

Simultaneous Determination of HQ and CC Using GE and Different Modified Electrodes (GE /PFA, GE/MWCNTs,GE/MWCNTs /PFA)

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Abstract:

Differential Pulse Voltammetric technique has been used to study the electrochemical behaviour of Hydroquinone (HQ) on Graphite electrode (GE), GE /Poly Furfurylamine (PFA), GE / Multiwalled Carbon Nano Tubes(MWCNTs), GE/MWCNTs /PFA in the present and absent of Catechol(CC) .A three – electrodes detection system was employed consist of bare or modified graphite electrodes as the working electrode , silver /silver chloride saturated potassium chloride (Ag/AgCl,sat.KCL) as reference electrode and 1.0 mm diameter platinum wire(Pt-wire) as auxiliary electrode.Calibration curves were constructed for each working electrode under the optimum conditions, stability and the effect of pH have been examined ,the standard deviation (S.D) and R² values have been calculated .The best working electrode was the GE modified by MWCNTs with PFA polymer ,a modification electrode was successfully applied for simultaneous determination of HQ in mixture containing CC.

Keywords: Modified Electrodes ,Conducting Polymer, Hydroquinone and Catechol , Differential Pulse Polarography ,MWCNTs.

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I. Introduction

Hydroquinone(1,4Dihydroxy benzene) is the important compound due to its wider biological and industrial applications,such as: reducing agent(1) ,antioxidant(2), cosmetics(3), pesticides, black white film developer(4), dye-generating materials , pharmaceutical intermediate .The US Enviromental Protection Agency has classified the HQ compound as highly toxic enviromental pollutant due to its effect on health such as sever liver injuries, abnormal pigmentation and hemolytic jaundice(5).Compared with many analytical methods,including capillary electrophoresis (6) ,synchronous fluorescence(7),chromatography(8), spectroscopy(9),colorometry(10),chemiluminescence with flow injection (11) ,electrochemical

techniques (12,13) electrochemical techniques are good candidates for detecting various substances like HQ because their cheap instrument ,simple operation ,high sensitivity ,high accuracy and time –saving (14).The simultaneous determination of HQ ,CC suffer from the peak overlaps specially at low concentration , because they have redox potential very closed to each other so it is difficult to distinguish between the oxidation peaks ,to solve this problem many sensing materials with high stability,high catalytic activity, such as polymer (15,16), quantum dots(17,18) , mesoporous silica (19) , were employed to modify electrodes surface . Carbon nano materials become a superior modifier to improve the electroconductivity and stability of electrochemical biosensor.Carbon nano tubes

(CNTs) have got much attention (20) due to their properties such as excellent electroconductivity, huge surface area and high electron transport rates make them base materials in the fabrication of electrochemical sensors. Many interests were concentrated on the detection of HQ and CC simultaneously by CNTs – based electrode (21-24). Modification electrodes by polymer film have been chosen by researchers because of their good stability, reproducibility and more active sites. To immobilize polymers the electropolymerization, has an important role because it is a one step polymerization, it can control film thickness, permeation, charge transport characteristic by adjusting electrochemical parameters (25,26).

In this work different modified electrodes were tested for simultaneous determination of HQ in the presence of CC, the best working electrode was GE/MWCNT/PFA modified electrode because it, has large surface area and gives good peaks separation.

II. EXPERIMENTAL

Apparatus

Differential pulse voltammetry (DPV) and Cyclic voltammetry (CV) measurements were performed using 797VA Computrace voltammetric analyzer supplied by Metrohm company, Switzerland, coupled with a three electrode detection system consists of solid electrodes (bare Graphite, GE/PFA, GE/MWCNTs, GE/MWCNTs/PFA as working electrodes, Ag/AgCl, sat. KCl as reference electrode and 1mm Pt-wire was used as an auxiliary electrode. pH measurements were performed using a digital pH meter supplied by HANNA Company, Portugal, model pH211, microprocessor pH meter with accurate to ± 0.05 .

Reagents and Chemicals

Hydroquinone was purchased from British Drug House LTD, Catechol was purchased from Hopking and Williams British LTD. Freshly standard solution of HQ was prepared in absolute

ethanol. Phosphate buffer solution (PBs) was prepared by mixing appropriate amount of K_2HPO_4 and KH_2PO_4 which is used as supporting electrolyte.

Procedure

Phosphate buffer solution was added to voltammetric cell and deoxygenated via passing N_2 gas for 5 minutes prior the measurements, and the voltammogram was recorded. Then test solution was added to the voltammetric cell and the voltammograms were also recorded under the optimum conditions for a sequence additions of stock solutions of CC, after which the calibration curves were constructed.

Fabrication of PFA Modified GE

Before modification, the bare GE was polished with $0.05 \mu m$ of Al_2O_3 powder, rinsed and ultrasonicated in water (27). Then the electropolymerization of Furfurylamine was performed in acetonitrile supporting electrolyte containing Furfurylamine (0.01 mol L^{-1}) with lithium perchlorate (0.06 mol L^{-1}) and sodium hydroxide (0.06 mol L^{-1}) (28). The electropolymerization performed using cyclic voltammetric technique by repetitive scanning the potential between (0.5-1.8) V versus Ag/AgCl, sat. KCl for 5 cycles with scan rate equal to 0.14 V/s , then the electrode was ready to use after the final wash in water to remove unwanted any physically absorbed materials.

Construction of MWCNTs / PFA Electrode

Before the modification, the GE was polished with $0.05 \mu m$ of Al_2O_3 powder, rinsed and ultrasonicated in water for 3 minutes. The freshly cleaned GE was electrochemically activated in a $0.1 \mu \text{mol L}^{-1}$ H_2SO_4 solution by repetitive scanning the potential, 20 cycles between (-0.5 – 2.0) V. A $20 \mu L$ of the freshly prepared (5mg/5ml) dispersion of MWCNTs in DMF was dropped onto the GE surface and the solvent was evaporated with IR lamp (29). Then MWCNTs – modified electrode was further modified with a

thin film by placing 10 μ L of PFA solution over the surface of the electrode and evaporating the solvent in air .

III. RESULTS AND DISCUSSION

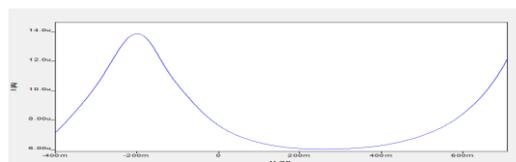
1- Electrochemical Behaviour of HQ at GE Using Differential Pulse Voltammetric Technique

Differential pulse voltammogram on GE was recorded for 14.778 $\times 10^{-6}$ M of HQ in phosphate buffer (pH= 8) under the default conditions of instrument. HQ gives a well defined oxidation peak current at -0.15 V versus Ag/AgCl.sat.KCl (Fig.1a).Optimum Conditions

In order to optimize the conditions of measurements , various instrumental and experimental variables were examined and optimized using 14.778 $\times 10^{-6}$ M of HQ in phosphate buffer a (pH= 8) ,the results obtained are shown in (Table 1) and the voltammogram after optimum conditions was recorded (Fig. 1b) .

Table(1):The optimum conditions for HQ in phosphate buffer solution (pH=8) at GE

Parameters	Optium Coditions Values
Deposition potential	-1.7V
Deposition time	20 s
Equilibration time	30 s
Pulse Amplitude	0.11V
Pulse time	0.03 s
Voltage step	0.009V
Voltage step time	0.1 s



b

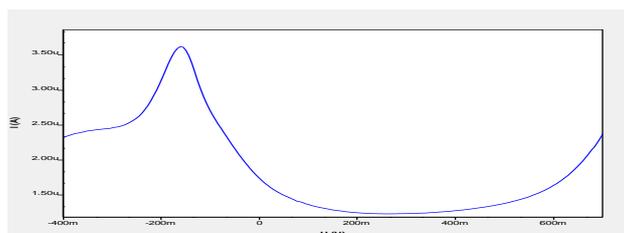
Fig: 1 D.P.voltammogram of HQ on GE , a - before and b- after optimum conditions

Stability

To study the stability of HQ oxidation peak , a voltammogram of 14.7 $\times 10^{-6}$ M was recorded versus time under the mentioned optimum conditions(Tabe 1) ,the results obtained are shown in (Table 2) ,its clear that the oxidation peak current is stable within the studied time (Fig.2) .

Table 2:Stability of HQ oxidation peak

Time(min)	Ip(μ A)
0	5.77s
5	5.98
10	6.09
15	6.11
20	6.17
25	6.17
30	6.2
35	6.24
40	6.23
45	6.19
50	6.21
55	6.21
60	6.21
S.D= \pm 0.131173	



a

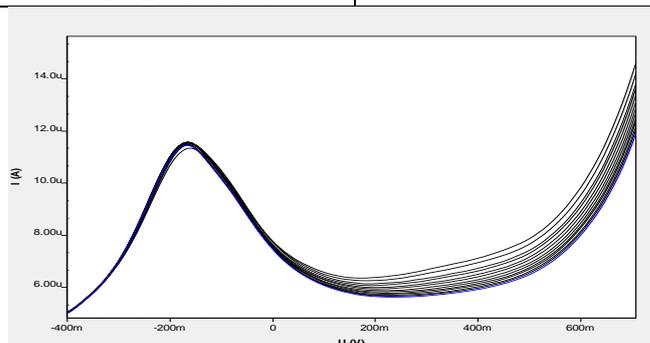


Fig:2 D.P.Voltammogram for HQ oxidation peak stability at GE

Calibraion Curve:

The calibration curve was constructed by adding a sequence additions of standard HQ solution ($10^{-3}M$) and the voltammogram was recorded for each addition under the previous optimum conditions , the plot of peak current versus concentrations give a two straight line, first at low concentration range(2.991×10^{-6} - 17.681×10^{-6})M,(Fig.3), and the second at higher concentration range (19.607×10^{-6} - 65.42×10^{-6}) M (Fig.4), with R^2 values equal 0.9909 and 0.9719 respectively .

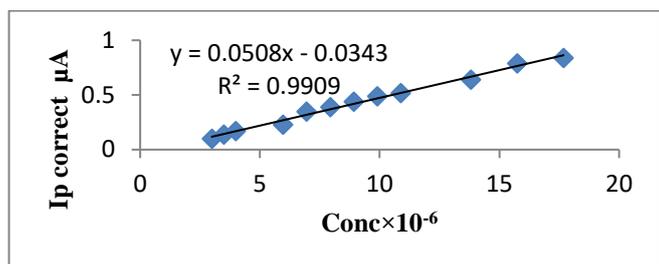


Fig:3 Calibraion curve of HQ at GE/PFA at low concentration

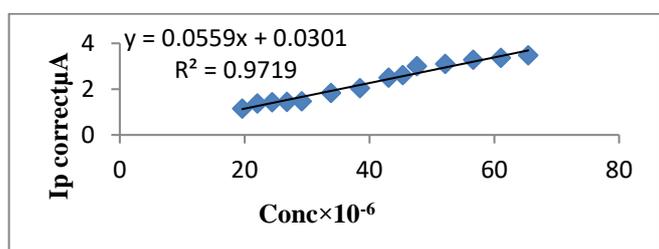


Fig:4 Calibraion curve of HQ at GE/PFA at high concentration

Hydroquinone and Catechol in mixture

The voltammogram in Fig.5 shows that we could obtained weak separation between HQ and CC in mixture on GE at cocentration value equal to 7.936×10^{-6} M, whereas at lower concentration we got one composite peak represent the overall concentrations of HQ and CC .So we tried to developpe the GE surface with PFA .

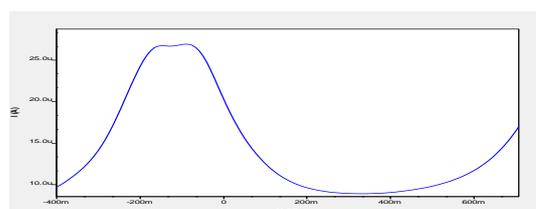


Fig: 5 Show the separation between HQ and CC in mixture at GE

2- Electrochemical Behaviour of Hydroquinone at GE /PFA Modified Electrode:

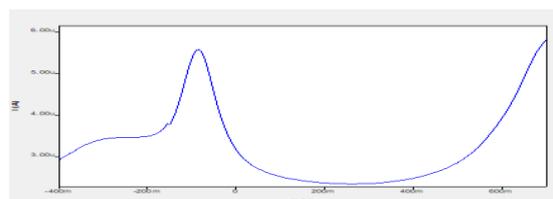
Differential pulse voltammogram of HQ on GE /PFA modified electrode was recorded for 14.778×10^{-6} M of HQ in phosphate buffer (pH=7) under the default conditions of instrument , HQ exhibit well-defined oxidation peak at (-0.084)V versus Ag/AgCl sat.KCl with oxidation current equal to 2.96 Aµ (Fig.6-a).

Optimum Conditions

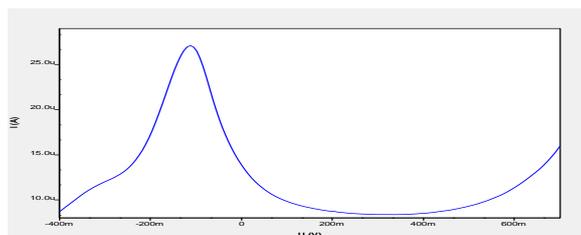
In order to optimize the conditions of measurments ,various instrumental and expeimental variables were tested and optimized using 14.778×10^{-6} M of HQ in phosphat buffer (pH7) ,the results obtained are shown in (Table 3) and the voltammogram after optimization can be seen in(Fig. 6-b) .

Table (3):The optimum conditions for HQ in phosphate buffer solution (pH=7) at GE /PFA modified electrode

Parameters	Optimum Condition Values
Deposition potential	-1.7V
Deposition time	20 s
Equilibration time	20 s
Pulse Amplitude	0.09V
Pulse time	0.02 s
Voltage step	0.007V
Voltage step time	0.1 s



a



b

Fig:6 D.P.voltammogram of HQ on GE/PFA, a-before and b-after optimum conditions

Stability

To study the stability of HQ oxidation peak voltammogram of 14.7×10^{-6} M HQ was recorded in different intervals time under the mentioned optimum conditions (Table 3), the results obtained are shown in (Table 4), its clear that the oxidation peak current is stable within the studied time.

Table 4: Stability of HQ oxidation peak

Time(min)	Ip(μ A)
0	11.6
5	12.2
10	12.5
15	12.7
20	12.8
25	12.6
30	12.6
35	12.8
40	13.0
45	12.8
50	12.7
55	12.7
60	12.4
S.D= 0.354459	

Calibraion Curve

The calibration curve was constructed by adding a sequence additions of standard HQ solution (10^{-3} M) and the voltammogram was recorded for each addition under the previous optimum conditions, the plot of peak current versus concentrations

(Fig.7) give a two straight lines ,one at low concentrations (1.497×10^{-6} - 9.9×10^{-6}) M with $R^2 = 0.9792$ (Fig.7a) and second at high concentrations (10.88×10^{-6} - 56.603×10^{-6}) M with $R^2 = 0.9895$ (Fig.7b) .

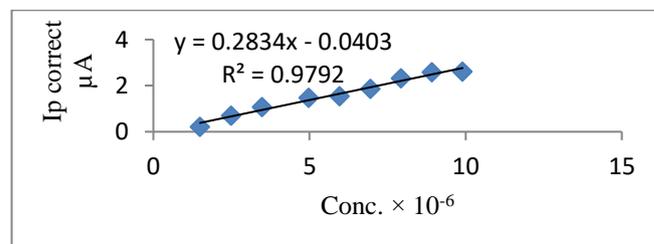


Fig: 7a Calibraion curve of HQ at GE/PFA at low concentrations

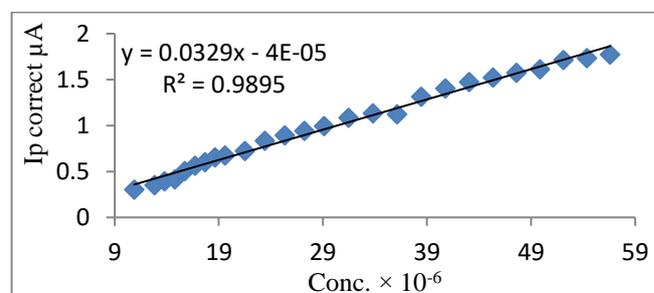


Fig: 7b Calibraion curve of HQ at GE/PFA at high concentrations

Calibration Curve of HQ in the Present of the CC at GE /PFA

A calibration curve of HQ in the present of CC was constructed by adding a sequence additions of HQ to the voltammetric cell containing (99.0×10^{-7})M of CC using phosphate buffer (PH=7) .A plot of peak current versus concentrations give a two straight lines ,first at low concentration range(4.479×10^{-6} - 10.39×10^{-6}) M ,(Fig. 8a),and second at higher concentration range(10.881×10^{-6} - 19.607×10^{-6}) M(Fig.8b) with R^2 values equal to 0.9697 and 0.9799 respectively. The voltammgram (Fig.9) shows a small separation between two peaks at(4.479×10^{-6} M)of HQ.

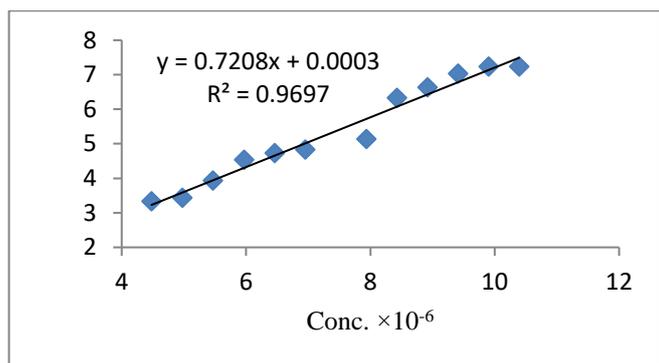


Fig:8a Calibration curve of HQ in HQ and CC mixture at GE/PFA at low concentrations

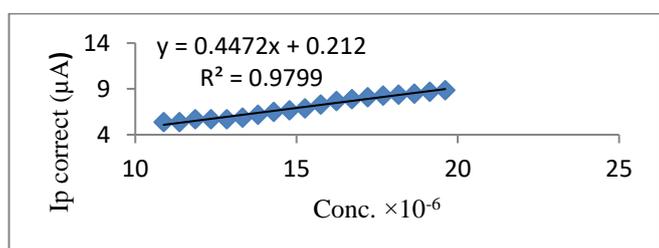


Fig:8b Calibration curve of HQ in HQ and CC mixture at GE/PFA at high concentrations

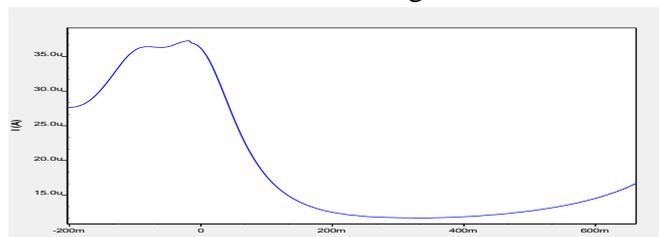


Fig:9 The voltammogram of HQ in HQ and CC mixture at GE/PFA modified electrode

5- Electrochemical Behaviour of Hydroquinone on GE /MWCNTs Modified Electrode

Differential pulse voltammogram of HQ was recorded for 14.778×10^{-6} M of HQ in phosphate buffer pH= 8 under the default conditions of instrument HQ exhibit oxidation peak at -0.215 V versus with oxidation peak current equal to 26.2 μ A (Fig .10-a).

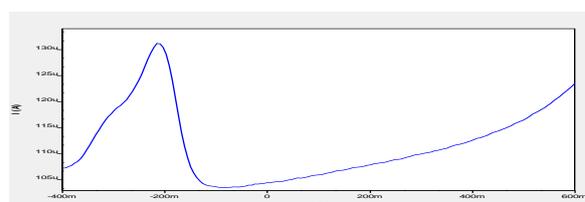
IV. Optimum conditions

In order to optimize the conditions of measurements ,various instrumental and experimental variables were examined and optimized using 14.778×10^{-6} M of HQ in phosphate buffer (pH= 8), the results obtained are shown in Table (5) and the voltammogram

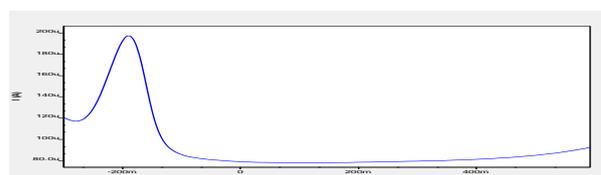
after the optimum condition can be seen in (Fig. 10-b) .

Table (5): Optimum conditions for HQ in phosphate buffer solution (pH=8) at GE /MWCNTs modified electrode.

Parameters	Optimum Condition Values
Deposition potential	-0.2V
Deposition time	5 s
Equilibration time	4 s
Pulse Amplitude	0.06V
Pulse time	0.05 s
Voltage step	0.001V
Voltage step time	0.2 s



a



b

Fig:10 D.P.voltammogram of HQ on GE /MWCNTs modified electrode : a-before and b-after optimum conditions

Stability

To study the stability of HQ oxidation peak , a voltammogram of 14.7×10^{-6} M of HQ was recorded at different intervals time under the mentioned optimum conditions (Table 5) ,its clear that oxidation peak current is stable within the studied time. the results obtained are shown in(Table 6) .

Table 6: Stability of HQ oxidation peak :

Time(min)	Ip(μA)
0	30.1
5	34.9
15	33.6
20	33.3
25	32.9
30	33.9
35	33.8
40	33.8
45	33.1
50	33.0
55	34.0
60	33.8
S.D=± 1.157976	

Calibraion Curve

The calibration curve was constructed by adding a sequence additions of standard HQ solution (10^{-4} M) and the voltammogram was recorded for each addition under the previous optimum conditions ,the plot of peak current versus concentrations give a two straight lines, one at low concentrations ($9.99 \times 10^{-8} - 44.798 \times 10^{-8}$) M with $R^2= 0.9861$ (Fig.11a) and second at high concentrations ($54.699 \times 10^{-8} - 99.009 \times 10^{-8}$) M with $R^2= 0.9873$ (Fig.11b) .

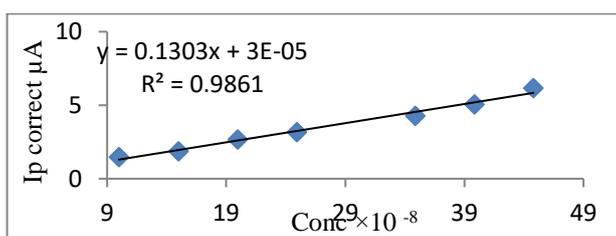


Fig:11-a Calibraion curve of HQ at GE/ MWCNTs at low concentrations

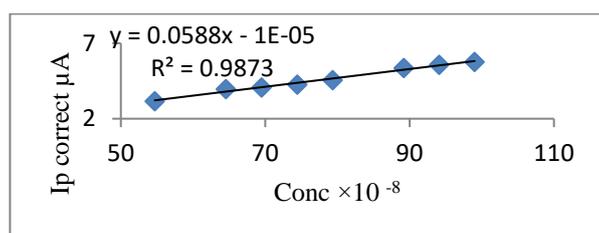


Fig:11b Calibraion curve of HQ at GE/ MWCNTs at high concentrations

Hydroquinone and Catechol in Mixture

HQ determined in the present of CC in phosphate buffer (pH=8) the voltammogram was recorded (Fig.12) and the calibraion curve was constructed (Fig.13) within the concentrations range ($9.99 \times 10^{-8} - 9.41 \times 10^{-7}$)M ,the calibration shows two straight line ,first at low concentrations ($4.997 \times 10^{-8} - 29.91 \times 10^{-8}$)M (Fig.13-a)with $R^2 = 0.992$ and the second at higher concentrations ($34.84 \times 10^{-8} - 94.1 \times 10^{-8}$)M with $R^2 = 0.9542$ (Fig.13-b) .

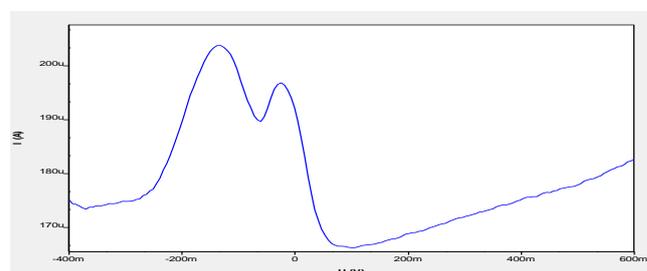


Fig.:12 The voltammogram of HQ in the pesent of CC at GE/MWCNTs modified electrode

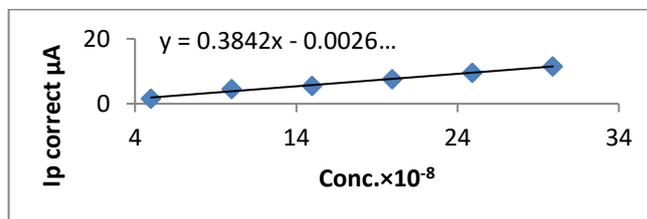


Fig.13-a Calibration curve of HQ in CC and HQ mixture at GE/MWCNTs modified electrode at low concentrations

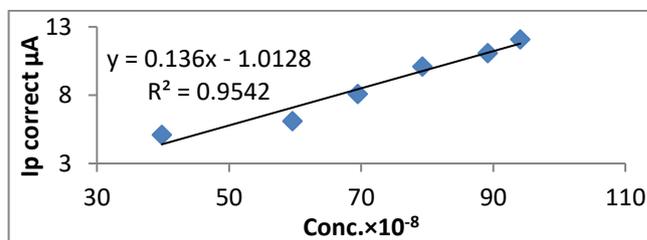


Fig:13-b Calibration curve of HQ in CC and HQ mixture at GE/MWCNTs modified electrode at high concentrations

6- Electrochemical Behaviour of Hydroquinone at GE /MWCNTs/PFA Modified Electrode

Differential pulse voltammogram of HQ at GE/MCNTs /PFA modified electrode was

recorded for 14.779×10^{-6} M of HQ in phosphate buffer (pH= 7) under the default instrument conditions, HQ exhibit oxidation peak at (-0.104) V and peak current equal to 151 μ A .

Optimum Conditions

In order to optimize the conditions of measurements, various instrumental and experimental variables were examined and optimized using 14.778×10^{-6} M of HQ in phosphate buffer (pH= 7) ,the results obtained are shown in Table (7) and the voltammogram can be seen in Fig. (14).

Table (7):The optimum conditions for HQ at GE /MWCNTs/PFA modified electrode

Parameters	Optimum Condition Values
Deposition potential	-1.1V
Deposition time	40 s
Equilibration time	30 s
Pulse Amplitude	0.07V
Pulse time	0.02 s
Voltage step	0.002V

Stability

To study the stability of the oxidation peak of HQ , a voltammogram of HQ was recorded under the measured optimum conditions (Table 7) versus time ,the results obtained (Table 8) indicates that the oxidation peak is stable within the studied time .

Table 8: Stability of oxidation peak current of HQ at GE/MWCNTs /PFA modified electrode

Time(min)	Ip(μ A)
0	84.6
5	81.2
15	84.6
20	82.4
25	83.7
30	79.7
35	80.1
40	81.6
45	75.4
50	79.7
55	80.0
60	82.0
S.D= \pm 2.564	

Calibraion curve

The calibration curve was constructed by adding a sequence additions of standard HQ solution (10^{-5} M) and the voltammogram was recorded for each addition under the previous optimum conditions ,the plot of peak current versus concentrations give a two straight lines ,one at low concentrations ($14.977 \times 10^{-9} - 74.441 \times 10^{-9}$) M with $R^2 = 0.9846$ (Fig.14a) and second at high concentrations ($79.365 \times 10^{-9} - 128.33 \times 10^{-9}$) M with $R^2 = 0.9747$ (Fig.14b) .

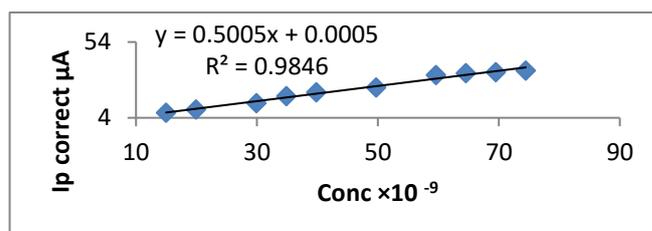
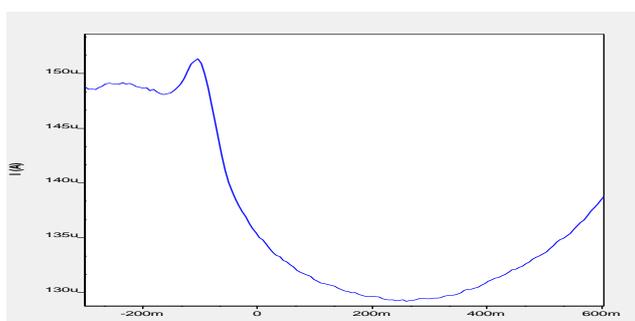
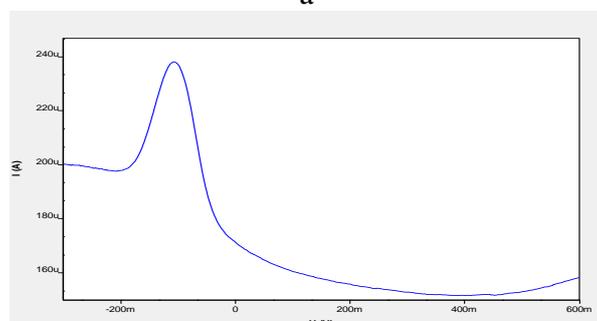


Fig.15a Calibraion curve of HQ at GE/ MWCNTs /PFA at low concentrations



a



b

Fig.14 D.P.voltammogram of HQ on GE /MWCNTs/PFA ,a-before and b-after optimum conditions

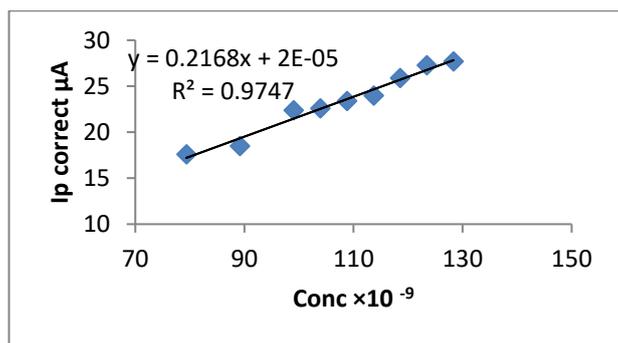


Fig.15b Calibration curve of HQ at GE/MWCNTs/PFA at high concentrations

4 Hydroquinone and Catechol in Mixture

HQ was determined in the present of CC in phosphate buffer (PH=8) on GE/MWCNTs/PFA modified electrode in the concentration range (14.977×10^{-9} – 69.513×10^{-9})M as shown in Fig.16, the voltammogram was recorded (Fig.17). The results obtained shows an excellent separation of HQ and CC oxidation peaks at low concentration which can not achieved with bare GE .

Table 9: HQ determination in the present of (99.0×10^{-7}) M CC at GE/MWCNTs/PFA modified electrode

Conc. × 10 ⁻⁹	Ip correct (µA)
14.977	3.41
19.96	4.41
29.911	8.41
34.877	9.41
39.84	12.41
49.751	14.41
59.642	15.41
64.58	16.41
69.513	18.41

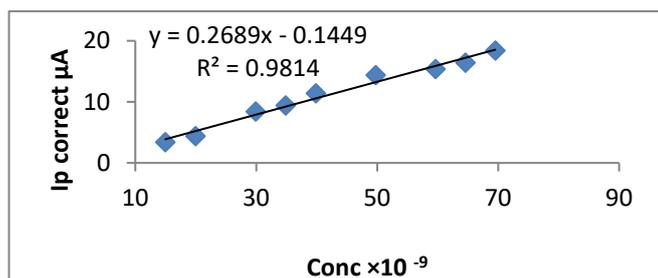


Fig.16 Calibration curve of HQ in the present of (99.0×10^{-7})M CC at GE/MWCNTs/PFA modified electrode

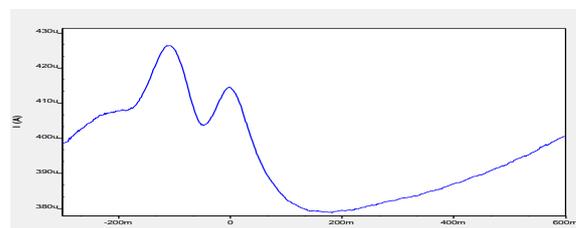


Fig.17 The voltammogram of HQ in the present of (99.0×10^{-7})M CC at GE/MWCNTs/PFA modified electrode

V. CONCLUSION

The modification of electrode by MWCNTs and PFA conducting polymer improve the response of electrode towards the enhancement of peaks separation of materials has very close oxidation-reduction potentials.

The results obtained shows an excellent separation of HQ and CC oxidation peaks at lower concentration can achieved with GE/MWCNTs/PFA modified electrode .

The proposed electrode exhibits good stability ,sensitivity and reproducibility towards the determination of HQ by differential pulse voltammetry.

REFERENCES

- [1]. Chen Y, Liu X, Zhang S, Yang L, Liu M, Zhang Yand Yao S (2017) Ultrasensitive and simultaneous detection of hydroquinone, catechol and resorcinol based on the electrochemical co-reduction prepared Au-Pd nanoflower/reduced graphene oxide nanocomposite. *Electrochim Acta*. 23:1677–685.
- [2]. Guevara I L , Pandya A G (2003) Safety and efficacy of 4%hydroquinone combined with 10% glycolicacid, antioxidants, and sunscreen

- in the treatment of melasma . *Int.J. Dermatol.*42: 966–972.
- [3]. Siddique S Z, Parveen Z Ali and Zaheer M (2012):Qualitative and quantitative estimation of hydroquinone in skin whitening cosmetics. *J.Cosmet. Dermatological Sci . Appl .*02:224–228.
- [4].Mendes R K , Cavalheiro P and Cervini É T G (2006) The use of a graphite-castor oil polyurethane composite electrode for the determination of hydroquinone in photographic developers. *Talanta* 68 : 708–712.
- [5]. Xie T, Liu Q, Shi Y and Liu Q (2006) Simultaneous determination of positional isomers of benzenediols by capillary zone electrophoresis with square wave amperometric detection. *J Chromatogr A* 1109 :317–321.
- [6]. Dong S Q, Chi L Z , Zhang S, He P G , Wang Q J and Fang Y Z (2008) Simultaneous determination of phenylenediamine isomers and dihydroxybenzene isomers in hair dyes by capillary zone electrophoresis coupled with amperometric detection. *Anal. Bioanal. Chem.* 391:653-659.
- [7]. Pistonesi M F , Nezio M S Di, Centurion M, Palomeque M E , Lista A G and Band B S F (2006) Determination of phenol, resorcinol and hydroquinone in air samples by synchronous fluorescence using partial least-squares (PLS). *Talanta* 69: 1265-1268.
- [8]. Ma T, Lan T, Ju Y, Cheng G, Que Z, Geng T, Fang Y and Sun X (2019)Comparison on the nutritional properties and biological activities of kiwi fruit (Actinidia) and their different forms products: how to make kiwifruit more nutritious and functional, *Food Funct.*
- [9]. Nagaraja P, Vasantha R A, Sunitha K R(2001) A sensitive and selective spectrophotometric estimation of catechol derivatives in pharmaceutical preparations ., *Talanta.* 55:1039–1046.
- [10]. Yang H., Zha J, Zhang P, Qin Y, Chen T and Ye F (2017) Fabrication of CeVO₄ as nanozyme for facile colorimetric discrimination of hydroquinone from resorcinol and catechol. *Sensors Actuators B*247:469–478.
- [11]. Wang Z , Tang Y, Hu H, Xing L, Zhang G and Gao R (2014) Chemiluminescence detection of hydroquinone with flow-injection analysis of luminol-hydrogen peroxide system catalyzed by Jacobsen's catalyst. *J. Lumin.* 145: 818–823.
- [12]. Kuskur C M , Kumara Swamy B E and Jayadevappa H (2019) Poly (Evans blue) sensor for cat- echol and hydroquinone: a voltammetric study. *J. Electroanal. Chem.* 833: 512–519.
- [13]. Harisha K V , Kumara Swamy B E and Ebenso E E (2018)Poly (glycine) modified carbon paste electrode for simultaneous determination of catechol and hydroquinone: a voltammetric study. *J. Electroanal. Chem.* 823: 730–736.
- [14].Hu F, Chen S, Wang C, Yuan R, Yuan D, Wang C (2012) Study on the application of re- duced graphene oxide and multiwall carbon nanotubes hybrid materials for simul- taneous determination of catechol, hydroquinone , p- cresol and nitrite. *Anal. Chim. Acta* 724: 40–46.
- [15].Ganesh P S, Kumara Swamy B E (2015)Simultaneous electroanalysis of hydroquinone and catechol at poly(brilliant blue) modified carbon paste electrode: a voltammetric study. *J. Electroanal. Chem.* 756: 193-200.
- [16].Peng J, Feng Y, Han X, Gao Z (2016) Simultaneous determination of bisphenol A and hydroquinone using a poly(melamine) coated graphene doped carbon paste electrode. *Microchim. Acta* 183:2289-2296.
- [17].Wang Y, Qu J, Li S and Dong Y(2015) Simultaneous determination of hydroquinone and catechol using a glassy carbon electrode modified with gold nanoparticles. ZnS/NiS@ZnS quantum dots and L-cysteine, *Microchim. Acta* 182:2277-2283.
- [18]. Hu S, Zhang W, Zheng J, Shi J, Lin Z., Zhong L, Cai G, Wei C, Zhang H.and Hao A (2015) One step synthesis cadmium sulphide/reduced graphene oxide sandwiched film modified electrode for simultaneous electrochemical determination of hydroquinone, catechol and resorcinol. *RSC Adv.* 5:18615-18621.
- [19]. Tashkhouriana J, Daneshia M, Nami-Anaa F, Behbahanib M, Bagheriba A, and Hazard J (2016)Simultaneous determination of hydroquinone and catechol at gold

- nanoparticles mesoporous silica modified carbon paste electrode. *J. Hazard. Mater.* 318: 117-124.
- [20]. Bathinapatla A, Kanchi S., Singh P, Sabela M I And Bisetty K (2015) Fabrication of copper nanoparticles decorated multiwalled carbon nanotubes as a high performance electrochemical sensor for the detection of neotame. *Biosens. Bioelectron.* 67: 200-207.
- [21]. Wang Y, Xiong Y, Qu J, and Li S (2016) Selective sensing of hydroquinone and catechol based on multiwalled carbon nanotubes/polydopamine/gold nanoparticles composites. *Sens. Actuators B* 223: 501-508.
- [22]. Goulart L. A, Mascaro L. H (2016) GC electrode modified with carbon nanotubes and NiO for the simultaneous determination of bisphenol A, hydroquinone and catechol. *Electrochim. Acta* 196: 48-55.
- [23]. Meng Z, Zhang H and Zheng J (2015) An improved synthesis of sunitinib malate via a solvent-free decarboxylation process. *Res. Chem. Intermed.* 41:3135-3146.
- [24]. Wei C, Huang Q, Hua S, Zhang H, Zhang W, Wang Z, Zhu M, Dai P And Huang L (2014) Simultaneous electrochemical determination of hydroquinone, catechol and resorcinol at nafion/multi-walled carbon nanotubes/carbon dots/multi-walled carbon nanotubes modified glassy carbon electrode. *Electrochim. Acta* 149: 237-244.
- [25]. Sha Y F, Qian Y L, Ma J, Bai H X, Yang X R. (2006) *Talanta* 70:556-560.
- [26]. Jin G Y, Huang F, Li W, Yu S N, Zhang S and Kong J L, (2008). *Talanta* 74:815-820.
- [27]. Murrin A, Killar A J, and Smyth M R (2003) Electrochemical Characterization of Commercial and Home-Made Screen-Printed Carbon Electrodes. *Analytical Letters* 36(9):2027-2028.
- [28]. Fu Y, Lin T, Chen T and Wang L (2012) Study on the poly furfural film modified glassy carbon electrode and its application in polyphenols determination. *J. Electroanal. Chem.* 687:25-29.
- [29]. Alothman Z A, Bukhari N, Wabidur S M, Haider S (2010) Simulation electrochemical determination of dopamine and acetaminophen using multiwalled carbon nanotubes modified glassy carbon electrode. *Sensor and Actuators B* 146:314-320.