Carbyne-enriched carbon- A novel binder-free electrode for supercapacitor application

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1. Introduction

Evolving technological innovations in the electronic field urge the need for renewable energy sources over fossil fuels to meet energy demand. To overcome this issue, significant interest in novel materials have been put forth. In this regard, carbon and carbon family is a promising candidate due to their peculiar properties in the arena of energy harvesting and storage system. In this work, we reported CEC-Ni as a binder free electrode for SCs application due to its fascinating physio-chemical properties. The valence electron of carbyne possesses sp, and sp^2 hybridized atom which are different from graphene and diamond like carbon. Generally, carbyne is a linear chain of 'n' number of carbon atom composed of either single and triple bond (-C≡C-) n or consecutive double bond (=C=C=)n over the liner chain[1-3]. The theoretical study by Liu et al. proposed that carbyne possesses high strength, high flexibility, and chemically stable in nature. Wesley A. Chalifoux et al. experimental result confirms that carbyne possesses the band gap of ~2.56 eV [4,5]. This outstanding property of carbyne opens the gateway towards the various application. Bettini et al. inspected the use of carbyne-rich carbon films (fabricated by low kinetic energy deposition method) as an electrode material for supercapacitors application. The work by Bettini et al. validates that forthcoming studies are important for improving the electrochemical properties of carbyne which can be attained either by changing the synthesis method, or removing the binder from the electrode, or applying both faradic and nonfaradic mechanism on charge storage and so on [6]. Therefore, in this report, we prepared the novel binder free carbyne-enriched carbon/Ni via extracting the halogen from the PVDF-Ni using chemical dehydrohalogenation method and examined its use as a potential electrode for supercapacitor application.

2. Results and Discussion

The micrograph of CEC-Ni before dehydrohalogenation process seen in Figure 1(A& B) affirms the uniform coating of PVDF on nickel foam at a different level of magnifications. Figure 1(C & D) present the micrograph of the prepared CEC-Ni after the removal of halogen process at different magnification, which revealed the uniform distribution of CEC on the Ni foam.

Further, the prepared PVDF-Ni and CEC-Ni film is used as such as an electrode for the supercapacitor application. At first, the CV curve of the PVDF-Ni and CEC-Ni electrodes have been studied (using three electrode tests) to know their charge storage behavior using 1M Na2SO4 electrolyte. The CV profile of PVDF-Ni and CEC-Ni electrode indicate that it can operate over the operating potential window (OPW) of 0.0 to 1.0 V measured at a scan rate of 100 mV s^{-1} as seen in the figure 2 (A &B).

3. Equations and figures.

The specific capacitance of the CEC/Ni electrode from CV profiles was calculated using relation:

$$C_{sp} = [\int IdV / (s \times \Delta V \times m)] \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Here, '∫ IdV' is the integral area under the CV curve, 's' is the scan rate (mV s-1), 'ΔV' is the potential window (V), and 'm' is the electroactive mass of the electrode (g). Here 'I' is the discharge current (A), 'Δt' is the discharge time (s), 'm' is the electroactive mass of the electrode (g), 'ΔV' is the potential window (V).

The specific capacitance (Csp) of the CEC/Ni electrode was calculated from the CD profiles using the relation.

$$C_{sp} = [(I \times \Delta t) / (m \times \Delta V)] \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Here 'Csp' is the specific capacitance of the CEC/ Ni electrode obtained using CD analysis (F g-1), 'ΔV' is the potential window (V) and 'Δt' is the discharge time (s).

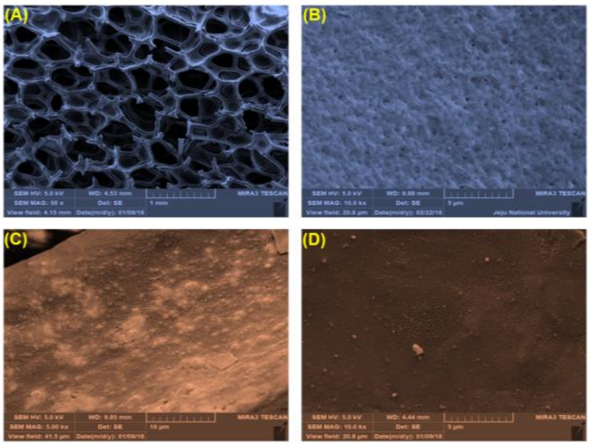

Fig 1. FE-SEM micrograph of PVDF-Ni (A-B) and CEC-Ni (C-D) at different magnification

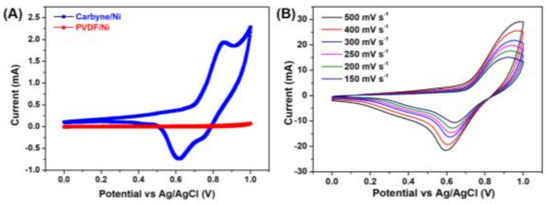

Fig 2. (A) Comparative CV profile of PVDF-NiE and CEC-NiE measured at a scan rate of 5 mV s^{-1} and (B) CV profile of CEC-NiE measured at various scan rate from 500 to 150 mV s^{-1}.

4. Deadline and other information

In conclusion, we used a simple and cost-effective dip and dry process for the fabrication of high-performance electrode for next generation supercapacitor application. The CEC-Ni were prepared via extraction of halogens from the PVDF-Ni using chemical dehydrohalogenation process. In depth physio-chemical characterization such as XRD, XPS, Laser Raman spectroscopy, FT-IR and FE-SEM with elemental mapping were analyzed to conform the extraction of halogen from the PVDF-Ni film using dehydrohalogenation process. CV and EIS studies suggested that the overall capacitance in CEC-Ni was contributed by both EDLC and ion intercalation/de-intercalation capacitance. The CEC-Ni electrodes delivered a specific capacitance of 106.12 F g-1 from the CV profile analysis performed at a scan rate of 5 mV s^{-1}. These studies suggested the potential applications of CEC-Ni as an electrode material for future energy storage application.

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