Effect of Different Aqueous Electrolytes on Electrochemical Performance of Activated Carbon Anchored by Multiwalled Carbon Nanotubes for Supercapacitor Applications

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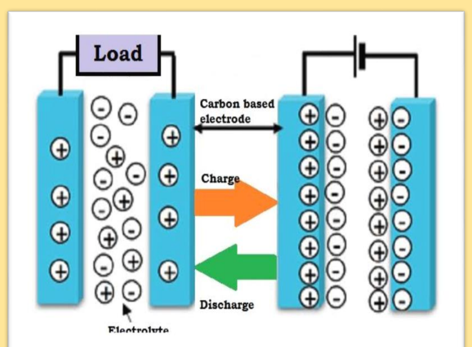
Abstract

Activated carbon anchored by multiwalled carbon nanotubes has been prepared by a simple method and have been reported the effect of various aqueous electrolytes such as KOH and Na_2SO_4 on electrochemical performance of activated carbon/multiwalled carbon nanotubes composite. The electrochemical performance of as-prepared composite has been investigated by cyclic voltammetry (CV) and galvanostatic charge-discharge (GCD) measurements in 1M KOH and 1M Na_2SO_4 aqueous electrolytes. Maximum capacitance of prepared composite was 194 F/g at scan rate of 10 mV/s and 56 F/g at scan rate of 100 mV/s in 1M KOH solutions whereas the composite gives maximum capacitance of 21 F/g at scan rate of 40 mV/s in 1M Na_2SO_4 analyzed by CV measurement. Also, form GCD measurement the composite gives maximum capacitance of 147 F/g at a current density of 60 A/g in 1M KOH and 18 F/g at a current density of 1 A/g in 1M Na_2SO_4 solutions. The finding suggests that prepared activated carbon/multiwalled carbon nanotubes composite in suitable aqueous electrolytes can be a potential candidate for supercapacitor applications.

Introduction

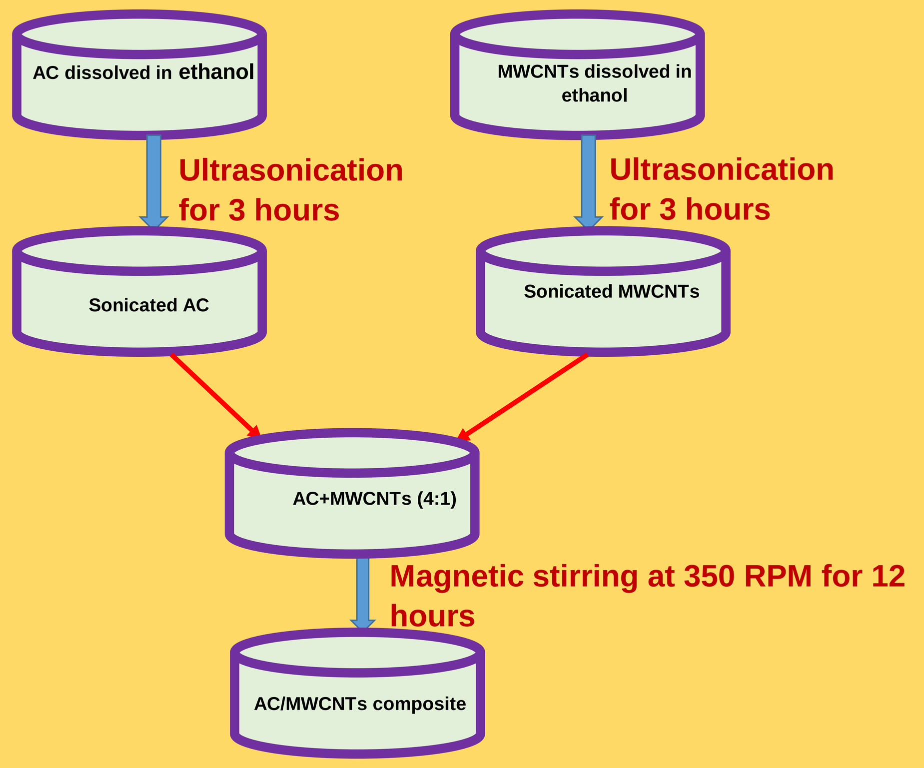
- Over the past decade due to the lake of fossil fuels, fast growing of population and growing demands of portable electronic devices.
- Supercapacitors (SCs) also known as an electric double-layer capacitor (EDLC), electrochemical capacitor (EC) or ultra-capacitor
- Performance of SCs device mostly depends on types electrode materials and electrolytes.
- Due to individual demerits of metal oxides such as high resistance, fabrication cost and material degradation limits their application in SCs intrinsically.
- Individual carbon materials (activated carbon, carbon nanotubes, graphene etc.) can not be used owing their some physical and chemical limitations.



- Composite structure of carbon materials i.e. AC/MWCNTs has been prepared owing to Unique physical and chemical properties of carbon materials.
- Effect of different aqueous electrolytes such as KOH and Na_2SO_4 on electrochemical performance of AC/MWCNTs composite.

Experimental

- **AC/MWCNTs composite has been prepared as shown in diagram:**



Results

Structural and morphological analysis

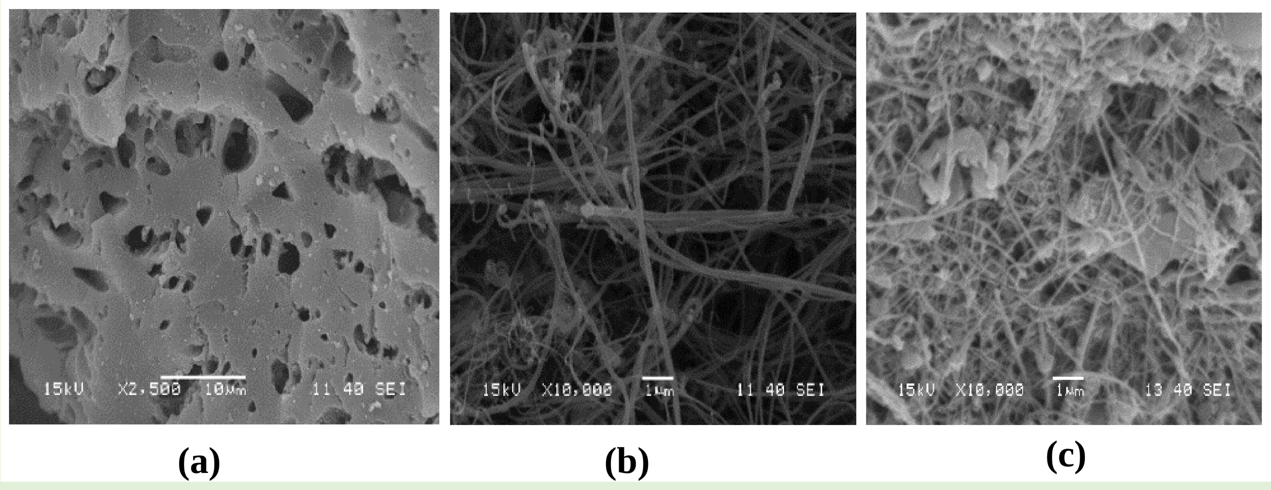


FIGURE 1. SEM images of (a) AC, (b) MWCNTs, (c) AC/MWCNTs composite.

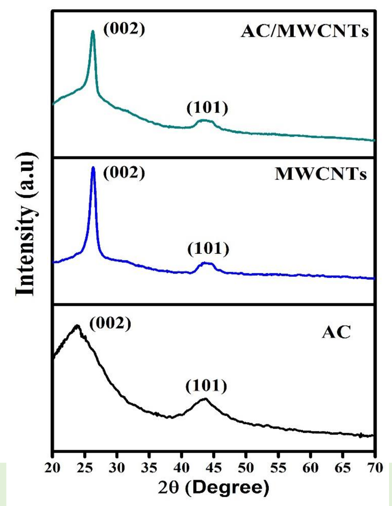


FIGURE 2. XRD pattern of AC, MWCNTs and AC/MWCNTs composite.

Electrochemical analysis

The specific capacitance, energy density and power density of prepared composite have been evaluated as follows:

$$C_{sc} = Ai/(2*\Delta V*(\text{scan rate})*m) \quad (1)$$

$$C_{sc} = I*\Delta t/m*\Delta V \quad (2)$$

$$E_d = \tfrac{1}{2}\,(C_{sc})*\Delta V^2*(1/3.6) \quad (3)$$

$$P_d = (E_d/(\Delta t))*3.6 \quad (4)$$

The electrochemical performance of synthesized AC/MWCNTs composite has been analyzed by Cyclic voltammetry (CV) and galvanostatic charge-discharge (GCD) in 1M KOH and 1M Na_2SO_4 aqueous electrolytes using 3-electrode setup as shown in Fig. 3.

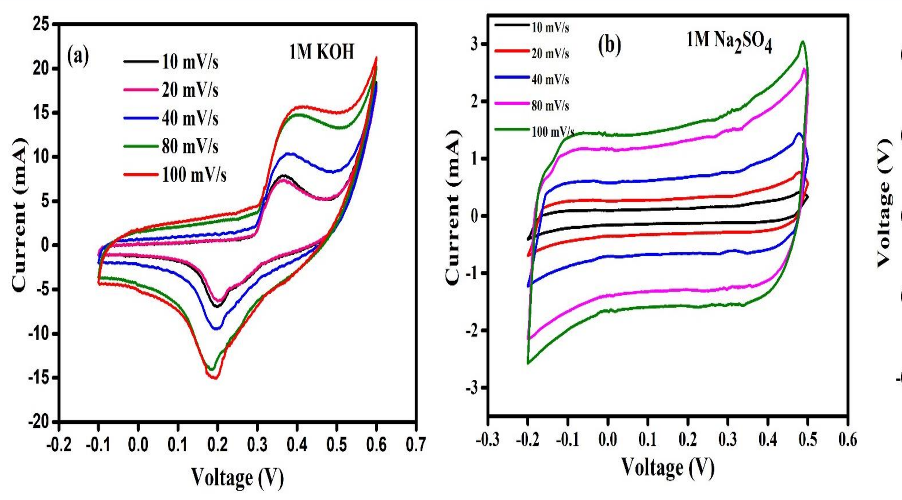


FIGURE 3. (a) CV curves in 1M KOH solution of AC/MWCNTs composite at different scan rates, (b) CV curves in 1M Na_2SO_4 solution of AC/MWCNTs composite at different scan rates.

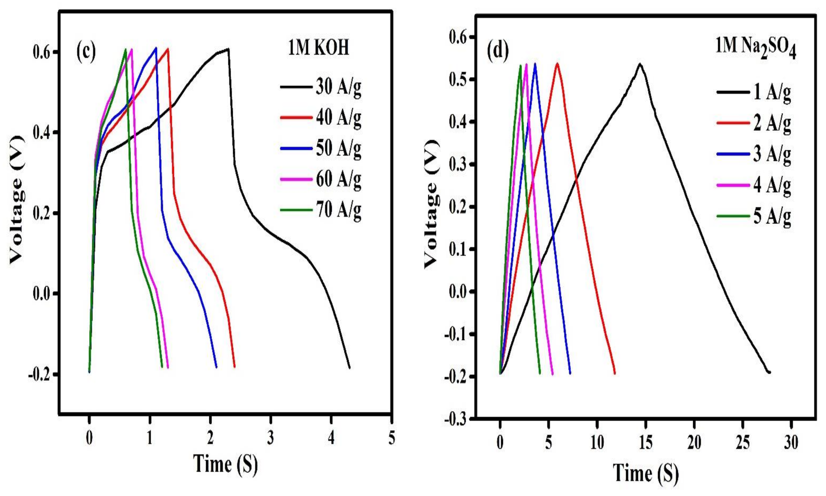


FIGURE 3. (c) GCD curves in 1M KOH solution of composite at various current densities, (d) GCD curves of composite at various current density in 1M Na_2SO_4 solution.

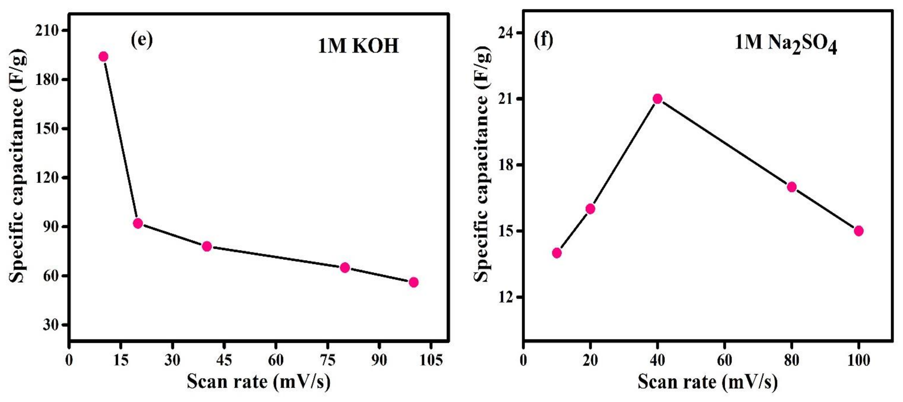


FIGURE 3. (e) Specific capacitance of composite in 1M KOH solution at different scan rates, (f) Specific capacitance of composite in 1M Na_2SO_4 solution at different scan rates.

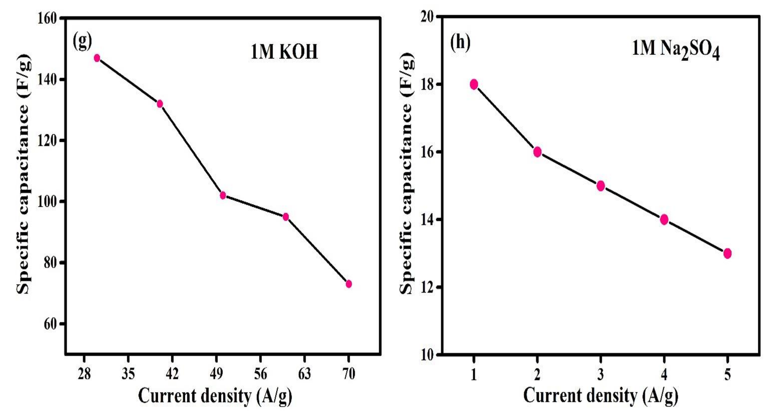


FIGURE 3. (g) Specific capacitance of composite in 1M KOH solution at different current densities, (h) Specific capacitance of composite in 1M Na_2SO_4 solution at different current densities.

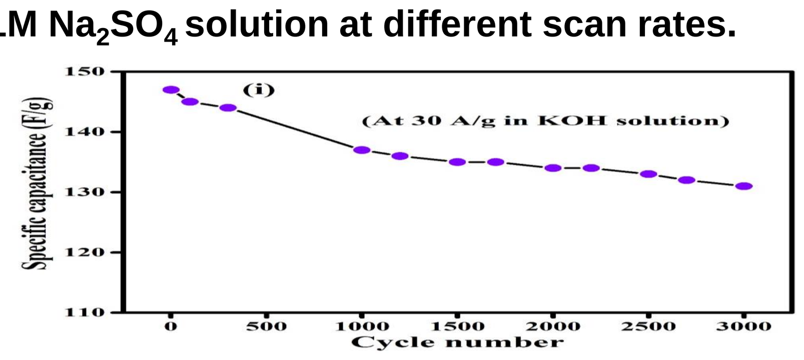


FIGURE 3. (i) Cycling performance of composite over 5000 cycle in 1M KOH solution.

Discussion

- The surface morphology and crystal structure of prepared composite have been investigated by Scanning electron microscope (SEM) and powder X-ray diffraction as shown in Fig. (1,2).
- The electrochemical performance of synthesized composite has been analysed by Cyclic voltammetry (CV) and galvanostatic charge-discharge (GCD) measurements in 3-electrode setup shown in Fig. 3.
- Two different aqueous electrolytes i.e. KOH and Na_2SO_4 has been used.
- The maximum specific capacitance of prepared composite has been found to be 194 F/g at 10 mV/s in 1M KOH and the composite gives maximum capacitance of 21 F/g at 40 mV/s in 1M Na_2SO_4 from CV measurement shown in Fig. 3(a, b).
- From GCD, the maximum capacitance of AC/MWCNTs composite was 147 F/g at 30 A/g in 1M KOH and 18 F/g at 1 A/g in 1M Na_2SO_4 shown in Fig. 3(c, d).
- The curves are the triangular form in 1M Na_2SO_4 and non-triangular in 1M KOH solutions (Fig. 3(c, d)).
- The maximum energy density of synthesized composite in 1M KOH solution found to be 10 Wh/kg and corresponding power density was 17.91 kW/kg at 30 A/g.
- In 1M Na_2SO_4 maximum energy density was 1.28 Wh/kg and power density was 0.34 kW/kg at 1 A/g.
- 90 % capacitance was retained even after 5000 cycles at 30 A/g in 1M KOH solution as shown in Fig. 3(i).

Conclusions

The composite structure of AC/MWCNTs has been prepared by a simple and low-cost method followed by ultra-sonication and magnetic stirring. The effect of various aqueous electrolytes on electrochemical performance of prepared composite has been studied successfully and found that AC/MWCNTs composite gives very good energy, as well as power performance in 1M KOH, compared to 1M Na_2SO_4 solution due to the redox reaction between functional groups (in materials) and electrolyte ions in 1M KOH. Also, it has been demonstrated the cycling performance of prepared composite and found 90 % capacitance was retained in 1M KOH which indicate excellent cyclic performance. Therefore, the composite not only gives good energy and power performance but also gives an excellent cyclic performance in 1M KOH solution and can be a potential candidate as electrode material for the application in SCs.

Acknowledgement

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References

1. M. Winter and R. J. Brodd, Chem. Rev. 104, 4245 (2004).
2. A. Burke, J. Power Sources 91, 37 (2000).
3. J. R. Miller and P. Simon, Science 321, 651 (2008).
4. L. L. Zhang and X. S. Zhao, Chem. Soc. Rev. 38, 2520-2531 (2009).
5. J. R. Miller and A. F. Burke, Electrochem. Soc. Interface Spring 17, 53 (2008).
6. L. B. Hu, J. W. Choi, Y. Yang, S. Jeong, F.L. Mantia, L. F. Cui and Y. Cui, Proc. Natl. Acad. Sci. 106, 21490–21494 (2009).
7. D. H. Jurcakova, A. M. Puziy, O. I. Poddubnaya, F. S. Garcia, J. M. D. Tascon and G. Q. Lu, J. Am. Chem. Soc. 131, 5026 (2009).
8. M. Kaempgen, C. K. Chan, J. Ma, Y. Cui and G. Gruner, Nano Lett. 9, 1872–1876 (2009).
9. E. Frackowiak, Phys. Chem. Chem. Phys. 9, 1774 (2007).
10. K. S. Novoselov, A.K. Geim, S.V. Morozov, D. Jiang, Y. Zhang, S.V. Dubonos, I.V. Grigorieva and A.A. Firsov, Science 306, 666-669 (2004).
11. D. Satapathy and G. S Natarajan, Indian journal of chemistry 45, 2006, pp 2011-2016.
12. P. Mahanandia, P. N. Vishwakarma, K. K. Nanda, V. Prasad, S. V. Subramanyam, S. K. Dev and P. V. Satyam, Materials Research Bulletin 41, 2311–2317 (2006).
13. P. Mahanandia, P. N. Vishwakarma, K. K. Nanda, V. Prasad, K. Barai, A. K. Mondal and S. Sarangi, Solid State Communications 145, 143–148 (2008).
14. C. S. Dai, P. Y. Chien, J. Y. Lin, S. W. Chou, W. K. Wu, P. H. Li, K. Y. Wu and T. W. Lin, ACS Appl. Mater. Interfaces 5, 12168−12174 (2013).
15. S. Chen, J. Zhu, H. Zhou and X. Wang, RSC Adv. 1, 484–489 (2011).
16. Q. Cheng, J. Tang, J. Ma, H. Zhang, N. Shinya and L. C. Qin, Phys. Chem. Chem. Phys. 13, 17615–17624 (2011).