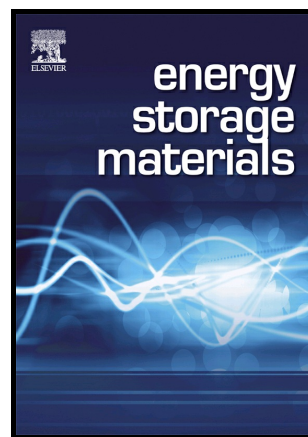


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# Red phosphorus nanoparticles embedded in porous N-doped carbon nanofibers as high-performance anode for sodium-ion batteries

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**Abstract:** In this paper, red phosphorus nanoparticles (~97.7 nm, 51 wt% content) homogeneously embedded in porous nitrogen-doped carbon nanofibers (denoted as P@C) are prepared using a feasible electrospinning technique for the first time. Meanwhile, red P@C with the character of free-standing membrane is directly used as binder- and current collector-free anode for sodium-ion batteries, exhibiting a highly reversible three-electron transfer reaction ( $3\text{Na}^+ + \text{P} + 3\text{e}^- \leftrightarrow \text{Na}_3\text{P}$ ) with excellent rate capability ( $1308 \text{ mA h g}^{-1}$  at  $200 \text{ mA g}^{-1}$  in comparison of  $343 \text{ mA h g}^{-1}$  at  $10000 \text{ mA g}^{-1}$ ) and remarkable cyclic stability (~81% capacity retention after 1000 cycles). Furthermore, a soft package Na-ion full battery with red P@C anode and  $\text{Na}_3\text{V}_2(\text{PO}_4)_2\text{F}_3/\text{C}$  cathode is assembled, displaying a high operation voltage of ~3.65 V and an outstanding energy density of  $161.8 \text{ Wh kg}^{-1}$  for the whole battery. This is owing to the distinctive structure of very small amorphous phosphorus nanoparticles uniformly confined in porous N-doped carbon nanofibers, which can effectively facilitate the electronic/ionic transportation and retard the active materials pulverization/fracture caused by volume fluctuation upon prolonged cycling. The

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