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Nanotechnology Open a New Era for the Evolution in Gas Sensors "Nano-composite Materials as Dissolved Oxygen Sensors"

Ph.D. Thesis

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List of Abbreviations

Word	Abbreviations
Zero-Dimensional	0D
One-Dimensional	1D
Two-Dimensional	2D
Anodic Stripping Voltammetry	ASV
Poly(bromocresol green)	BCG
Backscattered Detector	BSD
Counter Electrode	CE
Carbon Nanotube	CNT
Carbon Paste Electrode	CPE
Cathodic Stripping Voltammetry	CSV
Cyclic Voltammetry	CV
Chemical Vapor Deposition	CVD
Coated Wire Electrodes	CWES
Dopamine	DA
Dropping Mercury Electrode	DME
Dissolving Oxygen	DO
Differential Pulse Voltammetry	DPV
Energy Dispersive Spectroscopy	EDS
Energy Dispersive X-ray	EDX
Electrodeposited Graphene	EGR
Fetal Bovine Serum	FBS
Field Emission Scanning Electrone Microscope	FESEM
Field Effect Transistors	FETS
Fourier Transform Infrared Spectroscopy	FTIR
Fluorine-doped Tin Oxide	FTO
Graphene	G
Glassy Carbon	GC
Glassy Carbon Electrode	GCE
Graphene Nanosheet	GNS
Graphene Oxide	GO
Hanging Mercury Drop Electrode	HMDE
High Resolution Transmission Electron Microscope	HRTEM

International Center for Diffraction Data	ICDD
Infra-Red	IR
Ion Selective Electrode	ISE
Indium- Tin Oxide	ITO
Light Microscope	LM
Linear Sweep Voltammetry	LSV
Magnetic Bar Carbon Paste Electrode	MBCPE
Mercury Film Electrode	MFE
Molecularly Imprinted Star Polymers	MISP
Mercury-Mercury Oxide	MMO
Mercury-Mercurous Sulfate	MMS
Multi-Walled Carbon Nanotube	MWCNT
Nanopartcles	NPs
Normal Pulse Voltammetry	NPV
Organic Electrochemical Transistor	OECT
Organophosphate Compounds	OPs
Oxygen Reduction Reaction	ORR
Phosphate Buffer Solution	PBS
Reference Electrode	RE
Reduced Graphene Oxide	rGO, RGO
Reversible Hydrogen Electrode	RHE
Rizatriptan Benzoate	RZB
Selected Area Electron Diffraction	SAED
Saturated Calomel Reference Electrode	SCE
Secondry Electrdon Detector	SED
Standard Hydrogen Electrode	SHE
Silver-Silver Chloride Electrode	SSCE
Silver-Silver Sulfate Electrode	SSSE
Square Wave Voltammetry	SWV
Tetraethoxysilane	TEOS
Tetramethoxysilane	TMOS
Titanium (IV) Isopropoxide	TTIP
Working Electrode	WE
X-Ray Diffraction	XRD

Summary

The determination of dissolved oxygen (DO) is an important parameter for the indication of water quality for aquaculture farming and for various physiological and biochemical parameters, such as the monitoring of DO in cell culture and in vivo study is considered to be one of the most important requirements. This study is focused on tailoring an efficient nano-sized catalyst for DO sensing with high sensitivity and low detection limit to substitute the highly cost Pt catalyst and minimize the overpotential of oxygen reduction reaction (ORR).

In the thesis, the first chapter introduces a general introduction followed by literature review about the electrochemical sensors and their impacts in detection of many species. A review of the researches that had been done to develop such sensors using nanomaterials and their applications as dissolved oxygen (DO) sensors. Then the second chapter shows the methodology of the experiments, the fabrication techniques and the chemicals in addition to the characterization techniques. The last chapter reviews the results that have been reached and their interpretation.

The hydrothermal methods was used to prepare Graphene (G) nanosheets, Graphene- titanium dioxide (G-TiO_2), titanium dioxide –silver (TiO_2-Ag) and Graphene-titanium dioxide-silver (G-TiO_2-Ag) nanocompoites. The formation and the shape of the prepared nanomaterials were confirmed using X-ray diffraction (XRD), fourier-transform infrared spectroscopy (FTIR) and High resolution transmission electron microscope (HRTEM) and all results were discussed.

Glassy carbon electrode surface was cleaned and polished well then modified with the prepared nanocomposites each composite for one electrode. Field emission scanning electron microscope (FESEM) was used

to study the modified electrode surface morphology and confirm the presence and distribution of the nanomaterials on the electrode surface using energy dispersive X-ray (EDX) and mapping analysis techniques. The results showed the presence and the good distribution of the nanomaterials on the electrode surface.

The electrochemical behavior for the prepared electrodes toward the dissolved oxygen (DO) using the cyclic voltammetry technique (CV) was performed. The results showed that the highest response in DO saturated solution was for the electrode modified with G-TiO_2-Ag.

The response for the different concentrations of DO in the solution was varied according to the sensitivity for each electrode but was also matched with the results in case of saturated oxygen solution. The sensitivity and the detection limit for each electrode were evaluated using the amperometric technique.

The sensitivity for glassy carbon electrodes (GC) / G-TiO_2-Ag and GC/TiO_2-Ag was 1.363 $\mu Acm^{-2}\mu M^{-1}$ and 1.3034 $\mu Acm^{-2}\mu M^{-1}$, respectively. The detection limit (LOD) also was the best for the previous electrodes with detection limit of 0.011 µM for GC/G-TiO_2-Ag and detection limit of 0.022 µM for GC/TiO_2-Ag.

Material loading concentration factor indicated that 15 mg of the loaded material leads to better sensitivity for all materials examined but 20 mg decreases the sensitivity but still higher than that for 10 mg in case of G-TiO_2-Ag, except in case of TiO_2-Ag the sensitivity decreased at loading concentration of 25 mg and still higher than that for 10 mg.