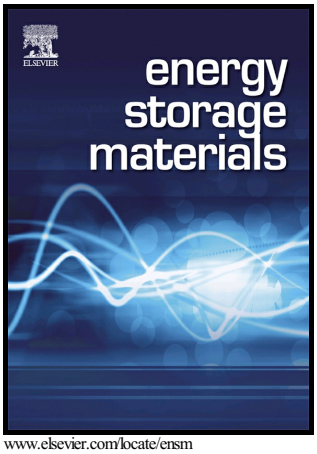

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PII: S2405-8297(17)30243-X
DOI: http://dx.doi.org/10.1016/j.ensm.2017.07.012
Reference: ENSM188

To appear in: *Energy Storage Materials*

Received date: 16 June 2017
Revised date: 20 July 2017
Accepted date: 24 July 2017

Cite this article as: Yongchang Liu, Ning Zhang, Xiaobin Liu, Chengcheng Chen Li-Zhen Fan and Lifang Jiao, Red phosphorus nanoparticles embedded in porou N-doped carbon nanofibers as high-performance anode for sodium-ion batteries *Energy Storage Materials,* http://dx.doi.org/10.1016/j.ensm.2017.07.012

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 ($3Na^+ + P + 3e^- \leftrightarrow Na_3P$) with excellent rate capability (1308 mA h g^{-1} at 200 mA g^{-1} in comparison of 343 mA h g^{-1} at 10000 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 $Na_3V_2(PO_4)_2F_3$/C cathode is assembled, displaying a high operation voltage of ~3.65 V and an outstanding energy density of 161.8 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