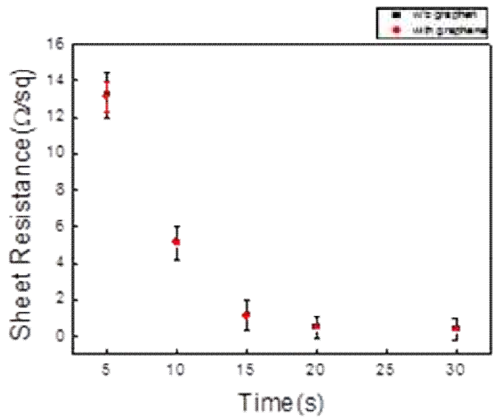
Transparent conductive electrodes (TCEs), which transmit light and conduct electrical charges in parallel, are of increasing significance and demand for diverse application areas such as energy (solar cell, architectural), information (displays, touch screen), and environment (sensors). Up to now, indium tin oxide (ITO) deposited by sputtering process is used as the main TCE substance. Although the ITO exhibits excellent properties of low sheet resistance (~ 30 Ohm/sq) and high transparency (~ 90 %), its fragility limits many potential applications in flexible and stretchable electronics. Several alternative materials to ITO, including conducting polymers, carbon nanotubes, graphene, and metal nanowires, have been studied as candidates of the flexible and stretchable TCEs. Although many of these candidates exhibit good mechanical flexibility and stretchability, none shows significantly higher conductivity and transparency together, compared to ITO.

Here, we present a simple fabrication process of high-performance, stretchable TCEs based on the metal nanotrough which have long and continuous random web geometries, constituting hybrid with 2D material graphene. These TCEs show superb electric conductivity (~ 1 ohm/sq) with high transparency (~ 91%) as well as excellent flexibility and stretchability. Hybrid transparent electrode shows very stable electrical properties even under 50 μm radius bending and 80% stretching (sheet resistance changed less than 20%). Also, hybrid film shows great uniformity, verified by the reduced standard deviation of sheet resistance by one-tenth compare to that of metal nanofiber only. Based on these outstanding mechanical and electrical properties, we demonstrate a transparent and flexible thin film transistor (TFT) backplane, composed of the AgNW-graphene hybrid film, zirconium aluminum oxide, indium oxide, and metal nanotrough-graphene hybrid film. Fabricated oxide TFT shows mobility as high as 100 cm2/V·s and transparency of ~90%. TFT backplane can be transferred to various substrates such as a leaf, glass cup, glass, and human skin. We believe these TCEs based on the nanostructures present a promising strategy toward flexible and wearable electronics beyond the limits of conventional ITO.





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