

A highly flexible and stretchable energy storage device

With rapid development of portable and wearable electronics, highly flexible and stretchable energy conversion and/or storage devices are required to be used as power sources. As one of the most important energy storage devices, supercapacitors (also called electrochemical capacitors or ultracapacitors) have been attracted great attention due to their high power density, long cycle life and easy fabricating process. However, for the stretchable supercapacitors, the stretchability and electrochemical performance were often suffered from the limited stretchability of the used electrodes because conventional electrodes often showed either high electrical conductivity with low stretchability or highly stretchability with poor conductivity. As a result, most reported stretchable supercapacitors exhibited relatively low stretchability (typically < 100%) and poor electrochemical energy storage performance. In this regard, carbon nanotubes (CNTs) with large aspect ratio as well as highly electrical and mechanical properties are very promising to be used electrodes for stretchable supercapacitors with high performance.

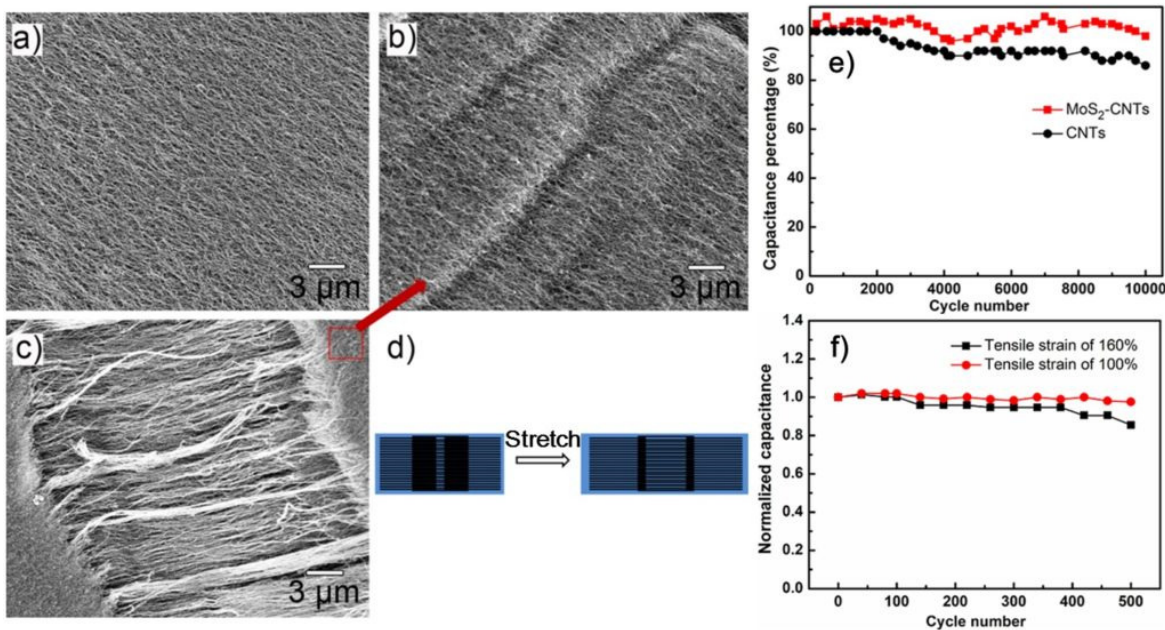


Fig. 1 (a,b) SEM images of aligned CNT film before and after stretched. (c) SEM image of the crack area after stretched. (d) Schematic of slippage of the aligned CNTs in the aligned CNT-based electrode before and after stretching. (e) Cyclic performance of supercapacitors based on bare CNTs films and CNT/MoS₂ composite. (f) Normalized specific capacitance of CNTs/MoS₂-based supercapacitor as a function of stretching cycles.

In this study, a three-dimensional vertically aligned CNT array was first synthesized through chemical vapor deposition, which was directly transferred onto an elastic substrate (Polydimethylsiloxane, PDMS) by pressing, formed a compact horizontally aligned CNT film on PDMS. The compact structure enabled CNTs inside the film with perfect contact with each other even under large tensile strain (Fig 1a-d), resulting excellent stretchability (up to 240%) as the CNT films embedded in PDMS and polyvinyl alcohol (PVA). For supercapacitor application, layered molybdenum disulfide (MoS₂) nanosheets were introduced into aligned CNT films to enhance the performance of the resulting energy storage devices. The stretchable

supercapacitors were fabricated by using the PDMS-supported CNT films or CNT/ MoS₂ composite films as both current collector and electrodes, which was sandwiched with a layer of polymer gel (served as both electrolyte and separator) in between. The newly-developed supercapacitor based on CNT/ MoS₂ composite showed a specific capacitance of 13.16 F cm⁻³, which also showed excellent cycling retention (98%) after 10,000 charge-discharge cycles (Fig. 1e). These all-solid-state supercapacitors can maintain their original performance even stretched up to 240% strain, which can also bare over hundreds of stretching cycles to 160%, suggesting excellent stretchability and stability (Fig. 1f). The excellent stretchability of supercapacitors can be attributed to the used highly stretchable PDMS substrate and the compact aligned CNTs bonded together by polymer chains in the gel electrolyte. In conclusion, this work presented a general and effective paradigm to develop high-performance electrodes for flexible and stretchable electronics, not only energy storage but also energy conversion devices.

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[Highly Stretchable Supercapacitors Based on Aligned Carbon Nanotube/Molybdenum Disulfide Composites.](#)

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