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Electrochemical performance of hybrid rGO/CuO/PPy nanocomposites for 2032 coin cell

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Abstract **–** In this work, hybrid 3 different materials (rGO, CuO and PPy) were formed by hybrid nanocomposites in 2032 coin cell for Supercapbattery applications. Pseudocapacitance behavior was obtained for transition metal oxides of copper (II) oxide (CuO) and conducting polymer of polypyrrole (PPy). Moreover, electrical double layer capacitance (EDLC) behavior was supplied by reduced graphene oxide (rGO) in nanocomposite. 3 different electrochemical performances were tested by cyclic voltammetry (CV), galvanostatic charge/discharge (GCD) and electrochemical impedance spectroscopic measurements (EIS). EIS measurements were given by 4 different plots, which are Nyquist, Bode-magnitude, Bode-phase and Admittance plots. Stability test was also performed by CV method using 1000 charge/discharge performances at a scan rate of 100 $mV \times s^{-1}$. The highest specific capacitance was obtained as C_{sp}= 2761.63 $F \times g^{-1}$ at 2 $mV \times s^{-1}$ (electrode weight was measured as 43.8 mg).

Keywords – Admittance Plot, 23032 Coin Cell, EIS, Specific Capacitance, Supercapbattery

I. INTRODUCTION

In this study, electrode-active materials (rGO/CuO/PPy) were performed by electrochemical performances using CV, GCD and EIS measurements. Electroactive materials have both pseudocapacitive and EDLC behavior in 2032 coin cell. The critical point is to improve electrochemical performances of supercapbattery device. So, we have designed electroactive material on Al and Cu film electrodes. Hybrid system was obtained both electrochemical cell design and electroactive material to improve the electrochemical performances of supercapbattery device. Both supercapacitor and battery were worked to form new type of supercapbattery design. 3 important points affects the electrochemical performances of supercapbattery device. These are pore size, surface area and conductivity of electroactive materials. There are two ways to improve conductivity in literature. One is the doping process which causes the decrease of band gap [1, 2]. The other method is to use a acetylene black as a conductive material. In this study, we used both conductive material and conducting polymer as polypyrrole (PPy) [3-6].

II. MATERIALS AND METHOD

Electrochemical measurements were performed with 2032 coin-type cells. The slurry was obtained by mixing the as-synthesized materials, acetylene black and *N*-methyl-2-pyrrolidone (NMP) as a solvent for materials. Polyvinyl pyrrolidone (PVP) was performed by binder. Then the slurry was pasted onto Al and Cu foils and dried at 60 ^{o}C in a vacuum oven for 12 h. The electrolyte was injected in ionic liquid (IL). And the total mass loading of electrode of 43.8 mg. Cyclic voltammetry (CV) measurements were taken potential range between 0.0 V to 0.8 V at a

scan rate from 2 $mV \times s^{-1}$ to 1000 $mV \times s^{-1}$ using ivium-vertex potentiostat-galvanostat instrument.

Galvanostatic charge-discharge measurements (GCD) were performed at a constant current densities from0.1 $A \times g^{-1}$ to 10 $A \times g^{-1}$.

Electrochemical impedance spectroscopic (EIS) measurements were performed frequency change from 0.01 Hz to 100 kHz as a sinusoidal behavior.

A. GO and rGO synthesis

Graphene oxide (GO) was synthesized from graphite powder according to modified Hummers method [7].

B. CuO synthesis

Copper (II) oxide (CuO) nanoparticles were synthesized by ultrasonication and precipitation by heat treatment method. For the synthesis form, 4.8 g of Copper (II) sulfur penta hydrate ($CuSO_4 \times 5H_2O$) was dissolved in 200 ml of DI water. 200 ml is added dropwise to the mixture containing 0.2 M NaOH and ultrasonication treatment at 60 ^oC for 2 hours. The dark brown precipitate was decanted by centrifugation and washed several times with DI water and kept in an oven at 80 ^oC for 1 night and CuO nanoparticles were obtained.

C. Polypyrrole synthesis

Polypyrrole was synthesized by chemical oxidation polymerization method. Pyrrole monomer, potassium dichromate ($K_2Cr_2O_7$) was used as oxidizer and H_2SO_4 as additive. Chemical polymerization was carried out by adding 1 M H_2SO_4 and 1 M pyrrole monomer solution dropwise addition to the above solution. Polymerization was carried out with constant stirring for 24 h with ice-bath condition. After the obtained product was filtered and washed with DI water. The black colored PPy powders were dried in an oven at 100 ^oC for 1.5 h [8].

D. Electrochemical performances of SupercapBattery device

rGO/CuO/PPy nanocomposite were measured by CV, GCD and EIS measurements.

E. CV measurements

CV plots of rGO/CuO/PPy nanocomposite at different scan rates from 1000 $mV \times s^{-1}$ to 2 $mV \times s^{-1}$ were given in Figure 1.

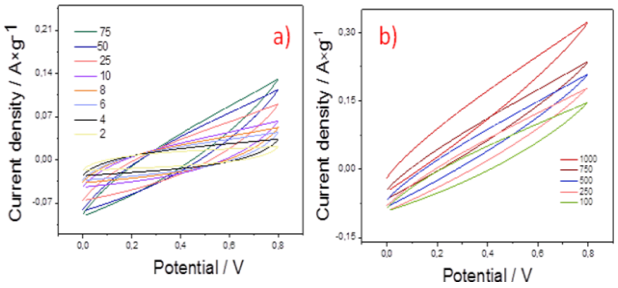

Fig. 1 C V plots of rGO/CuO/PPy nanocomposite at different scan rates, a) 1000-100 $mV \times s^{-1}$, b) 75-2 $mV \times s^{-1}$.

The lowest specific capacitance was obtained as C_{sp}= 14.68 $F \times g^{-1}$ at 1000 $mV \times s^{-1}$. However, the highest specific capacitance was found as C_{sp}= 2761.63 $F \times g^{-1}$ at 2 $mV \times s^{-1}$. There is a logarithmic decrease by increasing of scan rate due to fast ion movement from one compartment to another compartment (Figure 2).

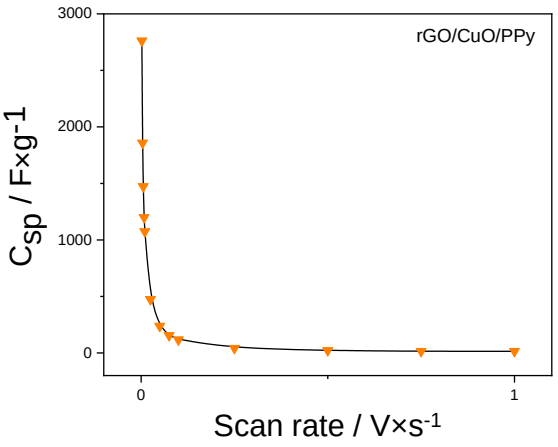

Fig. 2 C_{sp} vs. Scan rate plot of rGO/CuO/PPy nanocomposite at different scan rates from 1000 to 2 $mV \times s^{-1}$.

F. GCD measurements

GCD plots of rGO/CuO/PPy nanocomposite was given at constant current density from 0.1 $A \times g^{-1}$ to 10 $A \times g^{-1}$ as shown in Figure 3. The highest specific capacitance was obtained as C_{sp}= 1.99 $F \times g^{-1}$ at 0.1 mA by GCD measurements.

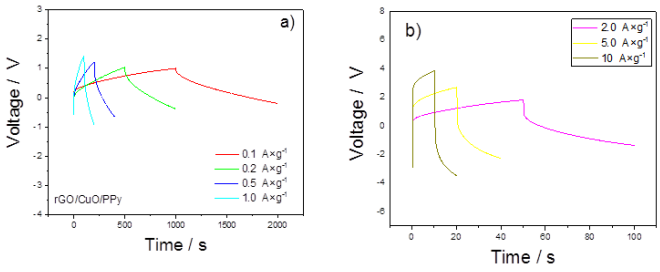

Fig. 3 GCD plots of rGO/CuO/PPy nanocomposite at constant current density from 0.1 A×g^{-1} to 10 A×g^{-1}.

G. *EIS measurements*

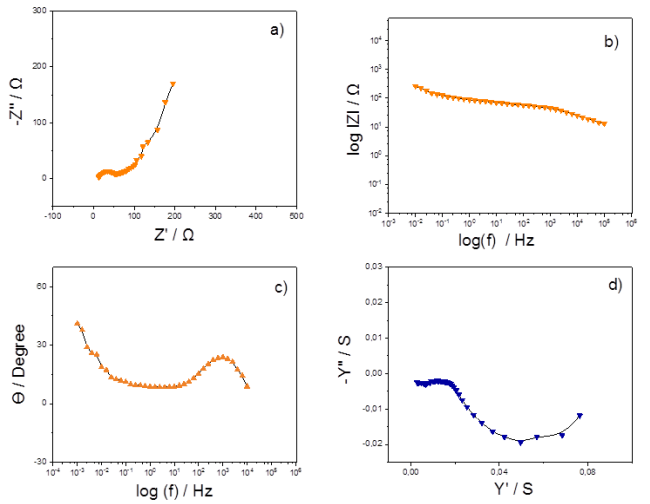

Fig. 4 EIS plots of rGO/CuO/PPy nanocomposite a) Nyquist plot, b) Bode-magnitude plot, c) Bode-phase plot, d) Admittance plot.

EIS plots of rGO/CuO/PPy nanocomposite were given in Figure 4. Specific capacitance was obtained as C_{sp}= 2.13 F×g^{-1} from Nyquist plot. Double layer capacitance and phase angle were obtained as C_{dl}= 0.26 F×g^{-1} and θ= 24.04^{o} at 811.83 Hz from Bode-magnitude and Bode-phase plots, respectively. Admittance plots defined conductivity of nanocomposite material (Y′= 0.0166 S, Y"= 0.0023 S).

H. *Stability tests*

The stability plots of the rGO/CuO/PPy nanocomposite for 2032 coin cell were given charge/discharge device performances for 1000 cycles (Fig.5). The first capacitance value after 1000 charge/discharge performances were obtained as 99.5% in ionic liquid in 2032 coin cell.

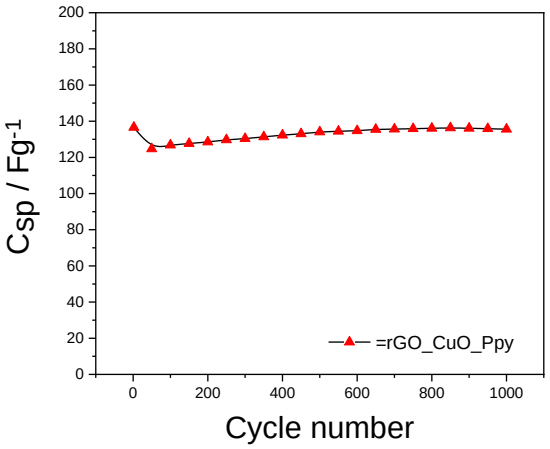

Fig. 5 Stability tests of rGO/CuO/PPy nanocomposite at a scan rate of 100 mV×s^{-1}, 1000 charge-discharge measurements.

III. RESULTS & DISCUSSION

Supercapbattery device performances were obtained by 2032 coin cell. The highest energy and power densities were obtained as E= 0.87 Wh×kg^{-1} at 10 mA and P= 322.03 W×kg^{-1} at 10 mA. EIS data were also presented as θ= 24.04^{o} at 811.83 Hz and 99.5% for initial capacitance preservation for 1000 charge-discharge measurements..

IV. CONCLUSION

The results have demonstrated that rGO/CuO/PPy nanocomposites will be considered as a promising symmetrical electrode materials for the next generation of supercapacitor applications. Our target is to focus on the overall supercapbattery device performance in energy storage applications in portable and wearable electronic, transport, electrical and hybrid vehicles.

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