UNIVERSITI PUTRA MALAYSIA

CARBON NANOTUBE - BASED MICROWAVE RESONANT SENSOR FOR ORGANIC CONTAMINANTS DETECTION

AHMAD MOHAMMADI

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By

AHMAD MOHAMMADI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATED

To

This thesis is dedicated to my beloved wife, Mahtab Mohammadi, to my dear mother Zahra, my dear father Ramazan that I owe them all of success in my life.

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

CARBON NANOTUBE - BASED MICROWAVE RESONANT SENSOR FOR ORGANIC CONTAMINANTS DETECTION

By

AHMAD MOHAMMADI

June 2014

Chairman: Associate Professor. Alyani Ismail, PhD

Faculty: Engineering

Organic contaminants are one of the most important kinds of environment pollutions which have been raised over the last century. Conventionally organic contaminants are measured using various methods which require extraction, cleaning procedures and organic solvent. These methods are time consuming and expensive. Fast and accurate detection of organic compounds is the important key to protect the environment and human health safety. Napropamide and phenolic compounds are two kinds of organic contaminants in the Malaysian environment which are chosen to be investigated in this thesis.

This thesis describes the design of proximity coupled feed patch antenna as an organic contaminates sensor. This sensor system consists of a two-layer Flame Retardant (FR-4) patch antenna coated with Multi Walled Carbon Nanotubes (MWCNTs) and Polypyrrole-Chitosan (PPy-CHI) for absorbing organic contaminates. Proximity coupled feeding was chosen to feed the patch antenna and the feeding is from the ground plane side without any physical contact to the material under test. The best design of patch antenna and feed line position in 5 GHz resonant frequency are chosen based on simulation results using full-wave electromagnetic simulator Computer Simulation Technology (CST) Microwave studio. The performance of the fabricated patch antenna was tested using Vector Network Analyzer (VNA) and the results are then be compared with simulations results.

Multi Walled Carbon Nanotubes (MWCNTs) and Polypyrrole-Chitosan (PPy-CHI) as a sensing layer were coated on the top of antenna using electric field deposition. Atomic Force Microscopy (AFM) was used to ensure successful coating result on the top of the antenna. Chemical interaction between applied materials to the sensing layer was investigated by Fourier Transform Infrared Spectroscopy (FT-IR).

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The whole system after coating and fabrication was tested using different amounts of phenol, 2-4 Dichlorophenol (24DCP), commercial napropamide and napropamide at room temperature (25oC). Changes in resonant frequency of patch antenna before and after applying phenol, 2-4 Dichlorophenol (24DCP), commercial napropamide and napropamide were measured. Based on measurement results, FR-4 patch antenna coated with MWCNTs and PPy-CHI are capable to detect small concentration of measured materials down to 0.5 ppm. At this operating frequency (5 GHz), the technique can be used in wireless network sensor systems to measure organic pollutions vapour in shielded area for future research.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah.

TIUBNANO KARBON - BERDASARKAN GELOMBANG MIKRO PENDERIA UNTUK PENGESAN PENCEMARAN ORGANIK

Oleh

AHMAD MOHAMMADI

Jun 2014

Pengerusi: Profesor Madya. Alyani Ismail, PhD

Fakulti: Kejuruteraan

Pencemaran organik adalah salah satu daripada ciri-ciri utama pencemaran persekitaran yang meningkat sejak beberapa abad yang lalu. Pengesanan terhadap sebatiaan organik yang pantas dan tepat merupakan kunci utama di dalam melindungi persekitaran dan keselamatan manusia. Pada kebiasaanya, sebatian organik diukur dengan menggunakan pelbagai kaedah dimana ia memerlukan kaedah pengekstrakan pembersihan, larutan organik dan kaedah ini amat mahal dan memakan masa. Sebatian napropamide and phenolic adalah dua jenis pencemaran organik yang terdapat di dalam Malaysia dan dipilih untuk dibuat kajian di dalam tesis ini. Tesis ini menerangkan tentang reka bentuk gandingan dua struktur antena yang digunakan sebagai penderia bagi organik yang tercemar. Sistem penderia ini mengandungi dua lapis (FR – 4) struktur antena yang dilapisi oleh *'Multi Walled Carbon Nanotubes'* (MWCNTs) dan *'Polypyrrole-Chitosan'* (PPy-CHI) untuk diserap oleh bahan organik yang tercemar. Saluran pendua yang berhampiran dipilih untuk di salurkan kepada struktur antena. Penyaluran adalah dari bahagian pembumian sentuhan fizikal kepada bahan yang dikaji. Reka bentuk struktur antena yang terbaik dan posisi garis saluran dalam 5GHz frequency salun dipilih berdasarkan kepada keputusan simulasi dengan menggunakan gelombang penuh simulator *'Computer Simulation Technology (CST) Microwave Studio'*. Pelaksanaan fabrikasi struktur antena diuji dengan menggunakan '*Vector Network Analyzer'* (VNA) dan berdasarkan hasil fabrikasi di buat perbandingan hasil simulasi. *'Multi Walled Carbon Nanotubes'* (MWCNTs) mempunyai ketebalan 5-10 μm dan *'Polypyrrole-Chitosan'* (PPy-CHI) adalah lapisan penderia yang telah dilapisi antenna di bahagian atas dengan menggunakan pemendapan medan elektrik. *'Atomic Force Microscopy'* (AFM) digunakan untuk menjayakan keputusan lapisan di bahagian atas antenna. Interaksi kimia antara bahan yang digunakan dan lapisan penderia telah dikaji dengan menggunakan *'Fourier Transform Infrared Spectroscopy'* (FT-IR). Keseluruhan sistem setelah dilapisi dan difabrikasi telah diuji

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oleh phenol, 2-4 Dichlorophenol (24DCP), komersial napropamide dan napropamide dengan menggunakan kuantiti yang berbeza pada suhu bilik (25^{o}C). Perubahan di dalam frekuensi salun pada struktur antena sebelum dan selepas menggunakan phenol, 2-4 Dichlorophenol (24DCP), komersial napropamide and napropamide telah diukur. Berdasarkan kepada hasil pengukuran, FR-4 struktur antena yang dilapisi dengan MWCNTs dan PPy-CHI berupaya menegesan kepekatan kecil bahan yang diukur dibawah paras 0.5 ppm. Pada frekuensi operasi ini (5 GHz), teknik ini boleh digunakan dalam sistem jarinaqn penderia tanpa wayar di dalam pengukuran pencemaran wap organik dalam kawasan penghadang untuk penyelidikan yang akan datang.

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I certify that a Thesis Examination Committee has met on 27 June 2014 to conduct the final examination of Ahmad Mohammadi on his thesis entitled "Carbon Nanotube-Based Microwave Resonant Sensor for Organic Contaminants Detection" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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DECLARATION

Declaration by graduate student

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