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Microwave synthesis of simonkolleite nanoplatelets on 3D nickel foam-graphene for supercapacitor applications

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Abstract

Simonkolleite nanoplatelets were deposited on 3D nickel foam-graphene (NiF-G/SimonK) by a rapid microwave-assisted hydrothermal method. Field emission scanning electron microscope (FE-SEM) of the NiF-G/SimonK electrode revealed that the SimonK nanoplatelets were evenly distributed on the surface of NiF-G and interlaced with each other, resulting in a higher electrochemical performance compared to NiF-G and NiF/SimonK. Utilizing this composite material, a supercapacitor with a specific capacitance of 836 F g^{-1} at a current density of 1 A g^{-1} has been achieved.

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Keywords: graphene, simonkolleite, energy storage, supercapacitor;

1. Introduction

Recently, supercapacitors (SCs) have received increasing attention as a promising energy storage device [1], such as portable electronic devices and will become an attractive power solution to renewable

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energy power generation [2]. Compared with conventional electrical double layer capacitors (EDLC) operating in a double layer formed on the electrode surface, which limits the specific capacitance and leads to lower energy density relative to their theoretical value, pseudocapacitors utilizing the charges accumulated during a faradaic reaction exhibit a higher capacitance (3–4 times) [3]. Up-to-date, the most attractive materials for pseudocapacitors are cheap transition metal oxides or hydroxides and conducting polymers [3]. However, they often result in compromises of rate capability and reversibility because redox kinetics is limited by the rates of ion diffusion and electron transfer [4]. To deal with the problems, attempts at novel electrode design have been extensively made, that is anchoring nanostructured active materials onto highly conductive substrates (e.g. carbon aerogels [5], conducting polymers [4], and graphene [6]) with large specific surface areas.

In these regards, we explore a new two-step approach for growing Simonkolleite (SimonK) nanoplatelets on nickel foam-graphene. The first step is to grow graphene directly on nickel foam using CVD technique, which is considered as the most effective way for fabrication of large-area and high-quality graphene films. The second is the deposition of SimonK on the as-prepared graphene-coated nickel foam by using a rapid microwave-assisted hydrothermal technique. The fabricated NiF-G/SimonK demonstrates larger specific capacitance at a higher current density.

2. Experiments and methods

2.1. Growth of graphene on nickel foam (NiF-G)

Nickel foams (Alantum, Munich, Germany), 420 g^1 m^{-2} in areal density and 1.6mm in thickness, was used as 3D scaffold templates for the CVD growth of graphene. It was cut into pieces of 1×2 cm^2 and placed in a quartz tube of outer diameter 5 cm and inner diameter 4.5 cm. The precursor gases were CH_4:H_2:Ar. The nickel foam was annealed at 800 ^oC in the presence of Ar and H_2 for 20 min, before the introduction of the CH_4 gas at 1000 ^oC. The flow rates of the gases (CH_4:H_2:Ar) were 10 sccm: 10 sccm: 300 sccm, respectively. After 15 min of deposition, the sample was rapidly cooled by pushing the quartz tube to a lower temperature region.

2.2. Growth of simonkolleite on NiF-G

Simonkolleite nanoplatelets $Zn_5(OH)_8Cl_2 \cdot H_2O$ were deposited directly on the NiF-G using a simple microwave-assisted hydrothermal technique . A 25 ml Pyrex® round-bottom tube was filled with an equimolar (10^{-1} M) aqueous solution of $Zn(NO_3)_2 \cdot 6H_2O$, HMT and NaCl. Subsequently, the NiF-G samples were immersed in the solution and subjected to microwave irradiation of 700 W under a pressure of up to 100 bar for 1h in a single-mode microwave reactor which is pre-pressurized with N_2 gas to prevent boiling of the solution. Thereafter, the microwave reactor was allowed to cool down to ambient temperature. The final NiF-G/SimonK composite was obtained after washing and drying.

2.3. Results and Discussion

Field-emission SEM (FE-SEM) was used in this study to confirm the morphology of the deposited SimonK nanoplatelets on NiF-G (NiF-G/SimonK) as shown in Fig. 1. It can be seen from Fig. 1(a) that the 3D NiF-G/SimonK is a porous structure (pore size of ~0.15–2 mm) and it is clearly shown that the nanostructured SimonK is densely anchored onto both sides of NiF-G surface. At higher magnification, it is observed that the SimonK nanostructures are hexagonal and platelet-like (Fig. 1(b)). The diameter of