FUNCTIONALIZED MULTI-WALLED CARBON NANOTUBES AND CARBON NANOFIBERS AS POTENTIAL SENSING MATERIALS FOR GAS SENSOR APPLICATION

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DOCTOR OF PHILOSOPHY

UNIVERSITI PERTAHANAN NASIONAL MALAYSIA

2019

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Thesis submitted to the Centre for Graduate Studies, Universiti Pertahanan Nasional Malaysia, in fulfilment of the requirements for the Degree of Doctor of Philosophy (Chemistry)

September 2019

ABSTRACT

Multi-walled carbon nanotubes (MWCNT) and carbon nanofibers (CNF) have been demonstrated as excellent sensing materials for sensitive chemical gas sensor because of the high surface area to volume ratio and their remarkable electrical properties. However, MWCNT and CNF tend to agglomerate and difficult to disperse uniformly in most solvent matrix due to their strong sp^2 bonding and high van der Waals attractive forces. These characteristics limited their potentials and applications in detecting various types of gases. Hence, functionalization of MWCNT and CNF with carboxyl, ester and amide group can enhance the dispersibility and chemical reactivity towards material surroundings. MWCNT and CNF were functionalized with carboxyl group via sulphonitric treatment, and further modified with ester and amide functional groups via Fischer esterification. Characterization analysis using FESEM, EDX, FT-IR, Raman spectroscopy and CHNOS elemental analyzer techniques shows that MWCNT and CNF were successfully functionalized and able to maintain their suspension in DMF solvent for few days. The potential of pristine and modified MWCNT and CNF as sensing material in detecting acetone, ammonia, benzene, hydrogen and methane gas were investigated in air tight gas chamber. The concentration of gases varied and their sensitivity, response time, reproducibility, reusability, recovery time and selectivity at room temperature were observed. The increment of MWCNT and CNF resistance upon detection of tested gases suggested that MWCNT and CNF are p-type semiconducting sensing material, and gases acts as electron donating group, which transferred their electron towards sensing layer. The increased number of mobile carrier charge, reduced the hole carriers and therefore, increased their resistance. Based on highest sensitivity at the lowest concentration, MWCNT-amide is the best sensing material (32.12 %) in detection of acetone gas, CNF-ester is the best sensing material (54,488.00 %) in detection of ammonia gas and MWCNT-carboxyl is best sensing material (521.31 %) in detection of benzene gas. While, CNF-amide is the best sensing material in detection of hydrogen (47.12 %) and methane (11.09 %) gas. Functionalized MWCNT and CNF showed high selectivity towards ammonia gas as compared to other gases. It was also observed that approximately all functionalized MWCNT and functionalized CNF showed response time and recovery time less than 60 s. The morphology and structure of CNF which has highest number of defects contributed to excellent performance as sensing material in most gases. Functionalized MWCNT and CNF exhibited outstanding performance by present fast response, high sensitivity and short recovery time as compared to pristine MWCNT and pristine CNF.

ABSTRAK

Nanotiub karbon berbilang dinding (MWCNT) dan nanoserat karbon (CNF) digunakan sebagai bahan pengesan yang baik untuk menghasilkan pengesan gas kimia yang sensitif kerana luas permukaannya yang tinggi terhadap nisbah isipadu dan mempunyai sifat elektrik yang baik. Namun begitu, MWCNT dan CNF cenderung untuk bergumpal dan sukar tersebar dengan homogen di dalam matriks pelarut. Ini kerana kekuatan ikatan sp^2 dan daya tarikan van der Waals, menjadikan aplikasi MWCNT dan CNF terhad untuk mengesan pelbagai gas lain. Oleh yang demikian, MWCNT dan CNF dimodifikasikan dengan kumpulan karboksil, ester dan amida bagi penyebaran yang lebih homogen dan meningkatkan reaktiviti kimia terhadap bahan sekeliling. MWCNT dan CNF difungsikan dengan kumpulan karboksil melalui proses sulfonitrik dan difungsikan dengan kumpulan ester dan amida melalui 'Fischer esterifikasi'. Keputusan analisis menggunakan pelbagai teknik seperti Mikroskop Elektron Imbasan Pancaran Medan (FESEM), Spektra Fourier Transform Inframerah spektroskopi (FTIR), Raman spektroskopi dan penganalisis elemen CHNOS menunjukkan bahawa MWCNT dan CNF berjaya dimodifikasikan dengan kumpulan berfungsi, stabil dan tersebar secara homogen di dalam larutan DMF untuk beberapa jam dan juga hari. Potensi MWCNT tulen, MWCNT yang difungsikan, CNF tulen dan CNF yang difungsikan dalam pengesanan gas aseton, ammonia, benzena, hidrogen and metana dilakukan di dalam ruang yang tertutup pada suhu bilik. Kepekatan gas yang diuji dipelbagaikan untuk mengkaji sensitiviti, selektiviti, masa tindakbalas, kebolehulangan dan masa pemulihan. Peningkatan rintangan MWCNT dan CNF semasa pengesanan gas mencadangkan MWCNT dan CNF sebagai semikonduktor jenis p iaitu gas yang diuji bertindak sebagai kumpulan penderma elektron dengan memindahkan elektron kepada lapisan bahan pengesan. Penambahan bilangan caj bergerak, mengurangkan pembawa lubang, seterusnya meningkatkan rintangan MWCNT dan CNF. MWCNT-amida merupakan bahan pengesan terbaik (32.12 %) untuk gas aseton, MWCNT-karboksil merupakan bahan pengesan terbaik (521.31 %) untuk gas benzena dan CNF-ester merupakan bahan pengesan terbaik (54,488.00 %) bagi gas ammonia. Manakala, CNF-amida merupakan bahan pengesan terbaik bagi gas hidrogen (47.12 %) dan gas metana (11.09 %). MWCNT dan CNF yang difungsikan menunjukkan keupayaan selektif terhadap gas ammonia berbanding gas-gas lain. Analisis juga menunjukkan MWCNT dan CNF yang difungsikan mempamerkan masa tindakbalas dan masa pemulihan kurang daripada 60 saat. CNF yang mempunyai struktur yang kurang sempurna meningkatkan ikatan kumpulan berfungsi dan menjadikan ianya lebih baik sebagai bahan pengesan untuk kebanyakan gas yang diuji. MWCNT dan CNF yang difungsikan menunjukkan prestasi yang cemerlang dengan memberikan tindakbalas yang pantas, sensitiviti yang tinggi dan masa pemulihan yang pendek berbanding MWCNT tulen dan CNF tulen.

ACKNOWLEDGEMENT

Every praise is due to Allah alone, the Merciful and peace be upon His prophet who is forever a torch of guidance and knowledge for humanity.

This research project would not have been possible without the support of many people. Firstly, I would like to express my deep gratitude to Prof. Madya Dr. Noor Azilah Mohd Kasim my research supervisor, for her patient guidance, enthusiastic encouragement and useful critiques of this research work. I would also like to thank Dr. Norli Abdullah and Dr. Faizah Md Yasin for their professional guidance and valuable support.

My grateful thanks are also extended to Dr. Mohd Hanif Yaacob, Dr. Muhammad Zamharir Ahmad and all technicians of the Wireless and Photonic Network Research Centre (WiPNET), UPM for their help in doing my sensing experimental measurements and offering me the resources in running the experiment. Without their help, my research would not be done successfully. Special thanks also should be given to all my graduate friends, management staffs and lecturers of Universiti Pertahanan Nasional Malaysia for providing the financial funds and laboratory facilities, respectively.

Lastly, I would like to express my love and gratitude to my beloved husband, Mohd Izzat Nazrin Mohamad Amin and my daughter, Nur Amani for their understanding and endless love, through the duration of my studies. Also, my families especially my parents who continuous support and love had driven me forward.

APPROVAL

The Examination Committee has met on 12th September 2019 to conduct the final examination of Nurjahirah binti Janudin on her degree thesis entitled 'Functionalized Multi-walled Carbon Nanotubes and Carbon Nanofibers as Potential Sensing Materials for Gas Sensor Application'

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES