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Electrochemical Performance of Graphene/Molybdenum Disulfide Hybrid Supercapacitors in 6M KOH

Raja Noor Amalina Raja Seman[1] and Mohd Asyadi Azam[1*]

[1] Carbon Research Technology Research Group, Advanced Manufacturing Centre,
Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[*]Phone: +606-331 6420 [*]E-mail: asyadi@utem.edu.my

Abstract

The development of high efficient nanostructures materials for energy conversion and storage system is now crucial for future energy demand. Herein, we investigated a graphene/molybdenum disulfide hybrid electrode in 6M potassium hydroxide (KOH) electrolyte with a combined of high electrical conductivity from graphene sheets and high intrinsic properties from molybdenum disulfide sheets. The resulting supercapacitor exhibited a high specific capacitance and fast charge discharge may be attributed from the synergistic effects of graphene and molybdenum disulfide. These an excellent electrochemical performance suggesting a promising application for supercapacitor application.

1. Introduction

Supercapacitors have been considered as a high performance electrochemical energy storage device possess remarkable properties due to higher power density compared with conventional capacitors and batteries [1]. Basically, supercapacitors can be classified into three types based on the charge storage mechanism [2]. Electrical double layer capacitors (EDLC) is based on the electrolyte-electrode interfaces (electrostatic) and pseudocapacitors arises from the redox reaction [3]. Meanwhile hybrid capacitor is based on both electrolyte-electrode interfaces (electrostatic) and redox reaction [4]. Activated carbon is usually used as the active material for commercial EDLC supercapacitor [5]. Until now, extensive effort has been made to design the electrode material which could deliver high electrochemical performance including high capacitance and cycling stability [6]. Recently, two-dimensional (2D) materials and other hybrid materials have attracted numerous attention in energy storage and conversion applications due to their outstanding physicochemical properties and structural flexibility [7]. Among them, graphene and molybdenum disulfide (MoS_2) were actively studied as electrode materials in supercapacitors and batteries applications [8]. In this work, graphene and molybdenum disulfide MoS_2 have been successfully synthesized by using coating technique. The functional activity of both graphene and MoS_2 materials has been measured to identify the energy storage capacity. The hybridizations boosted the properties of each material and thereby exhibited good electrochemical performance as a whole due to the synergistic contribution.

2. Experimental Procedure

2.1 Preparation of G/MoS_2 hybrid electrode

A mixture containing 80 wt% active materials (graphene and MoS_2 powders), 10 wt% carbon black, and 10 wt% polytetrafuoroethylene (PTFE) was well mixed in N,methylprrolidone (NMP) until they formed a slurry, and then the slurry was uniformly laid on a piece of Ni foam about 1 cm2 that was used as a current collector. The Ni foam coated with slurry was pressed for under 22 MPa and dried at 80 °C for overnight. The gravimetric specific capacitance (C_{sp}) is calculated from the cyclic voltammetry (CV) curves according to equation (1);

$$Csp = \frac{1}{2(E2 - E1)mv}\int_{E1}^{E2} i(E)dE \qquad (1)$$

E1, E2 are the cut-off potentials in CV. i(E) is the current, $\int_{E1}^{E2} i(E)dE$ is the total voltammetric charge obtained by integration of positive (charge) and negative (discharge) sweeps in CV, (E2−E1) is the width of the cell potential window, m is the average mass per electrode and v is the scan rate [9].

2.2 Characterizations

X-ray diffraction (XRD) patterns of the samples were measured by a PAN Analytical X-ray diffractometer with Cu Ka radiation (0.154187 nm). Raman spectra were collected from Renishaw micro-raman 3500 spectrometer. CV, galvanostatic charge/discharge (GCD) were measured by using Wonatech electrochemical workstation. For the real supercapacitor application, the two electrode system is highly desirable.

3. Results and Discussion

XRD and Raman spectroscopy analyses

The G/MoS_2 hybrid structure was characterized by XRD. In Fig. 1(a), the G/MoS_2 hybrid shows the major diffraction peaks, in agreement with the orthorhombic phase of MoS_2. The peaks at 44.1°, 52.2°, and 76.7° can be indexed to (006), (200), and (220) diffraction planes of MoS_2 (JCPDS, 37-1492), respectively. [10]. Fig. 1(b) show the D- and G-band peaks of graphene centered at 1346 cm^{-1} and 1599 cm^{-1}, can be observed for the two hybrids, respectively.

G-band is caused by the vibrations of sp^2 carbon in the carbon lattice and herein can be regarded as a proof for the presence of high crystalline graphite [11]. Generally, the D-band derives from the defects resided in the basal plane and edge of carbon-based materials, and the ratio of I_D/I_G is used to measure the defect density of the sample. One can easily discern that the I_D/I_G value of graphene is smaller than that of G/MoS_2, which is significantly lower than that of graphene prepared using other technique [12].

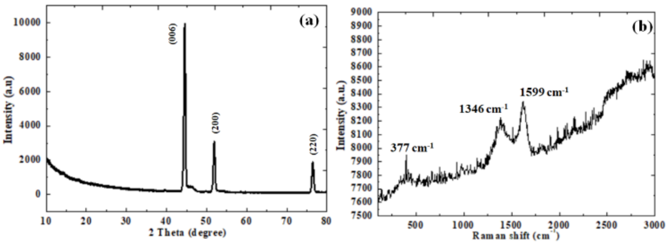

Fig. 1 (a) The XRD spectrum of G/MoS_2 hybrid and (b) The Raman spectrum of G/MoS_2 hybrid

Electrochemical performances of G/MoS2 hybrid supercapacitor

The electrochemical performance of G/MoS_2 hybrid was evaluated by using CV and GCD techniques in a two electrode system.

All CV curves measured in alkaline condition exhibit a quasirectangular shape (see Fig. 2(a)), attributing to the typical double-layer response. The C_{sp} of G/MoS_2 hybrid supercapacitor calculated based on the CV curves 48.58 F g^{-1} at scan rate 1 mV s^{-1}. An increase in capacitive performance of G/MoS_2 is intuitively observed from the surround CV area, which indicates that MoS_2 involved can trigger the EDLC-related properties of the electrode material, such as the wettability of the electrode surface and its electronic conduction ability [14]. For the quantitative study of this improvement, GCD curves were recorded (the obtained symmetrical CD lines are also the characteristic of EDLC behavior), from which the C_{sp} of the electrode can be obtained using the equation (2):

$$Csp = \frac{2I}{m(dV/dt)} \qquad (2)$$

Where C_{sp}, I, dt, dV, and m are specific capacitance (F g-1), constant current (A), discharge time (s), potential window (V) and mass of the active material (g), respectively.

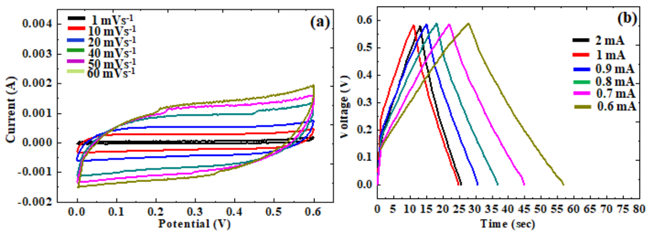

Fig. 2 (a) The CV curve of G/MoS_2 hybrid and (b) The CD curve of G/MoS_2 hybrid

Fig 2 (b) shows the constant current CD curves of G/MoS_2 hybrid at different currents (2, 1, 0.9, 0.8, 0.7, and 0.6 mA). During the charging and discharging steps, the charge curve of hybrid electrode is almost symmetric to its corresponding discharge counterpart with a small internal resistance (IR) drop [15], indicating the pseudocapacitive contribution along with the double layer contribution. The C_{sp} calculated from CD curves is 39.59, 38.46, 36.45, 35.22, 34.73, and 35.49 F g^{-1} at current 2, 1, 0.9, 0.8, 0.7, and 0.6 mA, respectively.

4. Conclusions

Layered G/MoS_2 hybridhas been successfully prepared via coating technique. The introduction of MoS_2 gives rise to the hybrid with certain crystal structure and morphology which enhances electrochemical performance. The different electrochemical behavior could be attributed to the EDLC effect in alkaline electrolyte.

Acknowledgements

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References

[1] S.P.S. Badwal, S.S. Giddey, C. Munnings, A.I. Bhatt and A.F. Hollenkamp, Front Chem **2** (2014) 1.
[2] Z.S. Iro, C. Subramani and S.S. Dash, Int. J. Electrochem. Sci. **11** (2016) 10628.
[3] S. Zheng, Z.-S. Wua, S. Wang, H. Xiao, F. Zhou, C. Sun, X. Bao and H.-M. Cheng, Energy Storage Materials **6** (2017) 70.
[4] R.N.A.R. Seman, M.A. Azam and A.A. Mohamad, Renew. Sustain. Energy Rev. **75** (2017) 644.
[5] T. Chen and L. Dai, Mater. Today **16** (2013) 272.
[6] Q. Xue, J. Sun, Y. Huang, M. Zhu, Z. Pei, H. Li, Y. Wang, N. Li, H. Zhang and C. Zhi, Small **13** (2017) 1701827.
[7] N.A. Kumar, M.A.A. Dar, R. Gul and J.-B. Baek, Mater. Today 18 (2015) 286.
[8] M.A. Bissett, I.A. Kinloch and R.A.W. Dryfe, ACS Appl. Mater. Interfaces 7 (2015) 17388.
[9] R.N.A.R. Seman, M.A. Azam and M.A. Mohamed, Adv. Nat. Sci.: Nanosci. Nanotechnol. **7** (2016) 045016.
[10] M.H. Yang, J.-M. Jeong, Y.S. Huh, B.G. Choi, Composites Science and Technology **121** (2015) 123.
[11] J.-B. Wu, M.-L. Lin, X. Cong, H.-N. Liu and P.-H. Tan, Chem. Soc. Rev. **47** (2018) 1822.
[12] B. Xie, Y. Chen, M. Yu, S. Zhang, L. Lu, Z. Shu and Y. Zhang, RSC Adv. **6** (2016) 89397.
[13] F. Barzegar, D.Y. Momodu, O.O. Fashedemi, A. Bello, J.K. Dangbegnon and N. Manyala, RSC Adv. 5 (2015) 107482.
[14] S. Shrestha, N. Morse and W.E. Mustain, RSC Adv. **4** (2014) 47039.
[15] M.A. Azam, N. Dorah, R.N.A.R. Seman, N.S.A. Manaf andT.I.T. Kudin, Materials Technology: Adv. Funct. Mater. 30 (2015) A1.