Prussian-blue Analogue Derived Anode Materials: High Performance WS_2, ReS_2 and FeP carbon composites for Sodium-Ion Batteries

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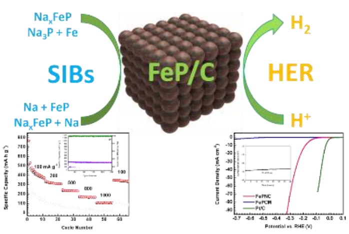
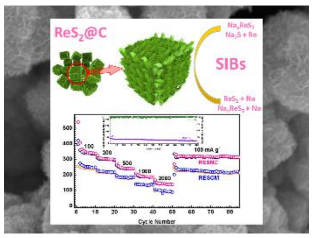
Sodium-ion batteries (SIBs) have recently garnered increasing research interest as a feasible and economical substitute for lithium-ion batteries (LIBs) owing to sodium's unmistakable economical advantage. However, the larger Na-ion size and its slower kinetics has rendered lackluster performance particularly in high rate capability and cycling stability. Anode materials that are commonly studied as LIBs anodes may not work as a result, due to volumetric deformation of active materials during rapid charge/discharge. To overcome these problems, highly conductive carbon-based allotropes such as graphene and carbon nanotubes can be incorporated as nanocomposite to enhance electronic conductivity to alleviate structural stress ascribed by the volumetric changes. The other method is to design hierarchical nanostructures with porous interiors, providing internal "breathing" space for volumetric deformation. In addition, constructing nanostructures leads to the increase of reaction kinetics by shortening ion diffusion path and thus provides facilitation in e-/Na+ transport properties. Prussian blue analogues (PBA), one of the metal-organic framework (MOF) materials, has recently being discussed as potential SIBs cathode materials due to its 3D open framework with large interstitial sites. By converting PBA into carbonaceous network *via* inert pyrolysis, the carbonaceous template retains its highly-ordered and highly porous nanostructure for transition metal disulfides growth (WS_2/ReS_2). *Via* a simple chemical vapor deposition method, PBA can also be phosphorized into transition metal phosphide (FeP@C) nanostructures that consisting of three dimensional, cubic-shaped with highly-ordered and porous nature. As SIBs anode materials, WS_2/C and ReS_2/C exhibits high specific capacity of 384 and 365 mAh g^{-1} (@100 mA g^{-1}), excellent rate capability of 151 (@5 A g^{-1}) and 145 mAh g^{-1} (@2 A g^{-1}) respectively, and stable cycling performance. FeP@C derived from PBA delivers high specific capacity of 376 mAh g^{-1} (@100 mA g^{-1}) with excellent rate capability of 110 mAh g^{-1} (@1 A g^{-1}). More importantly, as the one of the first studies on ReS_2 and FeP SIBs anode materials, the electrochemical nature of the performance were studied carefully on selected cycling states and revealed *via* X-ray diffraction (XRD) and microscopy methods (SEM and TEM) *ex-situ*. These results provide insights and suggest the potential of MOF-derived template as a form of conductive carbon allotropes in enhancing the rate capability as well as cycling stability of currently studied SIBs active materials.





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