



Original scientific paper

Yellow DS5R polymeric film modified glassy carbon electrode for voltammetric assay of uric acid

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Abstract

This work focuses on the development of a novel and affordable yellow DS5R polymeric film on the glassy carbon electrode surface (Po-YDS5R/GCE) for the detection of uric acid (UAC). Po-YDS5R/GCE was effectively developed using the cyclic potentiodynamic polymerization technique. The sweep rate study revealed that the overall electrode reaction is diffusion-controlled. The linear range of 10-60 μM of UAC was used to compute the limit of quantification and limit of detection, and the results yielded 3.12 and 0.87 μM , respectively. The interference of dopamine on the electrooxidation of UAC was tested at the developed sensor. It was discovered that the modified sensor allows selective detection of UAC. These impressive outcomes showed that a simple and less costly Po-YDS5R/GCE sensor has the potential to make significant improvements over current electrochemical sensor technology.

Keywords

Reactive dye; electropolymerization; electroactive biomolecules; cyclic voltammetry

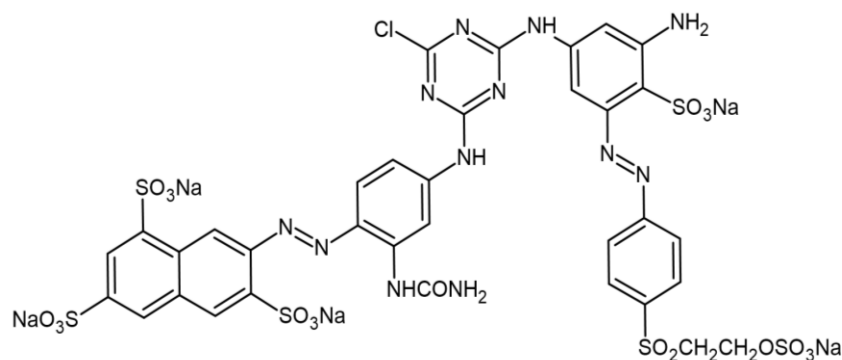
Introduction

Voltammetric methods are a crucial choice in drug analysis for detecting the active agent both qualitatively and quantitatively. The most effective voltammetric approaches offer great sensitivity, affordability, flexibility, time-saving, consistency, and an environmentally friendly nature [1-4]. These strategies have evolved in recent years, demonstrating that they constitute variable alternatives to other analytical methods.

Uric acid (UAC) is a by-product of the human body's purine nucleotide catabolism. The majority of UAC is dissolved in the blood and travels through the kidneys, which are excreted in urine [5-7]. UAC is an extremely biologically important molecule found in body fluids, forming the ions and salt referred to as urates and acid urates, including ammonium acid urate [8]. Massive content of blood UAC can induce hyperuricemia, which results in the development of UAC crystals and irreversible bone, joint, and tissue damage, as well as renal and heart illness. The crystals create urinary stones in the kidneys and gouty arthritis in the joints, which are the most prevalent and common associated disorders [9-13]. Several data revealed that increased blood UAC could be a substantial modifiable risk element [14]. As a response, UAC detection is crucial for reducing clinical consequences and preventing diseases that are linked to it. The frequent coexistence of UAC and dopamine (DA) body fluids in humans is well recognized. Due to their comparable oxidation potential, DA interferes the UAC detection [15,16]. Up to now, different modified electrodes have been designed to fix these issues.

In voltammetric methods, choosing an optional working electrode material is of the utmost importance. The glassy carbon electrode (GCE) is a practical conductive framework with a defined surface alignment, a large operating window, good mechanical properties, and ease of surface modification, all of which provide specific and selective results [17-20]. However, the naked GCE does not demonstrate substantial and selective separation of biomolecules in the presence of interferents [21-23]. Therefore, to get around this problem, electrochemical researchers have discovered electrode modification with unique conducting layers. There are a lot of prior literature articles on the modification of GCE by electropolymerization, producing materials like poly(neutral red), poly(4-amino-3-hydroxynaphthalene-1-sulfonic acid (AHNSA)), poly(aminobenzene sulphonic acid (ABSA)), poly(allura red), or poly(luminol) [24-28].

Here, we are concerned with the electropolymerization of Yellow DS5R (Scheme 1) polymeric film on the glassy carbon electrode surface by the potential cycling CV method. Such prepared Yellow DS5R polymeric film on the glassy carbon electrode surface (Po-YDS5R/GCE) was tested for the detection of UAC. By examining all outcomes of the CV technique, all experimental and voltammetric variables were checked. The objective of this work is to find a precise, ecologically safe, easy, and inexpensive approach for evaluating UAC.



Scheme 1. The structure of Yellow DS5R dye

Experimental

Chemicals, reagents and instruments

UAC, DA, NaOH, Na₂HPO₄, and NaH₂PO₄ were purchased from Nice Chemicals. Yellow DS5R was obtained from Astik Dyestuffs Pvt. Ltd. Gujarat. All analytical grade compounds were employed directly after delivery without any refining. 25 mM UAC was prepared in NaOH (0.1 M) solution, 25 mM DA in perchloric acid (0.1 M), and 25 mM Yellow DS5R in double distilled water. By mixing

appropriate amounts of Na_2HPO_4 and NaH_2PO_4 , a phosphate-borate buffer solution (PBS) of 0.2 M, pH 7.4 was made. Double-distilled water was used to prepare all solutions.

The electrochemical studies were conducted using voltammetric equipment of model CHI-660C (CHI-660 electrochemical workstation). The three-electrode cell system consisted of glassy carbon (GCE) and Po-YDS5R/GCE working electrodes, a saturated calomel reference electrode (SCE) and a platinum counter electrode. At all CV recordings, the initial potential scan was performed in a positive direction, denoted by arrows in all graphs.

Configuring GCE and Po-YDS5R/GCE

Alumina powder was used to polish the GCE before cleaning with de-ionized water. The GCE was successfully modified by electropolymerization from 1.0 mM aqueous solution of Yellow DS5R in 0.1 M NaOH as a supporting electrolyte. As illustrated in Figure 1a, the potential range was sustained between -0.6 and 1.6 V vs. SCE at a sweep rate (SR) of 100 mV/s for 10 cycles.

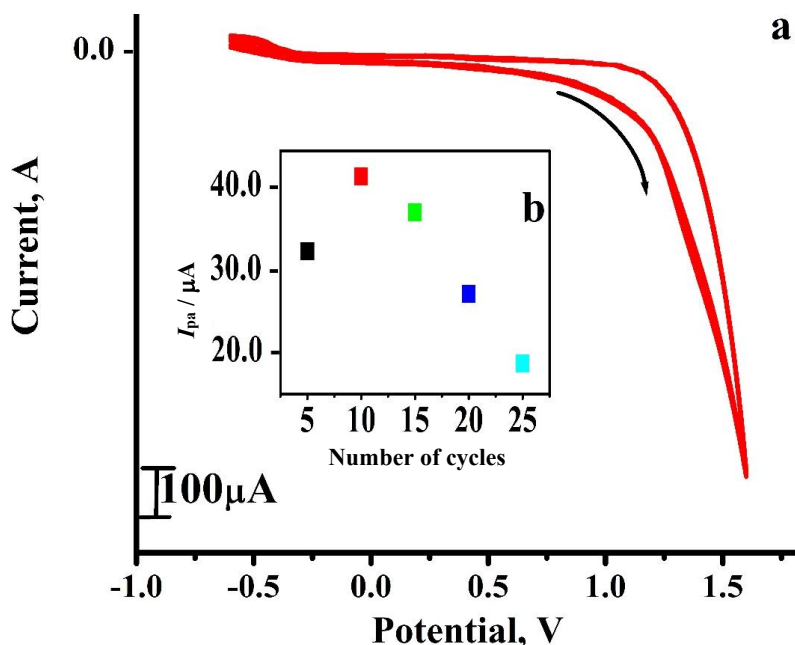


Figure 1. a) CVs of fabrication of Po-YDS5R/GCE from 1.0 mM Yellow DS5R in 0.1 M NaOH at 10 sweep cycles with sweep rate 100 mV/s; b) linearity plot of anodic peak current I_{pa} , vs. number of cycles

Results and discussion

Optimization and electrochemical characterization of Po-YDS5R/GCE

The electrode coating by the polymeric material affects the electrochemical reactivity of the modified electrode. It was simple to adjust the coating thickness during electropolymerization of 1.0 mM aqueous solution of Yellow DS5R in 0.1 M NaOH as supporting electrolyte on the GCE by increasing the number of sweep cycles from 5 to 25. The voltammogram was first gradually increased by increasing the sweep cycles due to the formation and development of the electroactive Yellow DS5R layer on the GCE surface. After a few further sweeps, however, the electrocatalytic ability of the Po-YDS5R/GCE decreased as the polymer film thickness increased, preventing the electron transfer process (inset Figure 1b) [29]. As a result, it was determined that 10 sweep cycles are ideal for obtaining the potent electrocatalytic response of the dye polymer layer.

Figure 2 demonstrates CVs for the $\text{K}_4[\text{Fe}(\text{CN})_6]$ system in 1 M KCl (supporting electrolyte) at GCE (line a) and Po-YDS5R/GCE (line b) with a sweep rate of 100 mV/s. The tiny peak current was detected on the GCE, which is hugely enhanced for the Po-YDS5R/GCE, indicating a significant

increase in the rate of electron transfer [30]. The electroactive area of the GCE and Po-YDS5R/GCE was computed using Randles-Ševčík equation (1) [31]:

$$I_p = 2.69 \times 10^5 n^{3/2} D_0^{1/2} \nu^{1/2} A C \quad (1)$$

where I_p / A is peak current, A / cm^2 is the active surface area of the electrode, n denotes the number of electrons transferred, $D / \text{cm}^2 \text{ s}^{-1}$ is the diffusion coefficient of electroactive species, $\nu / \text{V s}^{-1}$ signifies the sweep rate and $C / \text{mol cm}^{-3}$ designates the concentration of electroactive species.

Using Equation (1) and Figure 2, the active area was found to be 0.029 cm^2 for GCE and 0.039 cm^2 for Po-YDS5R/GCE, respectively.

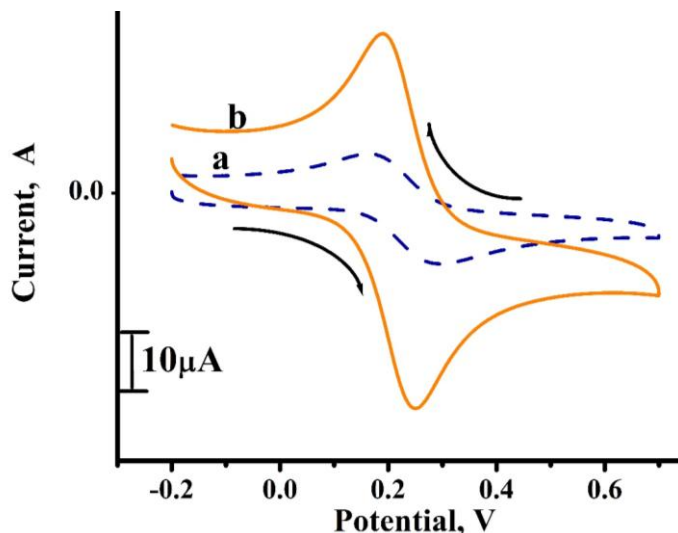


Figure 2. CVs at 100 mV/s of 1 mM $K_4[Fe(CN)_6]$ in 0.1 M KCl at GCE (line a) and Po-YDS5R/GCE (line b)

Voltammetric analysis of UAC at Po-YDS5R/GCE

Figure 3 depicts the CVs for electrochemical oxidation of 0.1 mM UAC at GCE (line a) and Po-YDS5R/GCE (line b) in PBS (0.2 M, pH 7.4) with SR of 100 mV/s. The UAC displays a lower current at 0.280 V with a broad peak at GCE, which suggests slow electron transfer kinetics because of fouling of the electrode surface as a result of the oxidation process. Po-YDS5R/GCE, however, shows a higher peak current at 0.266 V and a minimal shift in the potential. The rise in peak current is due to the fast electron transfer kinetics of UAC at the Po-YDS5R/GCE surface.

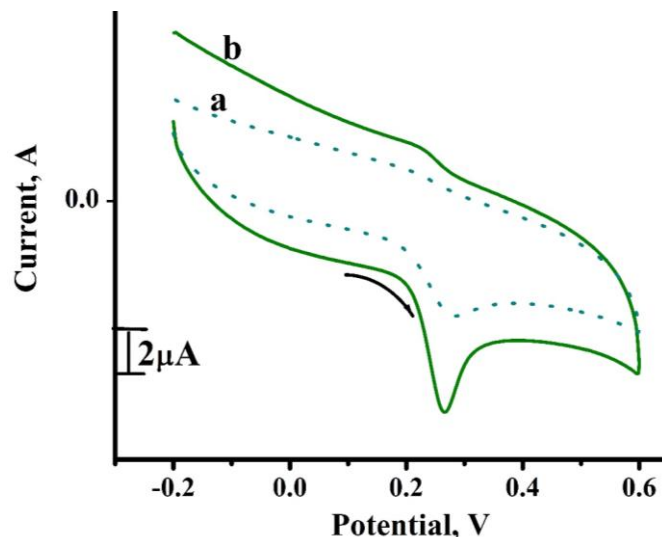


Figure 3. CVs at 100 mV/s of 0.1 mM UAC in PBS (0.2 M, pH 7.4) at GCE (line a) and Po-YDS5R/GCE (line b)

Sweep rate and pH impacts

Figure 4a details the CVs results for 0.1 mM UAC in PBS (0.2 M, pH 7.4) on Po-YDS5R/GCE at varied sweep rates from 50-500 mV/s. The raised electrode oxidation peak current and small positive shift in the oxidation potential is noticed when raising the sweep rate 50-500 mV/s, which agrees with Randles-Ševčík's relationship (equation 1). Figures 4b and 4c show good linearity of plots presenting anodic peak current (I_{pa}) vs. sweep rate and I_{pa} vs. square root of sweep rate. The procured outcomes were fitted to the following linear relations: $I_{pa} = 47.0 \nu + 5.70$ ($R^2 = 0.996$) and $I_{pa} = 11.4 \nu^{1/2} + 2.07$ ($R^2 = 0.996$), which reveals that the oxidation reaction of UAC at Po-YDS5R/GCE surface is diffusion controlled [32].

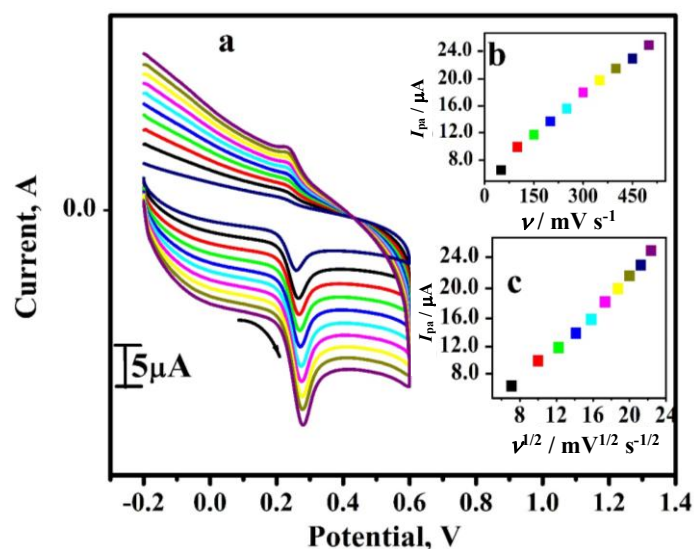


Figure 4. a) CVs of 0.1 mM UAC in PBS (0.2 M, pH 7.4) at Po-YDS5R/GCE at varied sweep rate of 50 to 500 mV/s; b) plot of I_{pa} vs. sweep rate; c) plot of I_{pa} vs. square root of sweep rate

For pH optimization, buffer solutions containing 0.1 mM UAC were made at a pH of 6.2 to 7.8. Figure 5a shows the CV responses at varied pH, clarifying that all peak potentials (E_{pa}) are shifted towards negative potential as pH increases, according to the Nernst formula [34]. The linearity graph of E_{pa} vs. pH (Figure 5b) was fitted with the linear regression equation, $E_{pa} = -0.071 \text{ pH} + 0.79$ ($R^2 = 0.999$), which confirms that the same quantity of protons and electrons are participating in the process (Scheme 2) [33,34].

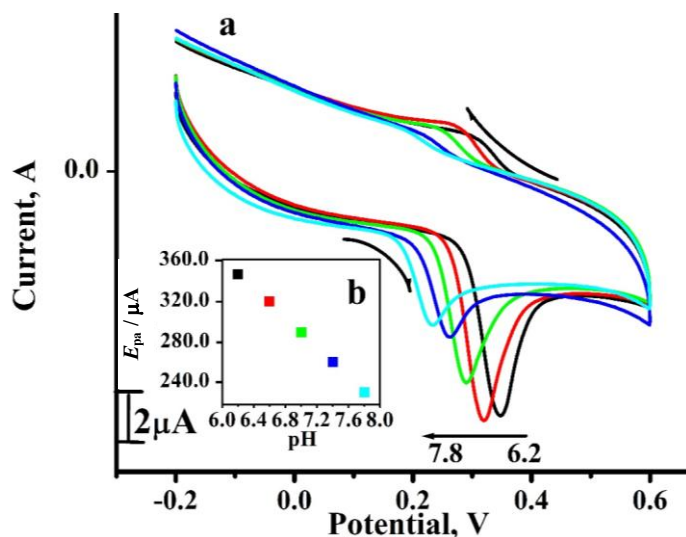
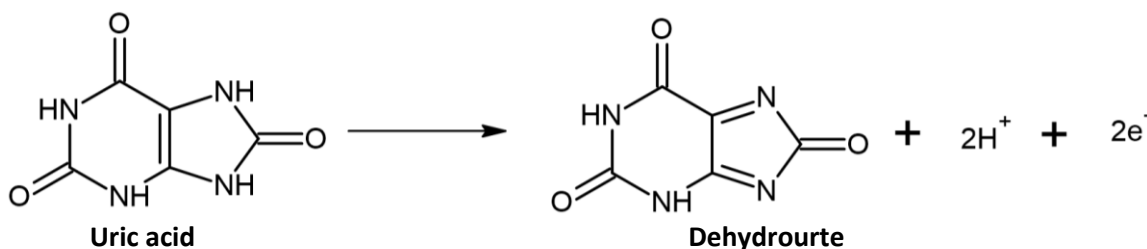


Figure 5. a) CVs responses for 0.1 mM UAC at Po-YDS5R/GCE in 0.2 M PBS of different pH (6.2 to 7.8); b) plot of E_{pa} vs. pH



Scheme 2. Electrooxidation of UAC

Assay of UAC at varied concentration

Po-YDS5R/GCE was employed to assay UAC in a range of different UAC concentrations (10 to 60 mM) in PBS buffer (0.2 M, pH 7.4) by CV method. As seen in Figure 6a, CV curves gradually grew as the UAC concentration increased. When I_{pa} was plotted vs. UAC concentrations (Figure 6b), the regression expression $I_{pa} / A = 3.18 C / M + 4.09$ ($R^2 = 0.999$) shows good linearity. The limit of detection and limit of quantification were detected to be 0.87 and 3.12 μM . The Po-YDS5R/GCE's achievement has been compared to others previously reported and depicted in Table 1.

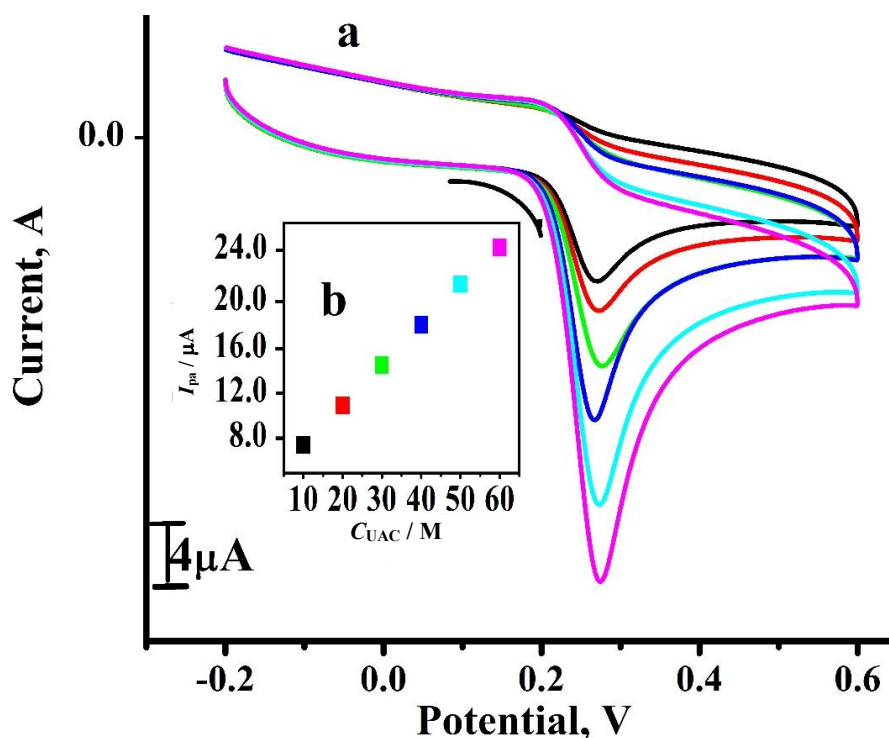


Figure 6. a) CVs at 100 mV/s of varied UAC concentrations (10 to 60 μM) at Po-YDS5R in 0.2 M PBS, pH 7.4; b) plot of I_{pa} , vs. UAC concentration

Table 1. Comparison of LOD values for UAC at Po-YDS5R/GCE with previous literature reports

Electrode	LOD of UAC, μM	Method	References
Poly (o-aminophenol)-MCPE	3.0	CV	[35]
GA/GO/MCPE	4.18	CV	[36]
Pd/RGO/GCE	1.6	DPV	[37]
Glu/GCE	1.1	DPV	[38]
Au-Cu ₂ O/rGO/GCE	6.5	DPV	[39]
Pdop@GR/MWCNTs	15.0	DPV	[40]
PG/GCE	4.82	CV	[41]
Po-YDS5R	0.87	CV	Present paper

GA: glibenclamide; GO: graphene oxide; RGO and rGO: reduced graphene oxide; Glu: glutamic acid; Pdop@GR: polydopamine coated graphene PG: pristine graphene

Simultaneous study of UAC and DA

Figure 7 shows CVs of 0.1 mM UAC and 0.1 mM DA mixture in PBS (0.2 M, pH 7.4) at a sweep rate of 100 mV/s at GCE (line a) and Po-YDS5R/GCE (line b). At GCE, the obtained CV curve was broad and slightly sensitive to the oxidation of the analytes UAC and DA. The use of Po-YDS5R/GCE results in two discrete oxidation peaks at E of 0.299 and 0.128 V for UAC and DA, respectively, with a ramp-up in peak current. The electrolytic peak-to-peak splitting between UAC and DA was 0.171 V. These findings imply that UAC can be selectively assayed in the vicinity of DA at Po-YDS5R/GCE.

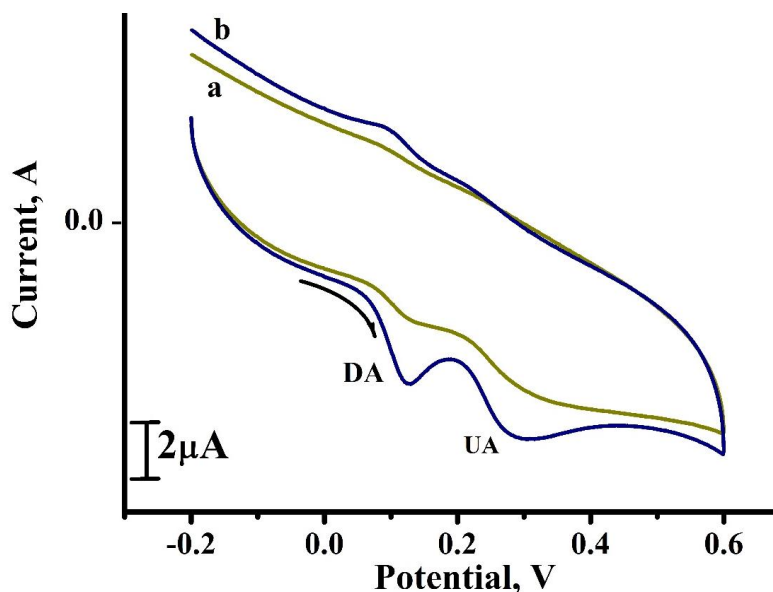


Figure 7. CVs at 100 mV/s of simultaneous analysis of 0.1 mM UAC and 0.1 mM DA in PBS (0.2 M, pH 7.4) at GCE (line a) and Po-YDS5R/GCE (line b)

Interference analysis

Interference analysis was done by combining UAC and DA in PBS (0.2 M, pH 7.4) at Po-YDS5R/GCE using the differential pulse voltammetry (DPV) technique. Figure 8 shows DPV responses of DA by boosting its concentration (10 - 60 μ M) while holding the UAC concentration (10 μ M) constant. It can be noticed in Figure 8 that only I_{pa} of DA increased significantly with increasing DA concentration.

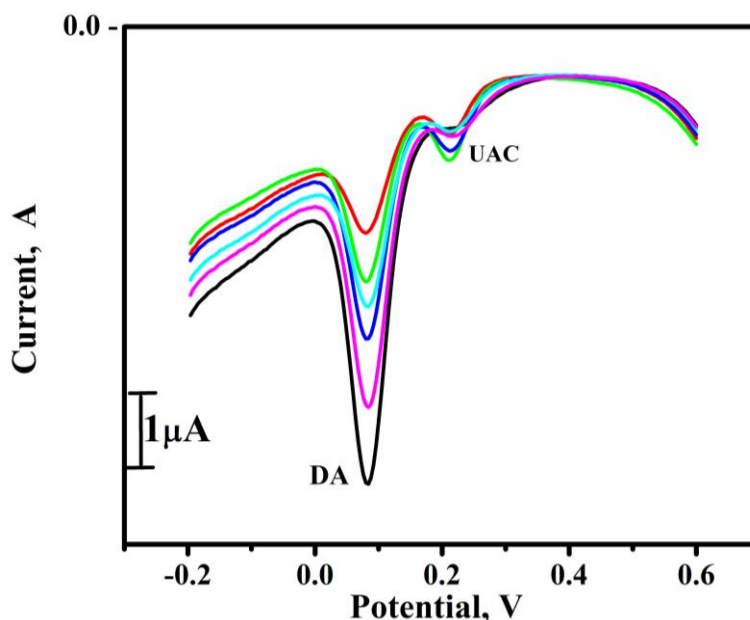


Figure 8. DPV responses at 100 mV/s for varied concentrations of DA (10-60 μ M) in the presence of UAC (10 μ M) in PBS (0.2 M, pH 7.4) at Po-YDS5R/GCE

On the other side, Figure 9 depicts the DPV responses of Po-YDS5R/GCE when the concentration of UAC was increased (10 to 70 μM) while DA concentration (10 μM) kept constant. Figure 9 clearly shows the enhancement of only I_{pa} of UAC in that case. The outcomes suggest that interference of DA did not affect the electrolytic activity of UAC. Therefore, the forecast method and Po-YDS5R/GCE are substantially free of interferences.

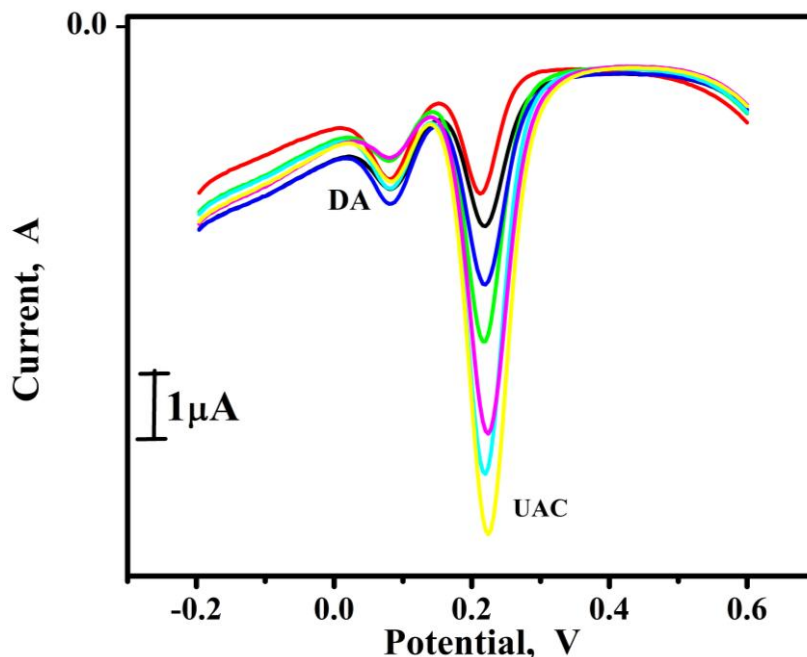


Figure 9. DPV responses at 100 mV/s for varied concentration of UAC (10-70 μM) GCE in presence of DA (10 μM) in PBS (0.2 M, pH 7.4) at Po-YDS5R/GCE

Stability and reproducibility

The stability of Po-YDS5R/GCE was tested by sweeping it for 20 cycles for 1 mM $\text{K}_4[\text{Fe}(\text{CN})_6]$ (data not shown). The I_{pa} signals recovered at about 97.6 % of the initial value. Because of these results, Po-YDS5R/GCE has a lifespan and exceptional stability. The reproducibility of Po-YDS5R/GCE was examined after 5 days when kept at room temperature. The I_{pa} signal recollected 97.9 % of the earlier start current response and did not influence the peak potential.

Analytical application

To verify the analytical applicability of Po-YDS5R/GCE for UAC assay, some UAC concentrations were added to the human urine sample. The recovery values of UAC in the range of 96.2 \pm 4 % to 98.1 \pm 2 % for UAC concentrations in the range of 10 to 30 μM were projected using the standard addition method (Table 2). The values obtained were revealed to be acceptable.

Table 2. Determination of UAC in human urine samples

Added	UAC concentration, μM		Recovery, %
	Added	Estimated	
10		9.8	98.1 \pm 2
20		19.6	96.2 \pm 4
30		29.2	97.4 \pm 3

Conclusion

We have proposed a simple technique of electropolymerization for producing a reactive dye polymer, Po-YDS5R film, at GCE *via* the CV method. The resulting Po-YDS5R/GCE was employed for

the assay of UAC. The key attractive properties of Po-YDS5R/GCE are the swift modification process, increased sensitivity, high selectivity, low cost, and sustainability. The LOD of 0.87 μM was achieved at the developed sensor with the merit of interference-free determination. The fabricated Po-YDS5R/GCE delivered good recovery in the human urine sample. As a result, the Po-YDS5R/GCE sensor will hold high potential in biosensors, where it can be employed to determine other electroactive biomolecules.

References

- [1] A. Cetinkaya, B. D. Topal, E. B. Atici, S. A. Ozkan, Simple and highly sensitive assay of axitinib in dosage form and biological samples and its electrochemical behavior on the boron-doped diamond and glassy carbon electrodes, *Electrochimica Acta* **386** (2021) 138443. <https://doi.org/10.1016/j.electacta.2021.138443>
- [2] E. Mehmeti, D. M. Stanković, A. Ortner, J. Zavašnik, K. Kalcher, Highly Selective Electrochemical Determination of Phlorizin Using Square Wave Voltammetry at a Boron-Doped Diamond Electrode, *Food Analytical Methods* **10** (2017) 3747-3752. <https://doi.org/10.1007/s12161-017-0935-x>
- [3] A. Savk, B. Özdil, B. Demirkan, M. S. Nas, M. H. Calimli, M. H. Alma, Inamuddin, A. M. Asiri, F. Şen, Multiwalled carbon nanotube-based nanosensor for ultrasensitive detection of uric acid, dopamine, and ascorbic acid, *Materials Science and Engineering C* **99** (2019) 248-254. <https://doi.org/10.1016/j.msec.2019.01.113>
- [4] N. T. V. Hoan, N. N. Minh, N. T. H. Trang, L. T. T. Thuy, C. Van Hoang, T. X. Mau, H. X. A. Vu, P. T. K. Thu, N. H. Phong, D.Q. Khieu, Simultaneous Voltammetric Determination of Uric Acid, Xanthine, and Hypoxanthine Using CoFe_2O_4 /Reduced Graphene Oxide-Modified Electrode, *Journal of Nanomaterials* **2020** (2020) 9797509. <https://doi.org/10.1155/2020/9797509>
- [5] K. Shi, K. K. Shiu, Determination of uric acid at electrochemically activated glassy carbon electrode, *Electroanalysis* **13** (2001) 1319-1325. [https://doi.org/10.1002/1521-4109\(200111\)13:16<1319::AID-ELAN1319>3.0.CO;2-C](https://doi.org/10.1002/1521-4109(200111)13:16<1319::AID-ELAN1319>3.0.CO;2-C)
- [6] H. Kaur, B. Halliwell, Action of biologically-relevant oxidizing species upon uric acid. Identification of uric acid oxidation products, *Chemico-Biological Interactions* **73** (1990) 235-247. [https://doi.org/10.1016/0009-2797\(90\)90006-9](https://doi.org/10.1016/0009-2797(90)90006-9)
- [7] D. Ortiz-Aguayo, M. Bonet-San-Emeterio, M. D. Valle, Simultaneous voltammetric determination of acetaminophen, ascorbic acid and uric acid by use of integrated array of screen-printed electrodes and chemometric tools, *Sensors* **19** (2019) 3286. <https://doi.org/10.3390/s19153286>
- [8] C. Zhao, J. Xiao, T. Liu, H. Shi, Q. Li, Z. Ruan, Electrochemical Sensor Based on Glass Carbon Electrode Modified with Graphene Quantum Dots (GQDs) for Detection of Uric Acid, *International Journal of Electrochemical Science* **17** (2022) 22096. <https://doi.org/10.20964/2022.09.17>
- [9] Y. J. Chang, M. C. Lee, Y. C. Chien, Quantitative determination of uric acid using paper-based biosensor modified with graphene oxide and 5-amino-1,3,4-thiadiazole-2-thiol, *SLAS Technology* **27** (2022) 54-62. <https://doi.org/10.1016/j.slast.2021.10.010>
- [10] U. Chandra, B. E. K. Swamy, O. Gilbert, B. S. Sherigara, Poly (Naphthol Green B) film based sensor for resolution of dopamine in the presence of uric acid: A voltammetric study, *Analytical Methods* **3** (2011) 2068-2072. <https://doi.org/10.1039/c1ay05179b>
- [11] T. Dhanasekaran, R. Manigandan, A. Padmanaban, R. Suresh, K. Giribabu, V. Narayanan, Fabrication of Ag@Co-Al Layered Double Hydroxides Reinforced poly(o-phenylenediamine) Nanohybrid for Efficient Electrochemical Detection of 4-Nitrophenol, 2,4-Dinitrophenol and Uric acid at Nano Molar Level, *Scientific Reports* **9** (2019) 13250. <https://doi.org/10.1038/s41598-019-49595-y>

- [12] H. Vidya, B. E. K. Swamy, S. C. Sharma, G. K. Jayaprakash, S. A. Hariprasad, Effect of graphite oxide and exfoliated graphite oxide as a modifier for the voltammetric determination of dopamine in presence of uric acid and folic acid, *Scientific Reports* **11** (2021) 24040. <https://doi.org/10.1038/s41598-021-01328-w>
- [13] E. Popa, Y. Kubota, D. A. Tryk, A. Fujishima, Selective Voltammetric and Amperometric Detection of Uric Acid with Oxidized Diamond Film Electrodes, *Analytical Chemistry* **72** (2000) 1724-1727. <https://doi.org/10.1021/ac990862m>
- [14] D. I. Feig, M. Mazzali, D. H. Kang, T. Nakagawa, K. Price, J. Kannelis, R. J. Johnson, Serum uric acid: A risk factor and a target for treatment?, *Journal of the American Society of Nephrology* **17** (2006) 69-73. <https://doi.org/10.1681/ASN.2005121331>
- [15] S. B Tanuja, B. E. K. Swamy and K. V. Pai, Electrochemical Response of Dopamine in Presence of Uric Acid at Pregabalin Modified Carbon Paste Electrode: A Cyclic Voltammetric Study, *Journal of Analytical and Bioanalytical Techniques* **7** (2016) 297. <https://doi.org/10.4172/2155-9872.1000297>
- [16] Y. Yang, M. Li, Z. Zhu, A novel electrochemical sensor based on carbon nanotubes array for selective detection of dopamine or uric acid, *Talanta* **201** (2019) 295-300. <https://doi.org/10.1016/j.talanta.2019.03.096>
- [17] K. S Chadchan, A. B Teradale, P. S Ganesh, S. N Das, Simultaneous sensing of mesalazine and folic acid at poly (murexide) modified glassy carbon electrode surface, *Materials Chemistry and Physics* **290** (2022) 126538. <https://doi.org/10.1016/j.matchemphys.2022.126538>
- [18] S. A. Kumar, C. F. Tang, S. M. Chen, Electroanalytical determination of acetaminophen using nano-TiO₂/polymer coated electrode in the presence of dopamine, *Talanta* **76** (2008) 997-1005. <https://doi.org/10.1016/j.talanta.2008.04.057>
- [19] M. Ławrywianiec, J. Smajdor, B. Paczosa-Bator, R. Piech, Application of a glassy carbon electrode modified with carbon black nanoparticles for highly sensitive voltammetric determination of quetiapine, *Analytical Methods* **9** (2017) 6662-6668. <https://doi.org/10.1039/c7ay02140b>
- [20] T. Kokab, A. Shah, J. Nisar, A. M. Khan, S. B. Khan, A. H. Shah, Tripeptide Derivative-Modified Glassy Carbon Electrode: A Novel Electrochemical Sensor for Sensitive and Selective Detection of Cd²⁺ Ions, *ACS Omega* **5** (2020) 10123-10132. <https://doi.org/10.1021/acsomega.0c00760>
- [21] V. Mani, M. Govindasamy, S. M. Chen, R. Karthik, S. T. Huang, Determination of dopamine using a glassy carbon electrode modified with a graphene and carbon nanotube hybrid decorated with molybdenum disulfide flowers, *Microchimica Acta* **183** (2016) 2267-2275. <https://doi.org/10.1007/s00604-016-1864-x>
- [22] S. B. Khoo, F. Chen, Studies of sol-gel ceramic film incorporating methylene blue on glassy carbon: An electrocatalytic system for the simultaneous determination of ascorbic and uric acids, *Analytical Chemistry* **74** (2002) 5734-5741. <https://doi.org/10.1021/ac0255882>
- [23] O. E. Fayemi, A. S. Adekunle, B. E. K. Swamy, E. E. Ebenso, Electrochemical sensor for the detection of dopamine in real samples using polyaniline/NiO, ZnO, and Fe₃O₄ nanocomposites on glassy carbon electrode, *Journal of Electroanalytical Chemistry* **818** (2018) 236-249. <https://doi.org/10.1016/j.jelechem.2018.02.027>
- [24] D. G. Dilgin, D. Gligor, H. I. Gökçel, Z. Dursun, Y. Dilgin, Glassy carbon electrode modified with poly-Neutral Red for photoelectrocatalytic oxidation of NADH, *Microchimica Acta* **173** (2011) 469-476. <https://doi.org/10.1007/s00604-011-0582-7>
- [25] M. Amare, S. Admassie, Potentiodynamic fabrication and characterization of poly(4-amino-3-hydroxynaphthalene sulfonic acid) modified glassy carbon electrode, *Journal of Materials Research and Technology* **9** (2020) 11484-11496. <https://doi.org/10.1016/j.jmrt.2020.08.002>

- [26] A. M. Abdel-Aziz, H. H. Hassan, I. H. A. Badr, Glassy Carbon Electrode Electromodification in the Presence of Organic Monomers: Electropolymerization versus Activation, *Analytical Chemistry* **92** (2020) 7947-7954. <https://doi.org/10.1021/acs.analchem.0c01337>
- [27] P. S. Ganesh, G. Shimoga, S. H. Lee, S. Y. Kim, E. E. Ebenso, Simultaneous electrochemical sensing of dihydroxy benzene isomers at cost-effective allura red polymeric film modified glassy carbon electrode, *Journal of Analytical Science and Technology* **12** (2021) 20. <https://doi.org/10.1186/s40543-021-00270-w>
- [28] R. Jerome, A. K. Sundramoorthy, Hydrothermal Synthesis of Boron Nitride Quantum Dots/Poly (Luminol) Nanocomposite for Selective Detection of Ascorbic Acid, *Journal of The Electrochemical Society* **166** (2019) B3017-B3024. <https://doi.org/10.1149/2.0041909jes>
- [29] N. Hareesha, J. G. Manjunatha, Electro-oxidation of formoterol fumarate on the surface of novel poly(thiazole yellow-G) layered multi-walled carbon nanotube paste electrode, *Scientific Reports* **11** (2021) 12797. <https://doi.org/10.1038/s41598-021-92099-x>
- [30] J. K. Shashikumara, B. Kalaburgi, B. E. K. Swamy, H. Nagabhushana, S. C. Sharma, P. Lalitha, Effect of RGO-Y2O3 and RGO-Y2O3:Cr³⁺ nanocomposite sensor for dopamine, *Scientific Reports* **11** (2021) 9372. <https://doi.org/10.1038/s41598-021-87749-z>
- [31] M. Amare, S. Admassie, Potentiodynamic fabrication and characterization of poly(4-amino-3-hydroxynaphthalene sulfonic acid) modified glassy carbon electrode, *Journal of Materials Research and Technology* **9** (2020) 11484-11496. <https://doi.org/10.1016/j.jmrt.2020.08.002>
- [32] N. Hareesha, J. G. Manjunatha, Fast and enhanced electrochemical sensing of dopamine at cost-effective poly(DL-phenylalanine) based graphite electrode, *Journal of Electroanalytical Chemistry* **878** (2020) 114533. <https://doi.org/10.1016/j.jelechem.2020.114533>
- [33] M. M. Charithra, J. G. G. Manjunatha, C. Raril, Surfactant modified graphite paste electrode as an electrochemical sensor for the enhanced voltammetric detection of estriol with dopamine and uric acid, *Advanced Pharmaceutical Bulletin* **10** (2020) 247-253. <https://doi.org/10.34172/apb.2020.029>
- [34] J. G. Manjunatha, Surfactant modified carbon nanotube paste electrode for the sensitive determination of mitoxantrone anticancer drug, *Journal of Electrochemical Science and Engineering* **7** (2017) 39-49. <https://doi.org/10.5599/jese.368>
- [35] E. Miland, A. Mirandaordieres, P. Tunonblanco, M. Smyth, C. Fagain, Poly(-aminophenol)-modified bienzyme carbon paste electrode for the detection of uric acid, *Talanta* **43** (1996) 785-796. [https://doi.org/10.1016/0039-9140\(95\)01825-5](https://doi.org/10.1016/0039-9140(95)01825-5)
- [36] L.S. Manjunatha, B.E.K. Swamy, Carbon paste-glibanclamide-graphene oxide modified electrode analysis for dopamine, *Chemical Data Collections* **53** (2024) 101157. <https://doi.org/10.1016/j.cdc.2024.101157>
- [37] J. Wang, B. Yang, J. Zhong, B. Yan, K. Zhang, C. Zhai, Y. Shiraishi, Y. Du, P. Yang, Dopamine and uric acid electrochemical sensor based on a glassy carbon electrode modified with cubic Pd and reduced graphene oxide nanocomposite, *Journal of Colloid and Interface Science* **497** (2017) 172-180. <https://doi.org/10.1016/j.jcis.2017.03.011>
- [38] L. Zhang, X. Lin, Covalent modification of glassy carbon electrode with glutamic acid for simultaneous determination of uric acid and ascorbic acid, *Analyst* **126** (2001) 367-370. <https://doi.org/10.1039/b009415n>
- [39] T. K. Aparna, R. Sivasubramanian, M. A. Dar, One-pot synthesis of Au-Cu₂O/rGOnanocomposite based electrochemical sensor for selective and simultaneous detection of dopamine and uric acid, *Journal of Alloys and Compounds* **741** (2018) 1130-1141. <https://doi.org/10.1016/j.jallcom.2018.01.205>
- [40] C. Wang, J. Li, K. Shi, Q. Wang, X. Zhao, Z. Xiong, X. Zou, Y. Wang, Graphene coated by polydopamine/multi-walled carbon nanotubes modified electrode for highly selective

detection of dopamine and uric acid in the presence of ascorbic acid, *Journal of Electroanalytical Chemistry* **770** (2016) 56-61. <https://doi.org/10.1016/j.jelechem.2016.03.038>

- [41] S. Qi, B. Zhao, H. Tang, X. Jiang, Determination of ascorbic acid, dopamine, and uric acid by a novel electrochemical sensor based on pristine graphene, *Electrochimica Acta C* **161** (2015) 395-402. <https://doi.org/10.1016/J.ELECTACTA.2015.02.116>