

PERPUSTAKAAN UMP



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GRAPHENE SHEETS FOR SELECTIVE ENHANCEMENT

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ENHANCEMENT

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## LIST OF SYMBOLS

$d$	Distance
$\lambda$	Wavelength
$a$	Lattice parameter
$\Delta E_p$	Peak separation
$E_{pa}$	Peak anode
$E_{pc}$	Peak cathode
$\Delta E_p$	Peak potential spacing
$E^\circ$	Formal potential
$i_p$	Peak current
$C_{sp}$	Specific capacitance
$V$	Voltage

## **LIST OF ABBREVIATIONS**

CDC	Charge discharge curve
CV	Cyclic voltammetry
EDLC	Electrochemical double layer capacitor
EDX	Energy-dispersive X-ray spectroscopy
EIS	Electrochemical impedance spectroscopy
ESR	External solution resistance
FTIR	Fourier transforms infrared spectroscopy
FESEM	Field emission scanning electron microscope
JCPDS	Powder diffraction standards
OCP	Open circuit potential
R <sub>s</sub>	Solution resistance
XRD	X-ray diffractometer

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## **ABSTRAK**

Graphene merupakan bahan karbon dua dimensi yang unik yang memiliki kekonduksian yang baik, sifat kimianya yang stabil, sifat-sifat mekanikal yang baik serta mempunyai kawasan permukaan yang luas ( $\sim 2600 \text{ m}^2 \text{ g}^{-1}$ ). Disebabkan oleh sifat mekanikal dan elektrik yang luar biasa, graphene dicadangkan sebagai bahan elektrod untuk aplikasi supercapacitor. Walau bagaimanapun, apabila dilarutkan dalam pelarut, graphene cenderung untuk bergumpal semula, sekali gus mengurangkan kawasan permukaan electroaktif dan seterusnya menghalang prestasi elektrokimianya. Oleh itu, suatu peningkatan terhadap kajian ini diperlukan untuk mengatasi masalah penggumpalan semula. Dalam kajian ini, sebuah pendekatan yang mudah digunakan untuk menaikkan kadar kemuatan N-methylpyrrolidone) NMP- graphene. Nikel hexacyanoferat (NiFeCN) iaitu bahan aktif redoks, menggunakan Ferum sebagai agen pengoksidaan-penurunan telah diekperimentasikan bersama graphene melalui kaedah mudah pemendakan bersama. Graphene telah disediakan oleh fasa cecair pengelupasan grafit (NMP). Gabungan ini dilakukan sebagai bahan nano komposit hibrid yang dimiliki kedua-dua elektrokimia kapasitor dua lapisan (EDLC) dan pseudo kemuatan. Dengan motivasi di atas, bahan komposit nano berdasarkan graphene telah dikaji secara meluas dalam tesis ini. Semua bahan-bahan yang diperiksa telah disediakan melalui mudah teknik bersama hujan sintesis dengan pelbagai berbeza nisbah komposit (NiFeCN/G-10, NiFeCN/G-25, NiFeCN/G-50, NiFeCN/G-75 and NiFeCN/G-90) ini kemudian diperhatikan melalui inframerah transformasi Fourier, x-ray difraktometer, mikroskop medan penyinaran pengimbas elektron dan tenaga dispersive X-ray Spektroskopi. Sifat-sifat elektrokimia komposit NiFeCN/graphene telah dikaji oleh sistem 3-elektrod. Seperti yang ditunjukkan dalam analisa voltammetry, nano komposit pada nisbah 25 : 75 NiFeCN/G-25 mempamerkan khusus kemuatan  $113.5 \text{ F g}^{-1}$ , yang 2 kali lebih tinggi daripada graphene ( $52 \text{ F g}^{-1}$ ) dan 6 kali lebih tinggi berbanding dengan NiFeCN ( $18 \text{ F g}^{-1}$ ). Hasil kajian mencadangkan bahawa NiFeCN / graphene boleh menjadi calon yang berpotensi untuk supercapacitors elektrod. Prestasi elektrokimia yang dipertingkatkan daripada komposit nano boleh dikaitkan dengan sumbangan graphene dan nanopartikel. Keputusan kajian ini menunjukkan komposit nano graphene mempunyai potensi besar dalam aplikasi penyimpanan tenaga.

## ABSTRACT

Graphene is a unique two-dimensional carbon material having good conductivity, stable chemical properties, and good mechanical properties with large surface area ( $\sim 2600 \text{ m}^2 \text{ g}^{-1}$ ). Due to the outstanding mechanical and electrical properties, graphene is proposed as an electrode material for supercapacitor applications. Nevertheless, graphene has issues where in the dry state it tends to agglomerate which hindering its full capability in electrochemical performance. Therefore, an improvement is needed in order to resolve the re-stacking issue. In this study, a facile approach is proposed to enhance the specific capacitance of (N-methylpyrrolidone) NMP-exfoliated graphene. Redox-active nickel hexacyanoferrate (NiFeCN) nanoparticles were grown on the surface of graphene sheets using a co-precipitation method. Apart from the synergetic effect of graphene and NiFeCN in the specific capacitance enhancement, the NiFeCN nanoparticles served as the spacer for graphene sheets to prevent the agglomeration between graphene sheets. This combination performed as a hybrid composite nanomaterial which possessed both electrochemical double layer capacitor (EDLC) and pseudo capacitance. With the above motivation, a graphene-based nanocomposite material has been extensively studied in this thesis. All the materials examined were prepared via simple co-precipitation synthesis techniques with different range of composite ratios (NiFeCN/G-10, NiFeCN/G-25, NiFeCN/G-50, NiFeCN/G-75 and NiFeCN/G-90). Characterization has been done using Fourier transform infrared spectroscopy, X-ray diffraction, energy-dispersive X-ray spectroscopy and field emission scanning electron microscope. Their electrochemical properties were evaluated for supercapacitors using three electrode system configurations. From this experiment, a nanocomposite at a ratio of 25: 75 (NiFeCN/G-25) is shown to have a very high specific capacitance of  $113.5 \text{ F g}^{-1}$  which is 2 times higher than the NMP-exfoliated graphene ( $52 \text{ F g}^{-1}$ ) and 6 times higher than the pure NiFeCN ( $18 \text{ F g}^{-1}$ ). The findings suggest that the NiFeCN/graphene could be the potential candidate for supercapacitors electrode. The enhanced electrochemical performance of these nanocomposite materials could be attributed to the dual contributions of graphene and nanoparticles. The results of this study indicated the graphene nanocomposite has great potential for application to practical energy storage devices.

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