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Two-dimensional nanosheets of tungsten vanadate (WV_2O_7) obtained by assembling nanorods on graphene as a supercapacitor electrode

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ABSTRACT

By cumulative assembly of tungsten vanadate (WV_2O_7) nanorods, novel two-dimensional (2D) nanosheets of interwoven tungsten vanadate were hydrothermally formed on graphene. When as-prepared material was applied into a supercapacitor electrode using H_2SO_4 electrolyte, it was clarified that charging process was based on the pseudocapacitive reaction and the average specific capacitance was 346.4 F g^{-1} with a high differential capacitance of 1211.4 F g^{-1} at −0.1 V. Furthermore, an outstanding improvement of charge retention during cyclic voltammetry was observed (68% @ scan rate 100 mV s^{-1}) while electrode loading was as high as 5 mg cm^{-2}, which was practically significant since the electrode fabrication was based on conventional slurry mixing process. From Ragone plot, it was revealed that the maximum energy density was as large as 27.8 Wh kg^{-1} at 950 W kg^{-1}, and the power density was excellent (23.8 kW kg^{-1} at 16.2 Wh kg^{-1}). The high energy and power capability were attributed to the optimized 2D assembly of WV_2O_7 nanorods with the easy availability of the electrolyte on the high-conductivity graphene layer.

1. Introduction

In recent years, many scientists have investigated the drawbacks of supercapacitors (SCs). Typically, electric double-layer capacitors (EDLCs) with carbon materials were combined with pseudocapacitors with metal hydro/oxide materials, because the latter exhibit much higher capacitance than the former. Moreover, some shortcomings of pseudocapacitors, such as poor electrical conductivity and deformation of electrode materials, were overcome using this approach [1–6]. As a representative example, Kumar et al. introduced three-dimensional (3D) hybrid materials of Fe_3O_4 nanoparticles (NPs) in reduced graphene oxide (rGO) nanosheets (NSs) using microwave methods [7]. The specific capacitance of these materials was highly dependent on the surface morphology of rGO NSs and Fe_3O_4 NPs — 455 F g^{-1} at a scan rate of 8 mV s^{-1}, which is better than that of bare Fe_3O_4 NPs. Moreover, $Ni(OH)_2$/MnO_2@carbon nanotube (CNT) composites with a 3D core-shell structure demonstrated high specific capacitance (2648 F g^{-1} at 1 A g^{-1}), good rate capability, and long cycle life, even at a high mass loading level [8]. In addition, several other metal oxides, such as V_2O_5, CuO_2, Co_3O_4, and ZnO, have been used to fabricate carbon-based composites [9]. Among them, transition metal oxides such as vanadium and tungsten, which possess multiple oxidation states in carbon-based materials, have become popular for use in recent years [10–12].

However, despite the wide variety of oxide structures of vanadium, such as VO, VO_2, V_2O_3, V_2O_5, and V_3O_5, vanadium-related oxides or hydrates with carbon-based composites have rarely been reported [13,14]. Owing to their instability at room temperature, it is difficult to obtain vanadium oxides other than V_2O_5, thereby necessitating expensive precursors and harsh experimental conditions. Patil et al. reported the synthesis of rGO/$BiVO_4$ hybrid fern/dendrite structures using an easy and cost-effective hydrothermal method. A symmetric cell based on rGO/$BiVO_4$ hybrid electrodes was successfully fabricated and showed excellent supercapacitive properties; this symmetric cell presents an excellent volumetric capacitance of 4.63 F cm^{-1} and improved cycling

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