

Research Article

Electrochemical Studies of Dicyclomine Hydrochloride at Cetyl Trimethyl Ammonium Bromide Modified Carbon Paste Electrode

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Abstract

An electrochemical method has been described for the voltammetric oxidation and determination of dicyclomine hydrochloride (DCH) at a carbon paste electrode (CPE) in the presence of surfactant, Cetyl trimethyl ammonium bromide (CTAB) using cyclic voltammetric and differential pulse voltammetric technique (DPV). The analyte showed one well-resolved irreversible oxidation peak at around 930 mV in phosphate buffer solution at pH 6.4, which served as the analytical response. The dependence of current on pH, concentration and scan rate were investigated. CTAB modified carbon paste electrode showed excellent electrocatalytic effect towards the detection of dicyclomine hydrochloride.

The low detection limit (LOD) and low detection quantity (LOQ) of dicyclomine hydrochloride has been found to be $0.12\mu\text{M}$ and $0.43\mu\text{M}$ with a correlation coefficient of 0.99812.

Keywords: Cyclic voltammetry, dicyclomine hydrochloride, Cetyl trimethyl ammonium bromide and Carbon paste electrode

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Introduction

Dicyclomine hydrochloride, 2-(diethylamino) ethylbicyclohexyl-1-carboxylate hydrochloride, is an antispasmodic and anticholinergic drug as shown in **Figure 1**. Its action is achieved by a dual mechanism, a specific anti cholinergic effect at Acetylcholine receptor and a direct effect upon smooth muscle, but rarely causes any side effect [1-3]. It is used to treat a certain type of intestinal problem called irritable bowel syndrome. It helps to reduce the symptoms of stomach and intestinal cramping. This medication works by slowing the natural movements of the gut and by relaxing the muscles in the stomach and intestine [4-6].

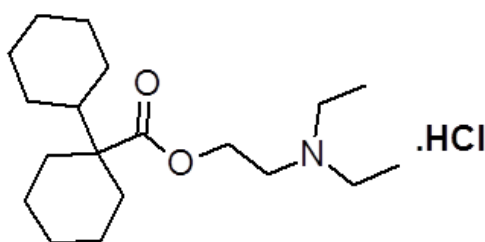


Figure 1 Structure of Dicyclomine hydrochloride.

Surfactants are a kind of amphiphilic molecule with a polar head on one side and a long hydrophobic tail on the other. The applications of surfactants in electrochemistry and electro analytical chemistry have been widely reported [7-10]. Some less soluble surfactants were employed in the immobilization of macro molecules or other functional materials. This electrode exhibited an electrocatalytic activity towards biomolecules and has been used as a sensor for the determination of these species [11-13]. The electrochemical responses of these compounds were greatly enhanced in the presence of trace surfactants. They proposed a synergistic adsorption mechanism to interpret these enhancement effects of surfactants i.e, surfactants might combine with the substrate in certain forms and strengthen their adsorption on the electrode surface, which facilitated the electron or substance transfer between the electrode and the solution and alter the properties of electrode/solution interface and finally influence the electrochemical process of electroactive species [14, 15].

In the present work a simple and sensitive voltammetric method is presented for the detection of dicyclomine hydrochloride based on the increase in the current signal of oxidation at bare carbon paste electrode in presence surfactant CTAB.

Experimental

Reagents

Dicyclomine hydrochloride and Cetyltrimethyl ammonium bromide were purchased from Merck and all other chemicals were of analytical grade. The stock solution of the Dicyclomine Hydrochloride (10 mM) was prepared by dissolving it in deionised water (Millipore water) and used without further purification. CTAB was prepared 10 mM stock solution by dissolving in deionised water. The phosphate buffer solution was prepared from KH_2PO_4 and K_2HPO_4 in deionised water and the pH was adjusted with 0.1 M NaOH solution. Other chemicals used were of analytical grade except for spectroscopically pure graphite powder. All Solutions were prepared with deionised water (Millipore water). Freshly prepared DICY solution is used prior to measurements.

Apparatus

Electrochemical measurements were carried out with a model-201 electrochemical analyzer (EA-201 chemlink systems) in a conventional three-electrode system. The working electrode was carbon paste electrode, having cavity of 3 mm diameter. The counter electrode was platinum electrode with a saturated calomel electrode (SCE) as a standard reference electrode completing the circuit.

Modification procedure

Preparation of bare carbon paste electrode

Bare carbon paste electrode was prepared by hand mixing of graphite powder 70% and silicon oil 30% in an agate mortar for about 30 min to get homogenous carbon paste. The paste was then packed into the cavity of a teflon tube electrode (3 mm diameter). Before measurement, the modified electrode was smoothed on a piece of transparent paper to get a uniform, smooth and fresh surface.

Preparation of modified carbon paste electrode

Carbon paste was then packed into the cavity of a homemade carbon paste electrode and smoothed out on a weighing paper. CTAB modified carbon paste electrode (CTAB/MCPE) was prepared by immobilizing 10 μL of CTAB on the surface of the carbon paste electrode for 10 mins

Results and Discussions

Electrochemical response of potassium ferrocyanide at CTAB modified carbon paste electrode

Figure 2 shows the cyclic voltammograms recorded for the 1 mM potassium ferrocyanide in 1M KCl at both BCPE (solid line) and CTAB/MCPE (dashed line) at the scan rate 50 mVs^{-1} . The low redox peak currents response was obtained at BCPE but in the same condition CTAB/MCPE exhibited stable enhancement of redox peak currents and also it shows the fast rate of electron transfer kinetics. The obtained result revealed that greatly improved voltammetric response of potassium ferrocyanide at CTAB/MCPE. This suggests that the surface property of the modified electrode has been significantly changed. Solid line curve shows the electrochemical response of BCPE having the cathodic peak current (I_{pc}) 21.4 μA and anodic peak current (I_{pa}) 29 μA . The electrochemical cathodic peak potential (E_{pc}) 154mV and anodic peak potential (E_{pa}) 257mV. After modification with CTAB/MCPE shows enhancement of both electrochemical anodic peak current (I_{pa}) 57.8 μA and cathodic peak current (I_{pc}) 44.3 μA anodic peak potential (E_{pa}) 252mV and cathodic peak potential (E_{pc}) 192 mV For CTAB/MCPE the electroactive surface area is 0.0378 cm^2 .

Electrochemical behavior of DCH at CTAB modified CPE

Figure 3 shows the cyclic voltammograms recorded for 0.1 mM DCH at pH 6.4 in phosphate buffer at bare CPE

(curve b) and at CTAB modified CPE (curve c) and at blank solution of CTAB modified CPE (curve a) with the scan rate 100mVs^{-1} . This studies showed that only one oxidation peak at 1028 mV and a anodic peak current of $44.9\ \mu\text{A}$ at bare CPE, whereas an oxidation peak at 930 mV and a anodic peak current of $156.3\ \mu\text{A}$ at the CTAB modified CPE, in the potential range $+400$ to $+1200\text{ mV}$. It is noticed that voltammogram obtained at BCPE was less sensitive and showed poor electrochemical response. However, at CTAB modified CPE showed a significant increment in oxidation peak current with an improvement in the electron transfer rate. No reduction peak was observed in the reverse scan, suggesting that the electrochemical reaction was a totally irreversible process and the oxidation peak at the bare CPE is broad due to slow electron transfer, while the response was considerably improved at the CTAB modified CPE and the peak potentials shifted to negative direction, the shape of the peak turns sharper and the peak current increased significantly

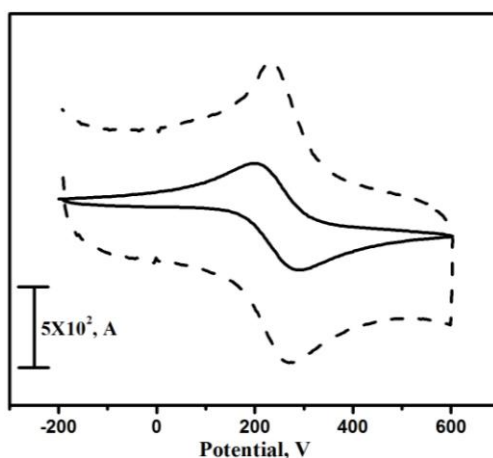


Figure 2 Comparison of $1\text{ mM K}_4[\text{Fe}(\text{CN})_6]$ in 1 M KCl solution at CTAB/MCPE (dashed line) and BCPE (solid line).

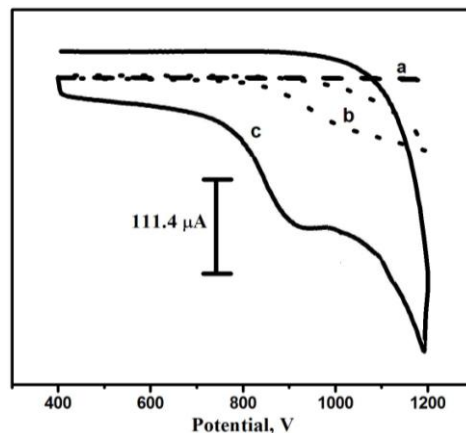


Figure 3 Comparison of DCH at CTAB modified CPE (curve c), Bare CPE (curve b) and Blank Solution in Phosphate buffer (curve a) at 100 mVs^{-1}

Effect of pH

The pH of the phosphate buffer solution has a significant contribution on the electrocatalytic oxidation of DCH at the CTAB/MCPE by affecting both peak currents and peak potentials. The effect of pH value on the determination of DCH at CTAB/MCPE was carefully evaluated in a wider pH range of $4.0 - 9.0$. **Figure 4a** shows cyclic voltammograms recorded for DCH at CTAB/MCPE and it was clear that I_{pa} attains maximum value at pH 6.4 . In order to obtain the maximum bioactivity and optimal sensitivity, phosphate buffer of pH 6.4 , 100 mVs^{-1} was selected for our experiments. The oxidation peak potential shifts to a more negative potential with increasing pH as shown in Figure 4b. The E_{pa} versus pH graph clearly indicated that the E_{pa} depends linearly on the pH value in the range of $4.0-9.0$.

The linear regression equation was given by:

$$E_{pa} \text{ (mV)} = 1059.47 - 58.56 \text{ pH} \text{ (} R = 0.99852\text{)},$$

This result shows, there are an equal number of protons and electrons are involved in the electrode reaction process.

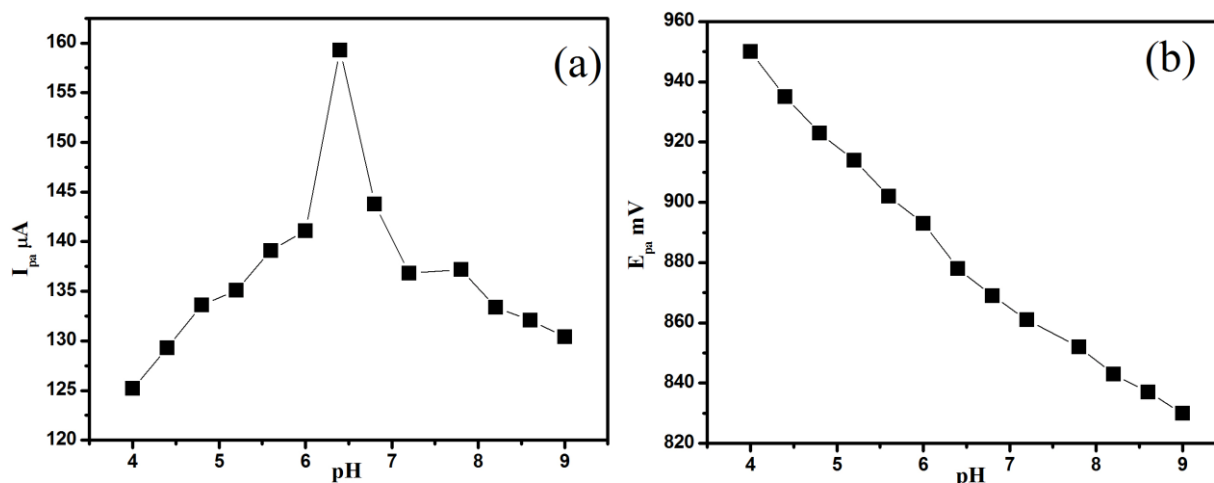


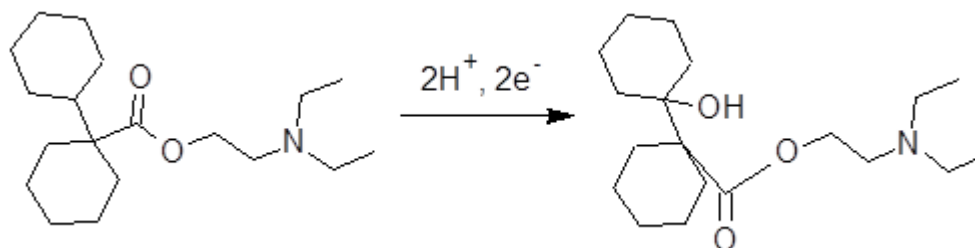
Figure 4 (a) Plot of anodic peak current versus pH (4.0 – 9.0) of DCH at CTAB/MCPE. (b) Plot of anodic peak potential versus pH (4.0 – 9.0) of DCH at CTAB/MCPE.

Effect of Scan Rate

The effect of variation of applied scan rate for DCH in 0.2 M PBS of pH 6.4 was examined by using CV technique at CTAB/MCPE as shown in **Figure 5a**. The experimental results obtained at CTAB/MCPE showed increase in the oxidation peak currents with increase in the applied scan rate. The graph of peak current (I_{pa}) versus scan rate (γ) was plotted and the obtained graph is a straight line with good linearity in the range from 25 to 200 mVs^{-1} as shown in Figure 5b with the correlation coefficient (R) 0.99821. The anodic peak current versus square root scan rate ($\gamma^{1/2}$) were plotted as shown in Figure 5c with the correlation coefficient (R) 0.99645. This indicates that the electrode process was controlled by adsorption rather than diffusion. The relationship between the anodic peak potential and scan rate can be explained by plotting the anodic peak potentials vs. Natural logarithm of scan rate in Figure 5d by considering the relation: $E_{pa} = 47.28 \ln v + 715.12$; $R = 0.9993$. The relationship between the anodic peak current and scan rate can be explained by plotting the Logarithm of anodic peak current vs. Logarithm of scan rate Figure 5e by considering the relation:

$$\log I_{pa} = 0.055 \log v + 1.04427; R = 0.99791.$$

According to Laviron's theory [16] the slope is equal to $RT/an_{\alpha}F$. For a totally irreversible electrode reaction the n_{α} was calculated as 1.743, which indicated that two electrons were involved in the oxidation process (**Scheme I**) [6] of DCH at the CTAB/MCPE.



Scheme I Oxidation of Dicyclomine hydrochloride.

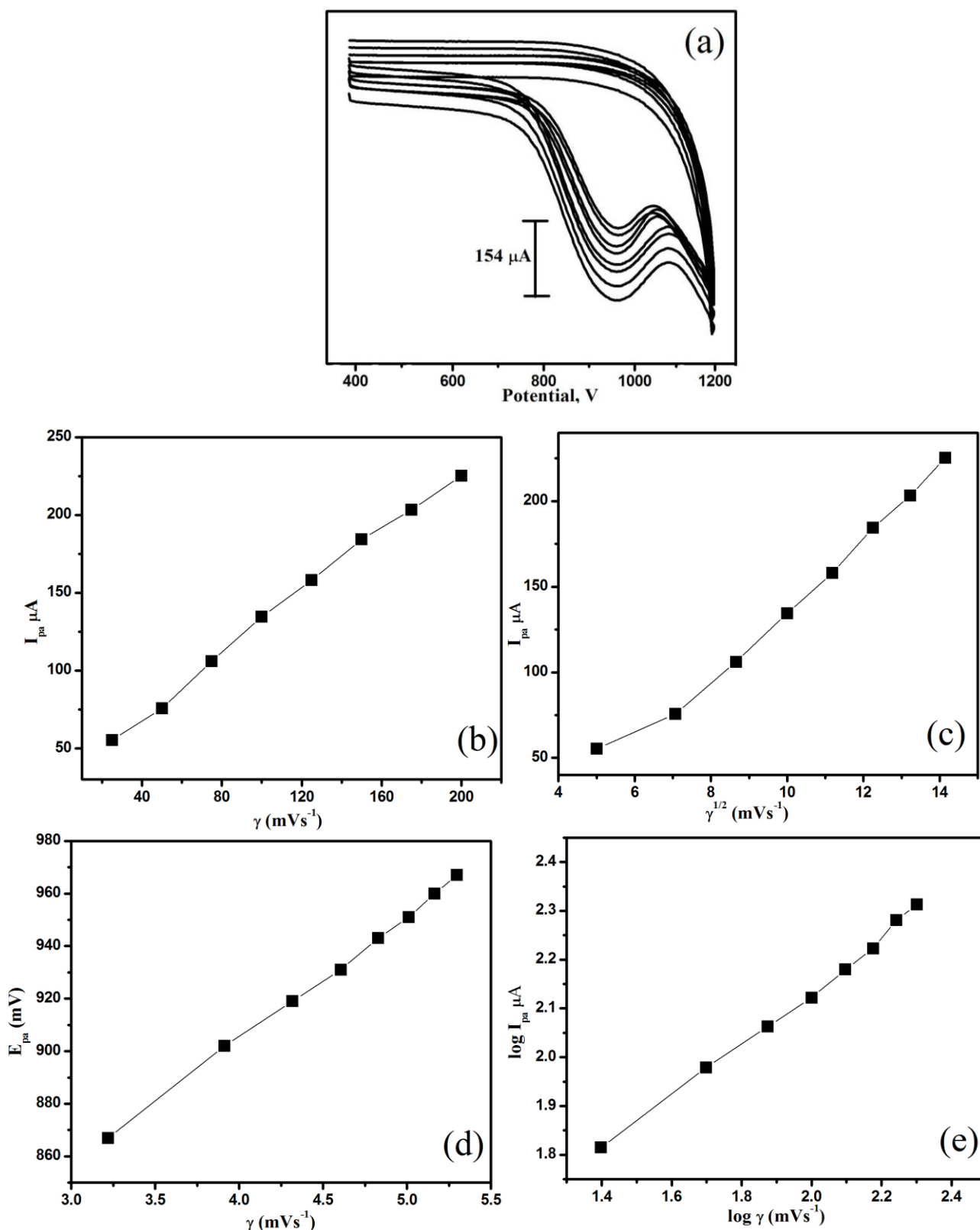


Figure 5a Cyclic Voltammograms of DCH at CTAB /MCPE with different scan rates were (A) 25, (B) 50, (C) 75, (D) 100, (E) 125, (F) 150, (G) 175 and (H) 200 mVs⁻¹. (b) Plot of Anodic peak current versus scan rates of DCH at CTAB/MCPE. (c) Plot of Anodic peak current (I_{pa}) versus Square root of Scan rates of DCH at CTAB/MCPE. (d) Plot of Anodic peak potential versus Natural logarithm of Scan rates of DCH at CTAB/MCPE. (e) The Plot of logarithm of Anodic peak current versus logarithm of scan rates of DCH at CTAB /MCPE.

Effect of DCH concentration

Cyclic voltammograms were recorded for the oxidation of dicyclomine hydrochloride in 0.2 M PBS of pH 6.4 at CTAB/ MCPE with the scan rate 100mVs^{-1} by varying the concentration from 0.2×10^{-6} to 0.8×10^{-6} as shown in **Figure 6**. This shows the increase in anodic peak current due to increase in the concentration of DCH. Figure 6b shows the linear relationship between the oxidation peak current (I_{pa}) with DCH concentration in the range.

The linear regression equation: $I_{pa} (\mu\text{A}) = 75.82857 + 350.213c$ ($R = 0.99812$). The limit of detection (LOD) and limit of quantification (LOQ) of TMP were found to be $0.1292\mu\text{M}$ and $0.4307\mu\text{M}$ respectively.

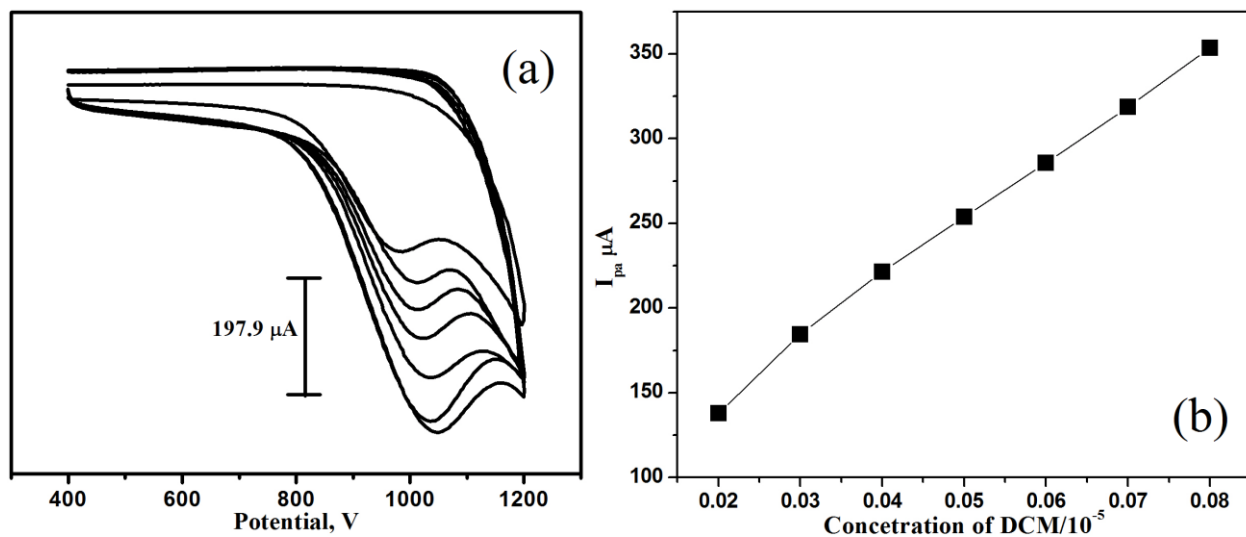


Figure 6 (a) Effect of variation of concentration of DCH on anodic peak current at CTAB/ MCPE; $v=100\text{ mVs}^{-1}$. (b) The plot of Anodic peak current versus DCH concentration at CTAB/MCPE.

Differential pulse Voltammetry (DPV) studies of DCH

Differential pulse voltammetry (DPV) was used to investigate the possibility of CTAB modified carbon paste electrode for determination of Dicyclomine hydrochloride. The current responses of this dicyclomine hydrochloride changed by changing the concentrations of DCH from $10\mu\text{M}$ to $50\mu\text{M}$ as illustrated in **Figure 7**, DPV responses of the modified electrode of DCH increased linearly with increase of their concentration.

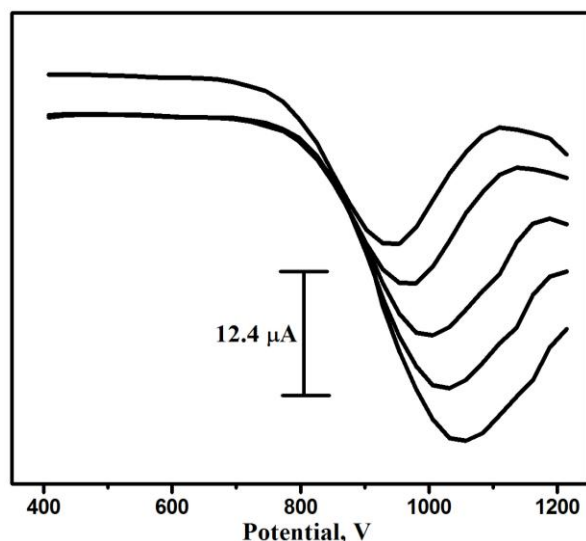


Figure 7 DPV of DCH at different concentrations (1×10^{-5} to 5×10^{-5} M).

Conclusion

In the present study, a simple, rapid and sensitive electrochemical procedure for the determination of dicyclomine hydrochloride at a surfactant modified carbon paste electrode based on the immobilization of surfactant has been prepared. The results showed that oxidation peak current of dicyclomine hydrochloride was improved at CTAB modified carbon paste electrode. The reaction is irreversible, controlled by adsorption.

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