

Research Article

Cyclic Voltammetric Investigation of Dopamine at Poly-(Gabapentin) Modified Carbon Paste Electrode

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The poly (gabapentin) film was prepared on the surface of carbon paste electrode by electrochemical method using cyclic voltammetric technique. The poly (gabapentin) film-modified carbon paste electrode was calibrated with standard potassium ferrocyanide solution in 1 M KCl as a supporting electrolyte. The prepared poly (gabapentin) film-coated electrode exhibits excellent electrocatalytic activity towards the detection of dopamine at physiological pH. The scan rate effect was found to be diffusion-controlled electrode process. The concentration effect of dopamine was studied, and the redox peak potentials of dopamine were dependant on pH.

1. Introduction

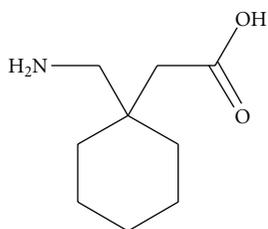
Dopamine (DA) is one of the most important neurotransmitters and plays a significant role in the functioning of central nervous system. A serious disease such as Schizophrenia and Parkinsonism may result from the loss of DA-containing neurons [1, 2], and patients with this disease show a low concentration of DA. Therefore, it is significant to develop sensitive and simple methods for the determination of DA. Many methods were introduced to determine DA, such as spectroscopy, chromatography, and electrochemistry [3–6]. Since DA is an oxidizable compound, it can be easily detectable by electrochemistry methods based on anodic oxidation. Carbon paste electrode was very much attracted towards the determination of biologically active molecules because of the easy preparation of modified electrode, renewability, low background current, and fast response. A number of modified carbon electrodes were developed for the determination of DA by using voltammetric techniques [7–10]. Modified carbon paste electrode can be prepared by adding different types of modifiers. Modification can be done by grinding in an agate mortar [11–13], by electropolymerisation [14–16], and also by immobilization method [17, 18]. The modified electrode has good electrocatalytic activity

such as sensitivity, selectivity, and also low detection limit when compared to traditional carbon paste electrode.

In the present work, the modification was carried out by preparing poly gabapentin for electrochemical investigation of DA by using cyclic voltammetry. Gabapentin, (1-(aminomethyl)cyclohexane-acetic acid; Gpn) (Scheme 1) is extensively used for the treatment of convulsive-type cerebral disorders, such as epilepsy, hypokinesia, and cranial trachoma [19]. It is sometimes prescribed for the management of neuralgia [20] and prescribed usually in combination with other medications for the prevention of seizure in people suffering from seizure disorders. Gabapentin was initially synthesized to mimic the chemical structure of the neurotransmitter gamma-aminobutyric acid (GABA) and used for the treatment of partial seizures in adults and children [21]. It has also been shown to be effective for neuropathic pain [22].

2. Experimental

2.1. Reagent and Chemicals. Gabapentin was obtained as a gift sample from AET Laboratories Pvt Ltd., Hyderabad. Graphite powder (50 micrometer particle size) was purchased from Merck, and silicon oil was purchased from



SCHEME 1: Structure of gabapentin.

Himedia. Potassium ferricyanide [$K_3Fe(CN)_6$] stock solution was prepared by dissolving in double-distilled water. DA stock solution was prepared by dissolving in 0.1 M perchloric acid ($HClO_4$) solution. 1 M potassium chloride (KCl) was used as a supporting electrolyte for the investigation of [$K_3Fe(CN)_6$], and the 0.2 M phosphate buffer solution was used as a supporting electrolyte for DA. Chemicals mentioned above were all purchased from Fluka were analytical grade.

2.2. *Apparatus.* The electrochemical experiments were carried out using a model-660 electrochemical workstation (CHI660C). All experiments were carried out in a conventional three-electrode system. The electrode system contained a working carbon paste electrode, home-made cavity of 3 mm diameter, a platinum wire as a counterelectrode, and a saturated calomel electrode as a reference electrode.

2.3. *Preparation of Bare Carbon Paste Electrode.* The bare carbon paste electrode was prepared by mixing 70% of graphite powder and 30% of silicon oil in an agate mortar by hand mixing for about 30 minutes to get homogenous carbon paste. The paste was packed into the cavity and smoothed on weighing paper.

2.4. *Preparation of Poly (Gabapentin) Film-Coated Carbon Paste Electrode.* The 0.5 mM aqueous gabapentin was placed in the electrochemical cell along with 0.2 M phosphate buffer solution at pH 10 to maintain basic condition to oxidize the monomer (gabapentin). The CPE was scanned 10 multiple cycles between the potential ranges from -0.4 to 1.8 V at 0.1 Vs^{-1} scan rate. After this process, the electrode was immersed in 0.2 M phosphate buffer solution of pH 7.0 until use.

3. Results and Discussion

3.1. *Electrochemical Characterization of Poly (Gabapentin) Film-Coated Carbon Paste Electrode.* The electrochemical characterization of poly (gabapentin) film-coated carbon paste electrode was done by using standard potassium ferricyanide in order to check its enhancement property. Figure 1 shows the cyclic voltammogram of 1 mM $K_3Fe(CN)_6$ at bare CPE and poly (gabapentin) film-coated carbon paste electrode in the potential range from -200 to 600 mV at 0.1 Vs^{-1} scan rate in 1 M KCl supporting electrolyte. The cyclic voltammogram of 1 mM $K_3Fe(CN)_6$ at both bare CPE

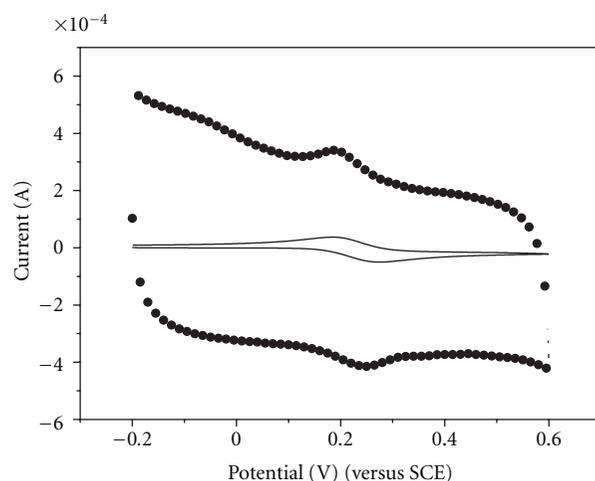


FIGURE 1: Cyclic voltammogram of 1 mM $K_3Fe(CN)_6$ at bare CPE (solid line) and poly (gabapentin) film-coated carbon paste electrode (dotted line) at 0.1 Vs^{-1} scan rate.

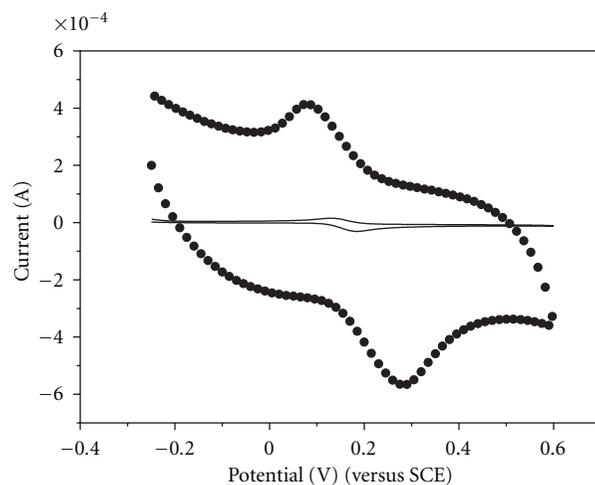


FIGURE 2: Cyclic voltammogram of 5×10^{-5} M DA in 0.2 M phosphate buffer solution at bare CPE (dashed line) and poly (gabapentin) film-coated carbon paste electrode (solid line) at 0.1 Vs^{-1} scan rate.

and poly (gabapentin) film-coated carbon paste electrode showed identical reversible cycles. The poly (gabapentin) film-coated carbon paste electrode showed very good electrochemical response when compared to bare CPE. The solid line shows the electrochemical response of bare CPE having the cathodic peak potential (E_{pc}) 0.2 V and anodic peak potential (E_{pa}) 0.28 V with less current sensitivity. After modification with poly (gabapentin) film, the electrode showed improvement in current signal enhancement of both electrochemical anodic and cathodic peak current; this was showed in dotted line. The E_{pc} and E_{pa} were found at 0.2 V and 0.25 V, respectively.

3.2. *Electrocatalytic Response of DA at Poly (Gabapentin) Film-Coated Carbon Paste Electrode.* Detection of DA was

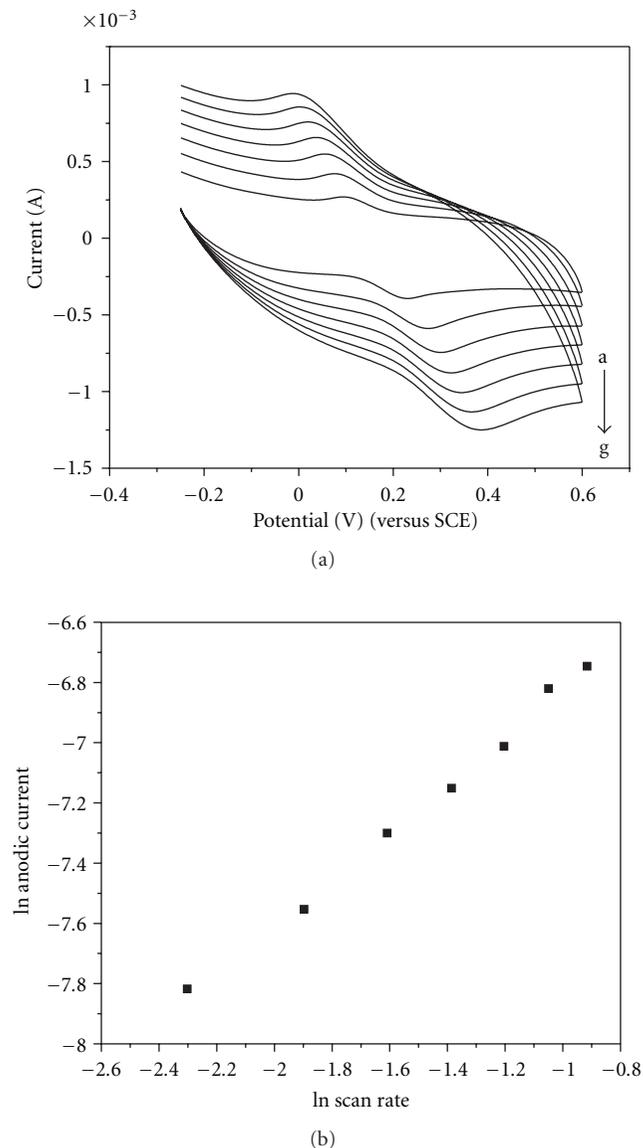


FIGURE 3: (a) Cyclic voltammogram of 5×10^{-5} M DA in 0.2 M phosphate buffer solution at different scan rate (a-g; 0.1 Vs^{-1} , 0.15 Vs^{-1} , 0.2 Vs^{-1} , 0.25 Vs^{-1} , 0.3 Vs^{-1} , 0.35 Vs^{-1} , and 0.4 Vs^{-1}). (b) Graph of current versus square root of scan rate.

very essential because it plays a very important role in the central nervous system and neurological disorders. DA being an easily oxidizable catecholamine, its voltammogram was recorded in the potential range from -0.25 to 0.6 V using 0.2 M phosphate buffer solution as a supporting electrolyte at 0.1 Vs^{-1} scan rate. Figure 2 showed a pair of redox peaks for 5×10^{-5} M DA at bare CPE (solid line) with E_{pa} at 0.2 V and E_{pc} 0.13 V (versus SCE) in 0.2 M phosphate buffer solution as a supporting electrolyte. The peak-to-peak separation (ΔE_{p}) was found to be 0.07 V . However, for the poly (gabapentin) film-coated carbon paste electrode, a pair of redox peaks was obtained with strong increase in both anodic and cathodic peak currents (dotted line). The E_{pa} was located at 0.28 V , and the corresponding cathodic peak potential was located

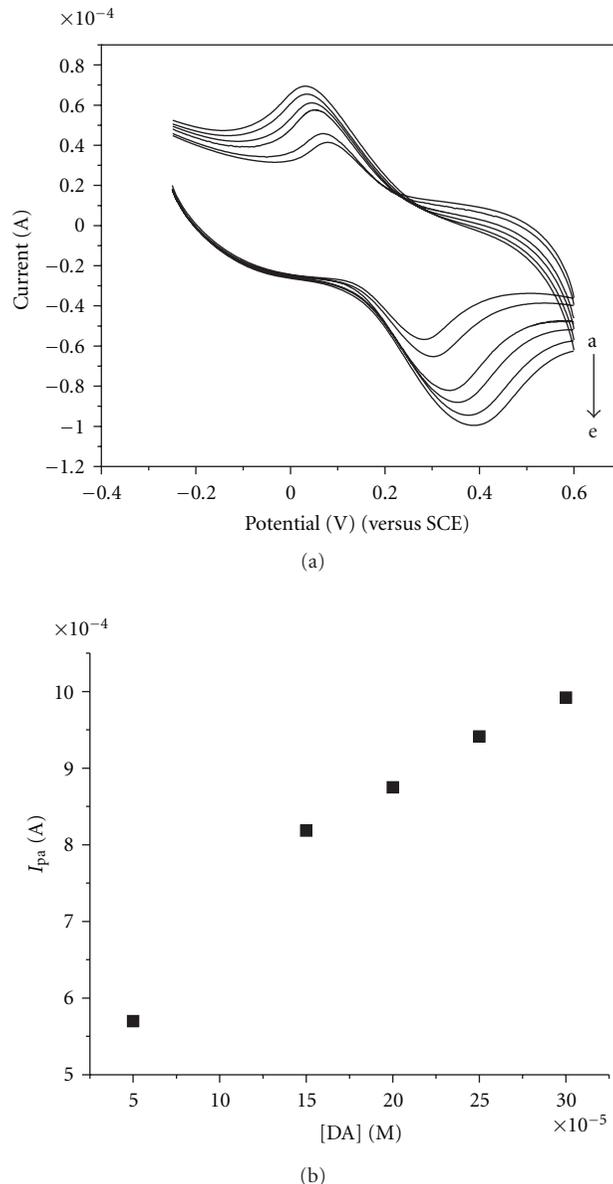


FIGURE 4: (a) Cyclic voltammogram for different concentrations of DA: (a) 5×10^{-5} M, (b) 15×10^{-5} M, (c) 20×10^{-5} M, (d) 25×10^{-5} M, and (e) 30×10^{-5} M at poly (gabapentin) film-coated carbon paste electrode with scan rate 0.1 Vs^{-1} . (b) Graph of current versus concentration of DA.

at 0.09 V (versus SCE). The peak-to-peak separation was calculated as 0.19 V . The cyclic voltammogram obtained for poly (gabapentin) film-coated carbon paste electrode was also quasireversible with good improvement in current signal of oxidation and reduction peaks.

3.3. Effect of Scan Rate. The scan rate effect was studied to understand the electrode process. Hence, the voltammogram of DA was recorded by varying the scan rate at poly (gabapentin) film-coated carbon paste electrode. The cyclic voltammogram showed an increase in both anodic and cathodic peak currents of DA with an increase of scan rate

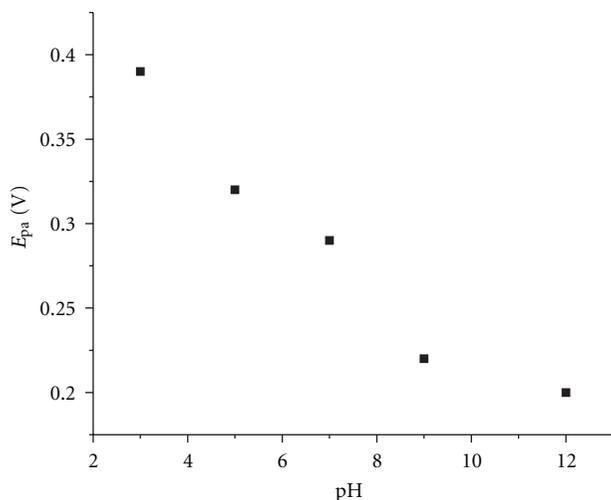


FIGURE 5: Graph of E_{pa} versus pH.

(Figure 3(a)) at the poly (gabapentin) film-coated carbon paste electrode in the range from 0.1 to 0.4 Vs^{-1} . The graph of current ($\ln I_{pa}$) versus $\ln \nu$ was plotted and the graph obtained was nearly straight line (Figure 3(b)). The slope was found to be 0.738 which lies in the middle of 0.5 and 1.0. Hence, the electrode transfer reaction was controlled by both adsorption and diffusion.

3.4. Effect of DA Concentration. The electrocatalytic oxidation of DA was carried out by varying the concentration at poly (gabapentin) film-coated carbon paste electrode (Figure 4(a)). With the increasing concentration of DA, both the I_{pa} and I_{pc} also increase, and the DA concentration was varied from 5×10^{-5} M to 30×10^{-5} M. The graph of I_{pa} versus concentration of DA shows an increase in electrochemical peak current (Figure 4(b)). The increase of concentration of DA is linearly proportion. The detection limit was calculated as reported in literature [23] and it was found to be 3.5×10^{-7} M.

3.5. Effect of pH. The electrochemical redox reaction of DA was generally dependent on pH. The effect of pH from 3 to 12 on the electrocatalytic oxidation of dopamine at poly (gabapentin) film-coated carbon paste electrode was studied. The current signals obtained for DA were dependant on pH. However, the better shape of the voltammogram of the redox peak obtained at pH 7 suggested it as an optimal pH value. We further studied the relationship between the anodic peak potential of dopamine and pH. Figure 5 shows the graph of E_{pa} versus pH. From the graph, it was found that the anodic peak potential negatively shifted with the increase in pH with slope 0.051 V indicating that equal number of protons and electrons take part in the reactions [23].

4. Conclusion

In this work, we chose gabapentin as a modifier to study the electrochemical response of an interesting neurotransmitter

DA. The fabricated poly (gabapentin) film-coated carbon paste electrode successfully enhanced both anodic and cathodic peak currents of DA when compared to bare carbon paste electrode. The increase in the concentration of DA results in an increase of electrochemical anodic and cathodic peak currents. The detection limit was found to be 3.5×10^{-7} M. We believe that this approach can readily be applied to the development of electrochemical sensors for other neurotransmitters.

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