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Electrochemical determination of propranolol by using modified screen-printed electrodes

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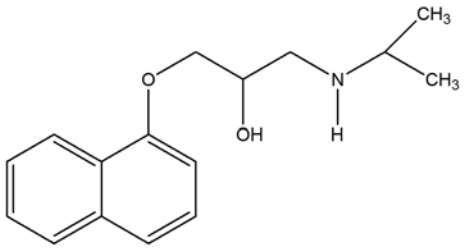
A simple and sensitive method for the determination of propranolol using modified screen printed carbon electrode (MSPCE) has been presented. The electrochemical measurements of propranolol are studied using differential pulse voltammetry (DPV), cyclic voltammetry (CV) and chronoamperometry (CHA). The MSPCE exhibite excellent catalytic activity towards electrochemical oxidation of propranolol in phosphate buffer solution (PBS) of *p*H 7.0. The MSPCE facilitate the determination of propranolol in the concentration range 0.4 – 200.0 μM and a detection limit and sensitivity of 80 nM and 0.052 μA/μM has been achieved.

Keywords: Propranolol determination, Magnetic core shell nanoparticles, Screen-printed carbon electrode, Voltammetry

Propranolol hydrochloride (PRO, DL-1-(isopropylamino)-3-(1-naphthyloxy)-2-propanol hydrochloride, shown in Scheme 1) is a non-selective b-adrenergic receptor (b-blocker)[1,2] and affect the heart and circulation system[3]. The World Health Organization (WHO) has put PRO on the list of essential medicines[4]. PRO most widely used to treat wide range of different diseases and disorders such as cardiac dysrhythmia, high blood pressure, pheochromocytoma (a neuroendocrine tumor), sinus tachycardia, angina pectoris (sensation of chest pain), heart attack (myocardial infarction), abnormal labor, migraine, essential tremor, performance anxiety, hyperthyroidism, capillary hemangioma and fainting[5,6]. The overdose of PRO causes side effects such as dizziness, fainting, bradycardia (abnormally slow heart action) and uneven heartbeats[6]. In some sports, the World Anti-doping Agency (WADA) declared it as a prohibited drug for athletes [7]. Therefore, the determination of PRO in the pharmaceutical, clinical and food samples has drawn significant attention and a reliable and sensitive detection method is highly expected.

Several methods for the analytical determination of PRO in pharmaceutical formulations have been reported in the literature, by colorimetry[8], spectrophotometry[9], atomic absorption spectrometry[10], spectrofluorometry[11], diffuse reflectance spectroscopy[12], chromatography[5,6], titrimetry[13], and chemiluminescence combined with flow injection analysis[3]. However, these methods suffer from some disadvantages, such as high cost, long analysis time and requirement for sample pretreatment; on the other hand, some methods present low sensitivity and selectivity, which make them unsuitable for routine analysis[14].

Electrochemistry is the most suitable technique for investigating the redox properties of drugs. Data obtained from electrochemical techniques are often correlated with molecular structures and pharmacological activities of drugs. In addition, electrochemistry has a well-defined role in drug analysis, and various electroanalytical methods have attracted more attentions because of quick response, high sensitivity, abilities to miniaturization, and analysis of drugs even in samples containing



Scheme 1 — Structure of propranolol

complex matrix. Most favorable property for modern electroanalytical methods is that they are not affected by interferences. Hence, sample can be prepared simply by dissolution of pharmaceutical ingredient in a suitable solvent. Whereas, the sensitivity of previously described methods was limited therefore, it is essential to develop a simple and rapid method for determination of these drugs for routine analysis[15].

The development of screen-printed electrodes (SPEs) has become a major revolution in the construction of electrochemical sensors/ biosensors[16]. The SPEs have been designed especially for miniaturization of electrochemical analytical systems[17]. SPEs are highly-versatile, easy to use, cost-effective analytical tools and also suitable to miniaturization[18]. Furthermore, a SPE avoids the cleaning process, unlike conventional electrodes such as a GCE[19].

Nowadays, it continues to be of interest in the developments of new materials capable to change the electrode surface with better analytical properties, including graphene, different nanoparticles, and carbon nanotubes[20–23]. Nanomaterials, because of their unique properties, have been extensively developed. Nanoparticles can act as conduction centers facilitating the transfer of electrons and provide great catalytic surface areas[24-28].

Among them, nanosized metal particle modified electrodes have emerged as a promising alternative for the electroanalysis of organic and inorganic compounds[29-33]. Metal nanoparticles have some distinct advantages such as higher mass transport, lower influence of the solution resistance, low detection limit, and better signal-to noise ratio over the conventional macroelectrodes[34-36].

In the present work, we synthesized magnetic core-shell manganese ferrite nanoparticles (MCSNP)[37] and screen printed carbon electrodes were modified with MCSNP. To the best of our knowledge, no study has been reported so far on the determination of propranolol by using MCSNP/SPCE.

Experimental section

Apparatus and chemicals

The electrochemical measurements were performed with an Autolabpotentiostat/galvanostat (PGSTAT 302N, Eco Chemie, the Netherlands). The experimental conditions were controlled with General Purpose Electrochemical System software. Screen printed carbon electrodes were purchased from Italsens Co. (DropSens, DRP-110, Spain).A Metrohm 710 *p*H meter (Metrohm 692 model,Herisau, Switzerland) was used for *p*H measurements.

Propranolol and all the other reagents were of analytical grade and were obtained from Merck (Darmstadt, Germany). The buffer solutions were prepared from orthophosphoric acid and its salts in the *p*H range of 3.0-9.0. Magnetic core-shell manganese ferrite nanoparticles were synthesized in our laboratory as reported previously[37].

Preparation of the electrode

The bare screen-printed electrode was coated with MCSNP as follows. A stock solution of MCSNP in 1 mL aqueous solution was prepared by dispersing 1 mg MCSNP with ultrasonication for 1 h, and a 2 µL aliquot of the MCSNP/H_2O suspension solution was casted on the carbon working electrodes, waiting until the solvent was evaporated in room temperature.

Preparation of real samples

Ten tablets of PRO (labeled 20.0 mg per each tablet) were completely ground and homogenized, 200 mg of this powder was accurately weighed and dissolved with ultrasonication in 20 mL of water. Finally the mixture was filtered and the clear filtrate was transferred into a 100 mL volumetric flask and diluted to the mark with using 0.1 M PBS with *p*H 7.0. Finally, suitable volume of the resultant solution was transferred to electrochemical cell and spiked with different amounts of PRO.Then, contents were analyzed by using the standard addition method in order to prevent any matrix effect.

Urine samples were stored in a refrigerator immediately after collection. Twenty milliliters of the sample was centrifuged for 10 min at 3000 rpm. The supernatant was filtered out using a 0.45 µm filter and transferred into a 50 mL volumetric flask and diluted to the mark with PBS (*p*H 7.0). The diluted urine sample was spiked with different amounts of PRO. The PRO contents were analyzed by the proposed method using the standard addition method in order to prevent any matrix effect.

Results and Discussion

Electrochemical behavior of propranolol at the surface MCSNP/SPCE

The electrochemical behavior of PRO is dependent on the *p*H value of the aqueous solution. Therefore, *p*H optimization of the solution seems to be necessary in order to obtain the best results for electrooxidation of PRO. Thus, the electrochemical behavior of PRO was studied in 0.1 M PBS in different *p*H values

(3.0–9.0) at the surface of MCSNP/SPCE by voltammetry. It was found that the electro-oxidation of PRO at the surface of MCSNP/SPCE was more favored under neutral conditions than in acidic or basic medium (Fig. 1). Thus, the *p*H 7.0 was chosen as the optimum *p*H for electro-oxidation of PRO at the surface of MCSNP/SPCE.

Figure 2 depicts the CV responses for the electro-oxidation of 150.0 µM PRO at an unmodified SPCE (curve a) and MCSNP/SPCE (curve b). The peak potential due to the oxidation of PRO occurs at 900 mV, which is about 150 mV more negative compared to unmodified SPCE.

Also, MCSNP/SPCE shows much higher anodic peak current for the oxidation of PRO compared to unmodified SPCE, indicating that the modification of unmodified SPCE with MCSNP has significantly improved the performance of the electrode toward PRO oxidation.

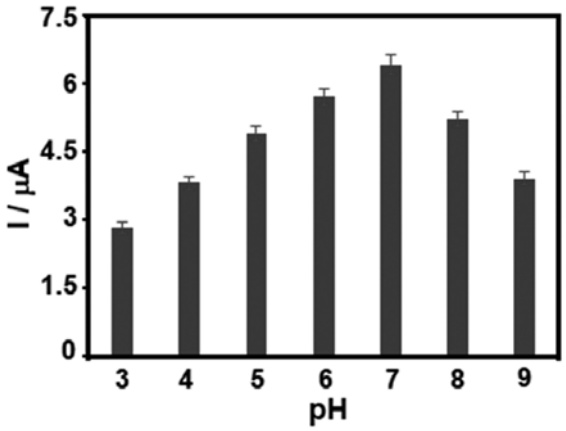


Fig. 1 — Current–*p*H curve for electrooxidation of 100 µM PRO at MCSNP/SPCEwith a scan rate of 50 mV s^{-1}

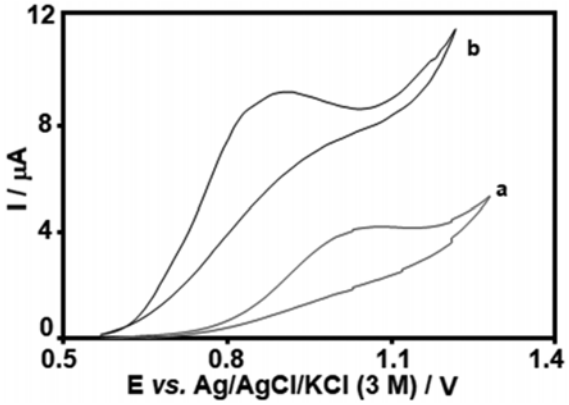


Fig. 2 — Voltammogramsof (a) unmodified SPE and (b) MCSNP/SPCE in the presence of 150.0 µM PRO at *p*H 7 (at 50 mV s^{-1})

Effect of scan rate

The effect of potential scan rate on the oxidation current of PRO (Fig. 3) have been studied. The results showed that increasing in the potential scan rate induced an increase in the peak current. In addition, the oxidation processisdiffusion controlled as deduced from the linear dependence of the anodic peak current (I_p) on the square root of the potential scan rate ($\upsilon^{1/2}$).

Tafel plot was drawn from data of the rising part of the currentvoltage curve recorded at a scan rate of 5 mVs^{-1} for PRO (Fig. 4). This part of voltammogram, known as Tafel region, is affected by electron transfer kinetics between substrate (PRO) and MCSNP/SPCE. Tafel slope of 0.0856 V was obtained which agree well with the involvement of one electron in the rate determining step of the electrode process[38] assuming charge transfer coefficients, α=0.31 for propranolol.

Chronoamperometricmeasurements

Chronoamperometric measurement of PRO at MCSNP/SPCE was carried out by setting the working electrode potential at 950 mV vs. Ag/AgCl/KCl (3.0 M) for the various concentrations of propranolol (Fig. 5) and in PBS (*p*H 7.0). For electroactive materials (PRO) with a diffusion coefficient of D, the current observed for the electrochemical reaction at themass transport limited condition is described by the Cottrell equation[38]:

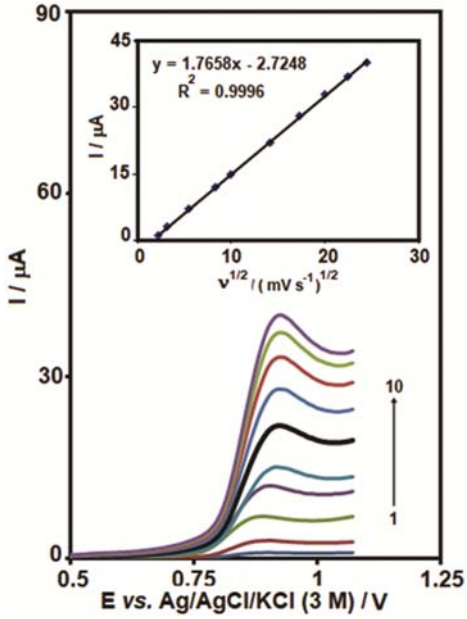


Fig. 3 — LSVs of MCSNP/SPCE in 0.1 M PBS (*p*H 7.0) containing 150.0 µM PRO at various scan rates; numbers 1-10 correspond to 5, 10, 30, 70, 100, 200, 300, 400, 500 and 600 mV s^{-1}, respectively. Inset: Variation of anodic peak current *vs.* square root of scan rate

$$I = nFAD^{1/2}C_b\pi^{-1/2}t^{-1/2} \quad \ldots (1)$$

Where D and C_b are the diffusion coefficient (cm^2 s^{-1}) and the bulk concentration (mol cm^{-3}), respectively. Experimental plots of I vs. $t^{-1/2}$ were employed, with the best fits for different concentrations of PRO (Fig. 5a). The slope of the resulting straight lines was then plotted vs. PRO (Fig. 5b) concentrations. From the resulting slope and Cottrell equation, the mean value of the D was found to be $2.85\times10^{-5}cm^2/s^{-1}$ for PRO.

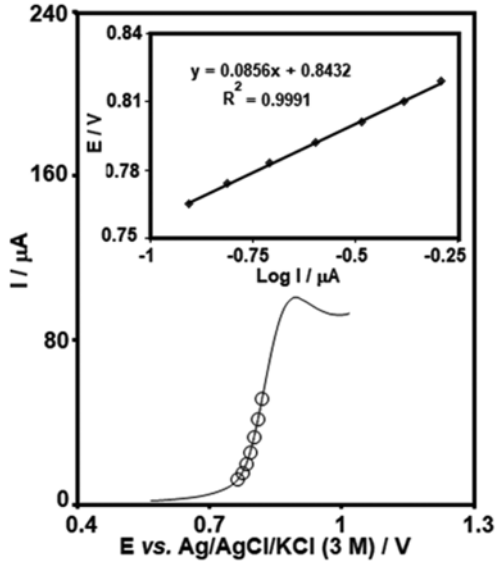


Fig. 4 — Tafel plot derived from LSV of MCSNP/SPCE in 0.1 M PBS (*p*H 7.0) containing 150.0 µM PRO at scan rate of 5 mV/s

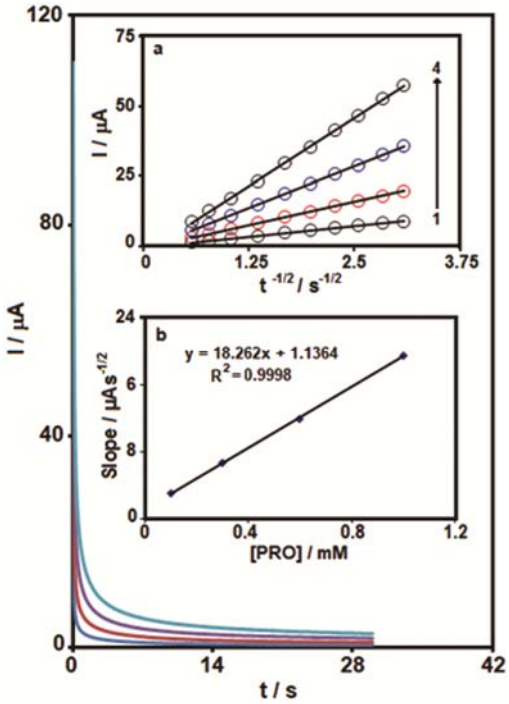


Fig. 5 — Chronoamperograms obtained at MCSNP/SPCE in 0.1 M PBS (*p*H 7.0) for different concentration of PRO. The numbers 1–4 correspond to 0.1, 0.3, 0.6 and 1 mM of PRO. Insets: Plots of I vs. $t^{-1/2}$ obtained from chronoamperograms 1–4 (a), and Plot of the slope of the straight lines against PRO concentration (b)

Calibration plots and limits of detection

The electro-oxidation peak current of PRO at the surface of the MCSNP/SPCE can be used for determination of PRO in solution. Since, DPV has the advantage of an increase in sensitivity and better characteristics for analytical applications, therefore, DPV experiments were performed using MCSNP/ SPCE in 0.1 M PBS containing various concentrations of PRO (Fig. 6). The DPV parameters were tested and the best currents were obtained by using (Initial potential= 750 mV, End potential=1100 mV, Step potential=0.01 V and pulse amplitude=0.025 V).

The results showedthatthe peak currents of PRO oxidation at the surface of MCSNP/SPCE was linearly dependent on the PRO concentrations, over the range of 4.0×10^{-7} – 2.0×10^{-4} M (with a correlation coefficient of 0.9995) and the detection limit (3s) was obtained 8.0×10^{-8} M.A comparison of the analytical performance of present work with other modified electrodes, is listed in Table 1. With respect to Table 1, linear dynamic range (LDR) and limit of detection (LOD) of the present work are comparable with values reported by other research groups for electrocatalytic

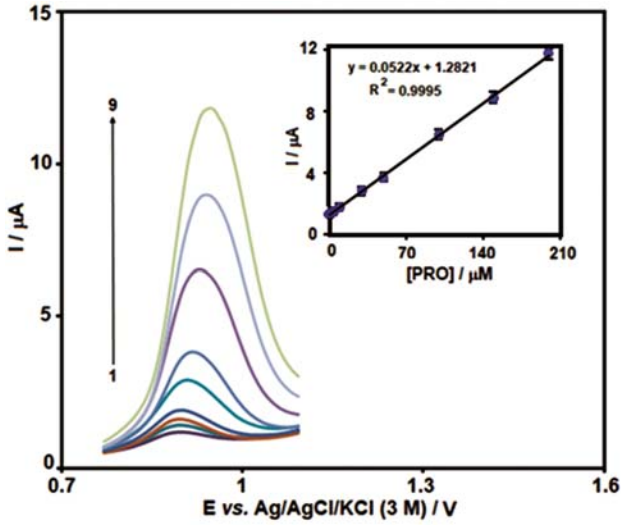


Fig. 6 — DPVs of MCSNP/SPCE in 0.1 M PBS (*p*H 7.0) containing different concentrations of PRO (0.4, 2.0, 5.0, 10.0, 30.0, 50.0, 100.0, 150.0 and 200.0 µM). Inset: The plot of the peak current as a function of PRO concentration in the range of 0.4-200.0 µM

Table 1 — Comparison of the efficiency of electrochemical methods used in detection of AC

Electrode	Modifier	LOD (μM)	LDR (μM)	Ref.
Glassy carbon electrode	Calixarene/multi-walled carbon nanotubes	0.135	0.338-54.1	1
Carbon paste electrode	Copper-oxide nanoparticles	1.12	10-104	15
Glassy carbon electrode	Graphene oxide, copper nanoparticlesand poly(3,4ethylenedioxythiophene)-poly(styrenesulfonate)	1.9	8-50	39
Screen printed electrode	Zirconium dioxide nNanoparticles	1.5	10-200	40
Boron-doped diamond electrode	---	0.18	0.2-9	41
Glassy carbon electrode	Platinum nanoparticles doped multi-walled carbon nanotubes	0.084	0.676-38	42
Nitrogen-containing tetrahedral amorphous carbon electrode	-----	0.75	0.9-9.8	43
Screen printed electrode	Magnetic core-shell manganese ferrite nanoparticles (MCSNP)	0.08	0.4-200	Present work

Table 2 — The application of MCSNP/SPE for determination of PRO in real samples (n=5)

Sample	Spiked (μM)	Found (μM)	Recovery (%)	R.S.D. (%)
PRO tablet	0.0	13.0	---	2.4
	5.0	18.7	103.9	3.0
	15.0	22.5	97.8	2.7
	25.0	38.2	100.5	3.1
Urine	0	Not detect	---	2.7
	10.0	9.9	99.0	3.5
	20.0	20.5	102.5	2.6
	30.0	29.1	97.0	2.9

oxidation of PRO at the surface of chemically modified electrodes by other mediators[1,15,39-43].

Stability and reproducibility of the modified electrode

The long-term stability of the MCSNP/SPCEwas tested over a 2-week period. In this regard, after the modified electrode was not used within 2 weeks and stored at atmosphere, the experiments were repeated. According to cyclic voltammograms, no change was observed in the peak potential of PRO oxidation except for a decrement less than 2.8% compared with initial response.

The antifouling properties of the modified electrode towards PRO oxidation and its oxidation products were studied by recording the CVs.Voltammograms were recorded in the presence of 80.0 μM PRO after cycling the potential 10 times at a scan rate of 50 mV s^{-1}. Results demonstrated no change in peak potential sand a decrement less than 3.2% in currents. According to the results, application of the modified MCSNP/ SPCE provides increased sensitivity and decreased fouling effect ofthe propranolol and its oxidation product.

Real sample analysis

Finally, MCSNP/SPCE was applied for measurement of PRO in PRO tablet and urine samples. For this purpose, the measurement of PRO in the real samples was carried out (Table 2). Also, the recovery of PRO from samples spiked with known amounts of PRO was assessed. The results were showed that, the added PRO were quantitatively recovered from the real samples. These results demonstrate the applicability of the MCSNP/SPCE for measurement of PRO in the real samples. Also, the reproducibility of the method was demonstrated by the mean relative standard deviation (R.S.D.).

The amount of PRO in tablet was found to be 20.02 mg/tablet. It was found that there is no significant difference between the results obtained by the MCSNP/SPCE and the nominal value on the tablet label (20.0 mg/tablet). The t-test was applied to the results and showed that there was no significant difference at the 95% confidence level.

Conclusion

In this work, by using magnetic core shell nanoparticles as modifier in modification of SPCEs, a novel sensor has been developed that provides a sensitive method for the determination of PRO. The proposed protocol demonstrated herein a novel, simple, portable, inexpensive and easy-to-use fabrication method for the measurement of PRO concentration

in tablet and urine samples with good analytical performance. Due to the unique properties of magnetic core shell nanoparticles, the sensor exhibited remarkable electrochemical activity toward the oxidation of PRO. Under optimized conditions, DPV exhibited linear dynamic ranges from 0.4–200 μM with detection limit of 80.0 nM.

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References

1 Kun Z, Shuai Y, Dongmei T & Yuyang Z, *J Electroana l Chem,* 709 (2013) 99.
2 Ensafi A A, Kazemifard N & Rezaei B, *Sens Actuat B,* 252 (2017) 846.
3 Townshend A, Pulgarın J A M & Pardo M T A, *Anal Chim Acta,* 488 (2003) 81.
4 Lindenberg M, Kopp S & Dressman J B, *Eur J Pharm Biopharm,* 58 (2004) 265.
5 Venkatesh G, Ramanathan S, Mansor S M, Nair N K, Sattar M A, Croft S L & Navaratnam V, *J Pharm Biomed Anal,* 43 (2007) 1546.
6 Imam S S, Ahad A, Aqil M, Sultana Y & Ali A, *J Pharm Bioallied Sci,* 5 (2013) 61.
7 WADA 2009 Prohibited List. <http://www.wada-ama.org>.
8 Idowu O S, Adegoke O A & Olaniyi A A, *J AOAC Int,* 87 (2004) 573
9 Salem H, *J Pharm Biomed Anal,* 29 (2002) 527.
10 Dela Pena A M, Salinas F & Duran M S, *Anal Chim Acta,* 255 (1991) 317.
11 Tabrizi A B, *J Food Drug Anal,* 15 (2007) 242.
12 Gotardo M A, Tognolli J O, Pezza H R & Pezza L, *Spectrosc Acta A,* 69 (2008) 1103.
13 Pathak V N, Shukla M S R & Shuklahukla I C, *Analyst,* 107 (1982) 1086.
14 Sartori E R, Medeiros R A, Rocha-Filho R C & Fatibello-Filho O, *Talanta,* 81 (2010) 1418.
15 Shadjou N, Hasanzadeh M, Saghatforoush L, Mehdizadeh R & Jouyban A, *Electrochim Acta*, 58 (2011) 336.
16 Cumba L R, Smith J P, Zuway K Y, Sutcliffe O B, do Carmo D R & Banks C E, *Anal Methods*, 8 (2016) 142.
17 Chan K F, Lim H N, Shams N, Jayabal S, Pandikumar A & Huang N M, *Mater Sci Eng C*, 58 (2016) 666.
18 Chatzipetrou M, Milano F, Giotta L, Chirizzi D, Trotta M, Massaouti M, Guascito M R &Zergioti I, *Electrochem Commun,* 64 (2016) 46.
19 Lezi N, Economou A, Barek J &Prodromidis M, *Electroanalysis,* 26 (2014) 766.
20 Parvin M H, *ElectrochemCommun,* 13 (2011) 366.
21 Mahmoud K A, Hrapovic S & Luong J H T, *ACS Nano,* 2 (2008) 1051.
22 Hyde M E, Davies T J & Compton R G, *Angew Chem Int Ed,* 44 (2005) 6491.
23 Streeter I, Baron R & Compton R G, *J PhysChem C,* 111 (2007) 17008.
24 Mohammadi S Z, Beitollahi H, Jasemi M & Akbari A, *Electroanalysis,* 27 (2015) 2421.
25 Beitollahi H, Ghofrani Ivari S & Torkzadeh MahaniM, *Mater Sci Eng C,* 69 (2016) 128.
26 Mohammadi S Z, Beitollahi H &Hassanzadeh M, *Anal BioanalChem Res,* 5 (2018) 55.
27 Jahani Sh. & Beitollahi H, *Electroanalysis,* 28 (2016) 2022.
28 Mohammadi S Z, Beitollahi H & Bani Asadi E, *Environ Monit Assess,* 187 (2015) 122.
29 Mohammadi S Z, Beitollahi H, Nikpour N & Hosseinzadeh R, *Anal Bioanal Chem Res*, 3 (2016) 187.
30 Yadav R & Kumar Singh N, *Indian J ChemTechnol,* 25 (2018) 189.
31 Dave S & Kumbhat S, *Indian J ChemTechnol,* 25 (2018) 201.
32 Zhang Y, Suryanarayanan V, Nakazawa I, Yoshihara S & Shirakashi T, *Electrochim Acta,* 49 (2004) 5235.
33 Pingarrón J M, Yanez-Sedeno P & Lez-Cortes A G, *Electrochim Acta,* 53 (2008) 5848.
34 Penner R M & Martin C R, *Anal Chem,* 59 (1987) 2625.
35 Reller H, Kirowa-Eisner E & Gileadi E, *J Electroanal Chem,* 161 (1984) 247.
36 Cassidy J, Ghoroghchian J, Sarfarazi F, Smith J J & Pons S, *Electrochim Acta,* 31 (1986) 629.
37 Mohammadi S Z & Seyedi A, *Toxicol Environ Chem,* 98 (2016) 705.
38 Bard J & Faulkner L R, *Electrochemical Methods: Fundamentals and Applications,*2nd ed. (Wiley, New York, NY) (2001).
39 Wong A, SantosA M, Silva T A & Fatibello-Filho O, *Talanta*, 183 (2018) 329.
40 MohammadizadehN, Mohammadi S Z & Kaykhaii M, *Anal Bioanal Electrochem,* 9 (2017) 277.
41 Sartori E R, Medeiros R A, Rocha-Filho R C & Fatibello-Filho O, *Talanta,* 81 (2010) 1418.
42 Kun Z, Yi H, Chengyun Z, Yue Y, Shuliang Z & Yuyang Z, *Electrochim Acta*, 80 (2012) 405.
43 Lourencao B C, Silva T A, Fatibello-Filho O & Swain G M, *Electrochimica Acta,* 143 (2014) 398.