Investigation of the Supercapacitive Performance of Modified Carbon Nanotube Materials by 1-methyl-3-octadecylimidazolium Bromide Ionic Liquid

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Abstract:

Supercapacitive properties of electrodes built from ionic liquid-Multi Walled carbon Nanotubes (MWNTs) gel electrodes have been investigated. IL/MWNTs gel was easily prepared by adding MWNTs into 1-methyl-3-octadecylimidazolium bromide ionic liquid aqueous solution, then the resulting gel deposited on Nickel foam by electrophoretic deposition. Electrochemical characterizations were carried out by cyclicvoltammetery and impedance spectroscopy in 1M KOH aqueous solution at room temperature. The specific capacitance of this electrode (120 F/gr) was larger than those were reported for bare carbon nanotube electrodes, and pseudo faradic reactions have been detected.

Introduction:

Ever since their discovery by Iijima in 1991[1], due to their novel properties such as high specific surface area, high mesoporosity, high electrical conductivity, high electrolyte accessibility, carbon nanotubes (CNTs) are attractive electrode materials for developing high-performance supercapacitors [2]. However, the van der Waals interaction between tubes makes CNTs aggregate, which is the major limitation to their practical applications. To favour the dispersion of individual nanotubes and prevent their reaggregation, different approaches have been investigated to modify the surface of CNTs [3]. Recently Room Temperature Ionic Liquids (RT-ILs) with unique physicochemical properties such as wide liquid temperature range, high

thermal stability, negligible vapor pressure, high viscosity, negligible vapor pressure, nonflammability, increased electrochemical window, and relatively high ionic conductivity have attracted considerable attention as novel materials to modified CNT based electrodes in supercapacitor fabrication [4]. However conventionally polymers like PVdF and PTFE are used as binder to prepare the supercapacoitor electrodes, one of the advantages of IL-stabilized CNT, which called Bucky gel, based electrodes is no need of binders [4].

In this paper we present the electrochemical behaviors of electrodes built from deposition of 1-methyl-3-octadecylimidazolium bromide/Multi Walled Carbon Nanotubes Bucky gel, on Ni-foam by electrophoretic deposition (EPD).

Experimental:

Preparation of electrode:

Multi walled carbon nanotubes (MWNTs) were purchased from Arkema and used as received. The suspensions of MWNTs were prepared by adding CNTs into 1-methyl-3-octadecylimidazolium bromide ionic liquid aqueous solutions, and were sonicated by probe sonicator (UP 400S, hielscher Ultrasound Technology, Germany). Then the resulting suspension was centrifuged to sedimentation of large bundles. Then the suspension was characterized by UV-vis-NIR (UV mini, 1240, Shimadzu, Japan).

The EPD was conducted in two electrode system, where Ni-foam with exposed area of 1cm×1cm, were used as cathode, and Nickel sheet with exposed area of 2cm×2cm, were used as anode. These two electrodes were used in an EPD cell, with an electrode gap of 7mm. Care was taken that the electrodes were parallel to each other. The DC electrophoretic deposition of CNT/IL gel on Ni-foam was carried out at 100V for 30seconds. After completing the deposition, the resulting electrode was dried under room temperature for 24 hrs. The microstructure was observed by using a scanning electron microscope (SEM) (TESCAN, VEGA, Czech Republic). Different electrochemical techniques were used to characterize the capacitive performance, and internal resistance of supercapacitor electrodes. Electrochemical characterizations were carried out by an electrochemical workstation (SAMA, 500 electro analyzer, Iran) in 1M KOH aqueous solution at room temperature in a three electrode configuration using a saturated Ag/AgCl as the reference electrode and graphite as the counter electrode. Cyclic Voltammetery (CV) were performed between -1.4V to 0.22V at different scan rates. The electrochemical impedance

spectroscopy (EIS) measurements were conducted by a Auto lab PGSTATE 30 model controlled by computer and Nova 1.7 software, applying an alternating current in the frequency range from 10 kHz to 0.1 Hz with 14 mV amplitude on the dc voltage of -0.4 V.

Results and Discussion:

Fig. 1 shows the UV-vis-NIR spectra of [C18C1im] Br-stabilized MWCNT dispersion, compared with [C18C1im] Br aqueous solution. The strong peak which appeared around 260 nm, approved that CNTs were successfully dispersed in [C18C1im] Br aqueous solution.

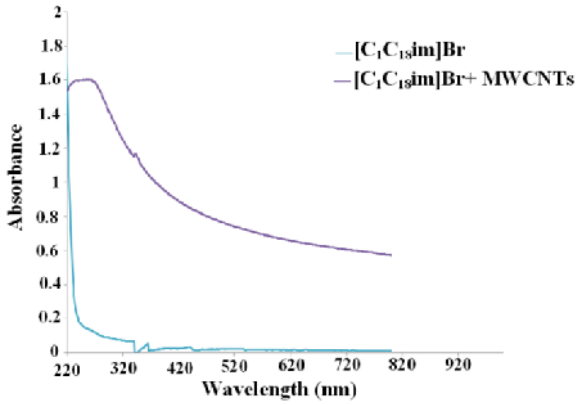

Fig. 1- UV-vis-NIR spectra of MWCNT suspensions (a) [C18C1im] Br aqueous solution and (b) MWCNTs dispersed in [C18C1im] Br aqueous solution.

Fig. 2 shows the SEM images of the surface morphology of resulting electrode. Obviously, dispersed CNTs with [C1C18im] Br were well deposited on the surface of Ni foam framework.

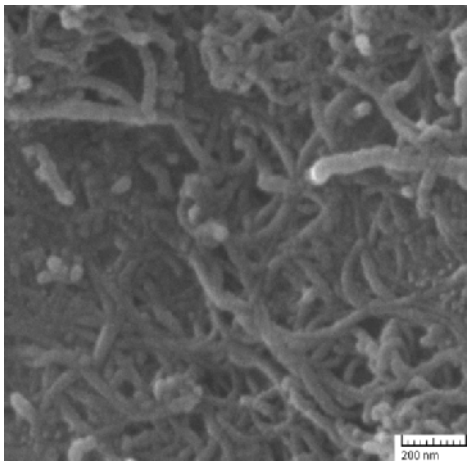

Fig. 2- SEM surface morphologies of modified CNTs by [C1C18im] Br deposited on the Ni foam.

Figure 3 illustrates the (a) Nyquist and (b) CV curves of Ni foam-CNT/[C1C18im] Br electrode, Which are evidences of well-developed capacitive properties of resulting Ni foam-CNT/[C1C18im] Br electrode. This electrode exhibits larger capacitive current than that of bare Carbon materials, and this electrode shows the redox activity characteristic. The specific capacitance of this electrode is about 120 F/g, and low internal resistance (~ 0.6Ω/cm^2).

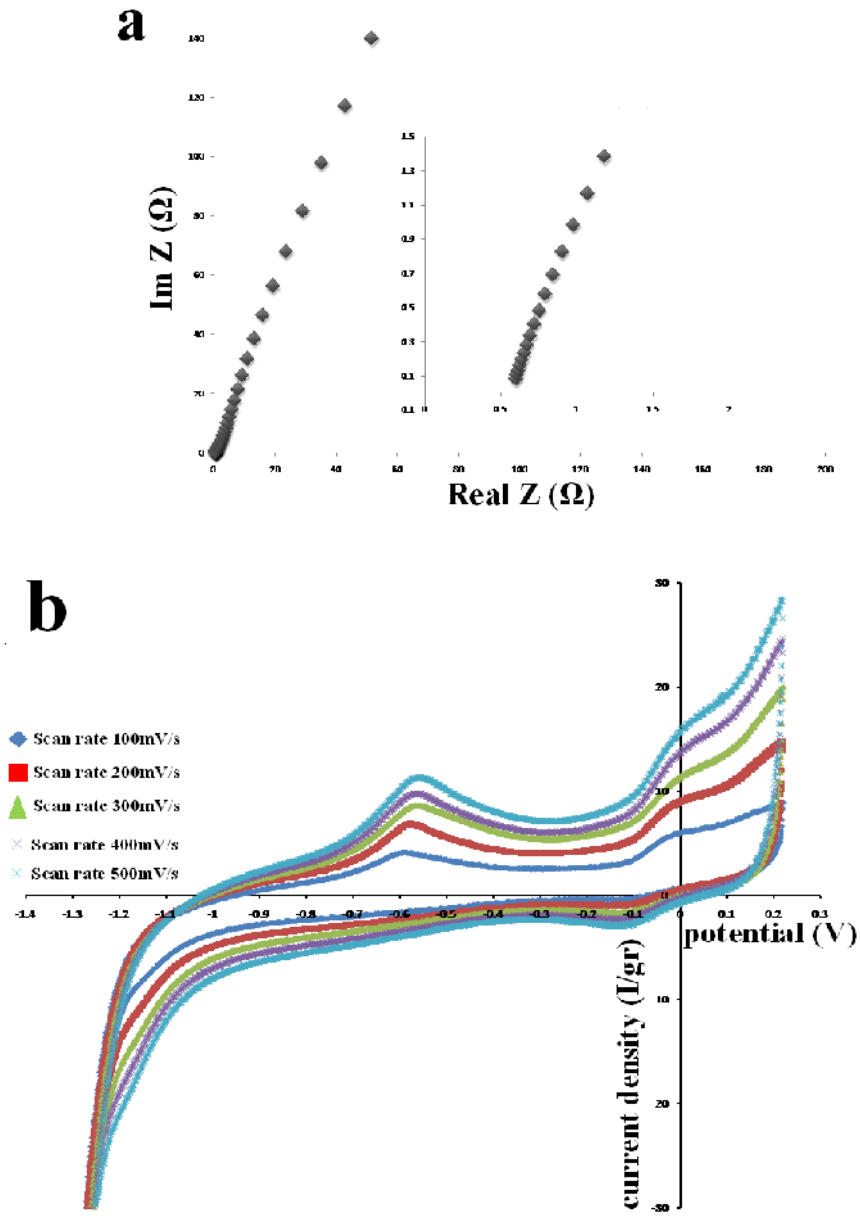

Fig. 3- (a) Nyquist plot (0.1 ~ 100000 Hz), upper inset is a local amplified image at high frequencies, (b) CV curves taken at different Scan rates.

The above experimental results indicate that the Ni foam-CNT/ [C1C18im] Br electrode has a significant high specific capacitance. This can be mainly attributed to the hierarchical porous structure of this Ni foam-CNT/IL electrode, which facilitates the charging and discharging of electric double layer by profiting the penetration of ion at the electrode/electrolyte interface through a proper–size distribution [5].

On the other hand, the better performance of Ni foam- CNT/ [C1C18im] Br electrode owes to the ion exchange and ion transfer induced by redox reactions within IL deposited on the electrode [7].

Conclusion:

In conclusion, the present process provides an effective approach for directly preparing a supercapacitor electrode from CNTs without any additional binder. It presents much higher specific capacitance, lower internal resistance and better capacitive performance at very high current densities.

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