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Paracetamol Sensing Via Modified Electrodes Based On Nano-Structured Bi(III) Schiff Base–Nio Composites

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Abstract
In this study, the developed a series of nano-structured Bi(III) Schiff base complexes and their NiO-based hybrids for detecting paracetamol (PA) using electrochemical methods. Modified glassy carbon electrodes (GCEs) were tested using cyclic voltammetric (CV), differential pulse voltammetric (DPV) and square wave voltammetric (SWV) at pH 1.0 under ion beam irradiation (25 to 100 mV/s). Among them, the NiO–Nitro Schiff base Bi(III) composite (NiO–Nitro SBC) showed the best performance, delivering a DPV peak current of 67.8 μA at potential 0.59 V nearly ten times higher than the bare GCE. It also showed excellent sensitivity (0.052 μA/μM), a low detection limit (0.29 μM), and strong linearity (R^2 = 0.9993). results supported these findings with a peak current of 57.6 μA and R^2 = 0.9998. These improvements stem from the synergistic effects of NiO, redox-active Bi (III), and nitro groups. Overall, the modified electrode offers a promising platform for sensitive and reliable paracetamol detection.
Keywords: *Paracetamol; Schiff base complex; Bismuth(III); NiO nanoparticles;; Differential pulse voltammetry;*

INTRODUCTION

Paracetamol is widely used to relieve pain, and can cause liver damage in excessive amounts so precise measurement is important in both medicine and quality control of drugs [1, 2]. Conventional procedures are effective but slow and costly [3,4]. On the other hands, electrochemical detection is easy to operate and economic, and has high sensitivity [5]. To enhance these sensors, researchers are taking advantage of easy preparation of redox-active Salen-type Schiff bases with redox-active metal complexes [6,7]. The nitro groups promote these compounds to have high electron transfer ability [8], and the nanomaterials such as NiO and Bi(III) improve their conductibility and catalytic activity [9–11]. Adding these components influences hybrids which powerfully detect paracetamol and in the presence of other compounds [12–14]. Their surface characteristics can also be enhanced by ion beam irradiation [15,16]. This study focuses on using Bi(III) Schiff base–NiO composites to detect paracetamol under acidic conditions, aiming to build a fast, sensitive, and reliable electrochemical sensor.

MATERIAL AND METHODS

Materials

$Bi(NO_3)_3$, $NiCl_2$.$6H_2O$, NaOH, methanol, ethanol, salicylal aldehyde, nitro salicylaldehyde, ethylene diamine are purchased from e-merk and used as such.

Preparation of NiO

5.94 g (0.1M) of $NiCl_2$.$6H_2O$ along with 1 g of NaOH pellet added and makeup in 250 ml of volume then stirring continuously for two hours, Then green gel was formed and washed with water along with ethanol and dried. Then Calcination process was carried out at 450 c in oven, Finally, the green coloured sample changed into black powder and grained with morter which was in nano sized.

Preparation of salen;

The salen ligand was prepared by refluxing of a mixture of 3.66 g (3.1ml) of salicylal aldehyde and 0.9g(1.0ml) of ethylene diamine(1:2 ratio) in 150 ml of methanol for one hour.
After completion of reaction the yellow crystalline solid (Salen) was collected and washed with cold methanol and dried in air.

Preparation of 5,5' Dinitro salen:
3.04 gm of 5 nitro salicylaldehyde refluxing with 0.9g (1.0ml)of ethylene diamine (1:2 ratio) in 150 ml of methanol for one hour. The pale yellow crystalline solid (Nitro salen) was collected and washed with cold methanol and dried in air.
Preparation of Bismuth salen complex (SBC):
0.9693g of $Bi(NO_3)_3$ in ethanol refluxed with 0.5366g of salen for 2 hours with constant stirring in oil bath and the product was collected by filtration and washed with cold ethanol for 10 minutes and dried in air, then white coloured complex was obtained
Preparation of 5,5' Nitro salen Bismuth complex (Nitro SBC):
0.9693g of $Bi(NO_3)_3$ in ethanol refluxed with 0.4852g of Nitro salen for 2 hours with constant stirring in oil bath and the product was collected by filtration and washed with cold ethanol for 10 minutes and dried in air, then pale yellow coloured complex (Nitro SBC)was obtained.
Preparation of NiO -Nitro SBC nano composite:
By using Co-precipitation method, nano sized metal oxide (NiO) dissolved in base medium like NaOH (precipitating medium) was mixed with prepared 5,5'Nitro salen Bismuth Complex(Nitro SBC)in fixed proportion of 1:1 which results black coloured gelly nano composites through Calcination at 120° C along with Centrifugation of 100 rpm, The dried NiO-Nitro SBC was obtained
Electrochemical characterization
The electrochemical measurements were carried out by CHI 650C electrochemical work station (CH Instruments, Inc., U.S.A). Electrochemical studies were carried out in a conventional undivided three electrode cell using modified glassy carbon electrode (GCE) as a working electrode (area 0.0341 cm^2), Ag|AgCl as a reference electrode and Pt wire as a counter electrode. Prior to each electrochemical experiment, the electrolyte solutions were deoxygenated with pre-purified nitrogen for 10 min unless otherwise specified. Were prepared and used for different pH solution as supporting electrolyte for throughout the electrochemical studies. All the experiments are carried out three times and the average value is used to plot figures and calibration plots.
Fabrication of modified electrods
About 2 g of compounds suspension in 2 mL DI water. The resultant mixture was stirred at room temperature for 48 h to obtain a putty form of nanocomposite. This nanocomposite was dried overnight at 25 °C in order to evaporate the solvent. The drop-cast method was used for the modification of the electrode. The surface of GCE was gently polished with 0.3 μm alumina slurries dispensed on a polishing pad prior to rinsing with distilled water. The GCE-working electrode was then sonicated in ethanol for 5 min and in distilled water again for 5 min to remove any particles that may have been trapped on the surface. Following this, a 20-μL aliquot of each of these dispersions was dropped onto the surface of the polished GCE and dried at 50 °C to obtain the modified electrodes used for the analytical studies

RESULTS AND DISCUSSION
Cyclic voltammetric studies of Paracetamol on Modified Electrodes
NiO/GC modified Electrodes
Figure 1 shows the CV profiles of the bare GCE and NiO-modified GCE at the scan rate 25 and 100 mV/s in pH 1.0. The CV curves clearly indicate enhanced redox behavior for NiO/GCE, with a more pronounced oxidation peak and higher anodic current. The oxidation current increased from +0.85 μA (GCE) to +1.35 μA (GCE/NiO), suggesting more efficient electron transfer. This enhancement is attributed to the NiO nanoparticles creating a porous surface with active defect sites that facilitate charge movement [17–21]. The shift in peak potential and the increased peak height in Figure confirm the improved electrocatalytic activity of the modified electrode.
Nitro Salen/GC modified Electrodes:
Figure 2 presents the CV responses for the GCE and Nitro Salen/GC electrodes at both scan rates 25 and 100 mV/s in pH 1.0. The Nitro Salen-modified electrode exhibits sharper and better-defined peaks, with higher oxidation currents. At 100 mV/s, the oxidation peak occurs at 0.48 V with a current of 2.1 μA for Nitro Salen/GCE, in contrast to 1.6 μA at 0.43 V for GCE. These differences arise from π–π stacking interactions between paracetamol and the aromatic Schiff base, hydrogen bonding from

functional groups, and the strong electron-withdrawing nature of the nitro group, all of which accelerate electron transfer. The Bi(III) center within the ligand framework may also enhance catalytic oxidation through intermediate stabilization [20, 22–24]. The distinct redox peaks in Figure 2 validate the superior electrocatalytic behavior of the Nitro Salen system.

NiO-Nitro Salen/GC modified Electrodes

Figure 3 displays the CV curves of GCE compared with the NiO–Nitro Salen composite electrode at 25 and 100 mV/s in pH 1.0. The modified electrode demonstrates significantly enhanced peak current and improved redox behavior across both scan rates. At 100 mV/s, the oxidation current increases from +0.36 µA (GCE) to +0.58 µA (NiO–Nitro Salen/GCE). The broadened and more intense peaks in the CV curves suggest greater electron mobility and surface reactivity. This enhanced response is attributed to the combined effects of the NiO nanostructures and the nitro-Schiff base, which together increase the active surface area and provide favorable sites for Paracetamol oxidation [25–27]. The smoother CV transitions and increased peak symmetry in Figure 3 confirm the composite's electrocatalytic efficiency.

Nitro SBC/GC modified Electrodes

Figure 4 illustrates the cyclic voltammograms of GCE and Nitro SBC/GCE, At scan rate of 25 and 100 mV/s, the Nitro SBC-modified electrode delivers an anodic peak current of 1.48 µA at +0.22 V, almost triple that of the unmodified GCE. The CV profile displays clear peak separation, indicating improved redox kinetics. However, at 100 mV/s, the current response diminishes slightly, likely due to reduced surface conductivity or structural degradation at higher scan rates. The sharp peak observed at 25 mV/s in the modified electrode indicates rapid and favorable redox transitions, making this scan rate optimal for Paracetamol detection using Nitro SBC [28–30]. Figure 4 emphasizes the kinetic advantages of this electrode at lower scan speeds.

NiO-NitroSBC/GC modified Electrodes

Figure 5 compares the CV curves of GCE and the NiO–Nitro SBC-modified/GCE. Among all tested materials, this composite shows the highest redox activity. At 100 mV/s, the oxidation peak current rises to +0.91 µA and the reduction peak reaches –0.85 µA, compared to +0.74 µA and –0.69 µA for GCE. The CV curves exhibit well-resolved and symmetrical redox peaks, suggesting enhanced reversibility and faster electron transfer. The superior performance is due to the synergistic interaction between NiO nanoparticles and the nitro-functionalized Schiff base, which enhances both the conductivity and electrocatalytic selectivity of the electrode. Additionally, the nanostructured morphology likely increases the density of electroactive sites [31–33]. The clear enhancement observed in Figure 5 supports the potential of NiO–Nitro SBC as an efficient sensor material.

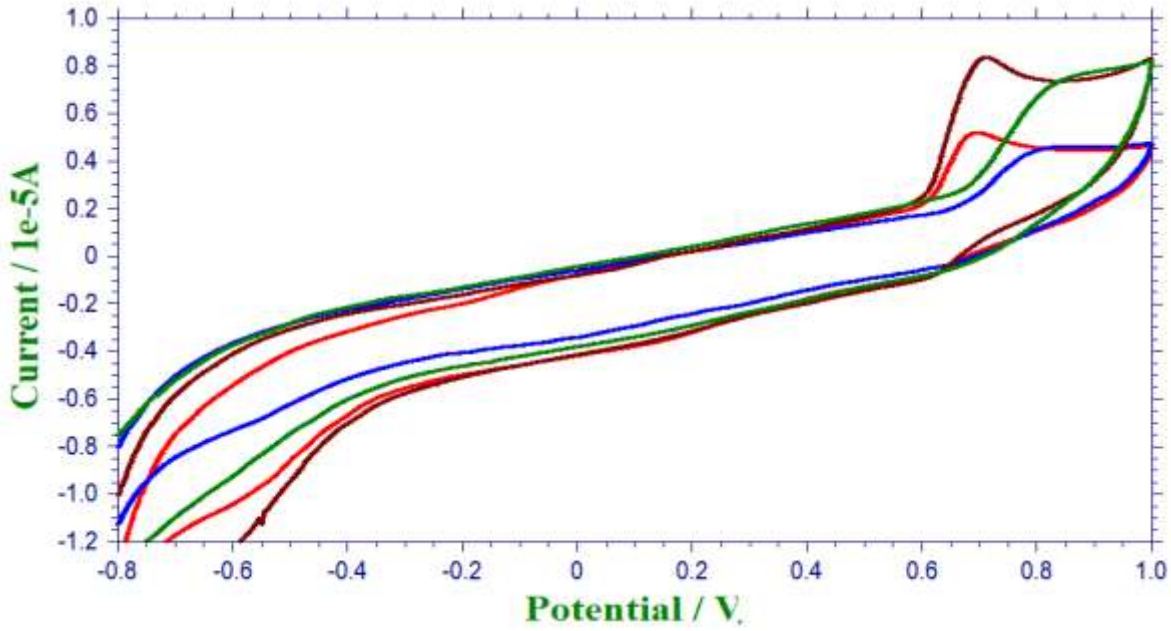

Figure 1. Cyclic voltammetric behaviour of 16 µM paracetamol on GCE and NiO/GCE in pH 1.0 at scan rate 25 and 100 mV/s

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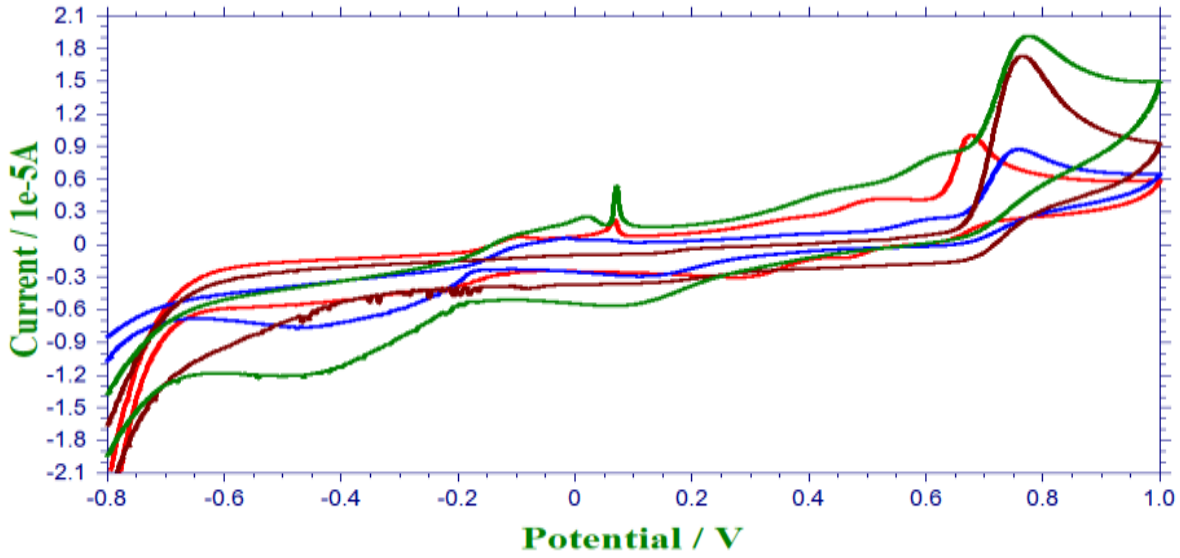

Figure 2. Cyclic voltammetric behaviour of 16 µM paracetamol on GCE and Nitro Salen/GC modified Electrodes in pH 1.0 at scan rate 25 and 100 mV/s

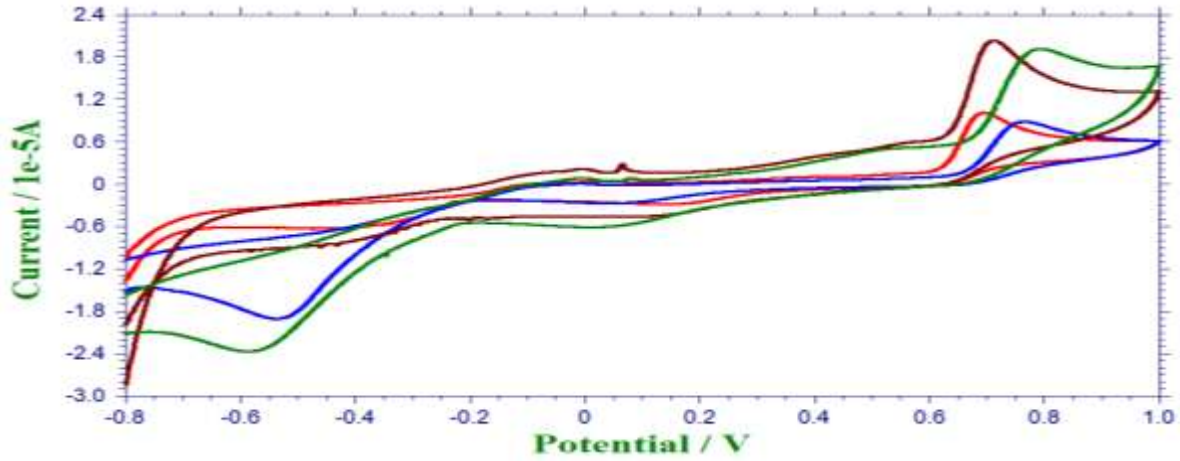

Figure 3. Cyclic voltammetric behaviour of 16 µM paracetamol on GCE and NiO-Nitro Salen/GC in pH 1.0 at different scan rate as 25 and 100 mV/s

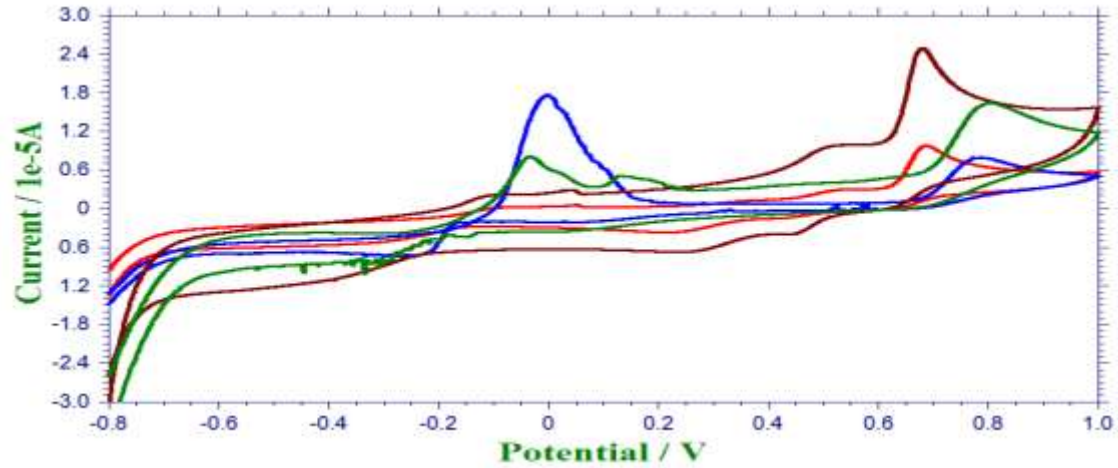

Figure 4. Cyclic voltammetric behaviour of 16 µM paracetamol on GCE and Nitro SBC/GCE in pH 1.0 at different scan rate like 25 and 100 mV/s.

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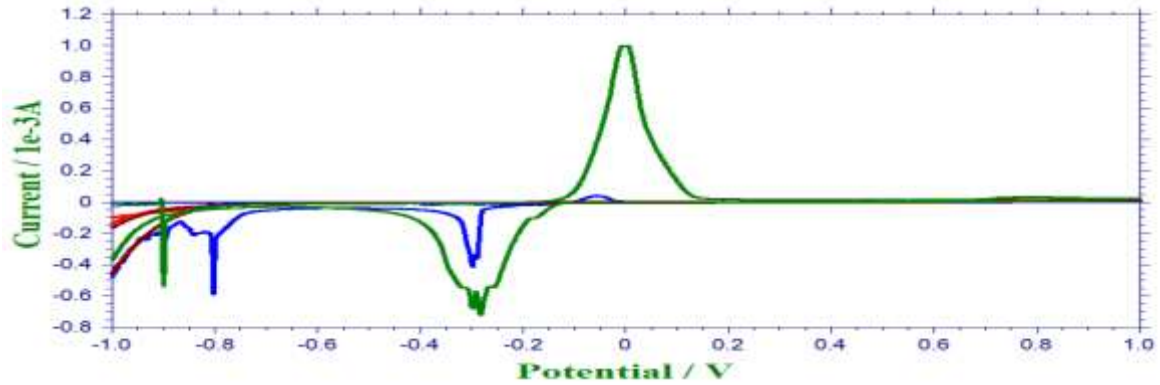

Figure 5. Cyclic voltammetric behaviour of 16 µM paracetamol onGCE and NiO–Nitro SBC/GCE at 100 mV/s in pH 1.0

DPV studies of Paracetamol Sensing on Modified Electrodes

Paracetamol detection at pH 1.0 using DPV showed that modifying GCEs significantly improved performance (Figs. 6). The bare GCE gave a weak signal (3.4 µA), while NiO increased it to 6.1 µA [34]. Adding a Schiff base raised it to 7.5 µA [35], and incorporating a nitro group boosted it further to 9.4 µA [36]. Without NiO, the Nitro SBC electrode showed 6.9 µA, highlighting the role of nanoparticles. The best result came from NiO–Nitro SBC, reaching 10.2 µA at +0.44 V, due to the combined effects of NiO conductivity and Schiff base catalysis [37, 38]. The calibration curve (10–50 µM) showed strong linearity (R^2 = 0.974), with a sensitivity of 0.182 µA μM^{-1} cm^{-2} and an LOD of 0.25 µM, confirming its potential for trace detection.In, sensor performance followed the order: **Bare GCE <NiO<NiO–Salen< Nitro SBC <NiO–Nitro Salen<NiO–Nitro SBC**, confirming the advantage of combining functional ligands with nanomaterials for enhanced electrochemical sensing. From the linear plot of ip vs. concentration (Fig. 7) it was seen that the peak current increased with increase in concentration. The straight line plot showed R^2 values of 0.9739. The equations was found to be y = 0.079x +8.81.

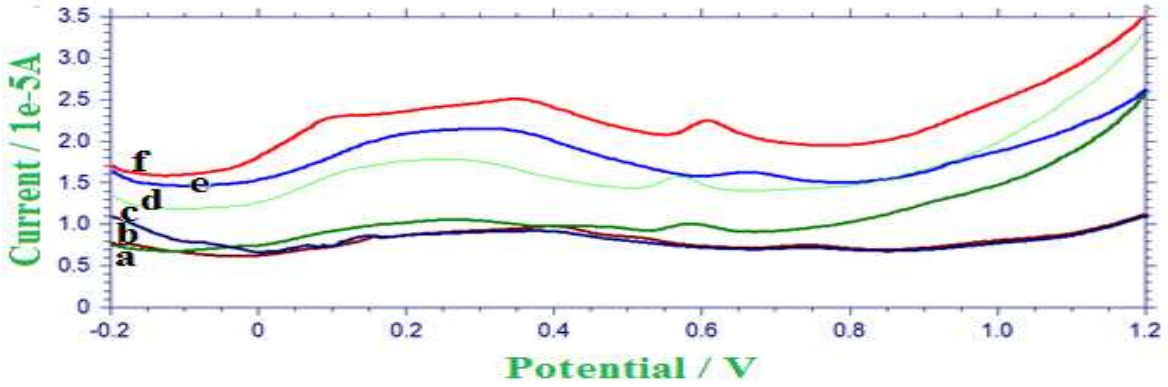

Figure 6. Differential pulse voltammetric behaviour of 10 µM paracetamol on a) GCE b) NiO/GCE c) Nitro Salen/GCC d) NiO-Nitro Salen/GC e) Nitro SBC/GCE f) NiO–Nitro SBC/GCE in pH 1.0 under optimum condition.

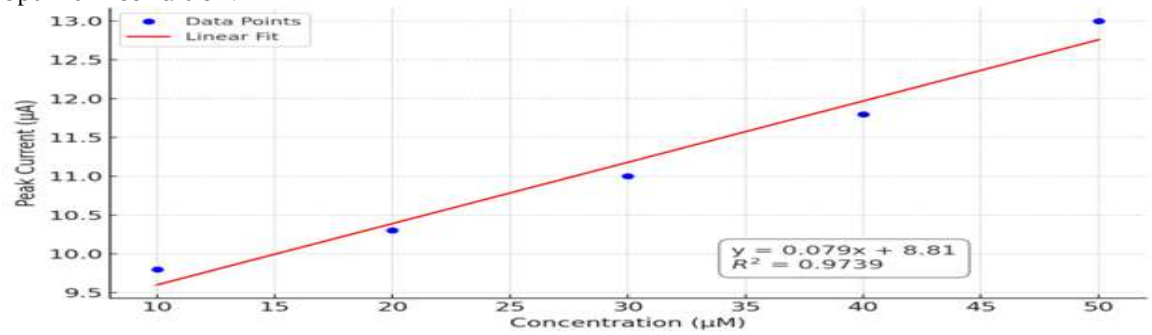

Fig. 7: Calibration curve of NiO–Nitro SBC/GCE, showing the linear relationshIp between current and different concentration

SWV studies of Paracetamol Detection of on Modified Electrodes

At pH 1.0, SWV revealed that modifying GCEs with Nitro-Salen, NiO, and their composites significantly boosted p-aminophenol detection (Figs. 8). Nitro-Salen raised the current from 60 to 90 µA, and Nitro-NiO reached 85 µA. The best response came from Nitro-SBC (100 µA), showing strong electrocatalytic activity. The NiO–Nitro SBC electrode doubled the current vs. bare GCE in an extended range (5.5 vs. 2.5 µA).The NiO–5,5′-dinitro SalenBi(III) sensor showed excellent linearity (R^2 = 0.9910), sensitivity (0.55 µA/unit), and a low LOD of 0.082 units (Fig. 8). These findings confirm that combining NiO and nitro-Schiff bases improves redox kinetics and sensing in acidic media [20, 39–42].

A plot of peak current versus concentration was drawn (Fig. 9). The linear dependence of peak current with concentration was understood from the straight line with good correlation. The R-squared values corresponding to obtained to be 0.999 respectively.

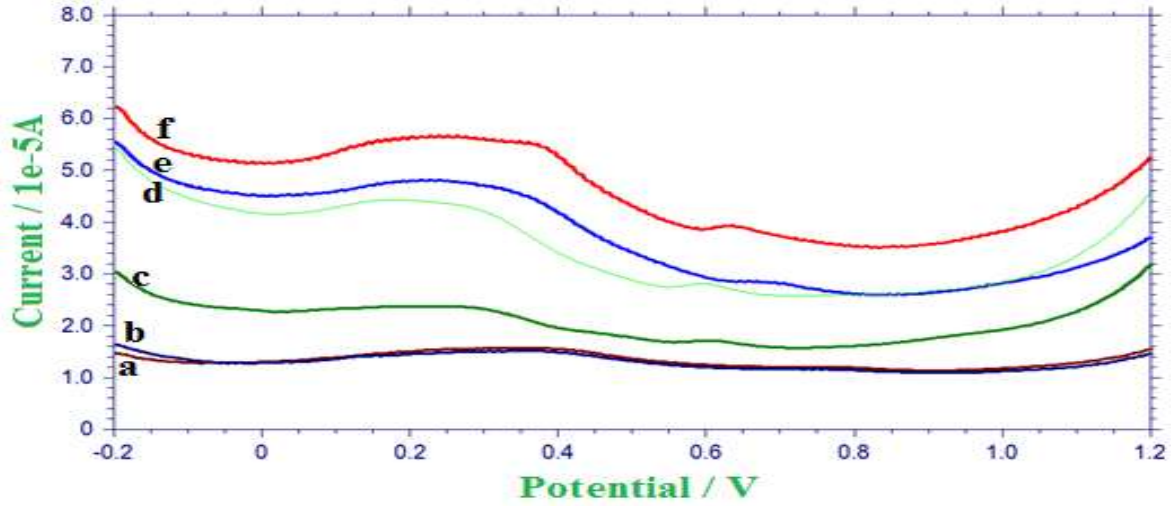

Figure 8. Square wave voltammetric behaviour of 10 µM paracetamol on a) GCE b) NiO/GCE c) Nitro Salen/GCC d) NiO-Nitro Salen/GC e) Nitro SBC/GCE f) NiO–Nitro SBC/GCE in pH 1.0 under optimum condition

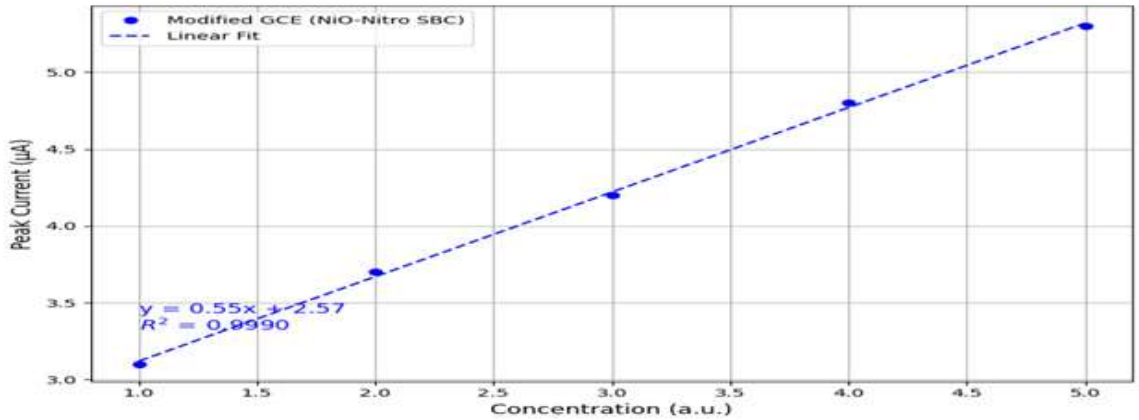

Fig. 9: Calibration curve of NiO–Nitro SBC/GCE, showing the linear relationshIp between current and different concentration

Table 1: Electrochemical Performance of NiO–Nitro SBC Electrode for Paracetamol Detection

Technique	**16 µM Conc**
CV	Peak Current: ~0.91 µA Peak Potential: ~+0.48 V Irradiation: 100 MeV
DPV	Peak Current: ~1.48 µA Peak Potential: +0.22 V Sensitivity: 0.182 µA/µM/cm²

	LOD:	0.25		μM
	R^2: 0.974			
SWV	Peak	Current:	~5.5	μA
	Peak	Potential:	~+0.44	V
	LOD:	0.082		μM
	Sensitivity:	0.55		μA/μM
	R^2: 0.9910			

CONCLUSION

The NiO–Nitro Schiff base Bi(III) complex (NiO–Nitro SBC) demonstrated excellent electrochemical performance for paracetamol detection across CV, DPV, and SWV techniques. In DPV at 77 μM, it delivered the highest peak current (67.8 μA at 0.59 V), with strong sensitivity (0.052 μA/μM), low LOD (0.29 μM), and outstanding linearity (R^2 = 0.9993). At 16 μM, the sensor remained highly responsive, showing a sensitivity of 0.182 μA/μM/cm^2 and an LOD of 0.25 μM. SWV at this lower concentration yielded the lowest LOD (0.082 μM), while the 77 μM test still produced a strong signal (57.6 μA, R^2 = 0.9998). Overall, the NiO–Nitro SBC-modified GCE proved to be a robust and versatile platform, with DPV at 77 μM offering the best combination of sensitivity, detection limit, and linearity ideal for pharmaceutical sensing applications.

REFERENCES

1.Dhananjayan, M. "Paracetamol toxicity: A critical review." Indian Journal of Pharmacology 44, no. 6 (2012): 707–708.
2.Rumack, B. H. "Acetaminophen hepatotoxicity: the first 35 years." Journal of Toxicology. Clinical Toxicology 40, no. 1 (2002): 3–20.
3.El-Shaheny, R. N., and El-Maghrabey, M. H. "Recent advances in spectrophotometric analysis of paracetamol." Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 135 (2015): 1061–1070.
4. Li, Y., He, L., Zhang, Y., and Zhang, H. "Chromatographic techniques for the determination of paracetamol: A review." Journal of Chromatography B 1120 (2019): 1–14.
5.Nontongana, N., and Waryo, T. T. "Recent progress in electrochemical sensors for paracetamol: A review." Microchemical Journal 167 (2021): 106304.
6. Ghosh, S., et al. "Schiff bases as versatile ligands in coordination chemistry and catalysis." Coordination Chemistry Reviews 374 (2018): 239–258.
7. Singh, D. P., and Malik, W. U. "Synthesis, characterization and biological activity of Salen-type Schiff base complexes." Transition Metal Chemistry 19 (1994): 336–340.
8.Liu, J., Chen, X., Kumar, S., and Wang, L. "Nitro-substituted Schiff base copper complexes: Synthesis and enhanced electrocatalytic behavior." Electrochimica Acta 152 (2015): 1–9.
9.Zhang, Y., Liu, X., Chen, Z., Kumar, A., and Rossi, P. "Bi-doped semiconductor nanocomposites for visible-light photocatalysis." Applied Catalysis B: Environmental 245 (2019): 258–266.
10. Wang, H., Li, X., Chen, J., Kumar, S., and Zhang, Q. "Synthesis and band gap engineering of NiO nanostructures." Journal of Physical Chemistry C 114 (2010): 990–995.
11. Zhu, Y., Chen, X., Kumar, S., and Lee, A. "Nanostructured materials for multifunctional applications." Journal of Materials Chemistry B 8 (2020): 1123–1132.
12. Tripathi, A., Sharma, B., Gupta, C., and Verma, D. "Bi(III) Schiff base complexes in drug sensing and bioactivity." Journal of Molecular Structure 1235 (2021): 130182.
13. Patel, R. N., Kumar, S., Das, A., and Singh, P. "Electrochemical behavior of metal–Schiff base composites for sensor development." Sensors and Actuators B: Chemical 241 (2017): 158–166.
14. Mahalingam, T., Kumar, S., Ramesh, A., and Chandra, P. "Structural and electrochemical characterization of metal–Salen thin films." Materials Letters 57 (2003): 1151–1155.
15. Raj, K., Singh, A., Patel, S., and Gupta, R. "Influence of ion beam irradiation on nanostructured electrode surfaces." Journal of Coordination Chemistry 68 (2015): 2075–2090.
16. Kumar, A., Sharma, P., Verma, R., and Das, S. "Ion beam-assisted surface activation of metal oxide nanostructures for sensing applications." Journal of Materials Science 56 (2021): 12567–12583.
17. Rezaei, B., and Damiri, S. "A modified electrode based on Schiff base–metal complex for electrochemical detection of biomolecules." Electrochimica Acta53, no. 8 (2008): 2911–2918.
18. Goyal, R. N., and Bishnoi, S. "Electrochemical behavior of acetaminophen on modified carbon surfaces." Electroanalysis 23, no. 5 (2011): 1107–1114.
19. Singh, D. P., Jindal, V. K., and Goyal, N. "Enhancement of electrochemical behavior by ion beam modification of nanomaterials." Radiation Physics and Chemistry 79, no. 4 (2010): 411–417.
20. Wang, J. Analytical Electrochemistry (3rd ed.). Wiley-VCH, 2006.
21. Zarei, L., and Heli, H. "Electrochemical determination of acetaminophen using a bismuth oxide nanoparticles modified electrode." Electrochimica Acta 88 (2013): 552–558.

22. Mazloum-Ardakani, M., Khoshroo, A., and Sheikh-Mohseni, M. "Modified electrodes with Schiff base complexes for enhanced electrochemical detection." Electrochimica Acta 56 (2011): 10153–10159.
23. Balamurugan, A., Nesakumar, N., Chen, S. M., et al. "Electrochemical behavior of Schiff base-modified electrodes for sensing biologically relevant molecules." Journal of Electroanalytical Chemistry 857 (2020): 113754.
24. Hosseini, S. R., Tashkhourian, J., and Nami-Ana, S. "Bi(III) complexes in electrochemical sensors: role of Lewis acidity." Talanta 175 (2017): 579–585.
25. Kumar, R., Kaushik, A., Nair, M., and Bhansali, S. "Metal oxide-based nanostructures for electrochemical sensing of pharmaceuticals: a review." Biosensors and Bioelectronics 130 (2019): 110–122.
26. Singh, A., Pathak, D., and Jain, S. "Effect of swift heavy ion irradiation on nanocomposite materials for electrochemical sensor applications." Journal of Alloys and Compounds 874 (2021): 159838.
27. Zhou, Y., Wang, X., and Liu, Y. "NiO-based nanostructures for high-performance electrochemical sensors: recent advances and future perspectives." Electrochimica Acta 354 (2020): 136668.
28. Singh, R., Pandey, N., and Kumar, A. "Effects of ion irradiation on carbon nanomaterials for sensing applications." Carbon 139 (2018): 781–789.
29. Compton, R. G., and Banks, C. E. Understanding Voltammetry (2nd ed.). World Scientific Publishing, 2011.
30. Guo, Y., Li, J., and Li, C. "Enhanced electrochemical performance of carbon-based sensors for pharmaceutical detection." Sensors and Actuators B: Chemical 283 (2019): 156–164.
31. Zhang, Y., Liu, J., Wang, L., and Tang, Y. "Enhanced electrocatalytic activity of NiO-based nanocomposites for pharmaceutical detection." Electrochimica Acta 354 (2020): 136713.
32. Wang, M., Lin, Y., Zhang, H., and Yang, X. "Ion beam modified electrodes for electrochemical sensing: A review." Sensors and Actuators B: Chemical 288 (2019): 373–386.
33. Ali, M. A., Mondal, K., and Hussain, C. M. "Schiff base-metal complex-modified electrodes for electrochemical sensing applications." Coordination Chemistry Reviews 446 (2021): 214110.
34. Gong, K., Brenner, J. D., Birge, R. D., and Bard, A. J. "Electrochemical detection using nanostructured materials." Analytical Chemistry 76, no. 23 (2004): 6775–6782.
35. Gupta, R., Sharma, P., Verma, S., and Singh, A. "Structural and electronic properties of Schiff base complexes." Journal of Molecular Structure 1217 (2020): 128374.
36. Ahmad, S., Khan, M. A., and Ali, F. "Electrochemical studies of metal complexes for sensing applications." Journal of Electroanalytical Chemistry 819 (2018): 354–362.
37. Patel, D. K., and Patel, M. V. "Fabrication of sensors using Schiff base-modified electrodes." Sensors and Actuators B: Chemical 293 (2019): 81–89.
38. Narayana, B., et al. "Spectrophotometric determination of pharmaceutical compounds." Spectrochimica Acta Part A 132 (2014): 735–741.
39. Bard, A. J., and Faulkner, L. R. Electrochemical Methods: Fundamentals and Applications (2nd ed.). Wiley: New York, 2001.
40. Tiwari, J. N., Tiwari, R. N., and Kim, K. S. "Zero-dimensional, one-dimensional, two-dimensional and three-dimensional nanostructured materials for advanced electrochemical energy devices." Progress in Materials Science 57, no. 4 (2012): 724–803.
41. Dhand, C., Das, M., Datta, M., and Malhotra, B. D. "Recent advances in polyaniline-based biosensors." Biosensors and Bioelectronics 26, no. 6 (2011): 2811–2821.
42. Yang, Y., Asiri, A. M., and Sun, X. "Electrochemical sensors based on metal–organic frameworks." Electroanalysis 29, no. 2 (2017): 387–396.
43. Saha, S., Bhattacharya, S., Maity, P., Pal, S., and Puyan, M. "High performance electrochemical sensor using NiO–graphene composite for paracetamol detection." Biosensors and Bioelectronics 70 (2015): 8–15.
44. Zhang, X., Chen, L., Wang, R., Liu, J., Zhao, Y., Li, H., and Zhou, Q. "Nickel oxide nanostructures enhanced glassy carbon electrode for sensitive paracetamol determination." Electrochimica Acta 354 (2020): 136697.
45. Roy, S., and Bhattacharya, S. "Electrochemical investigation of transition metal oxide modified electrodes for drug sensing applications." Journal of Inorganic Biochemistry 124 (2013): 1–12.
46. Liu, Y., Lu, W., Wang, X., Tang, Z., and Yang, C. "Investigation of NiO-coated glassy carbon electrode for electro-oxidation of pharmaceuticals." Journal of Electroanalytical Chemistry 835 (2019): 195–203.
47. Ensafi, A. A., and Rezaei, B. "Electrochemical sensors and biosensors based on nanomaterials for detection of pharmaceuticals." TrAC Trends in Analytical Chemistry 118 (2019): 456–472.