



## Highlight

## Advanced metal sulfide anode for potassium ion batteries

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## ABSTRACT

Potassium-ion batteries (KIBs) are a promising alternative to lithium-ion batteries owing to the abundance of potassium on Earth and the relatively low  $K/K^+$  redox couple. To date, KIBs remains its infancy and the investigation of anode materials mainly focused on carbon-based materials, which deliver limited reversible capacity. Hence, it is imperative to explore alternative anode materials with high reversible capacity for KIBs. Recently, a pioneering work from Chen's group reported a nanocomposite of  $Sb_2S_3$  nanoparticles anchored on porous S,N-codoped graphene (denoted as  $Sb_2S_3$ -SNG) as an advanced anode material for KIBs, which exhibited remarkable enhancements of both capacity and cycling stability, highlighting the rational structure design of  $Sb_2S_3$ -SNG for maximum utilization of  $Sb_2S_3$  nanoparticles and graphene layers for energy storage applications in high-performance KIBs.

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With potassium being both abundant and relatively low redox potential ( $-2.93$  V vs. NHE), potassium ion batteries (KIBs) is attracting significant attention with a viewpoint to material suitability and commercial availability [1,2]. Although carbon-based materials have been the dominant anodes in KIBs for their low cost and excellent safety, the limited reversible capacity and rapid capacity fading impeded their wide application in KIBs, which drives to explore emerging anode materials with high reversible capacity for energy-dense KIBs [1]. Metal sulfides represent promising anode materials for lithium/sodium-ion batteries because of superior theoretical capacity and redox reversibility to their metal oxide counterparts [3,4]. When the metal sulfides are employed in KIBs, their large volume variations and severe particle aggregation associated with the conversion reactions during cycling induce electrode pulverization and loss of interparticle contact, which consequently result in poor cycling stability [5].

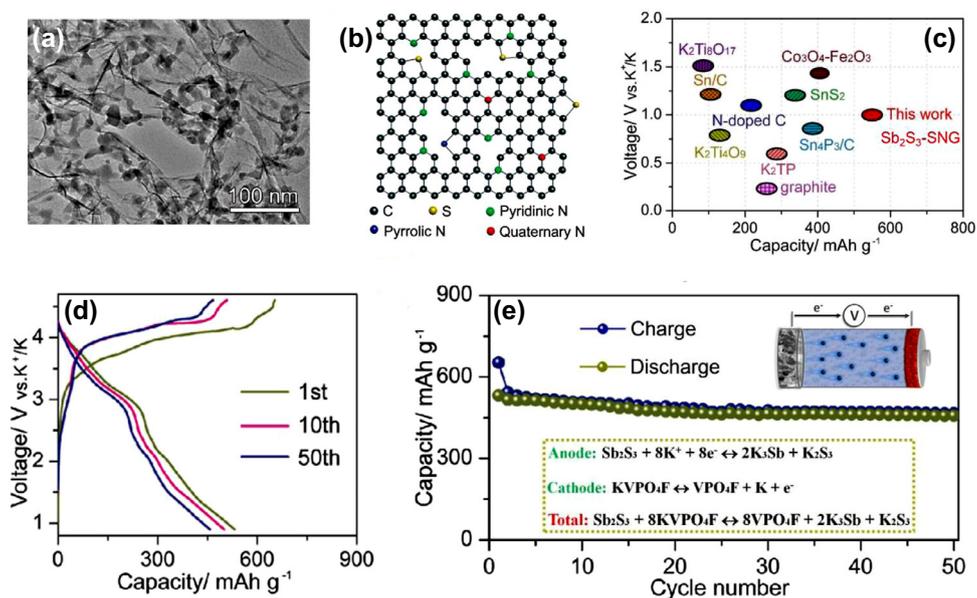
To address the above-mentioned issues, integrating metal sulfide nanoparticles with graphene is recently proposed by Chen and co-workers with a published paper in the Science China Chemistry [6]. This pioneer work described a facile hydrothermal method to obtain advanced nanocomposite of  $Sb_2S_3$  nanoparticles anchored on porous S, N-codoped graphene (denoted as  $Sb_2S_3$ -SNG) with attempts to simultaneously address volume fluctuation and reaction kinetics of  $Sb_2S_3$  (Fig. 1a). The surface properties of graphene

modified by S, N-codoping and microscopic defects occurrence of rGO created by the pyridinic N and pyrrolic N synergistically facilitate the ions diffusion and provide more active sites for K storage (Fig. 1b). In addition, the doped S and N can improve the affinity between  $Sb_2S_3$  and graphene. Such rational integration of  $Sb_2S_3$  and S, N-codoped graphene have the following advantages: Firstly, nanosized active particles shorten the path length for ion transport over their bulk counterparts. Secondly, graphene layers intimately contacting with  $Sb_2S_3$  nanoparticles provide express electron pathway for redox conversion, and meanwhile effectively accommodate the volume variations and prevent the aggregation of nanoparticles during repeated cycling. Moreover, the anchored nanoparticles act as pillars to reduce the degree of restacking of graphene sheets. This all-in-one approach enables the  $Sb_2S_3$ -SNG composite with remarkable enhancements of both capacity and cycling stability when compared with other reported anodes in KIBs (Fig. 1c). An initial charge capacity of  $537 \text{ mAh g}^{-1}$  with a capacity retention of 89.4% after 100 cycles was obtained at a current density of  $50 \text{ mA g}^{-1}$  in K half-cells. Moreover, the  $Sb_2S_3$ -SNG/KVPO<sub>4</sub>F-C full cell delivered an initial capacity of  $532 \text{ mAh g}^{-1}$  with an average output voltage of  $\sim 2.5$  V (Fig. 1d), which rendered an energy density of  $\sim 166.3 \text{ Wh kg}^{-1}$ . Impressively, this battery system exhibited superior cycling stability over 50 cycles (Fig. 1e).

The above highlighted  $Sb_2S_3$ -SNG composites exhibited remarkable enhancements of both capacity and cycling stability, underlining the rational structure integration of  $Sb_2S_3$  nanoparticles anchored on S, N-codoped graphene, shedding important light on

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**Fig. 1.** (a) HRTEM image of  $\text{Sb}_2\text{S}_3$ -SNG composites; (b) schematic for heteroatomic S and N defects in the SNG; (c) capacity and voltage comparison of  $\text{Sb}_2\text{S}_3$ -SNG with other reported anodes in KIBs; the charge/discharge profiles (d) and cycling performance (e) of the  $\text{Sb}_2\text{S}_3$ -SNG/KVPO<sub>4</sub>F-C full cell between 0.9–4.6 V at 50 mA g<sup>-1</sup> [6]. Copyright 2017 Springer.

structure design and interfacial modification for energy storage applications.

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#### Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.jechem.2017.12.009](https://doi.org/10.1016/j.jechem.2017.12.009).

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