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Review

Energy efficient capacitors based on graphene/conducting polymer hybrids

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ABSTRACT

Graphene (GRP) and conducting polymers (CPs) are interesting classes of emerging materials for various applications. To date, extensive research effort has been devoted to the investigation of diverse properties of graphene and conducting polymers such as polypyrrole (PPy), polyaniline (PAni), and polythiophene (PTh). The combination of these materials can be very advantageous in terms of practical applications in energy storage/conversion systems. Among various those systems, energy efficient electrochemical capacitors (ECs) have become popular due to the recent need for small and portable devices. Therefore, in this article, the application of GRP/CP hybrids for high performance capacitors is described concisely. In particular, an extensive and concise summary on the previous research activities regarding GRP/CP capacitors is covered. Subsequently, recent patents related to the preparation and application of GRP/CP capacitors are also introduced briefly. It is certain that this article can provide essential information for future study.

Contents

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Introduction

Graphene and conducting polymer

GRP is a monolayer of graphite with a hexagonal structure in which carbons have a sp^2 hybrid orbital [1]. However, their properties are dramatically different from those of carbon allotropes [1–3]. Owing to the unprecedented advantages of GRP such as a high carrier mobility and capacity, a tunable band gap, an ambipolar electric field effect, and quantum Hall effect [2–10], GRP has become a competitive material for various applications such as electronics, batteries, fuel cells, capacitors, photovoltaics, and sensors [11–18]. In general, GRPs can be produced by two methods, solution and chemical vapor deposition (CVD) [19–25]. Recently, numerous elegant preparation techniques have been developed, thus the usability of GRP is expanding rapidly.

On the other hand, CPs such as PPy, PAni, PTh, and poly (vinylphenylene) allow intermolecular charge transport, because they contain a large conjugation structure with a lot of sp^2 hybridized carbons. Nanocomposites having CPs can utilize their inherent characteristics, thus they have demonstrated excellent performances. CPs become popular for applications such as electronics, energy storage/conversion, environmental monitoring, and sensors since their discovery in 1976 [26–30]. Fig. 1 displays the most popular conducting polymers.

Considering the positive aspects of GRP and CPs, it is natural that GRP and CPs can be combined to generate more sophisticated structures and materials. In addition, novel components such as nanocrystals and biomolecules can be added to produce hybrid materials [29,30]. That is, GRP/CP hybrids can provide a mechanically robust and chemically stable flatform for many challenges such as energy devices, optoelectronic architectures, sensors, and air/water purification. To date, GRP/CPs have shown their feasibility for environmental protection and monitoring, for example removal of toxic molecules, oxidation/reduction, photocatalysis, and gas storage [31]. GRP/CPs has also been demonstrated as one of the most competitive candidates for energy storage/conversion systems [32–36].

Among various energy storage/conversion devices, ECs are attracting a dramatic interest owing to their high energy density and long cycle life [37]. There has been an enormous effort to improve their performance in material perspective [38]. Carbons such as carbon nanotubes and GRPs have been recently most popular due to relatively high energy density [39]. For example, it was calculated that the theoretical capacitance of a single-layer GRP was approximately 20 μF [40]. Although additional components such as metal oxides [41] have been incorporated to improve performance, however, the challenges were hindered by the low electrical conductivity of metal oxides [42]. Therefore, CPs can be a strong alternative candidate material for ECs owing to their excellent electrical conductivity. On the contrary, control over their morphology and physical properties is a difficult task [37].

Introduction to capacitor

An EC is a simple electrical component used to store energy electrochemically. ECs have irreplaceable advantages such as high power density, short charge time, a long cycle life, and favorable safety considerations. ECs aim to make up the critical gap between battery (high energy density) and conventional capacitor (high power density).

ECs, also called as supercapacitors can be classified into two broad categories, which are non-faradic (electrical double layer capacitors (EDLCs)) and faradic (pseudo-capacitors) depending on the charge storage mechanism [43,44]. For non-faradic process, charge adsorption take place between the interfaces of electrodes

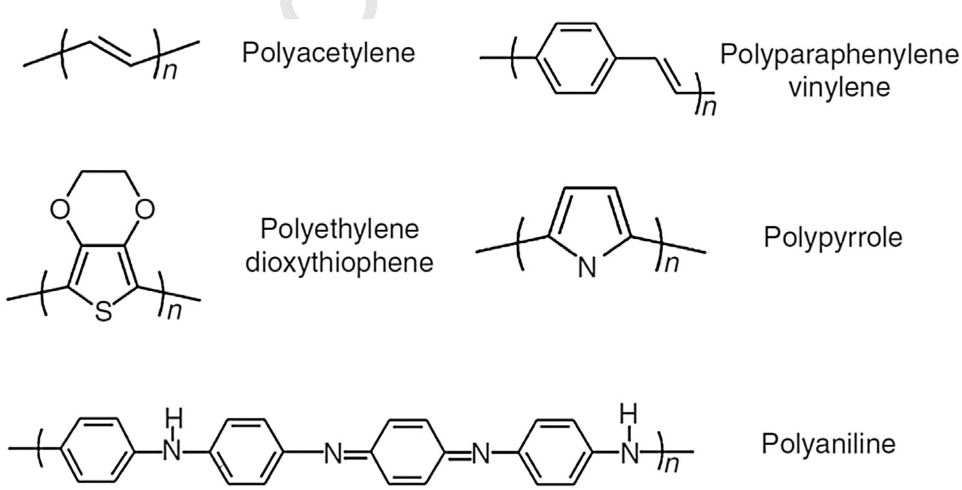

Fig. 1. Chemical structures of representative conducting polymers.

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