New Strategy and Easy Fabrication of Solid-State Supercapacitor Based on Polypyrrole and Nitrile Rubber

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Solid state redox supercapacitors were fabricated using a solid polymer electrolyte, nitrile butadiene rubber (NBR)-KCl and chemically deposited polypyrrole (PPy) as the conducting polymer electrodes on both surfaces of a NBR film. The optimal conditions for the preparation of the PPy/NBR electrode were confirmed as functions of the uptake of pyrrole monomer into the NBR matrix as well as the immersion time in an oxidant solution. The morphology of the PPy-NBR-KCl capacitor was observed using scanning electron microscopy. The performance of the capacitors was characterized using a galvanostatic charge–discharge technique.

Keywords: Solid State Supercapacitor, Polypyrrole, NBR, Conducting Polymer.

1. INTRODUCTION

Electronically conducting polymers are promising electrode materials for redox supercapacitors as the kinetics of their electrochemical charge–discharge processes, known as doping–undoping, are generally fast and occur throughout their entire volume. In addition, they have high charge densities, are easy to chemical/electrochemical synthesize in the form of extended surface thin films and less expensive than other alternative electrode materials, such as noble metal oxides.1–7

Among the extensively studied conducting polymers, polypyrrole (PPy) has drawn considerable attention due to its relatively high solid stability under ambient conditions and ease of synthesis.8 PPy is an important electrode material for use as redox supercapacitors, and has the advantages of a porous morphology, good electrical conductivity and a fast doping and dedoping process.9 It also acts as an intermediate power source between rechargeable batteries and conventional electrolytic capacitors, offering a power density higher than batteries and an energy density higher than conventional capacitors.3

Most reported redox supercapacitors are based on liquid electrolytes,10–15 which are associated with the well known disadvantages of corrosion, self discharge, bulky design and a low energy density, similarly to liquid electrolyte batteries. Major attention has been recently been devoted to the fabrication of solid-state capacitors using solid polymer electrolytes (SPEs), due to their high ionic conductivity and advantageous mechanical properties, including flexibility for proper electrode–electrolyte contact and ability to form thin films with a desirable surface area.19 Polymer redox capacitors, using different type SPEs: poly(methyl methacrylate)—ethylene carbonate (EC)—propylene carbonate (PC)—LiClO₄20–21 poly(ethylene glycol) (PEG)/PC-tetraethylammonium tetrafluoroborate5 and poly(vinyl chloride)-H₃PO₄,19 have been widely reported. Solid state capacitors are generally built in a configuration where the internal layer is a SPE sandwiched between two conducting polymer layers.

In the preparation of solid capacitors, several technical problems exist. A delaminating process can often occur, due to the poor cohesion between the conducting polymer film and the SPE layer, which can result in a limited lifetime of the capacitor. Also, when SPE is swollen with an electrolyte solution, the evaporation of the solvent must be minimized to allow facile ion transport to provide the system with optimum ionic conductivity. In order to resolve this problem, the conducting polymer should have an interpenetrating network-like structure with the SPE matrix. Therefore, most of the conducting polymer will be formed at the surface, conversely, some will be formed in the midst of the SPE matrix, providing a good interlocking structure.

Recently, we also introduced a single layer actuator system based on a poly(3,4-ethylenedioxythiophene) (PEDOT) and nitrile rubber (NBR) containing room temperature ionic liquid as a solid polymer electrolyte, which