

Short Communication

Voltammetric Determination of Ascorbic Acid using Cu Foil Electrode

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The electro-oxidation of ascorbic acid has been investigated by cyclic voltammetry on the Cu foil electrode at room temperature. The results show that the electrode exhibits good analytical performance for the electrochemical detection of ascorbic acid (AA) in phosphate buffer solution. The intensities of the anodic cyclic voltammogram peaks increase linearly with the increase of the ascorbic acid concentration from 2.5 to 15 mM at a low applied potential of 0.0 mV vs.SCE and scan rate from 200 to 500 mVmin⁻¹. The peak current densities are proportional to the square root of the scan rate. This demonstrates that the oxidation reaction on the Cu electrode is a typical diffusion-controlled electrochemical process. These sensors exhibited linear response to change in concentration of AA, the sensitivity was 58.51 μA/cm² mM. Cu electrode exhibits good reproducibility, stability, low detection limit of 0.1 mM, which is better than those at other modified electrodes.

Keywords: Cu electrode, Ascorbic acid, Cyclic voltammetry, Oxidation, Sensors.

1. INTRODUCTION

Vitamin C, an electroactive compound with important chemical and biological activities, is an important vitamin in the human [1]. Due to its antioxidant properties, it is also known as ascorbic acid (AA). AA is considered as a kind of vital bioactive antioxidant, which plays a versatile role in maintaining the balance of relevant physiological processes and normal functions of living organisms. The abnormal AA levels are connected to a series of diseases. The lack of AA may cause tiredness, scurvy and depression while the excessive level of it may lead to diarrhea, kidney stones and insomnia [2-8]. Considering its integral impacts in human bodies, the effective determination of AA is especially necessary.

Among the different methods applied to detect AA, electro-chemical sensing has been considered an excellent method at low cost, high sensitivity, convenience and rapid response. However, as an

essential component of the electrochemical sensing system, most of the sensor materials still have some limitations including low specific surface areas, weak chemical design capabilities and boring adaptability.

In this paper, we report the electrocatalytic oxidation of ascorbic acid on a Cu foil electrode material by Cyclic voltammetry. The best of our knowledge, the electrooxidation of AA on a Cu foil electrode has not been reported in the literature (novel functional of Cu foil electrode) [1,9]. Since copper is a common and inexpensive material, copper-based AA sensors might be very affordable. The present research reports on the characteristics of AA electrooxidation on Cu foil electrode at a low applied potential. The Cu foil electrode is compared with regard to factors such as sensitivity, Potential, Detection range, and long-term stability table1.

2. EXPERIMENT

2.1. Preparation of the sensing electrodes

The Preparation of the sensing electrodes (Cu foil electrodes (99.99% in purity)) were carefully polished, the cleaned Cu substrate was etched in a solution of 2 M hydrochloric acid (HCl) for 10 min and then rinsed several times with distilled water. This treatment aims to ensure strong adhesion and continuity of the oxide film, 1 cm² of each electrode was left uncovered and all other electrode surfaces were sealed with Teflon tape [10].

2.2. Electrochemical characteristics

All electrochemical measurements using a VoltaLab PGZ 301 potentiostat-galvanostat in three-electrode cell. A platinum foil counter electrode and a saturated calomel electrode (SCE); the working electrode was made of Cu foil. The supporting electrolyte was used, namely 0.1 M phosphate buffer solutions.

2.3. Sensing procedure

The electrocatalytic activity of the AA oxidation was investigated using cyclic voltammetry on the Cu foil electrode at room temperature in the presence and absence of AA, in 0.1 M phosphate buffer solution a pH of 7.0. The potential scan was performed from -135 to 400 mV.

3. RESULTS AND DISCUSSION

3.1. Electrocatalytic oxidation of AA

Fig. 1, are presented the electro-oxidation of AA at the Cu electrode by cyclic voltammetry in 0.1 M phosphate buffer solutions with and without 15 mM AA. without AA, the anodic reaction rate is low and remains low over the entire potential range covered. but in the presence of AA, a sharp anodic peak is observed at 0 mV. This peak is characteristic AA oxidation on the electrode surface [11].

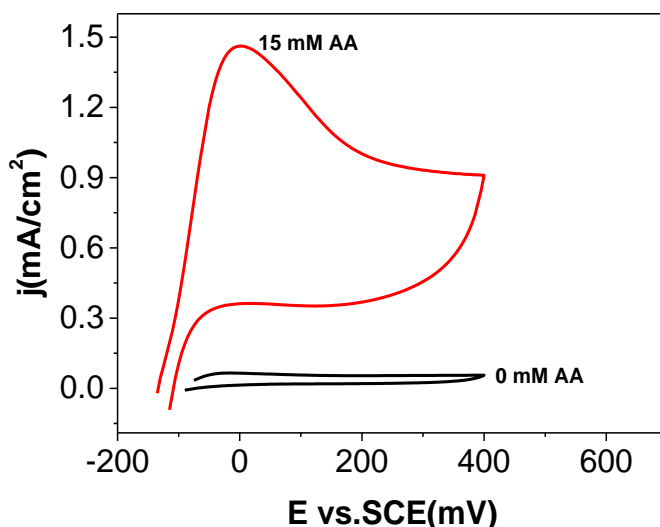


Figure 1. Cyclic voltammograms obtained with a Cu working electrode in the absence and presence of AA in 0.1 M phosphate buffer solution; potential scan rate 500 mV min⁻¹.

3.2. Effect of scan rate

Fig. 2a. presents the cyclic voltammograms of Cu electrode for the oxidation of AA in 0.1 M phosphate buffer over the scan rate ranging from 200 to 500 mV/min. It is observed that the anodic peak current density increases with increasing scan rate, furthermore, the peak current density is proportional to the square root of the scan rate, as shown in figure 2b. From these results, we can conclude that the oxidation reaction on the Cu electrode is a typical diffusion-controlled electrochemical process [12].

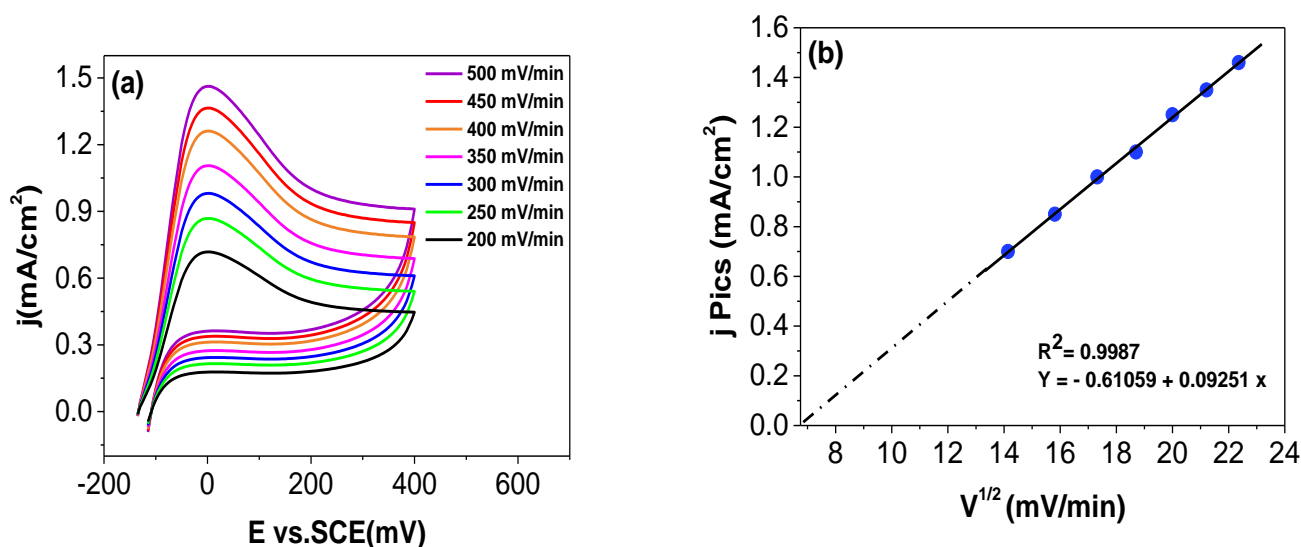


Figure 2. (a): Cyclic voltammograms obtained with a Cu working electrode at various scan rates; AA concentrations 15 mM; in 0.1 M phosphate buffer solution. **(b):** Plots of peak currents as a function of the square root of the scan rate.

3.3. Sensor response and calibration curve

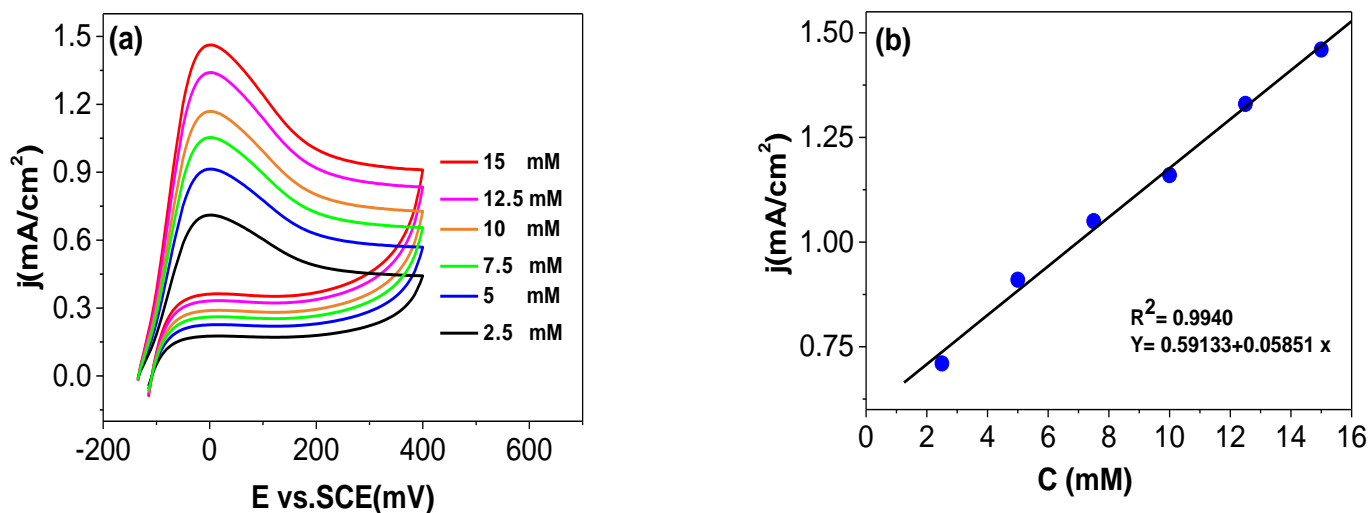


Figure 3. (a): Cyclic voltammograms obtained with a Cu working electrode for different ascorbic acid concentrations; scan rate 500 mV min^{-1} ; in 0.1 M phosphate buffer solutions. **(b):** Plots of peak currents as a function of AA concentration.

Fig. 3a displays cyclic voltammetric response of Cu foil electrode in solutions containing different concentrations of AA. The anodic peak current observed increases with increasing AA concentration in the solution. This catalytic peak current has a linear relationship with the concentration of AA in the range 2.5–15 mM with a correlation coefficient of 0.9940 Figure 3b. From these results, we can conclude that the electrooxidation of AA onto Cu electrode can be used for the determination of AA with good sensitivity $58.51 \mu\text{A/cm}^2 \text{ mM}$ a detection limit of 0.1 mM [8,11,16].

3.4. Stability and reproducibility of the Cu electrode

The stability of Cu foil electrode for AA electrooxidation was studied by monitoring the remained amount of current response after successive cycling the Cu electrode in the potential range of – 135 to 400 mV in 0.1M phosphate buffer solution for 500 circles.

The stability of the Cu was also examined. He found that the peak current for AA oxidation maintains 99% of its initial value and no apparent potential shift was observed. On the other hand. It was found that the current response to AA was not significantly reduced in the first 60 continuous days of daily use in 0.1M phosphate buffer solution (PH 7.0). After 2 months, 99% of its initial activity has been reserved.

Under the selected conditions, the method showed the sensor had good reproducibility and long-term stability. In addition, a series of repetitive measurements were carried out in 2.5 mM AA solution

to characterize the reproducibility of the sensor. This indicated that the Cu electrode had excellent reproducibility.

Table 1. Comparison of various AA sensors of some properties of the present work with other studies.

Electrode	Method	Sensitivity ($\mu\text{AmM}^{-1}\text{cm}^{-2}$)	Potential (mV)	Detection range (μM)	Detection Limit (μM)	Refs
β CD-nano Au/Fc-ITO	CV	1764	+572 vs.SCE	53-3000	4.1	[13]
Au-Pt alloy/ITO	CV	–	–	2– 400	–	[14]
Pt foil	Amperometry	178	+90	570–5680	–	[15]
Ni foil	Amperometry	169	+200 vs.Ag/AgCl	570–5680	–	[15]
Pt and Carbon electrode	CV	–	+530	310-2000	7.5	[16]
	CV	–	+470 vs.SCE	70-2000	6.2	
Cu(II)-A zeolite- modified electrode	CV	–	+400 vs.Ag/AgCl	3-6000	0.276	[17]
Ag NP/CPE	DPV	–	–	1000-2100	600	[18]
CuO-SPE	Amperometry	107	+400 vs.SCE	100–8000	88	[19]
CuO hollow sphere/SPE	Amperometry	533	+550 vs.SCE	100–7000	90	[20]
Cu electrode	CV	58.51	0.0 vs.SCE	2500-15000	100	This work

4. CONCLUSION

In this work, we did the determination of AA using Cu foil electrode in 0.1 M phosphate buffer solution by Cyclic voltammetry. The Voltammetric response current displayed a linear dependence on the Ascorbic Acid concentration in the range from 2.5 to 15 mM, at a low applied potential of 0.0 mV

vs.SCE. The Cu foil electrode showed good sensitivity toward AA, with values of $58.51 \mu\text{A}/\text{cm}^2 \text{mM}$. It should be noted that Cu foil electrode has shown better long-term stability and excellent reproducibility.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

1. A. M. Pisoschi, A. Pop, A.I. Serban, C. Fafaneata, *Electrochim. Acta*, 121 (2014) 443-460.
2. S.R. Ali, R.R. Parajuli, Y. Balogun, Y.F. Ma, H.X. He, *Sensors*, 8 (2008) 8423-8452.
3. R. Kand'ar, *Biomed. Chromatogr.*, 30 (2016) 13-28.
4. Y. Iida, T. Saroh, I. Satoh, *Electrochemistry*, 70 (2002) 515-517.
5. T. Luczak, *Electrochim. Acta*, 54 (2009) 5863-5870.
6. M. Sajid, M.K. Nazal, M. Mansha, A. Alsharaa, S.M.S. Jillani, C. Basheer, *Trends. Anal. Chem.*, 76 (2016) 15-29.
7. J.M. Zen, A.S. Kumar, D.M. Tsai, *Electroanalysis*, 15 (2003) 1073-1087.
8. Y. Li, W. Ye, Y. Cui, B. Li, Y. Yang, G. Qian, *J. Mol. Struct.*, 1209 (2020) 127986.
9. K. Dhara, R. M. Debiprosad, *Anal. Biochem.*, 586 (2019) 113415.
10. A. Hamam, C. Dehchar, M. Maiza, I. Chikouche, H. Merabti, *Int. J. Electrochem. Sci.*, 15 (2020) 3534 – 3542
11. S. Reddy, B.E. Kumara Swamy, U. Chandra, B.S. Sherigara, H. Jayadevappa, *Int. J. Electrochem. Sci.*, 5 (2010) 10 – 17
12. L. Lamiri, O. Belgherbi, C. Dehchar, S. Laidoudi, A. Tounsi, B. Nessark, F. belhames, A. Hamam, B. Gourari, *Synth. Met.*, 266 (2020) 116437
13. F. Zuo, C. Luo, Z. Zheng, X. Ding, Y. Peng, *Electroanalysis*, 20 (2008) 894-899.
14. Y. Lin, Y. Hu, Y. Long, J. Di, *Microchim. Acta*, 175 (2011) 259-264.
15. Y-C. Weng, Y-L. Hsiao, *J. Electroanal. Chem.*, 651 (2011) 160-165.
16. A.M. Pisoschi, A.Pop, Gh P. Negulescu, A. Pisoschi, *Molecules*, 16 (2011) 1349.
17. T. Rohani, M. Ali Taheri, *J. Talanta*, 78 (2009) 743-747.
18. H. Vidya, B.E. Kumara Swamy, M. Schell, *J. Mol. Liq.*, 214 (2016) 298-305.
19. M. Khairy, B.G. Mahmoud, *Electroanalysis*, 28 (2016) 2606-2612.
20. B.G. Mahmoud, M. Khairy, F.A. Rashwan, C.W. Foster, C.E. Banks, *RSC Adv.*, 6 (2016) 14474-14482.