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Carbon-coated vanadium selenide as anode for lithium-ion batteries and sodium-ion batteries with enhanced electrochemical performance

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ABSTRACT

A Carbon-coated vanadium selenium composites were synthesized through a facile ball-milling method. The VSe_2/C presents a structure that carbon layer covers around the pure VSe_2 particles. The VSe_2/C exhibits outstanding performances in electrochemical tests, showing an enhanced cycle capacities of 467 mA h g^{-1} for sodium-ion batteries and 453 mA h g^{-1} for lithium-ion batteries after 50 discharge-charge cycles.

1. Introduction

Nowadays lithium-ion batteries (LIBs) have been widely developed in electronic equipment, electric tools, electric vehicles, and power system [1,2]. Meanwhile, sodium-ion batteries (SIBs) are being recognized as an alternative to LIBs because of the elemental similarities between lithium and sodium and abundant sodium resources [3]. However, Na^+ has a larger radius than Li^+, which makes it important for SIBs to find an appropriate anode material as replacement [4].

Two-dimensional transition metal dichalcogenides MX_2 (M = Mo, Ti, W, V, etc. X=S, Se) have shown excellent mechanical and electrochemical performances in many researches [5–9]. Vanadium selenide is a kind of MX_2 crystals that has typical layered structure and lighter molecular mass than most MX_2, which makes its theoretical capacity higher. As early as 1978, Whittingham et al. used VSe_2 firstly in lithium cells [10]. In 2015 Li et al. synthesized VSe_2/graphene nanocomposites as anode materials for LIBs [8].

Herein, VSe_2/C composites synthesized by a facile ball-milling method are used as anode material for LIBs and SIBs for the first time. After further hybridize with Super P, a carbon layer is formed outside the VSe_2 particles, which work as a conductive matrix as well as a buffer for volume change of VSe_2 during Li^+ and Na^+ insertion and extraction [5,11]. The VSe_2/C exhibits excellent electrochemical properties, making it an appropriate application for LIBs and SIBs.

2. Experimental section

The VSe_2/C was synthesized by a ball-milling method. 0.5094g vanadium powder, 1.5792g selenium powder and Super P were placed into a planetary Ball Mill and react at the rate of 400 rpm for 8 h. The precursor was transferred into a tube furnace and heated in 600 °C for 3 h. For comparison, pure VSe_2 was synthesized in the same way without the participation of Super P. Scanning electron microscopy (SEM, Nova NanoSEM 230), transmission electron microscopy (TEM, Tecnai G2 20ST), Powder X-ray diffraction (XRD, Rigaku3014) and thermogravimetric analysis (TGA, SDTQ600) were employed to character.

Active material was mixed with Super P, sodium alginate at the ratio of 8:1:1 to prepare electrode. The CR2025 coin-type cells were assembled in argon-filled glove box. The electrolyte chosen for LIB was 1 M $LiPF_6$ in ethylene carbonate/dimethyl carbonate/diethyl carbonate (1:1:1 in volume) and for SIB was composed of 1 M $NaClO_4$ in ethylene carbonate/diethyl carbonate (1:1 in volume) with another 5 wt% fluoroethylene carbonate. Lithium/sodium plate and Celgard 2400 were used as the counter electrode and separator respectively. Galvanostatic charge-discharge (LAND CT2001A) and cyclic voltammetry tests (PARSTAT 2273 electrochemical measurement system) were carry out to detect electrochemical properties of VSe_2/C.

3. Result and discussion

To figure out the accurate content of VSe_2 in VSe_2/C composites,

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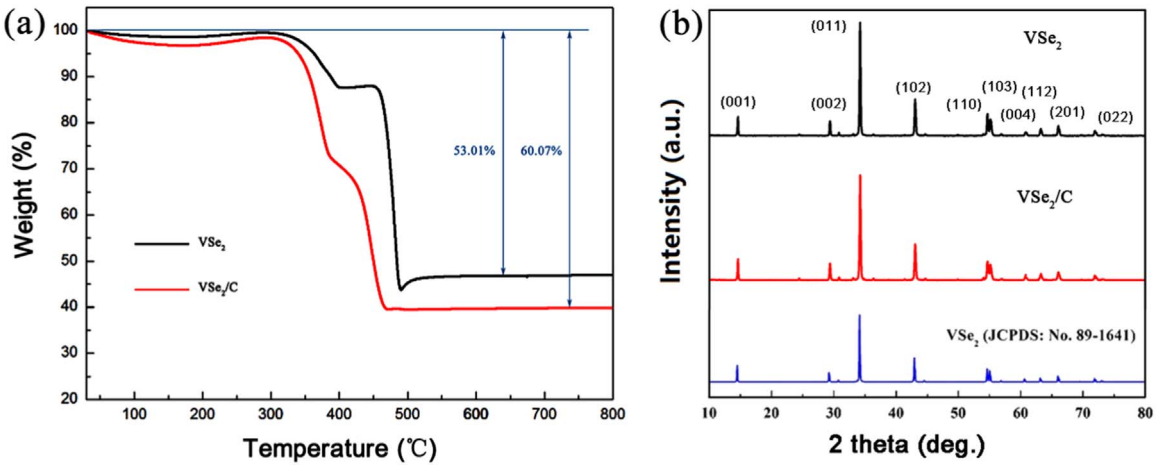

Fig. 1. (a) TGA curves of VSe_2 and VSe_2/C; (b) XRD patterns of VSe_2 and VSe_2/C.

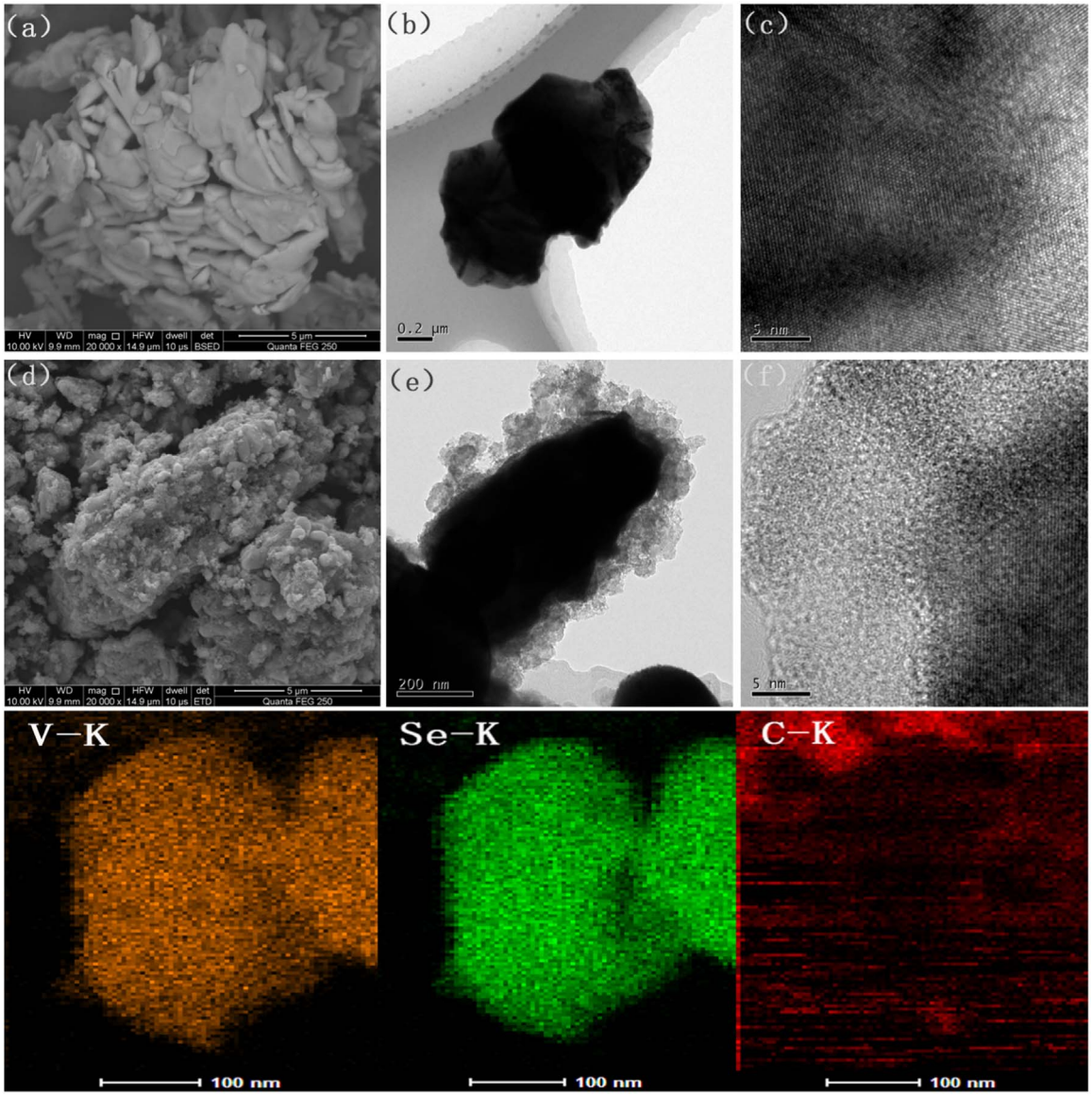

Fig. 2. SEM and TEM images of VSe_2 (a, b, c) and VSe_2/C (d, e, f); Elemental mapping image of VSe_2/C.