



A vapor-phase carbon-deposition route to efficient inorganic nanosheet-based electrodes

Jang Mee Lee, Nam Hee Kwon, In Young Kim, Seong-Ju Hwang*

Department of Chemistry and Nanoscience, College of Natural Sciences, Ewha Womans University, Seoul 03760, Republic of Korea



ARTICLE INFO

Article history:

Received 28 January 2016

Received in revised form

16 April 2016

Accepted 4 May 2016

Available online 6 May 2016

Keywords:

Inorganic nanosheets

Carbon deposition

Nanosize

Anode materials

Lithium ion batteries

ABSTRACT

Efficient inorganic nanosheet-based electrode materials can be synthesized by the calcination of exfoliated $\text{Ti}_5\text{NbO}_{14}$ nanosheets under C_2H_2 flow. While the calcination in Ar atmosphere causes a phase transformation from layered $\text{Ti}_5\text{NbO}_{14}$ to TiO_2 and Nb_2O_5 , employing C_2H_2 atmosphere leads to the maintenance of the original layered structure of $\text{Ti}_5\text{NbO}_{14}$ upon the heat-treatment, which is attributable to the stabilization of layered lattice by surface passivation by deposited carbon layer. The resulting carbon@titanoniobate materials show mesoporous house-of-cards-type stacking structure of 2D nanosheets. This carbon@titanoniobate material delivers large discharge capacity of $\sim 320 \text{ mA h g}^{-1}$ with excellent cyclability and rate performance, which is much superior to that of carbon-free homologue. The present study clearly demonstrates that the heat-treatment under C_2H_2 flow provides a simple and effective route to high-performance inorganic nanosheet-based electrode materials.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Recently 2D nanosheets of inorganic solids attract a great deal of research interest because of their unique physicochemical properties and valuable functionalities [1]. In comparison with graphene, these inorganic nanosheets boast much greater diversity in chemical compositions, crystal structures, and applicabilities [2]. Among them, 2D nanosheets of high-valent transition metal oxides such as titanoniobate are promising candidates for electrode applications for lithium ion batteries (LIB) and supercapacitors, since they can accommodate large amount of Li^+ ions via reduction process of Ti^{4+} and Nb^{5+} ions [3]. Of prime importance is that highly anisotropic 2D nanosheet morphology with very thin thickness is fairly advantageous for repeated lithiation–delithiation process because of the provision of many surface reaction sites, short Li^+ diffusion paths, and high electrochemical stability [4]. However, the poor electrical conductivity of this material severely limits its electrode performance especially under high current density condition. To circumvent this drawback of titanoniobate material, it is demanded to explore an efficient carbon deposition method for metal oxide 2D nanosheet without a significant frustration of 2D morphology. Taking into account excellent diffusivity and high reactivity of gaseous C_2H_2 reactant [5], a reaction with C_2H_2 vapor is supposed to be effective in depositing carbon species on the surface of inorganic 2D nanosheets. To the best of our knowledge, there is no other work about the carbon-deposition of inorganic 2D nanosheet via C_2H_2 treatment and its

application as LIB electrode.

In the present study, efficient electrode materials of carbon@titanoniobate nanosheets is synthesized by the heat-treatment of restacked precursor nanosheet under C_2H_2 flow, as illustrated in the left panel of Fig. 1. The carbon@titanoniobate nanosheets are applied as LIB electrodes to probe the usefulness of vapor-phase carbon-deposition method for exploring efficient inorganic nanosheet-based electrode materials.

2. Experimental

The exfoliated titanoniobate 2D nanosheet was prepared by the protonation of $\text{K}_3\text{Ti}_5\text{NbO}_{14}$ and the following intercalation of tetrabutylammonium cations [6]. The exfoliated titanoniobate nanosheet was restored by the electrostatically-derived restacking with proton. The restored titanoniobate nanosheet was heated at 400°C under 5% C_2H_2 gas diluted with Ar gas for 2, 5, and 10 h to synthesize carbon-deposited titanoniobate nanosheets (These materials are denoted as carbon@titanoniobate-2, carbon@titanoniobate-5, and carbon@titanoniobate-10, respectively). For comparison, the calcination in Ar atmosphere was also done at 400°C for 5 h (This carbon-free material is denoted as titanoniobate-5). Powder X-ray diffraction (XRD) and transmission electron microscopy (TEM)/field emission-scanning electron microscopy (FE-SEM) were carried out to examine the crystal structures and morphologies of the present materials, respectively. The chemical compositions, bonding natures, and pore structures of these materials were determined with energy dispersive spectrometry (EDS) – elemental mapping analysis, thermogravimetric analysis

* Corresponding author.

E-mail address: hwangju@ewha.ac.kr (S.-J. Hwang).

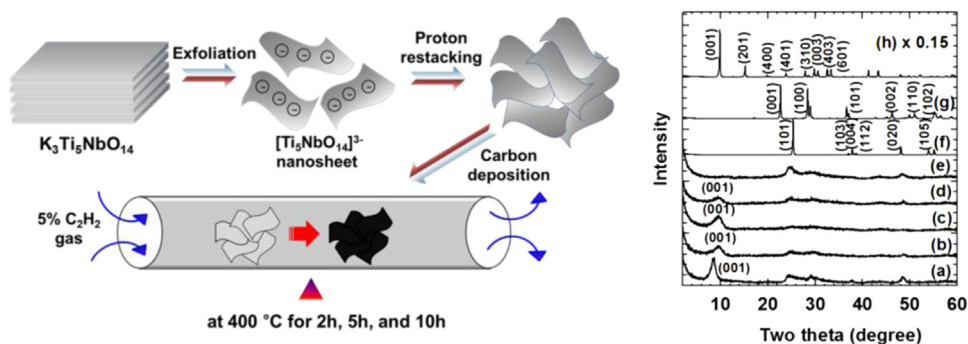


Fig. 1. (Left) Schematic illustration of the synthesis of carbon@titanoniobate nanosheet. (Right) Powder XRD patterns of (a) restored titanoniobate, (b) carbon@titanoniobate-2, (c) carbon@titanoniobate-5, (d) carbon@titanoniobate-10, (e) titanoniobate-5, (f) anatase TiO_2 , (g) Nb_2O_5 , and (h) layered $K_3Ti_5NbO_{14}$ (PDF 72-0908).

(TGA), micro-Raman spectroscopy, and N_2 adsorption-desorption isotherm measurement, respectively. The electrode functionalities of

the obtained nanocomposites were characterized with galvanostatic discharge-charge process with the 2016 coin-type cell of $Li/1\text{ M LiPF}_6$

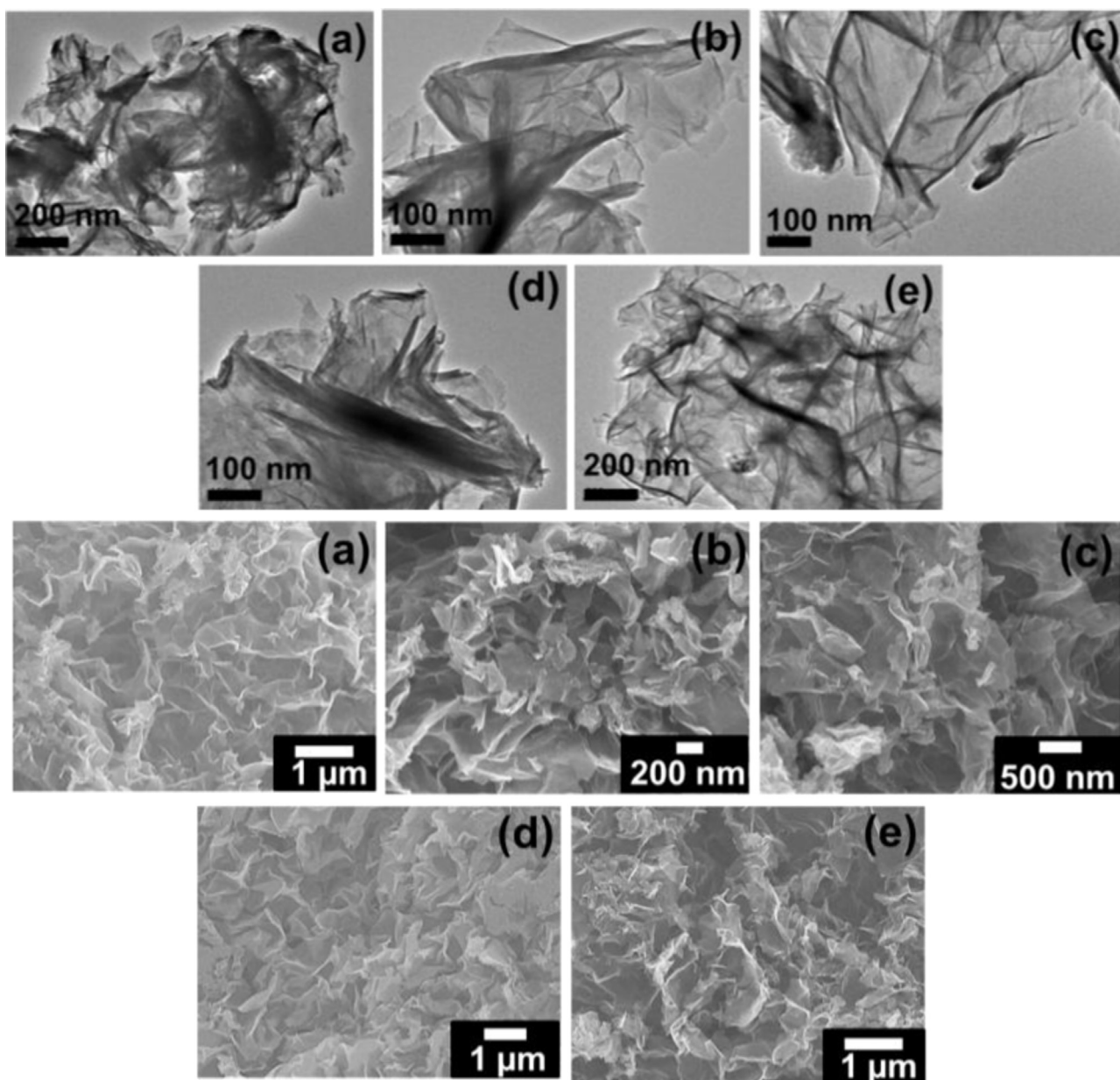


Fig. 2. (Top) TEM and (bottom) FE-SEM data of (a) restored titanoniobate, (b) carbon@titanoniobate-2, (c) carbon@titanoniobate-5, (d) carbon@titanoniobate-10, and (e) titanoniobate-5.

Download English Version:

<https://daneshyari.com/en/article/1641229>

Download Persian Version:

<https://daneshyari.com/article/1641229>

[Daneshyari.com](https://daneshyari.com)