

# Electrochemical behaviour of graphite paste electrode in aqueous and nonaqueous solvents

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**Abstract** - The electrochemical behaviour of graphite paste electrode has been studied by the use of several electrochemical methods like cyclic voltammetry, and chronoamperometry in aqueous and nonaqueous solvents like DMSO. In cyclic voltammetry study of anodic/cathodic peak potentials and peak currents of graphite paste were studied. Effect of various parameters such as concentration of compound, scan rate, potential reversal, number of cycles were investigated. The chronoamperometry study of graphite paste in water and nonaqueous solvent DMSO was carried out at different potential values. The current-time curve was recorded in the anodic region with an initial potential of 0.0 V. The current response as a function of time was measured. The chronoamperometry curves was measured using the graphite paste electrode as the working electrode.

Keywords - Graphite paste; DMSO; Chronoamperometry; Cyclic voltammetry.

## 1. INTRODUCTIONS

Electrochemical analysis has a long tradition in application for mineral and ore analysis. It allows the qualitative and quantitative analysis of electroactive solid materials. At present electrochemical methods are used mainly for the dissolution of individual phases and for the analysis of materials already dissolved. The use of graphite paste electrode makes it possible to a certain extent to combine these two possibilities. This technique widens the information of insoluble compounds and even poor conductors.

A large number of electrochemical technique have been used to study the electrochemical nature of mineral. Electrochemical technique can be carried out either by potentiodynamic, potentiostatic or galvanostatic mode. In potentiodynamic tests, the potential of an electrode is varied in continuous manner in a preset scan rate, whereas in potentiostatic tests, the potential of the electrode remains constant. In the case of galvanostatic tests, an electrode is maintained at a constant current in an electrolyte. The main difference between the constant current methods (galvanostatic methods) from that of constant potential method (potentiostatic methods) is that in the former, current is systematically varied and potential is noted at every point, while in the latter, the potential is varied in steps and the corresponding current values are noted. From these current-voltage data, plots are constructed.

Using cyclic voltammetric technique (CV), the potential at which current can be passed anodically and cathodically can be studied. A number of time based technique are also studied. The variation of potential with time at constant current by employing the chronopotentiometric (CP) technique and the variation of current with time at constant potential by employing chronoamperometric technique (CA).

The most common graphite paste electrode that is used in electrochemical analysis is graphite electrode<sup>1-8</sup>. The use of graphite electrode partly overcomes the disadvantages of solid electrodes. Adams is credited with the development of graphite electrode<sup>9</sup>.

The graphite paste electrodes are made by physically mixing graphite powder and a suitable liquid to produce a smooth paste. This paste is placed in a small well or other holder that is the electrode container. Precautions must be exercised to minimize the presence of pores, channels, voids and other irregularities in the pasted structure. The surface of the graphite electrode is prepared by removing the outer layer with a tissue paper. A wide variety of liquids are used in graphite paste electrode<sup>4-9</sup>.

In non-aqueous solvents graphite paste electrode tend to disintegrate by dissolution of the impregnating liquid or by preferential wetting of the carbon phase by the solvent<sup>10</sup>. This problem is overcome by the addition of a surface-active agent to the paste so that

the graphite is equally wetted by the non-aqueous solvent and the impregnating liquid. Since the impregnate and graphite electrode contact with the electrolyte is an electrochemical cell, it must have low volatility, low solubility in the working environment and a high purity to avoid introducing unwanted electroactive species. Several studies have been made to understand the effect of the impregnating liquid on the electrochemistry at graphite paste electrode<sup>5-6,9,11</sup>.

Cyclic voltammetry (CV) is often the first experiment in an electrochemical study of a compound, a biological material or an electrode system. It is the most versatile electrochemical techniques used in the field of electrochemistry, inorganic chemistry, organic chemistry and biochemistry<sup>12-17</sup>. It employs the isosceles-triangle wave form. This technique was apparently first practised by Seveil<sup>18</sup>. It is perhaps the most effective technique available for the mechanistic study of redox systems<sup>19-23</sup>. It enables the electrode potential to be rapidly scanned in search of redox couples.

Chronoamperometry(CA) is an electroanalytical technique based on the excitation function of one or more potential steps that are applied to an electrode immersed in a non-stirred solution<sup>24</sup>. It provides a square-wave voltage signal which steps the potential of the working electrode from a value at which no Faradic current occurs to a potential at which surface concentration of the species is effectively zero. The electrode potential is controlled at a value sufficient to react immediately any sample that diffuses to the surface.

There are various non-aqueous solvents like Dimethyl sulfoxide (DMSO), Dimethyl formamide (DMF), acetonitrile (ACN), etc.; which are used in the study of electrochemical techniques. Among the various non-aqueous solvents used DMSO finds a wide spread use in organic chemistry, biochemistry, industry and medicine<sup>25</sup>. DMSO has a strongly non-ideal behaviour which is revealed in many physical properties<sup>26</sup>. Extreme deviations from density<sup>27</sup>, viscosity<sup>27,27</sup>, relative permittivity<sup>28,29</sup> and surface tension<sup>28-30</sup> are observed in DMSO water solutions. DMSO solutions also violate Raoult's law even when very dilute<sup>26,31</sup>. Some of the above anomalous properties may be attributed to the tendency of DMSO to associate.

## **2. MATERIALS**

DMSO was of AR grade and was purified by keeping in 3A° molecular sieves to absorb water<sup>33</sup>. KCl was AR grade and was used as such. Graphite and paraffin oil used was of reagent grade. Nitrogen gas was obtained from Industrial Oxygen Ltd. with 99% purity. Double distilled water was used in the preparation of the solutions. In case of nonaqueous solutions, SO<sub>2</sub> gas was bubbled through DMSO. AR grade TBAP was obtained from Fluka and was oven dried for 1 hour at 100°C before the experiment.

0.1 M KCl and 0.1 M TBAP was used as the supporting electrolyte for aqueous and nonaqueous solutions respectively. pH of the solution was adjusted by addition of H<sub>2</sub>SO<sub>4</sub> or Na<sub>2</sub>SO<sub>3</sub> wherever necessary. All potentials were reported against Saturated Calomel Electrode (SCE) in case of aqueous solutions and in the non-aqueous solutions, potentials were reported against silver wire which served as the Quasi Reference Electrode (QRE).

### **2.1 Electrode systems**

Electrochemical studies were conducted using a five necked round bottom flask as shown in Electrochemical measurements were carried out using a three electrode system i.e., working electrode (WE), an auxiliary or counter electrode (CE) and a reference electrode (RE)<sup>34,35</sup>. The WE was made up of graphite paste, platinum wire served as a CE and the RE electrode used was SCE for aqueous solution and a silver wire which served as a quasi reference electrode (QRE) in non-aqueous solution. The solution was purged for about 1 hour before each experiment with pure nitrogen gas to remove the dissolved oxygen gas. The studies were performed in the inert nitrogen atmosphere which was maintained during the run of the experiment. The QRE was placed very near to the WE to eliminate the iR potential drop in the solution. The measurements were taken in an unstirred solution at room temperature.

### **2.2 Preparation of working electrode**

The working electrode was prepared by mixing graphite powder which was finely powdered with

mortar and pestle and mixed with paraffin oil. The ratio of graphite and paraffin oil was fixed at 8:2. The mixture was wetted for binding by adding paraffin oil. The mixture was made into a smooth homogeneous paste. The ratio graphite mixture to liquid paraffin was kept constant in all experiments. The paste was inserted into a hollow glass tube of area  $1\text{cm}^2$  at the open end. A platinum wire soldered with a copper wire was placed inside the tube for giving the necessary electrical connection. The free end of the tube was covered with teflon tape. The open surface of the electrode was cleaned with a spatula and the excess paste was removed with tissue paper after every run.

$\text{p}^{\text{H}}$  of the solution was measured with pH meter Elico instrument. The instrument was standardized using buffer tablets before each experiment. Electrochemical measurements were performed using a E.G & G Princeton Applied Research Corporation 273 Potentiostat / Galvanostat model. M270 electrochemical software was used to control the instrument. The instrument was hooked to a computer along with a printer.

### 3. RESULTS AND DISCUSSIONS :

#### 3.1.Cyclic voltammetry (CV) of Graphite paste in DMSO

The anodic / cathodic peak potentials and peak currents were studied using cyclic voltammograms. Effects of various parameters such as concentration of compound, scan rate, potential reversal, number of cycles were investigated.

A series of cyclic voltammograms were recorded by varying the sweep potential between  $-1.0\text{V}$  to  $+1.0\text{V}$ . Fig. 1A shows the typical cyclic voltammetry of graphite paste in DMSO using  $0.1\text{M}$  TBAP as a supporting electrolyte. It was observed that in the first cycle there is no anodic peak in the forward positive scan. The scan rate was kept constant at  $20\text{mV/s}$ . the first anodic scan is almost a straight line. The current rises sharply around  $0.8\text{V}$  versus the silver wire which serves as the quasi reference electrode. As the potential is reversed at  $1.2\text{V}$ , there appears a small cathodic hump near  $-0.6\text{V}$  which may be due to hydrogen evolution. In the second cycle, there appears one anodic peak around  $0.2\text{V}$  and on scan reversal, the cathodic peak appears near  $0.0\text{V}$ .

there is an increase in the cathodic current as seen in Fig 1B. Table 1 shows the peak anodic and cathodic potential and current values.

Fig.2A shows the multicyclic voltammogram of the graphite paste in DMSO. The first anodic peak and cathodic peak are similar to peaks as given above. In this case there is not only an increase in peak heights

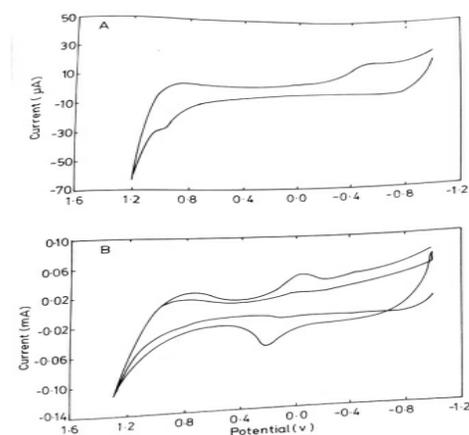


Fig.1.Cyclic voltammogram of graphite paste In Dimethylsulphoxide(A) I<sup>st</sup> cycle ,(B)II<sup>hd</sup> cycle

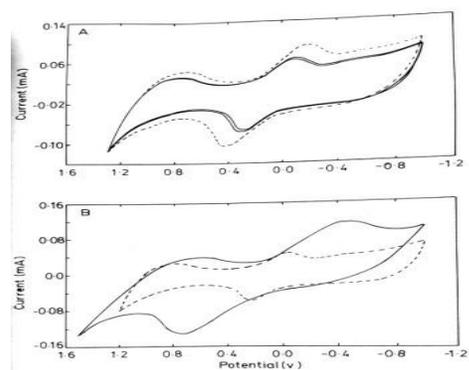


Fig.2.Cyclic voltammogram of graphite paste in DMSO (A)multicyclic, (B) beyond 1.3V

but there is also a shift in peak potentials. The anodic peak shifts towards more positive potential and the cathodic peak towards more negative potential. The shift observed in potential value may be either due to high dielectric constant of the organic solvent which

changes the solutions of ions due to adsorption of organic solvent at the working electrode surface<sup>36,37</sup>. When the positive potential was increased from 1.2V to 1.3V, the anodic and cathodic peak height increases drastically as compared to when the positive potential was 1.2V. When the positive potential was increased beyond 1.4V, the cyclic voltammograms gets distorted and the anodic and cathodic peak gets separated as seen in Fig. 2B. The anodic peak potential shift towards more positive potential and the cathodic peak towards more negative potential.

Table.1. Peak Anodic/Cathodic Potentials and current values of graphite in DMSO

Cycle No.	$I_{pa}$ $10^{-2}$ mA	$E_{pa}$ (V)	$I_{pc}$ $10^{-2}$ mA	$E_{pc}$ (V)
1	-	-	-	-
2	-5.47	0.22	4.50	0.064
3	5.95	0.24	4.77	0.082
4	7.86	0.30	6.61	0.116
5	10.57	0.42	9.09	0.188

In order to determine, whether the two peaks are reversible of each other, firstly the cyclic voltammograms was run from -1.0V to 0.0V. No anodic peak was observed, but the cathodic peak was observed, whereas when the cyclic voltammetry was run from 0.0V to +1.0V, only the anodic peak was observed and there was no cathodic peak. This demonstrates that the anodic and the cathodic peak are reversible to each other. Previous studies have indicated that the anodic and the cathodic peak may be caused by the oxidation of hydroquinone like groups to form quinone like groups while the cathodic peak was caused by the reduction of these quinone like groups<sup>38,39</sup>.

The stability of graphite paste electrode was tested in DMSO in the potential range studied. It was found that the graphite paste electrode was stable over the entire potential range and could be therefore regarded

as an inert electrode. At room temperature the background currents are small. It has been shown previously that with graphite paste, electrode work with 100% current efficiency.

### 3.2. Chronoamperometry study of graphite paste in water

The chronoamperometry study of graphite in water was carried out at different potential values. The current-time curve was recorded in the anodic region

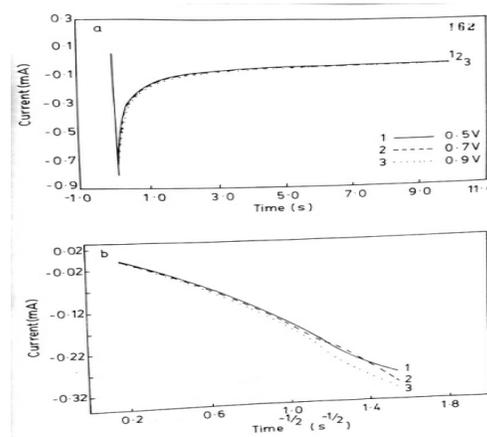


Fig.3. Chronoamperometric plot of graphite in water at various potential range (a) time vs Current, (b) time<sup>1/2</sup> current

with an initial potential of 0.0 V. The current response as a function of time was measured. The chronoamperometry curves was measured using the carbon paste electrode as the working electrode.

The i-t curve for graphite paste in water is shown in Fig. 3a. The curves were obtained at different potential value of 0.5, 0.7 and 0.9 V. The time period were varied from 10, 20, 40, 60 and 100 seconds.

It was observed that there is no change in the nature of the curve at different potential value. Here initially the charging current and later the Faradic current becomes dominant. Fig. 3.b shows the  $i-t^{1/2}$  curve of graphite paste in water. The curve shows a linear relationship between  $t^{-1/2}$  and current with negative slope. The current when extrapolated to  $t=0$ , represents the Faradic current. It was observed that the curve obtained with the application of potential above 1.0 V was ill defined. The slope value varied with change in the potential range. The potential was varied from 0.0 to 0.5 V, 0.0 to 0.9 V and 0.0 to 0.9

V at different time periods of 10, 20, 40, 60 and 100 seconds. Table 2 shows the variation of slope with change in potential. It was observed that the slope value decreased from  $-0.235 \mu\text{As}^{1/2}$  at 10 seconds to  $-0.162 \mu\text{As}^{1/2}$  at 100 seconds for 0.0 to 0.5 V range. Similarly at 0.0 to 0.7 V, the slope decreased from  $-0.242 \mu\text{As}^{1/2}$  to  $-0.156 \mu\text{As}^{1/2}$  with increasing time period and at 0.0 to 0.9 V, the slope value decreased from  $-0.264 \mu\text{As}^{1/2}$  to  $-0.161 \mu\text{As}^{1/2}$ . It was seen that the slope value increased from  $-0.235 \mu\text{As}^{1/2}$  to  $-0.264 \mu\text{As}^{1/2}$  at different potential range in the same time period.

Table 2 : Variation of slope with change in potential for graphite in water using chronoamperometric techniques.

SLOPE ( $10^{-6}\text{As}^{1/2}$ )				
Sr. No.	Time (s)	0.0to 0.5 (V)	0.1 to 0.7 (V)	0.1 to 0.9 (V)
1	10	-0.235	-0.242	-0.264
2	20	-0.217	-0.218	-0.238
3	40	-0.193	-0.194	-0.209
4	60	-0.179	-0.181	-0.191
5	100	-0.162	-0.156	-0.161

Table 3 : Area, Peak current and Peak time data at different potential and time period for graphite in water using chronoamperometric techniques.

Sr. No.	Volt (V)	Time (s)	Area ( $\mu\text{C}/\text{cm}^2$ )	Peak Cur. ( $\text{m}\mu/\text{cm}^2$ )	Peak Time (s)
1	0.5	10	-0.75	-0.74	0.12
2	0.5	40	-0.92	-0.29	0.45

3	0.5	100	-0.93	-0.23	0.70
4	0.7	10	-0.78	-0.76	0.12
5	0.7	40	-1.01	-0.32	0.43
6	0.7	100	-1.03	-0.22	0.70
7	0.9	10	-0.85	-0.84	0.12
8	0.9	40	-1.10	-0.33	0.45
9	0.9	100	-1.11	-0.23	0.70

The chronoamperometry data provided the area of the curve, peak current and peak time. Table 3 shows the value at different potential and time period. It was observed that area of the curve at a particular potential increases with increase in time period from  $-0.75 \mu\text{C}/\text{cm}^2$  at 0.5 V and 10 seconds to  $-0.93 \mu\text{C}/\text{cm}^2$  at 100 seconds and 0.5 V. Similar

Table 4 : Calculation of slope, diffusion coefficient, chi-square and correlation at different potential and time period for graphite in water using chronoamperometric techniques.

Sr. No.	Volt (V)	Time (s)	$it^{1/2}$ ( $10^{-6}\text{As}^{1/2}$ )	Diff. Coeff ( $10^{-7}\text{cm}^2$ )	Chi-squ. ( $10^{-9}$ )	Corre l.
1	0.5	10	-0.24	8.5	10.12	-0.997
2	0.5	40	-0.19	7.6	5.70	0.989
3	0.5	100	-0.16	6.9	3.40	0.985
4	0.7	10	-0.24	8.5	15.27	0.995
5	0.7	40	-0.19	7.2	6.48	0.988
6	0.7	100	-0.16	6.9	1.97	0.986
7	0.9	10	-0.26	8.8	21.21	0.995
8	0.9	40	-0.21	7.9	7.55	0.988
9	0.9	100	-0.16	6.9	2.77	0.982

trend is seen with higher potential range. The peak current decreases with increasing time period from 0.74 mA/cm<sup>2</sup> to -0.23 mA/cm<sup>2</sup> at 0.5 V. At different potential the peak current value remains almost constant. The peak time increases with increase in potential and time periods. It varies from 0.12 at 10 seconds to 0.70 seconds at 100 seconds. Above 1.0 V, the values for all the above parameters shows irregular behaviour.

The slope value, diffusion coefficient, chi-square and correlation value obtained from the  $it^{-1/2}$  curves are shown in Table 4. The diffusion coefficient value have been calculated from the slope according to Cottrell's equation :

$$i = \frac{nFAD^{1/2}C}{\pi^{1/2} t^{1/2}}$$

where symbols have their usual meaning

$$\text{or, } D^{1/2} = 3 \times 10^7 \times it^{1/2}$$

The diffusion coefficient decreased from 8.5 x 10<sup>-6</sup> cm<sup>2</sup>/s at 0.5 V and 10 seconds to 6.9 x 10<sup>-6</sup> cm<sup>2</sup>/s at 0.9 V and 100 seconds. Similar trend was seen in higher potential value. The chi-square at 0.5 V decreased from 10.12 x 10<sup>-9</sup> at 10 seconds to 3.40 x 10<sup>-9</sup> at 100 seconds. Similarly the chi-square value decreased with increasing potential range. The correlation value varied from 0.997 to 0.982.

A plot of diffusion coefficient versus time of graphite paste has been shown in Fig.4. It was seen that the diffusion coefficient value decreases in increasing potential and time period. At lower time period, the diffusion coefficient decreases, but at higher time period it almost shows a linear value.

### 3.3 Chronoamperometry (CA) study of graphite paste in DMSO

The current-time characteristic study of graphite paste in DMSO was carried out at different potential values. It was recorded in the anodic range with an initial potential value of 0.0 V. The current response as a function of time was recorded.

Chronoamperometry curves were obtained at different potential value of 0.5 V, 0.7 V, 0.9 V and

1.2 V. Fig. 5A shows a typical i-t curve for graphite paste in DMSO. It was observed that initially the

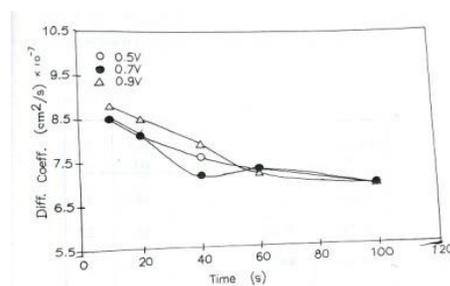


Fig.4. Chronoamperometric plot of time vs Diff. Coeff for graphite in H<sub>2</sub>O

charging current and latter the Faradic current was dominant. Fig. 5B shows a linear relationship between  $i$  and  $t^{-1/2}$ . The current when extrapolated to  $t=0$ , represents the Faradic current.

The slopes calculated from the chronoamperometry plots are shown in Table 5. The potential were measured at different time periods of 10, 20, 40, 60 and 100 seconds. It was observed that at potential range of 0.0 to 0.5 V and 0.0 to 0.7 V, the slope value decreases with increasing time period. However at potential of 0.0 to 0.9 V, the slope value are higher comparatively. But at potential value of 0.0 to 1.2 V, there is observed an increasing trend of slope value.

Table 5 : Variation of slope with change in potential for graphite in DMSO solution using chronoamperometric techniques.

SLOPE ( 10 <sup>-6</sup> As <sup>1/2</sup> )					
Sr. No	Time (s)	0.0 to 0.5 (V)	0.0 to 0.7 (V)	0.0 to 0.9 (V)	0.0 to 1.2 (V)
1	10	-1.23	-2.33	-14.23	-22.87
2	20	-1.09	-2.88	-14.0	--
3	40	-0.98	-2.64	-15.45	-100.3
4	60	-0.78	-2.55	-13.08	--

5	100	-0.60	-2.30	-12.47	-182.4
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The chronoamperometry data of area, peak current and peak time has been calculated from the i-t curves. Table 6 shows the different value. It was observed from the data that area increases in value with the increase in potential at different time periods. There is a sudden increase in magnitude of area at potential higher than 0.9 V. The peak current shows a decreasing trend at a lower potential value which increases with higher potential value. At potential above 1.0 V, the peak current decreases drastically. The peak time value also shows similar trends.

The diffusion coefficient value have been calculated from the slope value at different potential and time periods The diffusion coefficient value in DMSO was obtained according to Cottrell's equation<sup>40</sup>

$$i = \frac{nFAD^{1/2}C}{\pi^{1/2} t^{1/2}}$$

where symbols have their usual meaning.

$$it^{1/2} = \frac{nFAC \times D^{1/2}}{\pi^{1/2}}$$

Table 6 : Area, Peak current and Peak time data at different potential and timeperiod for graphite in DMSO solution using chronoamperometric techniques.

Sr. No.	Volt (V)	Time (s)	Area ( $\frac{\mu C}{cm^2}$ )	Peak Cur. ( $\frac{\mu A}{cm^2}$ )	Peak Time (s)

1	0.5	10	-8.23	-3.60	0.17
2	0.5	40	-15.21	-1.79	0.48
3	0.5	100	-19.32	-0.80	1.20
4	0.7	10	-24.14	-9.65	0.18
5	0.7	40	-48.53	-4.18	0.69
6	0.7	100	-84.53	-2.52	1.60
7	0.9	10	-111.5	-34.19	0.23
8	0.9	40	-260.1	-23.7	0.63
9	0.9	100	-459.7	-18.82	1.20
10	1.2	10	-1442	-0.198	0.18
11	1.2	40	-4835	-0.240	0.85
12	1.2	100	-9719	-0.245	1.6

By substitution of standard values,

$$\text{We get : } it^{1/2} = (3 \times 10^7)^{-1} \times D^{1/2}$$

$$D^{1/2} = 3 \times 10^7 \times it^{1/2}$$

Table 7 : Calculation of slope, diffusion coefficient, chi-square and correlation at different potential and time period for graphite in DMSO solution using chronoamperometric techniques.

Sr. No.	Vol t (V)	Time (s)	it <sup>1/2</sup> (10 <sup>-6</sup> As <sup>1/2</sup> )	Diff. Coef f. (10 <sup>-7</sup> cm <sup>2</sup> )	Chi-squ. (10 <sup>-12</sup> )	Correl.
1	0.5	10	-1.23	0.61	0.29	-0.996
2	0.5	40	-0.98	0.54	0.05	-0.997
3	0.5	100	-0.60	0.42	0.04	-0.982
4	0.7	10	-3.33	0.99	0.21	-0.999
5	0.7	40	-2.64	0.88	0.26	-0.997

6	0.7	100	-2.30	0.83	0.21	-0.991
7	0.9	10	-14.23	2.07	3.91	-0.999
8	0.9	40	-15.45	2.15	22.72	-0.991
9	0.9	100	-12.47	1.93	31.04	-0.966
10	1.2	10	-22.87	2.62	1890	-0.927
11	1.2	40	-100.3	5.49	3270	-0.966
12	1.2	100	-182.4	7.40	3970	-0.974

The diffusion coefficient value were obtained from the slope ( $it^{1/2}$ ) data using the above equation. Table 7 shows the diffusion coefficient, chi-square and

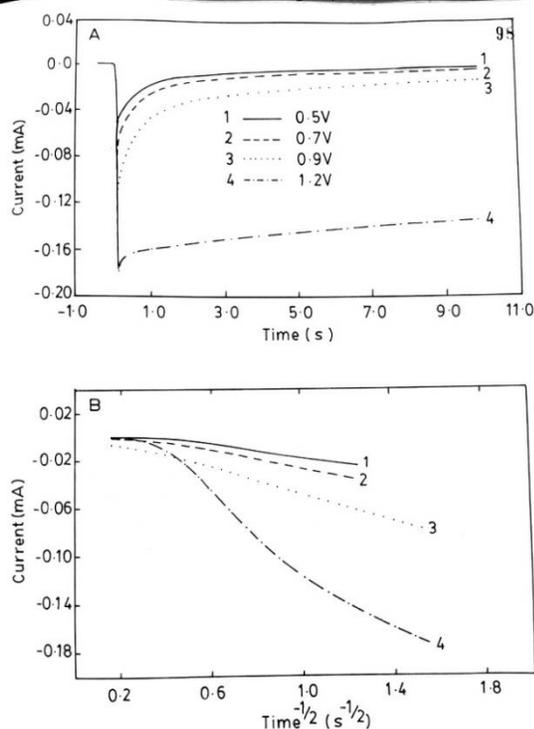


Fig.5. Chronoamperometric plot of graphite in DMSO at various potentials (A) time versus current ,(B)  $time^{1/2}$  vs current.

correlation value obtained at different potential and time period. The diffusion coefficient value varied from  $0.42 \times 10^{-7} \text{ cm}^2/\text{s}$  at 0.5 V to  $2.15 \times 10^{-7} \text{ cm}^2/\text{s}$  at 0.9 V. The value of diffusion coefficient increases at potential higher than 1.0 V. It increases from  $2.62 \times 10^{-7} \text{ cm}^2/\text{s}$  to  $7.40 \times 10^{-7} \text{ cm}^2/\text{s}$  at 1.2 V. The correlation coefficient value varied from 0.927 to 0.999. The chi-square ranged from  $0.04 \times 10^{-12}$  to  $3.97 \times 10^{-9}$ .

The variation of diffusion coefficient with increase in time period from 10 to 100 seconds is shown in Fig. 6 at different potential. It was found that at potential of 0.5 V and 0.7 V, the value is almost constant and linear. At potential of 0.9V, the diffusion coefficient value increases slightly from  $2.07 \times 10^{-7} \text{ cm}^2/\text{s}$  to  $2.15 \times 10^{-7} \text{ cm}^2/\text{s}$ . However at 1.2V, the value increases drastically from  $2.62 \times 10^{-7} \text{ cm}^2/\text{s}$  to  $7.40 \times 10^{-7} \text{ cm}^2/\text{s}$ .

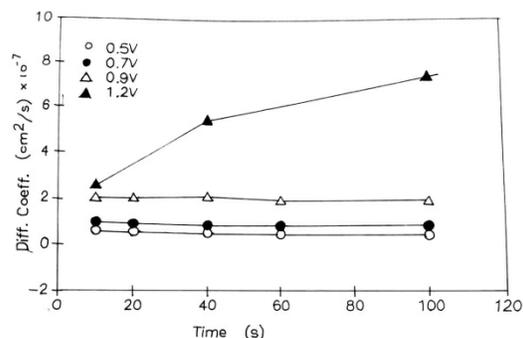


Fig.6. Chronoamperometric plot of time vs Diff.Coeff. for graphite in DMSO.

#### 4. CONCLUSIONS

1. The results of the electrochemical investigation showed that as the dissolution potential increases, the anodic current density increases with the increase of copper oxide concentration.
2. The  $it^{1/2}$  behaviour at very low and at very high values of current density does not remain constant in a particular solvent system. The  $it^{1/2}$  value varies with change in concentration.
3. Diffusion coefficients values were calculated using the chronoamperometric techniques. It varied in different solvent system and it generally depended primarily on the nature of the dissolved substances, the concentration of the diffusing substance, solvent system, pH etc.

Acknowledgement: The financial aid from Reliance Industries is thankfully acknowledged.

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