“Nano-spring” design within hard carbon cages for high-volumetric-performance noncarbon anodes

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With the miniaturization of energy storage systems, smaller and lighter lithium-ion batteries are urgently needed. This means that the battery should not only have a high gravimetric capacity but also a high volumetric capacity. However, the volumetric capacity of conventional carbonaceous anodes is usually less than 800 mAh cm^{-3}. To achieve a high volumetric energy density, the anode material should have both a high capacity as well as fast reaction kinetics and excellent structural stability during the charge-discharge process. Furthermore, to extend the cycle life of high-capacity and high-volume-change noncarbon anode, efforts need to be made in stabilizing the noncarbon particles and simultaneously retaining a large-surface-area electrical contact and continuous electron transfer when noncarbon active particles expands and contracts during cycling.

Here, we develop a strategy to prepare carbon cages with a high density and conductive buffer inside for noncarbon components. Typically, in the capillary drying of networked graphene hydrogels, flexible and conductive carbon nanotube (CNT), encapsulates noncarbon particles even of nanometer size. Thus, carbon nanotubes are used as ***nano-springs*** to endure the volume expansion of noncarbon in a 3D graphene cage, and an intimately large-surface electrical contact can also be ensured upon lithiation and delithiation. As a typical example, a tin oxide nanoparticle@carbon nanotubes filled graphene cage hybrid with 67 wt% tin oxide is prepared, which is characterized by a high specific capacity (800 mAh g^{-1}) and an expected ultrahigh volumetric capacity of 2000 mAh cm^{-3} with an ultralong cycle life (600 cycles).

References:

1. Tao, Y; Yang, Q. -H. et al, Sci. Rep. 3: 2975 (2013)

2. Zhang, C.; Lv, W.; Tao, Y.; Yang, Q. -H. Energy Environ. Sci. 8, 1390 (2015)

3. Han, J.; Kong, D.; Lv, W.; Tang, D. -M.; Yang, Q. -H. et al, Nat. Commun. 9, 402 (2018)