7.1. Introduction

In this paper, a green and facile approach to the synthesis of carbon nanoparticles (CNPs) by soot based method using natural precursor castor oil. In addition, the synthesized CNPs were used for the electrocatalytic applications. The synthesized product is characterized by Powdered X-ray diffraction (PXRD), UV-visible absorption spectroscopy, Scanning electron microscopy (SEM), Energy dispersive X-ray spectrum (EDS) and Infrared spectroscopy (IR). The synthesized carbon nanoparticles were used for the biosensor application. This CNPs modified carbon paste electrode was applied towards the electrochemical investigation of Dopamine (DA) in the presence of Ascorbic acid (AA) and Uric acid (UA). The detection limit for DA in the lower range region was found to be 1.2 ×10⁻⁷M. The cyclic voltammetric response of DA at carbon nanoparticles modified carbon paste electrode was excellent when compared to bare carbon paste electrode. The effect of scan rate, concentration and pH effects on the voltammogram of dopamine were studied and also the effect of surfactants like Sodium Dodecyl Sulfate (SDS), Cetyltrimethylammonium Bromide (CTAB), and Triton X-100 (TX-100) were studied.

7.2. Chemistry and Biological Relevance of Dopamine, Ascorbic acid and Uric Acid

The chemistry and biological relevance of dopamine and ascorbic acid has been explained in details in chapter 3 sections 3.2, 3.3 and 3.4.

7.3. Review of Cyclic Voltammetry of Dopamine, Ascorbic acid, Uric acid and Carbon nanoparticles

In the emerging field of nanomaterials, carbon nanostructures have potential significance. The various categories of carbon nanostructures include fullerenes, carbon nanotubes (CNTs), graphitic nanofibres (GNFs), graphene, etc. Carbon nanotubes (CNTs) have outstanding electrical, thermal and mechanical properties which make them interesting material for applications in nanoelectronics, sensors. Two-dimensional graphene nanosheets (GNS) and graphene based materials have received significant attention in recent years due to their unique electronic, mechanical, and thermal properties. This unique nanostructure holds great promise for potential applications in
many technological fields such as nanoelectronics, sensors, capacitors and nanocomposites [1-9]. Furthermore, their large surface areas and ability to be functionalized allow them to undergo high-capacity binding to various biomolecules. Considering their wide spectrum of applications, the economical synthesis of CNPs remains an attractive challenge. Soot-based syntheses of CNPs have attracted increasing attention recently; for example, it has allowed the simple preparation of luminescent nanocarbons and the raw candle soot mixed with nafion exhibited good electrochemical activity. In addition, carbon materials obtained from oil seeds and fibrous plant materials can be used for the storage of hydrogen [10-12].

Dopamine (DA) is a well-known biogenic amine acting as a neurotransmitter in the brain. It has received considerable attention because of its suspected role in a variety of neuropsychiatric disorders such as Parkinson’s disease and Schizophrenia [13–16]. It has been found that the dopamine possesses very strong electrochemical activity by giving dopamine-o-quinone as oxidation product. Uric acid (UA) is the primary end product of purine metabolism; abnormal levels of UA are subject to resulting in several diseases, such as gout, hyperuricemia, and Lesch Nyan disease [17, 18]. Similarly, ascorbic acid (AA) is the agent which prevents scurvy and is known to take part in several biological reactions. However the determination remains a challenge because of the presence of large excess of ascorbic acid (AA) and uric acid (UA). It is generally believed that direct redox reactions of these species at bare electrode are irreversible and therefore requires high over potential [19]. Moreover the direct redox reactions of these species at bare electrodes take place at very similar potential and often suffer from a fouling effect, which results in rather poor selectivity and reproducibility. The ability to determine DA, UA and AA selectively has been a major goal of electroanalytical research [20]. Development of both sensitivity and selectivity are of equal importance in voltammetric procedure [21, 22].

Surfactants, a kind of amphiphilic molecules with a hydrophilic head on one side and a long hydrophobic tail on the other, have been widely applied in electrochemistry to improve the property of the electrode/solution interface. Zheng and Zhau [23] reported that SDS formed a mono-layer on CPE surface with high density of negative charged end directed outside the electrode. Wen et al. [24] have investigated the micellar effect on the
electrochemistry of dopamine and found that the anodic peak current of dopamine is enhanced in sodium dodecyl sulfate micelle, but the interference coming from AA cannot be eliminated [23]. At the physiological pH, Dopamine (DA) and ascorbic acid (AA) existing in different ion forms, AA is in the anionic form (pKa=4.10) while DA in the cationic form (pKa=8.87). Taking advantage of the opposite micelle effect of DA and AA, these two bioactive compounds can be simultaneously determined in the ionic micelles or by using surfactant-modified electrodes. On the other hand, surfactants have proven effective in the electroanalysis of biological compounds and drugs. For example, it was recently shown that surfactants are highly effective in stabilizing the voltammetric response of serotonin by protecting the electrode surface from fouling [25-29]. In addition, the presence of ascorbic acid in SDS micelles greatly enhances the electrochemical response of dopamine via a catalytic electrochemical process that can be used for a sensitive determination of dopamine [30]. When using carbon paste electrodes (CPEs), the incorporation of the surfactant to the carbon paste material has proved to be very useful for voltammetric determination, improving the sensitivity and selectivity of the measurements [31, 32].

The aim of the work was to fabricate novel electrode modification material with low cytotoxicity, high stability, good catalytic activity and an excellent conductivity to achieve the challenge of simultaneous determination of DA in presence of excess amount of AA and UA in physiological pH. In this work modified the carbon paste electrode by CNPs/SDS to obtain good selectivity and sensitivity towards electrochemical detection of DA.

7.4. Experimental
7.4.1. Reagents

Castor oil was purchased from a local market. Dopamine (DA), ascorbic acid (AA), uric acid (UA) and sodium dodecyl sulfate were obtained from Himedia chemicals. Graphite powder, Sodium hydroxides, perchloric acid, sodium dihydrogen orthophosphate dehydrate and di-sodium hydrogen phosphate anhydrous were obtained from Merck and all were analytical grade quality. $25\times10^{-4}$M DA, $25\times10^{-3}$M AA and $25\times10^{-4}$ M UA stock solution were prepared by dissolving in 0.1M perchloric acid
solution, double distilled water, 0.1M NaOH respectively, and all the other reagents solutions were prepared by double distilled water.

7.4.2. Apparatus

Electrochemical measurements were carried out with a CHI model 660c. Electrochemical Workstation connected to a personal computer for control and data storage. All electrochemical experiments were performed in a standard three-electrode cell. The bare or CNPs/SDS/CPE was used as a working electrode, platinum electrode as counter electrode and saturated calomel electrode (SCE) as reference electrode. All potentials reported were versus the SCE.

Powder X-ray diffraction (PXRD) measurements were performed on a PAN analytical Xpert Pro X-ray Diffractometer using CuKα radiation (λ = 0.154 nm) at 40 kV, at a scanning rate of 2° min⁻¹. UV-visible spectra were performed using a UV-visible Spectro Photometer–Shimdazo (1650) using sonicated carbon nanoparticle in double distilled water. Samples were loaded in a quartz cell and the measurement was taken in the wavelength range 200–800 nm. The structural analysis and composition of the carbon nanoparticles was studied using a JEOL JSM-848 scanning electron microscope (SEM), operational with energy-dispersive spectroscopy (EDS). The infrared (IR) spectra of samples were collected using a Nicolet IR200 FT-IR spectrometer using KBr pellets, in the range 4000 to 400 cm⁻¹ with 4 cm⁻¹ resolution.

7.4.3. Preparation of CNPs

The CNPs was prepared according to the method reported in the literature [10] with slight modification. Castor oil is placed in a 50 ml glass beaker containing a cotton wick given with 1 cm residue in length above the oil surface. Castor oil soot was collected by sitting a stainless steel plate on top of the smoldering castor oil. The formation of soot particles was assembled (from the glass plate). The as obtained black soot particles are called as carbon nanoparticles (CNPs).
7.4.4. Preparation of bare carbon paste electrode

The bare carbon electrode was prepared by hand mixing of graphite powder and silicon oil at a ratio of 70:30 (w/w) in an agate mortar until a homogenous paste was obtained. The prepared carbon paste was tightly packed into a PVC tube (3 mm internal diameter) and the electrical contact was provided by a copper wire connected to the paste in the end of the tube.

7.4.5. Preparation of CNPs /SDS film modified carbon paste electrode

The CNPs/SDS/CPE was prepared by hand mixing of 70% graphite powder and 6mg CNPs with 30% silicon oil in an agate mortar to produce a homogenous carbon paste. The paste was packed into the homemade cavity (3mm in diameter) and then smoothed on a weighing paper and immobilize the 0.1mm SDS solutions on surface of the CNPs/CPE modified carbon paste electrode. The electrical contact was provided by a copper wire connected to the paste in the end of the tube.

7.5. Results and Discussion

7.5.1. Characterization of Prepared CNPs

The PXRD pattern of the obtained CNPs as shown in Fig. 1, which shows a high intensity diffraction peak at 2θ is 24.9° and the addition peak is 44.3° that are recognized as diffraction of graphitic carbon respectively [33]. The average particle size was calculated using Debye Scherer’s formula and was obtained 14 nm. The UV-visible absorption spectra of the CNP dispersed in double distilled water with double distilled water as a reference is shown in figure 2, which feature a peak in the 250-275 nm region, these peaks represents the typical absorption of an aromatic pi system, which is similar to that of polycyclic aromatic hydrocarbons [34,35] . A shown in the Fig. 3, the FT-IR spectra for the CNPs showing the peaks at 3440 and 1385 cm⁻¹ are recognized as O – H stretching vibration and a few small peaks in 2922 cm⁻¹, and 1611 cm⁻¹ recognized as C – H stretching mode and C=C bonds respectively[1,36]. The SEM observation reveal that spherical shaped structure were grown with a diameter of ~100 nm and some irregular shaped particles smaller than the ~300nm as shown in the Fig. 4. The EDS of CNP shows
the presence of carbon with a negligible of oxygen content. The carbon and oxygen peak observed at 0.265 eV and 0.514 eV as in the Fig.5.

7.5.2. Electrochemical response of dopamine at CNPs/SDS/CPE

Fig. 6 shows the cyclic voltammograms obtained for the electrochemical response of 0.1mM DA at the bare CPE (curve a), CNPs/CPE (curve b) and CNPs/SDS/CPE (curve c) in 0.1 M phosphate buffer solution at pH 7.0 at sweep rate of 100mVs\(^{-1}\). At bare CPE, the oxidation and reduction peak potentials occur at 157 mV and 113 mV (\(\Delta E_p=44\) mV) and at CNPs/CPE 162 mV and 120 mV (\(\Delta E_p=42\) mV) respectively. Under identical conditions, the CNPs/SDS/CPE produces increased peak current and a more reversible electron process of DA with the oxidation and reduction peak potentials at 183 mV and 147 mV respectively and the peak separation is about (\(\Delta E_p\)) 36 mV. The modified electrode shows strong promoting effect and high sensitivity towards DA and also observed that the peak currents enhanced greatly at the CNPs/SDS/CPE surface provides clear evidence to the electrocatalytic electrochemical response of DA.

7.5.3. Effect of concentration of surfactants on DA

Surfactants are having a polar head on one side and a long hydrophobic tail on the other. Fig. 6 shows that SDS exhibits a remarkable enhancement effect on the anodic peak current (Ipa) of DA. However Ipa of DA closely related to concentration of SDS. In this work, the three types of surfactants viz [sodium dodecyl sulphate (SDS) (anionic), cetyl trimethyl ammonium bromide (CTAB) (cationic) and Triton X-100(TX-100) (non ionic)] were used as immobilized method to check the electrocatalytic effect of DA. Among these the SDS was showed excellent electrocatalytic activity towards the investigation of DA. The trace amount of SDS i.e. 5mL (0.1 mM) was immobilized on the CNPs/CPE at fixed immobilization time 120 seconds, the modified electrode was enhanced both anodic and cathodic peak current signals. The concentration of all three Surfactants was varied from 1 to 8\(\mu\)L for immobilization. The graph of Ipa vs concentration of surfactants was shown in Fig. 7. In this work the concentration of SDS was chosen to be 5\(\mu\)L and 120 seconds respectively, for a higher peak current and a low background current.
7.5.4. Effect of scan rate on the peak current of DA

According to Randales-Sevick’s equation, the scan rate is directly proportional to peak current. Fig. 8a shows the cyclic voltammograms of 0.1mM DA at CNPs/SDS/CPE in 0.2M Phosphate buffer solution of pH 7.0 at different scan rates. This was carried out in order to investigate the kinetics of the electrode reactions and verify whether diffusion is the only controlling factor for mass transport or not. The observation shows that with the increased scan rate (v), the redox peak current also increased gradually. The graph of anodic peak current (Ipa) vs scan rate (v) was plotted (Fig. 8b). The graph obtained was good linearity between the scan rate (v) and Ipa. In the range from 100 to 450 mV s\(^{-1}\) the redox peak currents were proportional to the scan rate (v) and the obtained correlation coefficient was 0.9986, which indicates that the electron transfer reaction was adsorption controlled [43].

7.5.5. Effect of pH

The electrochemical response of DA at CNPs/SDS/CPE was generally dependent on pH. The voltammograms of 0.1 mM DA were recorded at 0.1 M phosphate buffer solution of different pH by cyclic voltammetric method. Fig. 9a demonstrates the pH dependence of DA at CNPs/SDS/CPE at sweep rate of 100mVs\(^{-1}\). Both anodic and cathodic peak potentials were shifted to less positive side with increasing in the pH values. The anodic peak potential of DA shifted from 249mV to 134 mV with increase in the pH 6 to 8. The potential diagram was constructed by plotting the graph of Epa vs pH of the solution (Fig. 9b). The graph shows good linearity with a slope of 61 mV/pH this behavior is nearly obeyed the Nernst Equation for equal number of electron and proton transfer reaction [22, 37, 38]. From the graph of Ipa vs pH, maximum current was obtained at pH 7.0 (Fig. 9c). The electrochemical investigation of DA at pH 7.0 and simultaneous determination in presence of AA and UA was carried out.

7.5.6. Effect of concentration of DA

To study the effect of concentration of DA, differential pulse voltammetric (DPV) technique was used [22, 39, 40], because of its more sensitivity than cyclic voltammetric
The electrocatalytic oxidation of dopamine was carried out at CNPs/SDS/CPE by varying its concentration from $1 \times 10^{-7}$ to $1000 \times 10^{-7}$ M shown in Fig. 10a. Fig.10b shows that the graph of peak current vs concentration of DA shows two linear relationships ranges $1 \times 10^{-7} - 10 \times 10^{-7}$ and $10 \times 10^{-7} - 1000 \times 10^{-7}$ M with the linear regression equations as $I_{pa} (A) = 8.204 \times 10^{-6} + 2.933 C \ M/L$ and $I_{pa} (A) = 8.714 \times 10^{-6} + 0.717 C \ M/L$, respectively. The correlation coefficient for the first linearity was $R^2 = 0.9929$ and for the second it was found to be $R^2 = 0.9918$. The decrease of sensitivity (slope) in the second linear range is likely to be due to kinetic limitation [41]. The detection limit for DA in the lower range region was found to be $1.2 \times 10^{-7}$ M and quantification limit was $4.06 \times 10^{-7}$ M. The detection limit and quantification limit was calculated by using the formulas (1) and (2) [22, 42] where $S$ is the standard deviation and $M$ is the slope obtained from the calibration plots. The detection limit of various electroanalytical methods proposed for determination of DA is compared with our analytical data in Table.1. From the data shown, a lower limit of detection (LOD) can be achieved using the proposed method.

$$LOD = 3S/M$$ (1)

$$LOQ = 10S/M$$ (2)

7.5.7. Simultaneous determination of DA, AA and UA

DA, AA and UA usually coexist in physiological samples, generally the concentrations of AA, UA were much higher than that of DA. Since, the oxidation potential of both AA and UA were nearly same as that of DA result in an overlapped voltammetric response at bare CPE [43]. Fig. 11a showed the cyclic voltammetric response of DA (0.02 mM) in presence of UA (0.06 mM) and AA (1 mM) in 0.1M phosphate buffer solution of pH 7.0 at bare CPE (a), CNPs/CPE (b) and modified electrode CNPs/SDS/CPE(c) at sweep rate of 100 mVs$^{-1}$. The voltammogram obtained for mixture of sample at bare CPE was broad, less sensible and overlapped waves at the potential of 233 mV for DA and AA and at 315 mV for UA. However, the modified CNPs/SDS/CPE shows separations. The resulted voltammogram had oxidation peak potentials of DA, AA and UA were at 196 mV, -6 mV and 313 mV respectively. The peak to peak separation of DA-AA was 204 mV and that of DA-UA was 117 mV. This
results were large sufficient to identify DA in presence of AA and UA at CNPs/SDS/CPE.

DPV was used for the determination of DA, AA and UA because it has more sensitivity and selectivity. The simultaneous study was carried out in the potential range from -200 to 500 mV (Fig. 11b) and DPV showed the simultaneous determination of DA, AA and UA with well separated three anodic peaks corresponding to their oxidation at CNPs/SDS/CPE. The 0.02 mM DA showed its Epa at 133 mV, 2 mM AA was at -76 mV and 0.06 mM UA was at 245 mV. The peak separation between DA- AA was 209 mV and for DA-UA the peak separation was 112 mV which were greater differences when comparing to peak separation occurred by CV technique.

7.5.8. Interference study

The simultaneous determination of DA, AA and UA in the mixture was carried out at CNPs/SDS/CPE when concentration of one species changed, whereas the others kept constant. From the Fig. 12a it can be seen that the peak current of DA was proportional to its concentration, which was increased from 0.0 mM to 0.16 mM when keeping the concentration of 0.1 mM UA and 1 mM AA. There were no change in the peak current and peak potential occurred for AA and UA. Similarly in the Fig. 12b and Fig. 12c self explains the concentration effect of AA from 1.5 mM to 2.5 M mM and UA from 0.18 mM to 0.3 mM respectively. These results shows that the DA, AA and UA were exist independently in their mixtures of samples.

7.5.9. Reproducibility and stability

To investigate the precision of the determination, the ability to generate a reproducible electrode surface was examined using cyclic voltammetric data from eight separately prepared CNPs/SDS/CPEs, obtained in optimum solution pH. The calculated RSD for 0.1 mM DA at sweep rate of 100 mVs⁻¹ was 2.16% indicated that surface reproducibility was satisfactory. In addition, the long-term stability of the eight CNPs/SDS/CPEs was tested over a three-week period. When CVs were recorded after the modified electrode was stored at room temperature, the peak potential for DA oxidation was unchanged and the modified electrode showed negligible decreases in anodic peak.
current as time lapses for one week time intervals. The RSD of the determination of 0.1mM DA in optimum solution pH at sweep rate 100mVs\(^{-1}\) was 3.92% shows that the electrode is highly stable over a long-period.

### 7.5.10. Analytical application

The modified electrode was applied to the determination of dopamine hydrochloride injection. The DA injection sample purchased from sterile specialties India Private Ltd with a specified content of DA of 40.0 mg/mL. The sample was used after suitable dilution. 0.1M phosphate buffer was used for diluting the injection samples. The results were shown in Table 2. The recovery and RSD were acceptable, showing that the proposed methods could be efficiently used for the determination of DA in injections with recovery in the range 98.2–100.2% (Fig. 10b).

### 7.6. Conclusion

In this work, a green and facile approach to the synthesis of carbon nanoparticles (CNPs) by soot based method using natural precursor castor oil. From the XRD data the synthesized CNPs having average particle size 14nm. CNPs/SDS/CPE has shown good selectivity towards DA in presence of excess of AA and UA. The detection limit of DA was found to 1.2×10\(^{-7}\) M and also resolved the overlapping anodic peaks of DA, AA and UA. The proposed methods can be applied to the detection of DA in injections. The CNPs modified electrode acts as a good sensor for DA and it can be further applied for the investigation of other neurotransmitter.
### Table 1  Comparison of this work and literature reported ones

<table>
<thead>
<tr>
<th>Electrode</th>
<th>Detection Limit (µM)</th>
<th>Method</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Au-CA SAMs</td>
<td>2.34</td>
<td>DPV</td>
<td>[44]</td>
</tr>
<tr>
<td>α-CD/CNT/PGE</td>
<td>1.0</td>
<td>DPV</td>
<td>[45]</td>
</tr>
<tr>
<td>Metallothioneins self-assembled gold electrode</td>
<td>6.0</td>
<td>CV</td>
<td>[46]</td>
</tr>
<tr>
<td>Hydrogenated cylindrical carbon electrodes</td>
<td>7.5</td>
<td>CV</td>
<td>[47]</td>
</tr>
<tr>
<td>CNPs/SDS/CPE</td>
<td>0.12</td>
<td>DPV</td>
<td>This Work</td>
</tr>
</tbody>
</table>
Table 2. Determination results of DA in injection (n=6)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Added (µM)</th>
<th>Found (µM)</th>
<th>RSD(%)</th>
<th>Recovery (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>4.94± 0.075</td>
<td>2.10</td>
<td>98.8</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>4.91± 0.033</td>
<td>1.15</td>
<td>98.2</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>4.99± 0.092</td>
<td>0.96</td>
<td>99.6</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>5.01± 0.053</td>
<td>1.06</td>
<td>100.2</td>
</tr>
</tbody>
</table>

Fig. 1. Powder X-ray diffraction pattern of the prepared CNPs.
Fig. 2. UV-visible absorption spectra of the prepared CNPs.

Fig. 3. FT-IR Spectra of the CNPs.
**Fig. 4:** SEM image of the CNPs.

**Fig. 5:** Energy-dispersive spectroscopy (EDS) spectrum of CNPs.
Fig. 6. The cyclic voltammograms of 0.1mM DA at the bare CPE (curve a), CNPs/CPE (curve b) and CNPs/SDS/CPE (curve c) in 0.1 M phosphate buffer solution at pH 7.0 at scan rate 100mVs⁻¹.

Fig. 7. Graph of Ipa vs concentration of surfactants.
Fig. 8a. The cyclic voltammograms of 0.1 mM DA at CNPs/SDS/CPE in 0.2 M Phosphate buffer solution of pH 7.0 at different scan rates (a–h; at scan rate 100 mVs$^{-1}$ to at scan rate 450 mVs$^{-1}$).

Fig. 8b: The graph of anodic peak current (Ipa) vs scan rate (v).
Fig. 9a: The cyclic voltammogram of 0.1 mM DA for different pH (from 6 to 8 pH) in CNPs/SDS/CPE at a sweep rate of 100 mVs$^{-1}$.

Fig. 9b: The graph of anodic peak potential (Epa) vs pH.
Fig. 9c. The graph of anodic peak current (Ipa) vs pH.

Fig. 10a. The differential pulse voltammogram of different concentration of dopamine (1×10⁻⁷ to 1000x10⁻⁷ M) at CNPs/SDS/CPE in 0.1M phosphate buffer (pH 7) at a scan rate of 100 mVs⁻¹.
**Fig. 10b.** Graph of $I_{pa}$ vs concentration of DA.

**Fig. 11a:** The cyclic voltammetric response of DA (0.02 mM) in presence of UA (0.06 mM) and AA (1 mM) in 0.1M phosphate buffer solution of pH 7.0 at bare CPE (a), CNPs/CPE (b) and modified CNPs/SDS/CPE (c) at sweep rate of 100 mV s$^{-1}$. 

$I_{pa}(A) = 8.714 \times 10^{-6} + 0.717$ C M/L

$(N=14, R^2=0.9918)$

$(N=7, R^2=0.9929)$

$I_{pa}(A) = 8.204 \times 10^{-6} + 2.933$ C M/L,
**Fig. 11b:** Differential pulse voltammogram for simultaneous detection of 0.02 mM DA, 1 mM AA and 0.06 mM UA in 0.1M phosphate buffer solution of pH 7.0 at CNPs/SDS/CPE with the scan rate of 50mVs$^{-1}$.

**Fig. 12a:** Differential pulse voltammograms of 0.0 mM to 0.16 mM DA in 0.1 M phosphate buffer solution (pH 7.0) in the presence of 1mM AA and 0.1mM UA at the CNPs/SDS/CPE at scan rate 50mV$^{-1}$.s$^{-1}$.
**Fig. 12b:** Differential pulse voltammograms of 1.5 mM to 2.5 M mM AA in 0.2 M phosphate buffer solution (pH 7.0) in the presence of 0.1mM DA and 0.1mM UA at the CNPs/SDS/CPE at scan rate 50mVs$^{-1}$.

**Fig. 12c:** Differential pulse voltammograms of UA from 0.18 mM to 0.3 mM in a 0.1M phosphate buffer solution (pH 7.0) in the presence of 0.1mM DA and 1mM AA at the CNPs/SDS/CPE at scan rate 50mVs$^{-1}$. 
7.7. References.


