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Short communication

Construction of reduced graphene oxide supported molybdenum carbides composite electrode as high-performance anode materials for lithium ion batteries

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ABSTRACT

Metal carbides are emerging as promising anodes for advanced lithium ion batteries (LIBs). Herein we report reduced graphene oxide (RGO) supported molybdenum carbides (Mo_2C) integrated electrode by the combination of solution and carbothermal methods. In the designed integrated electrode, Mo_2C nanoparticles are uniformly dispersed among graphene nanosheets, forming a unique sheet-on-sheet integrated nanostructure. As anode of LIBs, the as-prepared Mo_2C-RGO integrated electrode exhibits noticeable electrochemical performances with a high reversible capacity of 850 mAh g^{-1} at 100 mA g^{-1}, and 456 mAh g^{-1} at 1000 mA g^{-1}, respectively. Moreover, the Mo_2C-RGO integrated electrode shows excellent cycling life with a capacity of ~98.6 % at 1000 mA g^{-1} after 400 cycles. Our research may pave the way for construction of high-performance metal carbides anodes of LIBs.

1. Introduction

Lithium ion batteries (LIBs), the current "king" of batteries in the market, have been the research focus in the past decades because of their fascinating characteristics such as high working voltage, large energy density, low toxicity and long cycling life [1,2]. However, the LIBs technology still falls short of meeting the demands dictated by the large-volume and high-power of applications [3–5]. In parallel with the research of cathode, to perform best, great efforts are made to search for advanced anodes to replace the current graphite anode with a relative low theoretical specific capacity (372 mAh g^{-1}) [6]. In recent years, transition metal carbides (such as molybdenum carbides, Mo_2C) are emerging as new kinds of anode materials for LIBs. Among the explored metal carbides candidates, Mo_2C is considered as one of the most promising anodes due to its high reversible capacity arising from the reaction: $Mo_2C + xLi^+ + xe^- \rightarrow 3Mo + Li_xC$, and high electrical conductivity (~10^2 S cm^{-1}), which is highly favorable for high-rate capability. Currently, porous nanostructured Mo_2C with a high surface area and enhanced electrochemical reactivity, is particularly attractive. However, the electrochemical performance of Mo_2C is always compromised in the powder formed materials for LIBs because of the extra fabrication process of electrode. The active Mo_2C powder materials need to be mixed with polymer binders and additives and processed into electrode pellets. This process introduces supplementary and undesirable interfaces, and increase inner resistance. Therefore, integrated binder-free nano-structured Mo_2C electrode is an important issue for their applications.

For the integrated electrode design, the active Mo_2C materials are growth on current collectors directly. This electrode design ensures good mechanical adhesion and electric connection of the active material to the current collector. Meanwhile, no extra preparation process of electrode and avoid undesirable supple-mentary interfaces. To further improve the electrochemical performance, integrated Mo_2C-based composite electrode design strategy is the new research focus. This hybrid strategy is to combine MoS_2 with conductive matrix or coating (such as CNT and graphene). This approach provides better and faster electron transfer path required by high-rate application by introducing highly conductive media [7,8]. Zhu et al. reported integrated molybdenum carbide/ graphitic carbon nanosheets electrode with enhanced capacity and rate capability [9].

Despite some progress achieved in the Mo_2C-based electrode, there are no report about fabrication of Mo_2C/reduced graphene oxide integrated electrodes and their application in LIBs. In this

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paper, we report reduced graphene oxide (RGO) supported molybdenum carbides (Mo_2C) integrated electrode by the combination of solvothermal and carbothermal methods. As anodes of LIBs, the Mo_2C-RGO electrode shows impressive electrochemical performances with high capacity and excellent high-rate cycling stability, which are attributed to the synergistic effect between well-dispersed molybdenum carbides and reduced graphene oxide.

2. Experimental

2.1. Preparation of graphene oxide (GO)

GO was prepared from natural flake graphite powder according to an improved Hummers method [10]. Typically, 5 g of graphite was added into breaker including 300 ml concentrated H_2SO_4 and keep stirring at an ice bath. Afterwards, 10 g of $KMnO_4$ was then

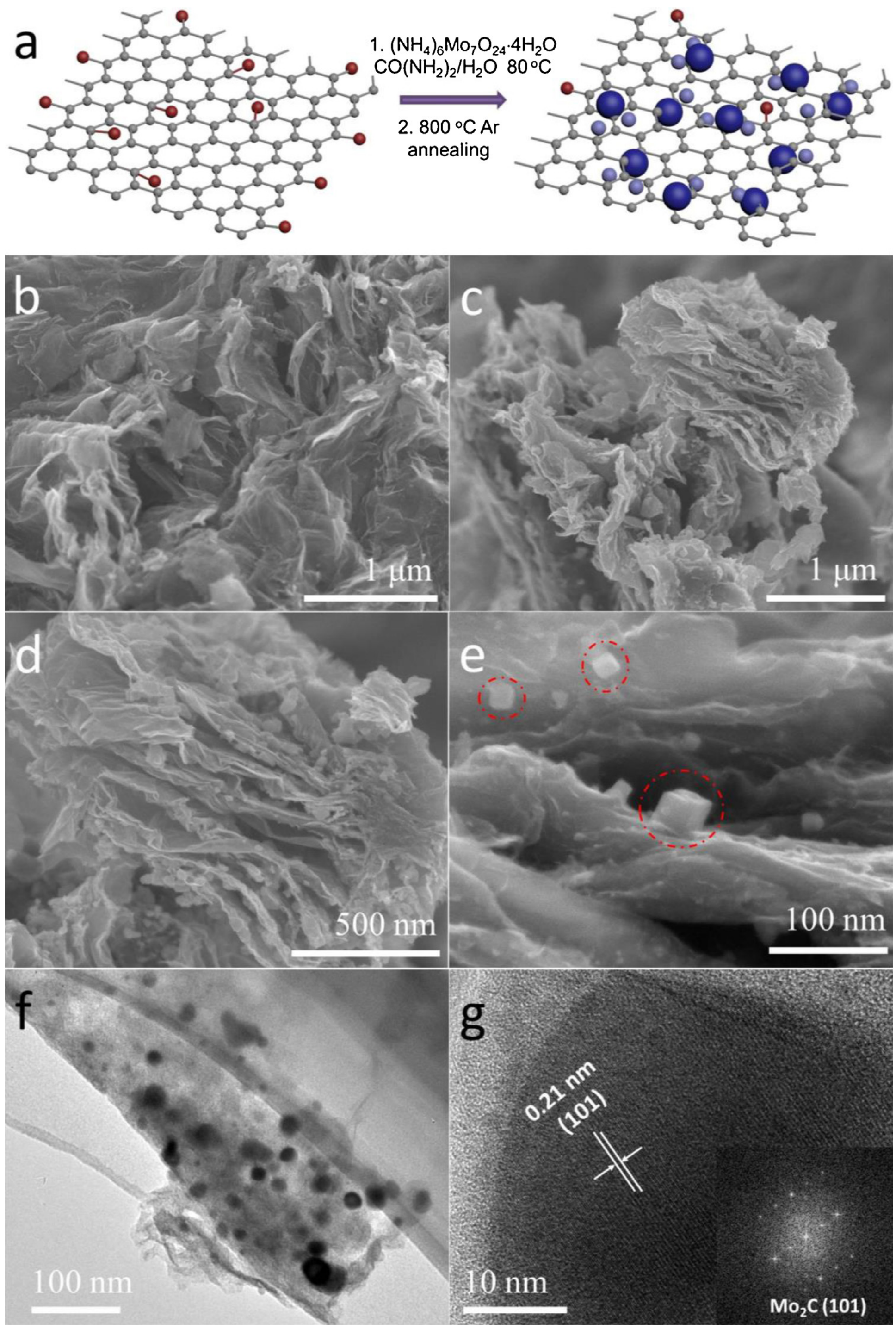

Fig. 1. (a) Schematic illustration for preparation of Mo_2C nanoparticles dispersed on reduced graphene oxide (Mo_2C-RGO). SEM images of GO (b) and Mo_2C-RGO (c–e). TEM (f) and HRTEM images (g) of Mo_2C-RGO. The insets in Fig. 1g are SAED patterns of nanoparticle.