

## Journal of Global Pharma Technology

Available Online at <u>www.jgpt.co.in</u>

RESEARCH ARTICLE

# Electrochemical Determination of Tetracycline at SPCE modified with Nanocomposite

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#### Abstract

An electrochemical sensor based on manganese dioxide nanorodMnO2and Graphene oxide (GO) 3-substituted functionalized with 4-amino, 1H, 1. 2Triazole 5(4H) thion 4 (FGO)/MnO<sub>2</sub>Nanocompositewas developed for voltammetric determination of Tetracycline (TET). The working electrode WE of SPCE was modified by a drop casting method. X-ray powder diffractometer (XRD), scanning electron microscopy (SEM) and FT-IR were employed to characterize the synthesized FGO/MnO<sub>2</sub>. The determination of TET at the modified electrode was studied by cyclic voltammetry (CV) and differential pulse voltammetry (DPV) in the phosphate buffer solution (PBS).TET show sharp increase in the oxidation peaks in the pH 2. Voltammetric characteristics of TET ( $E_{pa}$ ,  $I_{pa}$ ) were estimated. From effect of scan rate, the average surface coverage ( $\Gamma$ ) of TET on the surface of SPCE modified with  $FGO/MnO_2$  nanocomposite, the electron transfer coefficient and electron transfer constant rate  $k_{et}$  was obtained as  $10.56 \times 10^{14}$  molecule cm<sup>-2</sup>, 0.5, and 10.41 cm.s<sup>-1</sup> respectively. Under the optimal conditions, the peak current shows linear relationship with concentration of Tetracycline (TET) ranges 1–9 µM with the detection limit of 0.2µ M. The modified SPCE was successfully used to detect TET

Keywords: SPCE, Functionalize graphene oxide, Cyclic voltammetry.

## Introduction

Carbone Nanomaterials, have great attention in the electrochemical researches [1] due to their unique physical properties. They were used as modifiers for electrodes. Moreover, the carbon Nanomaterials such as graphene oxide GO and graphene G and their functionalized can be used as modifier on account of the affected both the morphology and the surface area of the electrodes. The functional groups attached in the edge and basal plane can be used as starting point to covalent Functionalize which include esterification, acylation, nucleophilic and electrophilic Substitution and acylation [2,3]. Graphene oxide [Fig(1a)] is one layer of a

polycyclic hydrocarbon network and is partially aromatic, has various oxygen functional groups (CO, OH, and COOH) prepared from the oxidative treatment of bulk graphite (Hummer method) [4] [5].GO non-conductive and has high energy gap in the electron density of states [6]due to presence high density electronegative oxygen atoms. Carboxyl groups attached at the edge can be used to react with thiocarohydrizde (TCH) by cyclo condensation reaction to form GO-4-amino, 3-substituted 1H, 1, 2, 4 Triazole 5(4H) thion (ASTT), (GOT) as shown in Fig. (1b) [7].



Figure: 1: Reaction of GO with thiocarohydrizde (TCH)

Tetracycline(Fig.2) antibiotics are strongly effective antibacterial agents against grampositive and gram-negative bacteria composed from 4 fused with rings substituent containing three ionizable functional groups that undergo can protonation or deprotonation, depending on solution pH [8,9]. This work is concerned with study of voltammetric behavior of Tetracycline (TET) at screen printed carbon electrode modified with Graphene oxide functionalized at the edge of sheet with  $MnO_{2}nanorods$  and studies their impact to determination Tetracycline (TET).



Figure 2: Structure of Tetracycline

## **Material and Methods**

Tetracycline drug from samara drugs industry was used as received. .All chemicals purchased from sigma Aldrich and used without further purification. Electrochemical experiments were performed  $\mathbf{at}$ room temperature using a potentiost at model 200 u stat (drop Sens S.L. Oviedo, Spain). The SPCEs consists of three-electrodes an Ag/Ag Cl electrode as reference RE, a carbon electrode( with 4 mm diameter) as working WE and counter electrode CE. All electrodes printed on a ceramic plate. The pH measurements were made with a PH-meter BP3001 (Singapore).

A soniprep 150(United Kingdom) Ultrasonic instrument was used to get stable dispersions of FGO/MnO2 nano composite. Powder XRD analysis was carried out by using powder diffractometer (Japan) XRD Shimadzu 6000 with an incident Cu-Ka radiation of  $1.54A^{\circ}$ . FTIR spectra were obtained on Shimadzu IR affinity 8400s, Japan. Scan range (4000–400) cm<sup>-1</sup> with a resolution of 4 cm<sup>-1</sup>. Scanning Electron Microscopy SEM (Zeiss)(Germany).

## **Experimental Set-up**

The SPCE was pretreat to increase sensitivity of sensors as well as to obtain a

stable baseline [10] the potential was swept  
between 
$$-0.5$$
 and  $+1.0$  V in 0.1 M sulfuric  
acid at scan rate 0.1V then, the SPCE was  
washed with double distilled water and dried  
at room temperature 25°.

## Preparation of Graphene Oxide (GO)

Graphite oxide (GTO) was synthesized by hummers' method[5] The GTO mixture formed was filtered and washed with 5% aqueous solution HCL and distilled water until the pH of the rinsing water became (6-7). The product was dried at 55° for 48h. The Graphite oxide GTO aqueous solution mixture was exfoliated by sonication [11] to obtain aqueous colloidal of Graphene oxide GO sheet.

## **Preparation of**

## Thiocarbohydrazide (TCH)

Thiocarbohydrazide TCH prepared [12] by reaction of hydrazine  $N_2H_4$  with carbon disulfide  $CS_2$  at  $10^\circ$  with stirring until formation yellow precipitate to produce hydrazinium dithiocarbazinate HDTC as in equation below.

$$CS_2 + 2N_2H_2 \rightarrow H_2NHNCS_2H.N_2H_4 \tag{1}$$

The resultant mixture refluxed for half hour to remove hydrogen sulfide  $H_2S$  as in equation below.

$$H_2 NHNCS_2 H. N_2 H_4 \rightarrow H_2 N - NH - CS - NH - NH_2$$
<sup>(2)</sup>

The reaction mixture was filtrated to separate the crystalline precipitate of TCH then washed with ethanol and water. The TCH crystals were dried with vacuum oven for 6 hours at  $40^{\circ}$ .

#### Functionalization of GO with TCH (FGO)

Carboxylic groups in GO can be used as starting point to react with TCH at its melting temperature in cyclocondensation reaction. The product GOT was cooled, washed with distilled water to dissolve the non-reacted TCH and dried at  $60^{\circ}$ .

Preparation of Nanocomposite of GOT with MnO<sub>2</sub>

$$2Mn^{+2} + MnO_4^- + 2H_2O \rightarrow 3MnO_2 + 4H^+$$

#### **Fabrication of the Modified Electrode**

1 mg of purified FGO/MnO<sub>2</sub> was dispersed into 10 ml of redistilled water and 3µL Nafion and sonicated for 1 h. The modified electrode was made by coating the US by dropping of 4  $\mu$ L from the above mixture. The CV measurement was performed in guiescent solution at room temperature  $(25 \pm 1 \text{ °C})$  by dropping 50µL from freshly prepared solution of  $(1 \times 10^{-4} \text{M})$  TET solution on reservoir area to cover modified working electrode, counter and reference electrodes for at least one minute.

#### Results

## Identification and Characterization of Nanomaterial

#### FT-IR spectra of graphene oxide (GO)

Saturated solution of MnSO<sub>4</sub> was prepared, then 0.5g from GOT was added to the filtrated MnSO<sub>4</sub> and sonication for 1h to bond Mn (II) ions to the surface of GOT and RGOT by electrostatic force[13]. The mixture GOT/ Mn<sup>+2</sup> was filtered and 0.3 M KMnO<sub>4</sub> was added with 1-2 drops of HNO<sub>3</sub> the reaction mixture cap with Para film were put in an oven for 8 to 10 h to transform  $Mn^{+2}$  to  $MnO_2$ as shown in the following equation [14].

(3)

The chemical composition of GO has been characterized with FT-IR measurement. Fig. (3) Shows the FT-IR spectrum of GO. The stretching vibration of (C-OH, COOH, and residue of  $H_2O$ ) appeared at 3401 cm<sup>-1</sup> with broad and strong band. The peak at 1587cm<sup>-1</sup> was assigned to unoxidized graphitic domain. The two bands at 1221 cm<sup>-1</sup> and 1400 cm<sup>-1</sup> were corresponded to (C-O) stretching vibration of epoxide groups (C-O-C) and (C-O-H) bending vibration of COOH group or C-OH group respectively. Vibration at 1060 cm<sup>-</sup> <sup>1</sup> is assigned to alkoxy (C-OH) groups. Besides, the band at 1721 cm<sup>-1</sup> might referred to not only the carbonyl group stretching vibration of COOH situated at the edges but also to ketones or guinone [15].



#### FT-IR Spectra of Nanocomposite FGO/ **MnO<sub>2</sub>nanopatricles**

Fig. (4) show FT-IR spectrum for FGO / MnO<sub>2</sub> nanocomposite, the NH<sub>2</sub>bending and wagging vibrations contributed to the two peaks at 1618 and 1157 cm<sup>-1</sup> respectively [16]. Absorption bands at 1342.46, 1527.62,

1126 cm<sup>-1</sup> correspond to stretching vibration of (C=S), (C=N) and (N-N) respectively which denotes to stretching vibrations of Triazole ring . The peaks appear at  $532 \text{ cm}^{-1}$  and 493cm<sup>-1</sup> were assigned to the Mn-O bond [17].Beside, a peak at 721 cm<sup>-1</sup> referred to stretching mode of MnO<sub>6</sub> octahedral along the double chain [18, 19].



Figure 4: FT-IR spectrum of FGO/MnO2nanocomposit

#### XRD of Nanocomposite FGO/ MnO2nanopatricles, GO and MnO2

Figure (5) show XRD of FGO/MnO<sub>2</sub>and inset refer to XRD of GO and MnO<sub>2</sub>.It is found that GO exhibits a strong diffraction at 11.95° corresponding to d-spacing of 7.3 A [20, 21] which is higher than that of graphite (3.36 A) indicates introduce functional groups (carboxylic acid, carbonyl, hydroxyl and epoxy) on the basal and edges planes of GO sheets [22]. The XRD pattern of MnO<sub>2</sub> show presence of diffraction at  $2\theta = 12.69$ , 18.1, 28.75, 37.5, 42.02, 49.8, 56.4 and 60.09 were matched well with the diffraction peak of crystal planes of  $\alpha$  –MnO<sub>2</sub> standard data (JCPDS card No.44-0141) [23].it can be seen that XRD of FGO/MnO2 nanocomposite possess the diffraction of MnO<sub>2</sub> and TCH in addition the peaks at  $2\theta = 24$  and  $25^{\circ}$  with interlayer space 3.6 and 3.5 A° respectively lower than the GO may due to removal of carboxylic groups via cyclocondensation reaction and to reduced GO.



Figure 5: XRD of nanocomposite FGO/ MnO2nanopatricles, GO and MnO2

#### SEM

SEM image of unmodified WE surface [Fig. (6a)] shows individual carbon particles. A close look at the SEM image of

 $FGO/MnO_2[Fig.~(6b)] \mbox{ would clearly observed the existence of } MnO_2 \mbox{ nanoparticles dispersed on the surface of } FGO$ 



Figure 6: the SEM image of bare and modified SPCE with FGO/MnO<sub>2</sub>

of

Electrochemical Behavior (FGO)/MnO<sub>2</sub> Modified SPCE Electrochemical behavior of (FGO)/MnO<sub>2</sub> modified SPCE have been invistgated in

 $0.5 \text{mM K}_3[\text{Fe}(\text{CN})_6]$ +0.1 M KCl solution using CV technique at scan rate $0.1 \text{V.s}^{-1}$  [Fig.(7)]A

depicts the CVs for (a) bare SPCE, (b) (FGO)/  $MnO_2$  modified SPCE



Figure 7: CV gram of bare and FGO/MnO<sub>2</sub>-SPCE in presence potassium ferricyanide at 0.1V.s<sup>-1</sup>.

The oxidation-reduction current at the  $FGO/MnO_2$  modified SPCE is larger than the bare SPCE, inferring FGO/MnO2 film would increase the redox current. The microscopic areas of the bare SPCE and  $FGO/MnO_2$ 

Nafion-SPCE in ferricyanide system were estimated to be 0.04 and to 0.05 cm<sup>2</sup>respectivelyusing Randles-Sevcik equation (4) [24] at different scan rate.

$$I_p = 2.69 \times 10^5 \mathrm{A} n^{3/2} D_R^{1/2} c \, v^{1/2} \tag{4}$$

Where  $(I_p)$ , (C),(u) and (A) refers to peak current. concentration of potassium ferricyanide, scan rate V.s-1and the surface area of electrode  $cm^2$  respectively. For potassium ferricyanide the number of electrons (n)equal 1 and  $D_R = 7.6 \times 10^{-6} \text{ cm}^2$ s<sup>-1</sup>.The larger peak currents and higher surface area for the FGO/MnO2 modified SPCE indicate that FGO and MnO<sub>2</sub> nanorod could increase the electron transfer rate between the redoxprobe and modified SPCE. (TET) in PBS (pH 2) exhibits electron

transfer resistance on bare SPCE, but on FGO/MnO<sub>2</sub>modified SPCE the voltammogram exhibited a well-defined peaks at 0.698Vreferring to an oxidationMnO<sub>2</sub> [25].And at 0.2197Vreferring to MnO<sub>2</sub> reduction [26].The other two peaks $E_p^{c2}$  = -0.3841V and  $E_p^{a2}$  = 0.08V were assigned to redox of TET. The CV experiment has been conducted by scanning the potential from- 0.6V to 0.8V (vs. Ag/Agcl) at scan rate  $0.1V.s^{-1}$  as depicted in [Fig. (8)].



Figure 8: cyclic voltammograms of bare and modified SPCE with FGO/MnO<sub>2</sub>in PBS only and TET in PBS (pH2) at scan rate  $0.1V.s^{-1}$ 

Fig. (9) Displays the CVs of the FGO/MnO<sub>2</sub>-SPCE in PBS (pH2) containing 0.1mM TET at different scan rates (0.02–0.1 V.s<sup>-1</sup>).the electrochemical oxidation of TET were totally irreversible reaction. According to an electron transfer – irreversible chemical reaction  $(EC_{irr})$  mechanism the oxidized form of TET will be converted to product and no corresponding reduction peaks observed at the reverse scan.



Figure 8: CV of modified SPCE in presence 0.1mM TET in pH2 PBS with different scan rate (0.02-0.1 V.s<sup>-1</sup>).Based on eq.(7) and involvement of two electrons in the process[27][Fig. (9)], the average surface coverage ( $\Gamma$ ) of TET on the surface of modified SPCE can be estimated to be about  $10.56 \times 10^{14}$ [28] which is higher than bare -SPCE  $26.26 \times 10^{11}$ molecules.cm<sup>-2</sup>.



Figure 9: Linear relationship between I  $_{\rm pa} \textit{vs.scan}$  rate v V.s<sup>-1</sup>for FGO/MnO<sub>2</sub>-SPCE in presence 0.1mM TET according eq.7

The slope of straight line of A plot log ( $I_p \mu A$ ) vs log (v Vs<sup>-1</sup>) [Fig. (10)] was 1.002 with

correlation coefficient 0.9927 which is similar to the theoretical value of the adsorption controlled electrode process [29].



Figure 10: linear relationship between log current vs. log scan rate v

Additionally, plotting E (V) *vs.* Scan rate v  $(V.s^{-1})$ [Fig.(11)] show that the oxidation potential  $E_{pa}$  of TET gradually shifted to the

positive direction with increasing the scan rates which confirms the irreversibility of the process [30].

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Figure 11: Linear relationship between E (V) vs. Scan rate v (V.s-1)

For an adsorption-controlled and irreversible electrode process, Ep was defined according

to Laviron equation [31, 32].

$$E_p = E^{\circ} + \left(\frac{2.303RT}{\alpha nF}\right) \log\left(\frac{RT\kappa^{\circ}}{\alpha nF}\right) + \left(\frac{2.303RT}{\alpha nF}\right) \log \upsilon \quad (9)$$

The slope of the linear regression of Ep vs. logv [Fig (12)] was equal to  $2.303RT/\alpha nF$ . an can be calculated to be 1.3111 and by

assuming a equal 0.5 for a totally irreversible electron transfer ,number of electrons can be concluded to be approximately 2



Figure 12: Variation of peak potential with logarithm of scan rate

The value of  $\kappa^{\circ}$  was determined from the intercept of the [Fig. (11)].By extrapolating to the vertical axis at u=0 [33] E° can be obtained to be 0.0425 V. So the apparent electrochemical rate constant  $k^{\circ}$  was calculated to be 10.41 cm.s<sup>-1</sup>.

#### **Calibration Plot and Limit of Detection**

Under the optimized experimental conditions the performance of the  $FGO/MnO_2$  SPCE

$$I_P(\mu A) = 0.3421c(\mu M) + 10.679$$

The detection limit was estimated to be  $0.2 \ \mu M$ 

sensor for the determination of TET concentration [Fig. (13)] Differential pulse voltammetry (DPV) technique was used. The increasing of TET concentration (over the range of 1–9  $\mu$ M) increased the peak current linearly. The linear regression equations can be expressed as

(10)



Figure 13: DPV grams at a FGO/MnO  $_2\mbox{-}SPCE$  for TET concentrations ranging 1-9 $\mu M$ 



Figure 14: Calibration curve that depicts the lowest level at which TET detection is done

The LOD of TET in other work, Fluorescence optical fiber sensor and Molecularly Imprinted Technique was found 0.106 ( $\mu$ M) and 0.0558( $\mu$ M) respectively.

## Conclusion

we successfully prepared carbon nanomaterial GO and functionalized with -4amino,3-substituted 1H,1,2,4 Triazole 5(4H)thion(ASTT) (FGO) and made a composite with MnO<sub>2</sub> nanorod (FGO/MnO<sub>2</sub>). The peak current ratios, and surface area, demonstrate a faster potassium ferricyanide reaction at FGO/MnO<sub>2</sub> modified SPCE electrode than bare SPCE. The electrochemical behavior of

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TET was investigated on the novel FGO/MnO<sub>2</sub> nanocomposite in BPS of pH 2.0, and the electrochemical parameters were calculated by cyclic voltammetry technique. Under the optimized conditions, the anodic peak current was proportional to the TET concentration in the range from 1  $\mu$ M to 9  $\mu$ M with the detection limit estimated to 0.2  $\mu$ m.

## Acknowledgments

The authors would like to thank Central Laboratory service management in Collage of Education for Pure Science Ibn-Al-Haitham for supporting this research.

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