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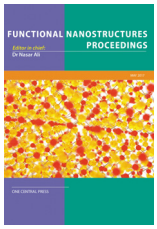

Assessing the electrochemical performance of a supercapacitor electrode made of copper oxide and activated carbon using liquid phase plasma

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ABSTRACT

Metal nanoparticles supported on carbon were synthesized using an innovative plasma-in-liquid method, which is known as liquid phase plasma (LPP) method. LPP was applied to synthesize copper oxide/carbon composite by precipitating copper on carbonaceous material, aimed at developing novel supercapacitor electrode. The specific capacitance of copper oxide/carbon composite increased with increasing LPP process duration time.

I. INTRODUCTION

High electrical conductivity, fast cation diffusion process and high specific surface area are the main factors for pseudocapacitors to achieve high energy and high power densities. RuO_2 have been previously demonstrated to show excellent pseudocapacitive behavior with a high specific capacitance of 1300 Fg^{-1} [1]. However, the high cost limits their application and many researchers have tried to introduce some alternates with reasonable features. MnO_2 [2], NiO [3], Co_3O_4 [4], and VOx [5] were later considered and extensively studied as supercapacitor materials. Among these metal oxides, CuO can be promising candidate due to low cost, abundant resources, non-toxicity, and easy preparation in various shapes of nanosized dimensions. Hence, in this present work, we developed a simple and easy method for the synthesis of copper oxide/activated carbon composite as dielectric material for supercapacitor by LPP reduction system. The effects of plasma discharge conditions are discussed and the resultant products are characterized.

II. EXPERIMENTAL

Materials. Copper chloride dihydrate ($CuCl_2 \cdot 2H_2O$, Daejung Chemical & metals Co. Ltd.) was used as the precursor. Cetyltrimethylammonium bromide (CTAB, $CH_3(CH_2)_{15}N(CH_3)_3Br$, Daejung Chemicals & metals Co., Ltd) was used as a dispersant. Carbonaceous material was used as the activated carbon powder (YP-50F, Koraray chemical co. ltd.) in this study. The particle size and specific surface area of YP-50F were 5~20 μm and 1,500~1,800 m^2/g, respectively.

Preparation of composite. $CuCl_2 \cdot 2H_2O$ was dissolved in 250 mL of ultrapure water to make a 6 mM aqueous solution. CTAB was added to the solution with a 50% molar ratio relative to $CuCl_2 \cdot 2H_2O$ (3 mM). After sufficient stirring, 25 mg of activated carbon (AC) was added. Ultrasonification for 5 min and stirring for 1 h were performed for complete dispersion of the reaction solution. The LPP reactor was filled with the reaction solution and plasma was applied for pre-determined duration (30 min, 60 min, or 90 min) to allow Cu nanoparticles to precipitate on AC surface. After the LPP reaction, centrifugal process (4,000 rpm) and washing were repeated five times to remove reactant and surfactant remaining in the solution from composites. The separated Cu/AC composite

was dried at 353 K in a vacuum oven for 48 h. Copper oxide/AC composite was prepared by oxidizing the dry Cu/AC composite for 30 min, 60 min, or 90 min in a 423K furnace under an oxygen atmosphere.

III. RESULTS AND DISCUSSION

The chemical compositions of the copper oxide/AC composites synthesized with different LPP process times, analyzed using EDX spectrum, are summarized in Table 1. The bare AC consisted of 97.75 % of carbon and 2.25 % of oxygen, in atomic %. Table 1 also shows the composition of the composite prepared through 60-min LPP process only (without oxidation). The oxygen quantity of this composite was 2.43 At%, which was higher than that of bare AC (2.25 At%) but lower than that of the composite prepared through 60-min LPP process and oxidation (2.54 At%). For the composites that passed through the oxidation process, the quantity of Cu precipitation increased with increasing LPP process time.

Table 1 Chemical composition of bare AC and copper oxide/AC composites as a different LPP process times.

LPP process time	Carbon		Oxygen		Copper	
[min]	Wt %	At %	Wt %	At %	Wt %	At %
Bare AC	97.03	97.75	2.97	2.25	-	-
60 (Non-oxidation)	96.17	97.45	3.19	2.43	0.64	0.12
30 (Oxidation)	96.58	97.58	3.11	2.36	0.31	0.06
60 (Oxidation)	95.99	97.33	3.34	2.54	0.67	0.13
90 (Oxidation)	95.38	97.03	3.64	2.78	0.98	0.19

Figure 1 compares the current-voltage curves, plotted using the cyclic voltammetry measurement with a potential scan rate of 10 mV/s in the range of 0.1~0.8 V, of composite prepared with different LPP process time and heat treatment. All the electrodes tested showed ideal rectangular CV curves of electric double-layer capacitor (EDLC). Although it is difficult to distinguish the CV curves shown in Figure 1, the Cu/AC composite showed the worst charge–discharge characteristic, whereas the charge–discharge characteristic of copper oxide/AC composite became better with increasing LPP process duration. The CV curve provides the measure of supercapacitors charge response with charging voltage and hence can be used to evaluate the capacitance. The pseudocapacitance of transition metal oxides have been attributed to redox transition of species at various oxidation states. It is presumed that the copper oxide/AC composite has enhanced charge storage and improved C-V characteristics due to the existence of copper oxide produced by thermal treatment. In the case of Cu/AC composite, on the other hand, Cu^0 acts as impurity, resulting in the worst charge/discharge characteristics.

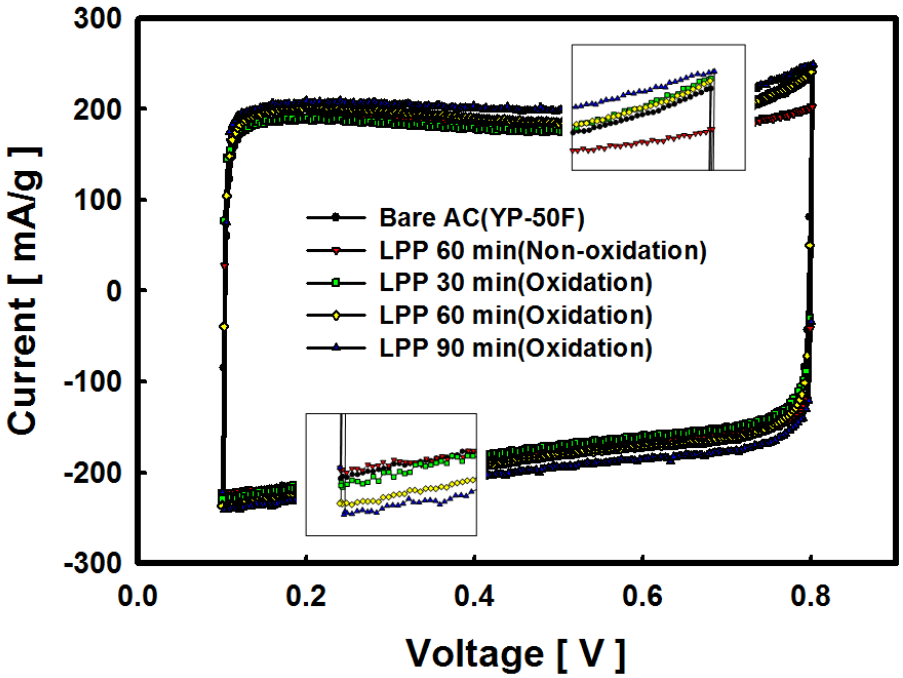

Figure 1 C-V curves of bare AC and as-prepared composite by LPP process as a function of process time and heat treatment.

IV. SUMMARY

Copper oxide/AC composite electrodes for supercapacitor were prepared using the LPP method. Cu was evenly dispersed on the surface of AC and that the quantity of Cu precipitated increased with increasing LPP duration time. The specific capacitances of copper oxide/AC composites prepared through the LPP process and thermal oxidation were higher than that of bare AC.

V. REFERENCES

[1] C.C. Hu, K.H. Chang, M.C. Lin, Y.T. Wu, Design and tailoring of the nanotubular arrayed architecture of hydrous RuO2 for next generation supercapacitors, Nano Letters 6 (2006) 2690-2695.

[2] J.W. Long, M.B. Sassin, A.E. Fischer, D.R. Rolison, A.N. Mansour, V.S. Johnson, P.E. Stallworth, S.G. Greenbaum, Multifunctional MnO_2−carbon nanoarchitectures exhibit battery and capacitor characteristics in alkaline electrolytes, J. Phys. Chem. C 113 (2009) 17595-17598.

[3] P. Justin, S.K. Meher, G.R. Rao, Tuning of capacitance behavior of NiO using anionic, cationic, and nonionic surfactants by hydrothermal synthesis, J. Phys. Chem. C 114 (2010) 5203-5210.

[4] S.K. Meher, G.R. Rao, Ultralayered Co_3O_4 for high-performance supercapacitor applications, J. Phys. Chem. C 115 (2011) 15646-15654.

[5] Q. Qu, Y. Shi, L. Li, W. Guo, Y. Wu, H. Zhang, S. Guan, R. Holze, $V_2O_5.0.6H_2O$ nanoribbons as cathode material for asymmetric supercapacitor in K_2SO_4 solution, Electrochemistry Communications 11 (2009) 1325-1328.