Printable Electrodes for Flexible Supercapacitors

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1. (AEM) Advanced Energy Materials

INTRODUCTION

Wearable electronics in various forms being applied in several applications. For example, skin or tattoo like sensory patches have been reported for health monitoring and for tactile feedback in robotic and rehabilitation devices. Typically, these applications require an operating power in the range of nW to µW[1-3]. However, it is difficult to meet these power requirements as current solutions such as batteries cannot be integrated in wearable systems as they are heavy, lack flexibility and produce heat, etc. The frequent charging of battery also limits their applications in wearable system. This calls for new ways of storing the energy needed for the operation of electronic components on wearable systems[3]. To some extent, the self-powered systems, such as solar powered sensors in energy autonomous e-skin[1] could overcome the issue of power supply in wearables sensors. However, power generation alone is not constant as key element needed for energy harvesting (e.g. sunlight) may not available all the time. In this regard, as an energy storage device is critical. In this regard, the progress in the field of supercapacitors (SC) has raised hopes. SCs can have excellent power density (range of $kWkg^{-1}$ or Wcm^{-2}), shorter charging time (minutes), longer charging/discharging lifecycle (>10^6) and no thermal breakdown. Further, they have low cost of fabrication, can be flexible and shaped as needed and are environmental-friendly[4, 5]. Here, we present our initial investigations related to evaluation of the electrochemical performance of printable carbon-based electrodes for the fabrication of a flexible SCs.

EXPERIMENTAL/THEORETICAL STUDY

Low cost screen-printing method is used for the fabrication of electrodes of SC on a flexible polyethylene terephthalate (PET) substrate. We are preparing different printable pastes and inks for the fabrication of SC. In this work, we investigate the performance of a carbon paste prepared by mixing activated carbon powder with suitable binder. The fabricated electrodes of SC are packed by using hot lamination with polyvinyl chloride (PVC) sheet for wearable applications. The electrochemical performances of the as-prepared SC using aqueous electrolyte H_3PO_4 were evaluated using electrochemical impedance spectroscopy (EIS) and cyclic voltammetry (CV) analysis (Autolab PGSTAT302N). Galvanostatic charge –discharge (GCD) measurements were carried out using source meter (Agilent, U2722A with controlled with LabVIEW program) in a two-electrode electrochemical cell system. The flexibility of the SC was tested by under different bending conditions.

RESULTS AND DISCUSSION

The CV analysis in the range of scan rate 10-200 mV/s indicates the diffusion-controlled reaction of the electrode. The quasi-rectangular shape of the CV curves as shown in Fig. 1a indicate the ideal electrochemical double layer (EDLC) mechanism of the fabricated SCs. The charge transfer resistance and ionic exchange of the electrodes were analyzed by using EIS in the range of frequency 10 mHz -100 kHz. The Nyquist plot obtained from complex impedance data of the SC is shown in Fig. 1b. The negligible charge transfer and contact resistance reveals excellent electrochemical performance of printed electrodes. GCD analysis was used to measure the two key parameters which govern the performance of SC such as potential window (V) and the specific capacitance (C_A). These parameters influence the energy density ($E_A = 0.5\ C_A\ V^2$) of the SC and are investigated in this work. In addition to this, it was found that the printable electrode of SC enables more than 10^6 cycles of charging and discharging. We investigated the static and dynamic bending of printed SC electrode in different angle. The negligible variation in the performance of SC during bending reveals its suitability in wearable systems.

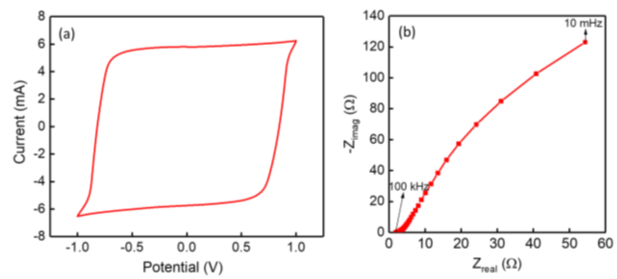

Fig.1: Electrochemical performance of the printed SC electrode (a) CV curve and (b) Nyquist plot

CONCLUSION

The printed carbon-based SC electrodes exhibits excellent electrochemical performance. The flexibility of the electrodes shows their applications in wearable systems. The performance of SC demonstrates its implementation as an energy source in wearable sensors, which works in the power range of nW to µW.

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