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FLEXIBLE SUPERCAPACITORS

MATERIALS AND APPLICATIONS

WILEY

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Chapter 7

Flexible Supercapacitors

Materials and Applications

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Preface

As an emerging and exciting research field, flexible electronics have attracted tremendous interests from both the academic and industrial communities. Till now, many kinds of flexible electronic devices and systems have been developed, such as flexible displays, electronic skins, health monitoring bioelectronics, chemical and biosensors, wearable smart textile, and intelligent soft robots, etc. This area develops very fast and some flexible products are already commercially available. For example, flexible organic light-emitting diode displays have been widely used in smart phones, smart watches, and tablet personal computers.

The booming development of flexible electronics has driven the demand for compatible flexible energy storage devices, ideally to make the whole electronic system flexible. Although conventional energy storage devices, such as lithium-ion batteries, lead acid batteries, supercapacitors, have been widely used in our modern society and affected our daily life, their rigid shape, heavy weight, and thickness make them not suitable for flexible electronics. Among different energy storage devices, supercapacitors have the advantages of simple device structure, high power density, short charge and discharge time, long cycle life and wide operating temperature range. When making supercapacitor flexible, it will also possesses the required features of excellent flexibility, portability, stretchability, miniaturized size, ultrathin thickness for flexible electronic devices. During the past several years, researches on flexible supercapacitors are very active and this field expanded very fast. Thus, it is considered timely to provide a survey of a number of important developments in this filed.

This book provides an up-to-date survey of the state of flexible supercapacitors. It contains a selection of 11 chapters contributed by a number of research teams. All the contributors are active researchers in the field of flexible supercapacitors. The most important topics related to flexible supercapacitors are included in this book, ranging from the selection and design of different active electrode materials, the design of different device structures, suitable fabrication techniques, and different functions. I hope this book will be a source of inspiration for graduate students, researchers, and industrial engineers, and will stimulate new developments in this challenging but exciting field.

Guozhen Shen, Professor
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1
Flexible Asymmetric Supercapacitors: Design, Progress, and Challenges

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1.1 Introduction

Recently, flexible electronic products, such as flexible microphones [1], elastic circuits [2–4], pressure and strain sensors [5–7], artificial skin sensors [8–10], intelligent garments [11], and wearable health monitoring devices have boomed as a new and important field of modern electronics (Figure 1.1). Therefore, the development of suitable energy storage devices, which can serve as an excellent power supply while sustaining high mechanical flexibility, are becoming increasingly necessary to power these electronics [13–21]. Supercapacitors (SCs), also known as electrochemical capacitors or ultracapacitors, have emerged as the bridge between batteries and traditional capacitors due to their promising merits of high power density (about 10 kW kg^{-1}), good reversibility, excellent cyclic stability (over 10^6 cycles), and safety [22, 23]. Meanwhile, accompanied with the advanced development of lightweight, foldable, and stretchable materials, substantial effort has been invested in the fabrication of flexible supercapacitors (FSCs) [24–28].

In order to satisfy the further demand for practical usage, the configuration of the two electrodes as well as the geometry of the devices are of vital importance and worth careful considerations [29]. The major obstacle of early designed FSCs is their relatively low energy density (E) to mismatch basic requirements of future applications. Thus, tremendous efforts have been denoted to optimize the overall performance of FSCs according to the Eq. (1.1), without sacrificing their power density and service life.

$$E = \frac{1}{2} C V^2 \tag{1.1}$$

In general, either enhanced capacitance (*C*) or enlarged operating voltage (*V*) of the device should make sense. Of which, the *C* of a FSC device can be equivalent to the negative electrode capacitance (C_n) and positive electrode capacitance (C_p) connected in series (Figure 1.2a), which can be calculated using Eq. (1.2)

$$\frac{1}{C} = \frac{1}{C_n} + \frac{1}{C_p} \tag{1.2}$$

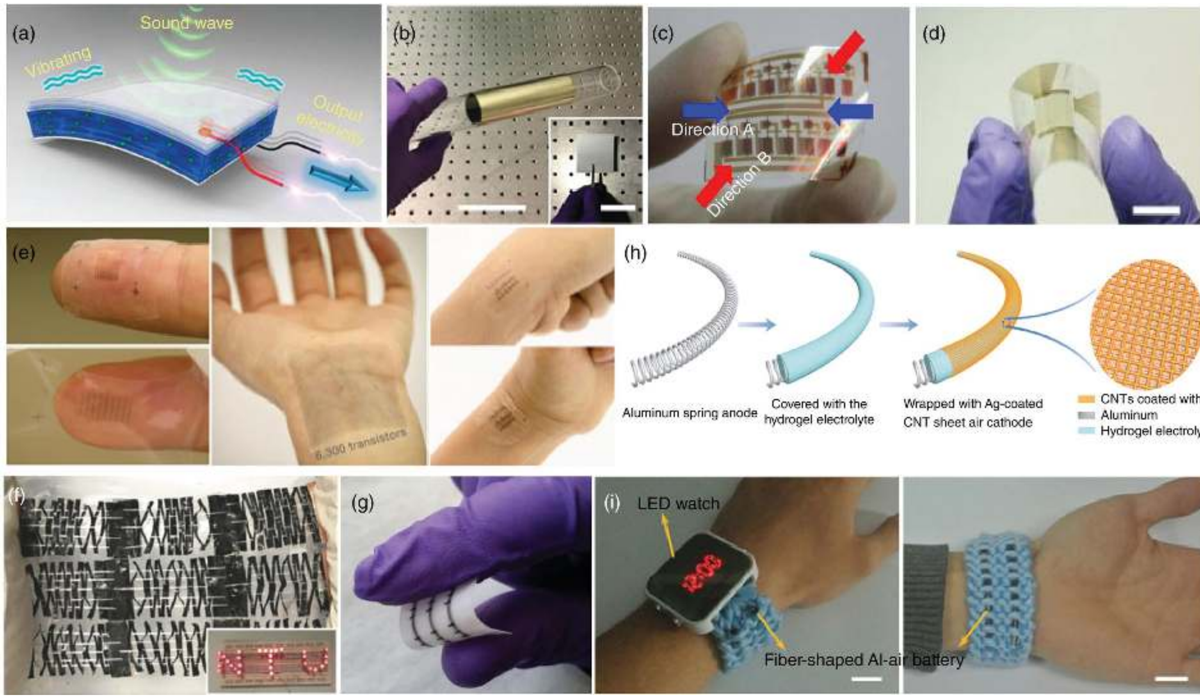
(a)
Sound wave
Vibrating
Output electricity
(b)
(c)
Direction A
Direction B
(d)
(e)
6,300 transistors
(h)
Aluminum spring anode
Covered with the hydrogel electrolyte
Wrapped with Ag-coated CNT sheet air cathode
CNTs coated with Ag
Aluminum
Hydrogel electrolyte
(f)
(g)
(i)
LED watch
Fiber-shaped Al-air battery

Figure 1.1 (a, b) Scheme and optical image of a flexible acoustic device.

Source: Reproduced with permission from Ref. [121], © 2017, Springer Nature.

Optical image of (c) a flexible circuit

Source: Reproduced with permission from Ref. [2], © 2018, NPG

, (d) multiplexed fingerprint sensor. Scale bar, 1 cm.

Source: Reproduced with permission from Ref. [5], © 2018, NPG

and (e) artificial skin electronics

Source: Reproduced with permission from Ref. [8], © 2018, NPG.

(f) 3×3 honeycomb-like supercapacitor array powering LED panel.

Source: Reproduced with permission from Ref. [13], © 2017, Wiley.

(g) Image of an array of field-effect heterojunctions on textile.

Source: Reproduced with permission from Ref. [14], © 2017, NPG.

(h, i) Fabrication and optical image of the fiber-shaped Al-air battery.

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