

CHAPTER 1

Introduction

1.1 Research Overviews

Electrochemical energy storage devices have recently earned great attention due to increasing demand for use in power grid systems, electric vehicles, and portable electronic devices such as smartphones, tablets, laptops and cameras. Much research has thus been focusing on the development of high-performance electrochemical energy storage devices with high power/energy capacity, high charge/discharge rates, high charge/discharge efficiency, small size, light weight, long cycle life, low cost and environmental friendliness [1, 2]. According to charge/discharge behaviors, electrochemical energy storage devices may be broadly categorized into two main groups, namely supercapacitor and battery-type charge storage [3, 4]. Supercapacitor is a class of electrochemical devices that exhibit a linear dependence of the charge versus potential within a potential window and displays triangular-shape charge/discharge as well as rectangular-shape cyclic voltammetric (CV) curves. Its energy storage mechanism is primarily based on electric double-layer capacitors (EDLCs), which store energy through electrostatic adsorption/desorption of ions taking place at the interface between electrode and electrolyte [5, 6]. Well-known EDLC materials are noble metals and carbonaceous materials such as activated carbon [7, 8], carbon nanotubes [9, 10], and graphene [11, 12]. The other alternative mechanism for supercapacitor is pseudocapacitance, which implicates charge passage through the double layers like faradaic process but having a linear relationship between charge and potential due to thermodynamic reasons [13]. Pseudocapacitive materials include some metal oxides such as MnO_2 and RuO_2 as well as some conductive polymers such as polyaniline and polypyrrole [14-17].

In contrast, the battery-type devices show oxidation/reduction CV peaks and nonlinear charge/discharge characteristics. The mechanism of a battery-type device is

purely faradaic involving redox reactions at the surfaces of active electrode material [4]. Some transition metal oxides (TMOs) and hydroxides including NiO [18], Co₃O₄ [19], V₂O₅ [20, 21], MoO₃ [22], Ni(OH)₂ [23, 24] and Co(OH)₂ [25, 26] are recently reported as promising battery-type electrode materials. Among these, NiO is particularly attractive due to its high charge capacity, fast faradaic reactions, high stability, environmental harmlessness and low cost [27, 28]. The electrochemical energy storage performances of a NiO electrode depend considerably on its production method and electrode structure since they directly affect electronic conductivity and specific surface area [29]. For instance, NiO thin films fabricated by a spray deposition process exhibited a specific capacity of ~162 C g⁻¹ at 5 mV s⁻¹ [30]. In addition, NiO thin films produced by a chemical precipitation technique displayed a good specific capacity of ~200.4 C g⁻¹ at 20 mV s⁻¹ [31]. Moreover, NiO nanoparticles synthesized via a hydrothermal method showed a high specific capacity of ~476.3 C g⁻¹ at 1 A g⁻¹ [32]. Similarly, NiO nanostructures with spherical sponge morphologies fabricated by another chemical precipitation process offered a decent specific capacity of ~505 C g⁻¹ at 1 A g⁻¹ [33]. Likewise, NiO nanoplatelets prepared using a microwave-assisted method demonstrated a superior specific capacity of 548 C g⁻¹ at 1 A g⁻¹ [34]. From these reported results, the energy storage performances of NiO-based electrode can be enhanced by the creation of nanostructures by an effective synthesis method. It is thus compelling to explore an alternative method for the preparation of NiO-based electrode in order to yield high-performance NiO-based energy storage devices.

Sparking is a relatively new method for production of TMOs nanostructures including NiO [35], In₂O₃ [36], TiO₂ [37, 38] and ZnO [39, 40] nanoparticles due to its ability to produce highly porous nanostructured films with very small structural size, homogeneous composition and well controlled film thickness in one step at low cost. It has been demonstrated to be promising for a variety of applications including electrochemical energy storage devices, gas sensors, photocatalysis, and double-layered photoelectrodes in dye-sensitized solar cells. In this work, sparking method has been successfully employed to fabricate a porous NiO film on flexible chromium/gold coated polyethylene terephthalate substrates and NiO film on porous nickel foams that offers a promising specific capacity of 402.75 C g⁻¹ at 1 A g⁻¹ [35] and high specific capacities of 920 C g⁻¹, respectively. The structures and electrochemical performances of the NiO

films are systematically characterized for energy storage applications.

1.2 Research objectives

In this study, the aim is to fabricate the fabrication of NiO nanostructures film coated on a flexible chromium/gold coated polyethylene terephthalate substrate and a porous nickel foams by sparking method. The varying sparking times related to their structures and electrochemical performances are systematically characterized for energy storage applications. The main purposes of this thesis are shown as followed:

- 1.2.1 To develop a new-high performance battery-type electrochemical energy storage electrode base on nickel oxides nanomaterials.
- 1.2.2 To develop a new synthesis method of nickel oxide based electrodes for battery-type electrochemical energy storage applications.
- 1.2.3 To study and optimize electrode materials properties for battery-type electrochemical energy storage application.