Amorphous Phosphorus Filled Graphene Paper for Ultrastable Sodium-Ion Energy Storage

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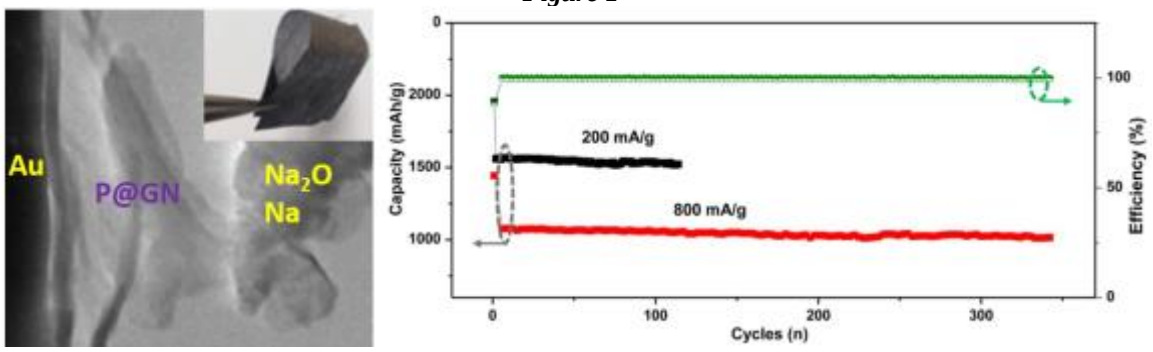
As a very promising anode material for future sodium-ion energy batteries, phosphorus (P) has recently attracted a lot of interest due to its high theoretical capacity of 2596 mAh/g. The core disadvantage of a P anode is its low conductivity and rapid structural degradation caused by the large volume expansion (>490%) during cycling.[1-2]

We renovated the anode structure by using a special methodology and fabricated a flexible paper made of nitrogen-doped graphene and amorphous phosphorus that effectively solves this problem. The restructured anode exhibits an ultra-stable cyclic performance and excellent rate capability (809 mAh/g at 1500 mA/g). The excellent structural integrity of the novel anode was further visualized during cycling by using in situ experiments inside a high-resolution transmission electron microscope (HRTEM), and the associated sodiation/desodiation mechanism was also thoroughly studied. Finally, Density Functional Theory (DFT) calculations confirmed that the N-doped graphene not only contributes to an increase in capacity for sodium storage, but is also beneficial in regards to improved rate performance of the anode.[3] The as designed flexible sodium-ion energy storage can be used in consumers electronics as well as biomedical applications such as sensing devices attached to skins.

Figure 1



TEM image of the nano-SIB fabricated inside a microscope (the inset image shows the paper material for battery device fabrication), cyclic performance and Coulombic efficiency of P@GN at 200 mA/g and 800 mA/g.

References
[1] Ren, W.; Cheng, H.-M. *Nat. Nanotechnol.* **9**, 726-730 (2014).
[2] Sun, J.; Cui, Y. et al. *Nat. Nanotechnol.* **10**, 980-985 (2015)
[3] Zhang, C.; Golberg D. et al. *Nano Lett.* **16**, 2054-2060 (2016)

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Research interests: in situ TEM, energy storage, flexible optoelectronics